Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	)	ET Docket No. 14-165
	)	
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268

REPORT AND ORDER

Adopted: August 6, 2015 **Released: August 11, 2015**

TABLE OF CONTENTS

Heading Paragraph #

I. INTRODUCTION

1. Recent actions by the Commission to repurpose broadcast television band spectrum for new wireless services as set forth in the *Incentive Auction R&O* will significantly alter the regulatory landscape for unlicensed white space devices and wireless microphones operating in the bands currently allocated for television broadcasting.[1] White space devices can be used to provide a variety of wireless services, including broadband data. The fixed devices that are being deployed today are typically used to provide backhaul services for Internet connectivity offered by wireless internet service providers (WISPs), schools and libraries.[2] Indeed, the propagation range of the TV bands is well suited to providing high data throughput service to un-served or under-served areas of the country at relatively low cost. In the future, we anticipate that fixed devices could also be used as internet access points in conjunction with personal/portable devices, and personal/portable devices could be used separately for short-range device-to-device connectivity.[3] Commercial wireless providers increasingly rely on unlicensed spectrum to complement their licensed networks in meeting their customers' growing demands for broadband services. Wireless microphones enable broadcasters and other video programming networks to cover breaking news and live sports events. They are also used in theaters and music venues, film studios, conventions, corporate events, houses of worship, and internet webcasts.

2. In the *Incentive Auction R&O*, the Commission made several decisions to balance the spectrum needs of all incumbent uses of the TV bands. Unlicensed white space devices and wireless microphones will continue to operate on vacant channels in the TV bands, albeit they may be fewer in number in certain geographic areas. They also will be permitted to operate on segments of the 600 MHz spectrum that will be recovered and repurposed for new wireless services. The Commission initiated this proceeding to develop rules for unlicensed operation of white space devices and wireless microphones in

[1] *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions,* GN Docket No. 12-268, Report and Order, 29 FCC Rcd 6567 (2014) (*Incentive Auction R&O*). The frequency bands allocated for television broadcasting are 54-72 MHz (channels 2-4), 76-88 MHz (channels 5-6), 174-216 MHz (channels 7-13) and 470-608 MHz (channels 14-36) and 614-698 MHz (channels 38-51). Channel 37 (608-614 MHz) is allocated for land mobile and radio astronomy services and is not allocated for television broadcasting. Channels 2-13 are in the VHF band, and channel 14-51 are in the UHF band.

[2] Some deployments use white space technology for transmission to remote areas where the signals are converted to Wi-Fi signals for direct access by users. For example, AIR.U is a consortium of higher education associations, public interest groups and high-tech companies focused on deploying white space networks in combination with Wi-Fi access to upgrade broadband available to underserved campuses and their surrounding communities. *See* www.airu.net. The Gigabit Libraries Network, a consortium dedicated to expanding Internet access to library users, uses a similar approach in six pilot projects in the U.S. and three countries in Europe and Asia. *See* www.giglibraries.net.

[3] Neul, Ltd. has developed an air interface standard for white space devices that is specifically designed to support machine-to-machine applications. *See* www.neul.com.

the reconstituted TV bands and the 600 MHz band after the incentive auction.

3. In this Report and Order, we make certain changes to our Part 15 rules for unlicensed operations in the frequency bands that are now and will continue to be allocated and assigned to broadcast television services (TV bands), including fixed and personal/portable white space devices and unlicensed wireless microphones. Today, we modify our rules to allow for more robust service and efficient spectral use without increasing the risk of harmful interference to authorized users. We also codify in Part 15, rules for the operation of unlicensed wireless microphones in the TV bands.

4. In the *Incentive Auction R&O*, the Commission also made several decisions to balance the spectrum needs of new wireless services and unlicensed operations in the 600 MHz band.[4] In this Report and Order, we adopt technical and operational rules for unlicensed devices and wireless microphones in the 600 MHz guard bands, including the duplex gap, and in the 600 MHz band that will be repurposed for new wireless services. We also adopt rules for fixed and personal/portable white space device operation on channel 37.

5. We also modify our Part 15 rules for white space databases to guide their implementation of some of our decisions here, including protecting areas where new 600 MHz service licensees commence operation and areas used by incumbent services on channel 37. Finally, we adopt transition dates for the certification and marketing of unlicensed white space devices and wireless microphones to ensure compliance with the new rules.

II. EXECUTIVE SUMMARY

6. In this Report and Order, we maximize unlicensed white space device's access to spectrum in the television broadcasting band and the 600 MHz band in a number of ways, while at the same time protecting licensed users from harmful interference. We accomplish this by modifying our Part 15 rules to permit fixed and personal/portable devices to use TV channels previously unavailable to them while continuing to protect TV services from harmful interference by, for example, adjusting power limits, specifying separation distances, and specifying antenna heights. We also adopt technical rules for white space device operations in the 600 MHz band—including the duplex gap, guard bands, 600 MHz service band and channel 37—by limiting power and specifying frequency and distance separations as needed to protect authorized services in those bands from harmful interference. White space devices will continue to access the white space databases for channel assignments in the TV bands, as well as in the 600 MHz band and channel 37. These are the specific actions we take to ensure that white space devices have sufficient spectrum to provide broadband services in these bands.

- In the TV Bands, we modify our Part 15 rules to permit:
  - Fixed white space devices to operate
    - adjacent to occupied TV channels at 40 mW at antenna heights of 10 meters above ground level or less (within the TV station contour)
    - at 100 mW at antenna heights of 10 meters above ground level or less if there are two contiguous vacant TV channels,
    - closer to co- and adjacent-TV channels
    - by using location technologies with a lower degree of accuracy than ±50 meters
    - by bonding contiguous or non-contiguous channels

[4] In this Report and Order, we use the term "600 MHz band" to refer to all of the frequency bands that, after the incentive auction, will no longer be allocated and assigned only for broadcasting services but instead will be used for new wireless services and guard bands. The 600 MHz spectrum that will be allocated and assigned for new wireless services is referred to either as the "repurposed 600 MHz band" or "600 MHz service band" since the spectrum will be used for the new 600 MHz service pursuant to Part 27 of the Commission's rules. The term "600 MHz guard band" refers to frequency bands that prevent interference between licensed services in the 600 MHz service band, the TV bands or channel 37, and the term "600 MHz duplex gap" refers to the frequency band that separates the 600 MHz service uplink and downlink bands.

        - up to 10 W in areas with fewer than 50 percent occupied TV channels
        - on TV channels 3 and 4, where available
        - on two vacant channels above and below channel 37 now reserved for wireless microphone use
    - Personal/portable white space devices to operate
        - closer to co- and adjacent-TV station contours
        - by using location technologies with a lower degree of accuracy than ±50 meters
        - on channels 14-20, where available
        - on two vacant channels above and below channel 37 now reserved for wireless microphone use
- In the 600 MHz band, we permit fixed and personal/portable white space devices to operate in:
    - Duplex gap (between wireless uplink/downlink bands)
        - in six megahertz adjacent to the wireless uplink band at 40 mW
    - Guard bands (between TV and wireless downlink bands)
        - if the guard band is 9 MHz or 11 MHz, at 40 mW in six megahertz adjacent to the TV band
        - if the guard band is 7 MHz, at 40 mW in the four megahertz adjacent to the TV band
        - with at least three megahertz frequency separation from wireless downlink band regardless of guard band size
    - 600 MHz service band (allocated for new wireless services)
        - fixed white space devices operate up to 10 W and personal/portable devices up to 100 mW, at specified distances outside the wireless licensee's service areas

- We permit white space devices to operate on channel 37:
    - Depending on whether TV or wireless downlinks are in adjacent channels, fixed devices operate from 40 mW to 4W and personal/portable devices operate from 40 mW to 100 mW
    - Subject to frequency and distance separations from TV, wireless medical telemetry service (WMTS) and radio astronomy service (RAS)

7. We also take actions that will continue to accommodate unlicensed wireless microphone use in the TV bands and the 600 MHz band, while at the same time protecting licensed users from harmful interference. By codifying Part 15 rules for unlicensed wireless microphone use, we bring these devices under the traditional policy tenets for unlicensed devices, *i.e*., they are not entitled to interference protection and they must not cause harmful interference to authorized services. We accomplish this objective by limiting power and specifying frequency and distance separations as needed to protect authorized services. Unlicensed wireless microphones will access the white space databases to identify frequencies available for their use in the duplex gap, guard bands and 600 MHz service band, but they will not be permitted to reserve channels for their use (*i.e*., to be protected from interference from white space devices). These are the specific actions we take to accommodate unlicensed wireless microphone use in the TV bands and the 600 MHz band.

- In the TV bands, we codify Part 15 rules for unlicensed wireless microphone use:
    - technical rules are similar to Part 74 rules for licensed wireless microphones, but unlicensed wireless microphones limited to lower power (50 mW EIRP)
    - adopt tighter emission mask based on ETSI standard to improve spectrum sharing
    - no longer reserve two vacant channels above and below channel 37 for wireless microphone use
    - eliminate Part 15 rule that permits unlicensed microphone users to register with the white space databases to reserve vacant channels for their use
- In the 600 MHz band, we permit unlicensed wireless microphones to operate in:
    - Duplex gap (between wireless uplink/downlink bands; 1/4/6 plan)

        - may operate up to 20 mW in six megahertz shared with unlicensed white space devices, adjacent to the wireless uplink band
        - unlicensed wireless microphone users will need to access the white space databases to identify frequencies available for their use
    - Guard bands (between TV and wireless downlink bands, adjacent to channel 37)
        - may operate up to 20 mW with one megahertz separation from wireless downlink band
        - if the guard band is 9 MHz, unlicensed wireless microphones may use eight megahertz, only six of which is shared with white space devices
        - if the guard band is 11 MHz, unlicensed wireless microphones may use 10 megahertz, only six of which is shared with white space devices
        - if the guard band is 7 MHz, unlicensed wireless microphones may use six megahertz, only four of which is shared with white space devices
        - may use two megahertz in 3 MHz guard bands above and below channel 37
        - users will need to access the white space databases to identify frequencies available for their use
    - 600 MHz service band
        - may operate at 50 mW during the post-auction transition period[5]
        - at specified separation distances beyond wireless licensee's service areas
        - users will need to access the white space databases to identify frequencies available for their use

8. In addition to the rules accommodating unlicensed wireless microphones, this Report and Order reserves 4 megahertz of spectrum in the duplex gap for licensed wireless microphones. This action will provide licensed wireless microphones with spectrum where they can operate on an as-needed basis that is not shared with white space devices. Operation will be limited to the same technical requirements as unlicensed wireless microphones operating in the guard bands. We also adopt rules to permit, for a limited time, operation of licensed wireless microphones in the new 600 MHz service band.

9. In this Report and Order, we also expand location and frequency information in the white space databases, and make certain changes to database procedures.

- 600 MHz service licensees will provide the white space database administrators with information on where they have commenced operation so that the databases can calculate the separation distances beyond the perimeter of those areas to permit operation of unlicensed white space devices and unlicensed wireless microphones.
- Health care facilities that operate wireless medical telemetry networks on channel 37 will provide the white space database administrators with their location information so that the databases can calculate the separation distances beyond the perimeter of those areas to permit operation of unlicensed white space devices.
- White space database administrators will update their systems to include the exclusion areas we adopt to protect radio astronomy sites operating on channel 37 and to include the TV channel on which private land mobile base stations operate.
- Fixed white space device operators must register with the white space databases if they operate in the 600 MHz guard bands, duplex gap, 600 MHz service band, or channel 37.
- Unlicensed wireless microphone users must register with the white space databases if they operate in the 600 MHz guard bands, duplex gap, or 600 MHz service band.
- White space database administrators will "push" information about changes in channel availability to white space devices operating in the area where licensed wireless microphones reserve channels so that these channels can be reserved quickly.

[5] *See* 47 C.F.R. § 27.4 (definition of "post-auction transition period").

10. Finally, we adopt transition periods for the certification, manufacturing and marketing of white space devices and unlicensed wireless microphones to comply with the requirements we adopt in this Report and Order.

- White space devices: New certification applications filed six months after the effective date of the "push" notification rule shall comply with the rule. All white space devices imported and marketed within the United States must comply with the "push" notification requirement within nine months after the effective date of the rule, and devices that do not comply with the "push" requirement shall cease operating within one year of the effective date of the rule.
- Unlicensed wireless microphones:
  - Wireless microphone certified under Part 74 rules may continue to be used in the TV bands under the waivers already in place and in the 600 MHz service band until they must cease those operations no later than 39 months after release of the *Channel Reassignment PN*.[6]
  - Responsible parties may file applications to certify wireless microphones under new Part 15 rules as soon as those rules are effective, and new applications to certify wireless microphones are required to comply with the new Part 15 rules nine months after the release of the *Channel Reassignment PN* or no later than 24 months after the effective date of the new rules, whichever occurs first.
    - Manufacturing and marketing of all wireless microphones that would not comply with the 600 MHz Band Plan and rules must cease 18 months after release of the *Channel Reassignment PN* or no later than 33 months after the effective date of the new rules, whichever occurs first.

III. BACKGROUND

11. The Commission's Part 15 rules allow unlicensed devices to operate in the TV bands at locations where frequencies are not in use by licensed services.[7] These devices, which are commonly referred to as white space devices, may be either fixed or personal/portable. The TV bands currently consist of six-megahertz channels designated 2 to 51 in four bands of frequencies in the VHF and UHF regions of the radio spectrum.[8] White space devices are not permitted to operate on channel 37, which is allocated for the Radio Astronomy Service (RAS) and Land Mobile Service (the latter being limited to Wireless Medical Telemetry Service (WMTS)),[9] or on any other channel within 2.4 kilometers of protected radio observatories.[10] To prevent harmful interference to broadcast television stations and other authorized users of these bands, white space devices obtain a list of available TV channels that may be used at their location from databases administered by private entities selected by the Commission.[11]

12. Fixed devices must incorporate a geo-location capability and a means to access a database that provides a list of available TV channels that may be used at their location.[12] Such devices must contact a database to obtain a channel list before operating and re-check the database at least once daily.[13]

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[6] *See* 47 C.F.R. § 73.3700(a)(2).

[7] *See* 47 C.F.R. Part 15 subpart H.

[8] *See* 47 C.F.R. § 73.603(a). These frequency bands are 54-72 MHz, 76-88 MHz, 174-216 MHz, and 470-698 MHz.

[9] *See* 47 C.F.R. § 2.106. The frequency range of channel 37 is 608-614 MHz.

[10] *See* 47 C.F.R. § 15.712(h).

[11] *See* 47 C.F.R. §§ 15.703(c), 15.703(i) and 15.703(n).

[12] As an alternative, fixed devices may have their geographic coordinates determined and programmed by a professional installer. *See* 47 C.F.R. § 15.711(b)(1).

[13] *See* 47 C.F.R. § 15.711(b)(3)(i).

Fixed devices are permitted to operate with up to one watt transmitter power output and may use an antenna that provides up to 6 dBi of gain to produce a maximum power of 4 watts EIRP.[14] They may not operate on channels adjacent to those occupied by TV stations. Portable devices can operate in either "Mode I" or "Mode II".[15] A Mode II device must incorporate similar geo-location and database access capabilities to fixed devices.[16] A Mode I device is not required to incorporate geo-location or database access capabilities but instead obtains a list of available channels on which it can operate from either a fixed or Mode II device that has database access.[17] Personal/portable devices are permitted to operate with up to 100 milliwatts EIRP except when operating on channels adjacent to a TV service, in which case they may operate with up to 40 milliwatts EIRP.[18] All white space devices are required to incorporate transmit power control to limit their operating power to the minimum necessary for successful communication.[19] The databases used by white space devices are established and administered by third parties.[20]

13. The TV bands are used also by wireless microphones. Certain entities may be issued licenses under Part 74, Subpart H of the rules to operate low power auxiliary stations in the TV bands.[21] Devices authorized as low power auxiliary stations are intended to transmit over distances of approximately 100 meters for uses such as wireless microphones, cue and control communications, and synchronization of TV camera signals.[22] Because the operators of Part 74 wireless microphones are licensed, they may register the times and locations of their operation in the TV white space databases to obtain interference protection from white space devices. The Commission also allows the operation of wireless microphones in the VHF and UHF TV bands on an unlicensed basis under a waiver of the Part 15 rules granted in the

[14] *See* 47 C.F.R. § 15.709(a).

[15] *See* 47 C.F.R. §§ 15.703(e) and 15.703(f).

[16] *See* 47 C.F.R. §§ 15.711(b)(2) and 15.711(b)(3)(ii). Unlike fixed devices, there is no option for a Mode II personal/portable device to be professionally installed as an alternative to incorporation of a geo-location capability. Additionally, a personal/portable device must re-check its location at least once every 60 seconds except when in a sleep mode.

[17] *See* 47 C.F.R. §§ 15.703(e) and 15.711(b)(3)(iv).

[18] *See* 47 C.F.R. § 15.709(a)(2).

[19] *See* 47 C.F.R. § 15.709(a)(4).

[20] *See* 47 C.F.R. § 15.715. The Office of Engineering and Technology designated ten entities to administer white space databases by two separate Orders. The ten designated database administrators are: Airity, Inc. (formerly WSdb LLC); Comsearch; Frequency Finder, Inc.; Google, Inc.; LS Telcom; Key Bridge Global LLC; NeuStar, Inc.; Spectrum Bridge, Inc.; iconectiv; and Microsoft Corporation. *See Order* in ET Docket Nos. 02-380 and 04-186, 26 FCC Rcd 554 (2011) (designating the first nine of these listed parties as database administrators) and *Order* in ET Docket Nos. 02-380 and 04-186, 26 FCC Rcd 10599 (2011) (designating Microsoft Corporation at the tenth database administrator).

[21] *See* 47 C.F.R. Part 74 subpart H. These entities fall within the following categories: (1) licensees of AM, FM, TV, or International broadcast stations or low power TV stations; (2) broadcast network entities; (3) certain cable television system operators; (4) motion picture and television program producers as defined in the rules; (5) certain entities with specified interests in Broadband Radio Service (BRS) and Educational Broadcast Service (EBS) licenses; (6) large venue owners or operators; and (7) professional sound companies. *See* 47 C.F.R. § 74.832(a)(1)-(8).

[22] *See* 47 C.F.R. § 74.801. We refer to these types of devices collectively as wireless microphones. Wireless microphones may operate with a maximum bandwidth of 200 kilohertz and a maximum power of 50 milliwatts in the VHF TV band and 250 milliwatts in the UHF TV band. *See* 47 C.F.R. §§ 74.861(e)(1) and (e)(5). Wireless microphones are secondary to the broadcast television service and must comply with minimum separation distances from co-channel TV stations. *See* 47 C.F.R. § 74.802(b).

2010 *TV Bands Wireless Microphones R&O and Further NPRM,*[23] subject to proposed Part 15 technical requirements in the *Further NPRM*.[24] Operators of unlicensed wireless microphones are generally not permitted to register in the white space databases, but parties operating large numbers of wireless microphones on an unlicensed basis at event and production/show venues may register in the white space database if they meet certain criteria specified in the rules and obtain Commission approval to do so.[25]

14. In adopting the Spectrum Act and authorizing an incentive auction of broadcast television band spectrum, Congress preserved our authority to implement our white spaces rules in the spectrum that remains allocated for broadcast television use after the reorganization."[26] Congress also provided that nothing in the Spectrum Act "shall be construed to prevent the Commission from using relinquished or other spectrum to implement band plans with guard bands" and that "the Commission may permit the use of such guard bands for unlicensed use."[27] The Spectrum Act further stipulates that "unlicensed use shall rely on a database or subsequent methodology as determined by the Commission" and "the Commission may not permit any use of a guard band that the Commission determines would cause harmful interference to licensed services."[28]

15. In the *Incentive Auction R&O*, the Commission adopted rules to implement the broadcast television spectrum incentive auction authorized by the Spectrum Act. Under the Spectrum Act, full power and Class A broadcast licensees may participate in a reverse auction that will allow them to voluntarily relinquish some or all of their spectrum usage rights in exchange for financial compensation. A broadcast licensee that participates in the auction will have the option to turn in its license, move to a channel in the VHF band, or cease using its channel and share a channel with another licensee. The Commission will reorganize or repack the remaining full power and Class A television stations to clear the UHF band from channel 51 down.[29] During the post-auction transition process, low power television (LPTV) and translator stations displaced by repacking may seek to relocate to new channels in the remaining TV bands. The Commission decided not to relocate incumbent RAS and WMTS operations from channel 37. When the transition is completed, the TV bands will occupy a smaller frequency range than they do today and fewer vacant TV channels may be available for white space devices and wireless microphone uses at any given location.

16. The Commission also developed a plan for organizing newly claimed spectrum for wireless use. To that end, the 600 MHz Band Plan adopted in the *Incentive Auction R&O* provides for a guard

[23] *See* Revisions to Rules Authorizing the Operation of Low Power Auxiliary Stations in the 698-806 MHz Band, WT Docket No. 08-166, Public Interest Spectrum Coalition, Petition for Rulemaking Regarding Low Power Auxiliary Stations, Including Wireless Microphones, and the Digital Television Transition, WT Docket No. 08-167, Amendment of Parts 15, 74 and 90 of the Commission's Rules Regarding Low Power Auxiliary Stations, Including Wireless Microphones, ET Docket No. 10-24, *Report and Order and Further Notice of Proposed Rulemaking*, 25 FCC Rcd at 643, 682-87, para. 81-90 (2010) ("*TV Bands Wireless Microphones R&O and Further NPRM*").

[24] *Id.* at 733-734, Appendix E (2010). These technical requirements limit wireless microphones to 50 milliwatts in the VHF and UHF TV bands, but are otherwise similar to the technical requirements for Part 74 wireless microphones, including a bandwidth limit of 200 kHz and minimum separation distances from co-channel television stations.

[25] *See* 47 C.F.R. § 15.713(h)(9). Parties wishing to register unlicensed wireless microphones on channels where white space devices can operate must first make use of all channels where white space devices cannot operate, and must use at least 6-8 microphones per channel.

[26] *See* 47 U.S.C. §1452 (h)(i)(2) (providing that nothing in section 1452(b) "shall be construed to . . . prevent the implementation of the Commission's 'White Spaces' Second Report and Order . . . in the spectrum that remains allocated for broadcast television use after the reorganization required by" section 1452(b)).

[27] *See* 47 U.S.C. §1454 (a), (c).

[28] *See* 47 U.S.C. §1454 (d), (e).

[29] *See Incentive Auction R&O,* 29 FCC Rcd at 6617-6621, para. 109-118.

band between television spectrum and 600 MHz downlink services, a guard band between 600 MHz uplink and downlink services (a duplex gap), and guard bands between 600 MHz downlink services and channel 37.[30] These guard bands are necessary to separate uplink and downlink transmissions within the 600 MHz service and to separate transmissions of dissimilar services (*e.g.*, television and 600 MHz service) to prevent harmful interference in the receivers.[31] Under the 600 MHz Band Plan, the size and location of the guard bands depends on the amount of spectrum that is recovered through the auction. The guard band between wireless downlink services and TV spectrum could be seven, nine or 11 megahertz.[32] The duplex gap will be 11 megahertz wide under all spectrum recovery scenarios, but its frequency location will depend on the amount of spectrum recovered. There will be no guard bands adjacent to channel 37 if less than 84 megahertz of spectrum is recovered, a single three megahertz guard band above channel 37 if 84 megahertz of spectrum is recovered, and a three megahertz guard band on each side of channel 37 if more than 84 megahertz of spectrum is recovered.

17. In the *Incentive Auction R&O*, the Commission decided that unlicensed devices could operate on vacant channels in the frequency bands that are now and will continue to be allocated and assigned to broadcast television services; in the 600 MHz Band Plan spectrum that, following the Incentive Auction, will be designated as guard bands (including a duplex gap); in the portion of that spectrum allocated and assigned to new Part 27 licensees where they have not commenced operations; and in Channel 37.[33] In the *Incentive Auction R&O,* the Commission decided that, at the end of the post-auction transition period, unlicensed microphones could operate in the guard bands, including a portion of the duplex gap, and that licensed microphones could operate in a different portion of the duplex gap.[34] During the post-auction transition period, microphones will be permitted to operate in the 600 MHz service spectrum assigned to new 600 MHz service licensees provided they do not cause harmful interference to those licensees' operations, and microphones must cease all operations in that spectrum no later than the end of the transition period.[35] The Commission found that the record in the Incentive Auction proceeding was inadequate to adopt rules for these unlicensed operations and stated that it planned to develop technical rules in a separate proceeding.

18. In the *Notice* in this proceeding, the Commission proposed and sought comments on rules for unlicensed operations in the frequency bands that are now and will continue to be allocated and assigned to broadcast television services, including white space devices and unlicensed wireless microphones.[36] It also proposed and sought comment on changes to our Part 15 rules for white space devices in the TV bands that would allow for more robust service and efficient spectral use without increasing the risk of harmful interference to authorized users, and proposed to codify in Part 15 rules for the operation of unlicensed wireless microphones in the TV bands. The Commission also proposed and sought comment

[30] *See Incentive Auction R&O,* 29 FCC Rcd at 7017-7025, Appendix C, para. 115-141.

[31] Wireless uplinks are transmissions from mobile devices to fixed base stations. The receivers of concern in developing protection criteria are those in fixed base stations. Wireless downlinks are transmissions from fixed base stations to mobile devices. The receivers of concern in developing protection criteria in the wireless downlink spectrum are mobile device receivers.

[32] If exactly 84 megahertz of spectrum is recovered, channel 37 and its associated three megahertz guard band between wireless downlink spectrum and channel 37 also serves as the guard band between wireless downlink and television spectrum.

[33] *See Incentive Auction R&O*, 29 FCC Rcd at 6576-6577, para. 22.

[34] *See Incentive Auction R&O*, 29 FCC Rcd at 6845, para. 683-684.

[35] *See Incentive Auction R&O,* 29 FCC Rcd at 6846, para. 687.

[36] *See Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap,* ET Docket No. 14-165, *Notice of Proposed Rulemaking*, 29 FCC Rcd 12248 (2014) (*Notice*).

on rules for the operation of unlicensed white space devices, unlicensed wireless microphones and wireless microphones licensed under Part 74 in the 600 MHz service band.

IV. DISCUSSION

19. In this Report and Order, we first address modifications to our Part 15 rules for white space devices and unlicensed microphone operations in the TV bands. We then address issues regarding the operation of white space devices and wireless microphones in four segments of the 600 MHz band. First, we discuss requirements for white space devices and unlicensed wireless microphone operation in the 600 MHz guard bands to protect adjacent TV and wireless downlink services from harmful interference. Second, we discuss requirements for white space devices and wireless microphone operation in the 600 MHz duplex gap to protect adjacent wireless downlink and uplink services from harmful interference, and apportion the spectrum in this band among unlicensed and licensed wireless microphones and white space devices. Third, we address requirements for white space device and wireless microphone operations in the portion of the 600 MHz band that will be allocated and assigned to new Part 27 licensees to protect incumbent TV and new wireless services from harmful interference. White space devices can continue to operate in the 600 MHz service band where new wireless licensees have not commenced operations, and wireless microphones can operate in the band during the post-auction transition period on a non-interference basis. Finally, we address issues regarding the operation of white space devices on channel 37.

20. Following the frequency band discussion, we address modifications to our Part 15 rules for white space databases to implement some of our decisions here, and transition dates for the certification and marketing of unlicensed white space devices and unlicensed wireless microphones to ensure compliance with the new rules.

A. TV Bands

21. In this section, we address issues regarding white space device operations in the TV bands to achieve more efficient use of spectrum by providing flexibility for their operation without causing harmful interference to broadcast services.[37] We modify our Part 15 rules to permit the operation of fixed white space devices closer to or adjacent to occupied TV channels and specify technical requirements for fixed device operation at power levels below four watts (*e.g.,* conducted, PSD and adjacent channel limits). The decisions we make for modifying our fixed device rules in the TV bands inform our analysis below for fixed device operation in the 600 MHz guard bands. We also expand the permissible frequencies for fixed and personal/portable operation to include spectrum below TV channel 20, as well as the vacant channels above and below channel 37 that are now available only for wireless microphone use.

22. We also address here modification to our Part 15 rules for unlicensed wireless microphone operations in the TV bands. These decisions become the foundation for our analysis for wireless microphone operation in the 600 MHz guard bands and duplex gap, discussed below.

23. Today, the Commission's Part 15, Subpart H rules allow unlicensed fixed and personal/portable devices to operate in the TV bands at locations where frequencies are not in use by licensed services. These devices are commonly referred to as TV white space (TVWS) devices because

[37] NAB argues that the Commission cannot reasonably liberalize the white space rules before correcting flaws with the white space databases. *See* NAB *ex parte* filing dated June 22, 2015 at 1. It suggests that the Commission review the functioning of the databases and revisit its rules as needed to ensure that the rules provide a sharing framework that function for all stakeholders. *See* NAB Comments at 13. NAB recently came to an agreement with white space device manufacturers regarding certain aspects of the database. *See* NAB *ex parte* filing dated July 17, 2015. Commission staff continues to collaborate with stakeholders to improve the databases. The Commission will commence a proceeding by the end of this year to address a petition for rulemaking filed by NAB asking that the white space rules be modified to ensure that location information for white space devices is accurate and addressing NAB's recent agreement with manufacturers. *See* Public Notice, Report No. 3016 (April 1, 2015).

the rules were designed specifically for unlicensed operations in the TV bands. In the *Notice* in this proceeding, we proposed to modify these rules to refer instead to "white space devices" to create one unified set of rules for unlicensed white space operations in the TV bands and the 600 MHz band spectrum.[38] In this Report and Order, we modify the Part 15 rules to replace the term "television band device" or "TVBD" with the term "white space device" throughout Subpart H.[39]

1. Fixed white space devices

24. To protect licensed and certain other protected services from interference, the rules prohibit white space devices from operating within specified minimum distances of those services. These minimum distance standards vary according to the nature of the protected service and its susceptibility to interference and the power level and antenna height of the white space device. The range at which a white space device could cause harmful interference to authorized services increases with power and antenna height. To limit the interference potential from white space fixed devices, the Commission limited them to 1) one watt conducted transmitter power (*i.e.,* power supplied to the antenna) and up to four watts EIRP using an antenna with 6 dBi of gain, and 2) an antenna height of 30 meters above ground level (AGL) and 250 meters above average terrain (HAAT).[40] The Commission adopted the 30-meter AGL limit as a balance between the interests of providing for white space device transmission range and minimizing the interference impact on licensed services.[41]

25. We modify our Part 15 rules to provide fixed white space devices access to more vacant TV channels than permitted under the current rules. We adopt rules to allow fixed white space to operate where there are two contiguous vacant channels, rather than requiring three contiguous vacant channels under the current rules. We also adopt rules to allow fixed white space devices to operate with power levels ranging from 40 milliwatts EIRP to four watts EIRP and to specify the conducted power, power spectral density (PSD), and adjacent channel emission limits within this range. This will allow fixed white space devices at a maximum power level of 40 milliwatts EIRP to operate adjacent to occupied TV channels, *i.e.*, within the contour of adjacent channel TV stations, consistent with the rules for similarly powered personal/portable white space devices. We will also allow fixed devices with a power level of four watts EIRP or less to operate at closer separation distances from the protected contours of co-channel and adjacent channel TV stations than the rules currently allow.[42] Mode I personal/portable devices will continue to operate in the TV bands as the rules currently permit.[43] Because we are adopting changes that allow the operation of fixed and Mode II personal/portable devices at shorter distances from co-channel

[38] No parties objected to this proposal.

[39] This change requires the modification of terminology in a large number of places in the white space device rules. Therefore, for clarity, Appendix A shows Subpart H in its entirety with the revisions to terminology and the technical rule changes adopted in this Report and Order.

[40] *See* 47 C.F.R. § 15.709(b)(2). The antenna height above ground level (AGL) is the distance from the antenna center of radiation to the ground directly below the antenna. To calculate the antenna height above average terrain (HAAT), the average elevation of the surrounding terrain above mean sea level must be determined along at least 8 evenly spaced radials at distances from 3 to 16 km from the transmitter site. The HAAT is the difference between the antenna height above mean sea level (the AGL plus the site elevation) and the average elevation of the surrounding terrain.

[41] *See White Spaces Third MO&O,* 27 FCC Rcd at 3697, para. 14.

[42] Because the separation distances for personal/portable devices are based on those for fixed devices at low antenna height, we will also allow personal/portable devices to operate at shorter separation distances from the contours of co-channel and adjacent channel TV stations. However, fixed and personal/portable devices operating at a power level of 40 milliwatts or less will not have to comply with minimum separation distance requirements from the protected contour of adjacent channel TV stations.

[43] Mode I TVWS devices do not have an internal geo-location capability and must obtain a list of available operating channels from a nearby fixed or Mode II personal/portable TVWS device. *See* 47 C.F.R. § 15.703(e).

and adjacent channel TV contours, we also make certain changes to the separation distance requirements for Mode I devices to ensure that they do not cause harmful interference to TV reception.

a. Operation in less spectrum

26. *Background.* Fixed white space devices, which can operate with a maximum power of four watts EIRP, are not permitted to operate on channels that are adjacent to occupied TV channels under the current rules. They must always operate outside the defined service contours of adjacent channel TV stations by a minimum distance specified in the rules.[44] The Commission adopted this requirement because it initially established separation distances for fixed devices based only on the maximum four watt power level to minimize complexity for compliance, and it determined that white space devices could not operate at this power level within the service contours of adjacent channel TV stations.[45] The Commission recognized that prohibiting fixed devices from operating on first adjacent channels would have the effect of limiting the number of channels that are available for use by those devices in some markets, and stated that it would revisit this matter if a solution to allow adjacent channel operation is developed.[46]

27. Like fixed white space devices, personal/portable devices, which can operate with a maximum power of 100 milliwatts EIRP, are generally required to operate outside the defined service contour of adjacent channel TV stations. However, personal/portable devices are permitted to operate within the service contour of adjacent channel TV stations if they reduce their power to 40 milliwatts EIRP. There is currently no corresponding provision in the rules that permits fixed devices to operate within the service contour of adjacent channel stations at reduced power. The requirement for fixed white space devices to avoid adjacent channel operation means that they may operate only at locations where there are three contiguous vacant TV channels, regardless of how low they reduce their operating power. After the incentive auction and subsequent repacking, we expect that there will be fewer locations where three contiguous vacant channels exist, particularly in urban areas, thus limiting the locations where fixed devices may be used.

(i) Adjacent to occupied channels

28. *Background.* In the *Notice*, the Commission proposed to allow fixed white space devices to operate adjacent to occupied TV channels (*i.e.,* within their service contour), provided the operating power is reduced to 40 milliwatts EIRP. This is the same maximum power level that the rules permit for personal/portable devices that operate adjacent to occupied TV channels. Parties representing the interests of white space device users support this proposal; those representing broadcasters oppose it.[47]

29. *Discussion.* We will allow fixed white space devices to operate adjacent to occupied TV channels at a power level of 40 milliwatts EIRP. This action provides consistent treatment of similarly powered devices and will allow the use of fixed devices in more locations than the current rules allow, *i.e.,* where there are fewer than three contiguous vacant channels, while at the same time protecting licensed users from harmful interference. It will also allow fixed white space devices to operate in the 600 MHz guard band immediately adjacent to the remaining TV spectrum. We will limit the height of 40

[44] *See* 47 C.F.R. § 15.712(a)(2). These separation distances vary from 0.7 to 2.4 kilometers, depending upon the height above average terrain (HAAT) of the fixed device antenna.

[45] *See White Spaces Second Report and Order,* 23 FCC Rcd at 16870-16871, para. 181.

[46] *See White Spaces Second Report and Order,* 23 FCC Rcd at 16876, para. 170. The Commission encouraged interested parties to continue to explore possible options for operating on first adjacent channels that will not increase the potential for harmful interference to television service.

[47] *See* Alarm Industry Communications Committee Reply Comments at 5, Adaptrum Comments at 7, Google Comments at 43, Motorola Comments at 4, NAB Comments at 4-6 (opposing proposal), Spectrum Bridge Comments at 3, White Space Alliance Comments at 16, Wi-Fi Alliance Comments at 12, and WISPA Comments at 8.

milliwatt fixed devices to 10 meters above ground level (AGL) to limit their interference potential to TV reception on adjacent channels.[48]

30. We disagree with NAB that operation of fixed devices at 40 milliwatts EIRP on channels adjacent to occupied TV channels poses a high risk of harmful interference to television reception. We first note that in establishing the technical rules for white space devices, the Commission considered and decided not to permit fixed white space device operation adjacent to occupied TV channels, based on fixed devices operating at a power level of four watts EIRP.[49] However, the Commission also stated that these rules were a conservative first step, and that it would consider in the future any changes to the rules that may be appropriate to provide greater flexibility for development of this technology.[50] In this case, we are allowing fixed devices to operate on adjacent channels at a much lower power level than the Commission previously considered, specifically, the same 40 milliwatt power level that the Commission previously determined could be used by personal/portable devices operating adjacent to occupied TV channels without causing harmful interference.[51] We recognize NAB's argument that there are certain differences between fixed and personal/portable devices that can affect their interference potential, such as the antenna height and building and body losses.[52] In particular, NAB argues that fixed devices may operate with a higher antenna height than portable devices and thus could have a greater chance of causing harmful interference to adjacent channel TV reception than portable devices at the same power level. We agree that, as antenna heights get higher above ground, the signals generally can be received at longer distances as there are fewer losses due to ground clutter. By limiting antenna height, however, we can limit the distance at which a fixed white space device could cause interference to television reception. Therefore, we are taking the added measure in our rules of limiting antenna height above ground level for 40 milliwatt fixed devices operating adjacent to an occupied TV channel to no more than 10 meters, where the current rules allow such heights up to 30 meters.[53] By limiting the white space antenna height to the same height assumed in OET Bulletin 69 (OET-69) for television antennas,[54] this requirement will keep the transmission distance for white space systems sufficiently short to minimize the potential of causing harmful interference to TV reception while still providing increased opportunities for the provision of service.

31. There are also a number of additional factors that, coupled with the antenna height restriction, will limit fixed devices' potential for causing harmful interference. First, interference to TV reception from an adjacent channel transmitter occurs only when the signal from that transmitter is substantially greater than the received TV signal level (*i.e.*, at least 33 dB greater).[55] Thus, adjacent channel interference from a white space device to television reception is most likely to occur where the television signal is weak, such as at the edge of a station's coverage area and an outdoor directional rooftop TV antenna is needed. Fixed white space devices must also use directional antennas to transmit at the

[48] The antenna height above ground level (AGL) is the distance from the antenna center of radiation to the ground directly below the antenna.

[49] *See White Spaces Second R&O,* 23 FCC Rcd at 16867-16868, para 172.

[50] *See White Spaces Second R&O,* 23 FCC Rcd at 16808, para 1.

[51] *See Second Report and Order and Memorandum Opinion and Order* ("*White Spaces Second R&O*") in ET Docket Nos. 02-380 and 04-186, 23 FCC Rcd 16807, 16868-16869 (2008), para. 176-177.

[52] *See* NAB Comments at 6.

[53] *See* 47 C.F.R. § 15.709(b)(2).

[54] *See* OET Bulletin 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference;" Available at: https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf.

[55] The Commission previously found that the median adjacent channel rejection of TV receivers was about 5 dB better than the ATSC standard when the desired TV signal was near the threshold of service. *See White Spaces Second R&O*, 23 FCC Rcd at 16869, para. 177.

maximum EIRP allowed by the rules.[56] Under these conditions, the worst case for harmful interference occurs when both the white space device antenna and TV receive antenna are pointed directly towards each other over a short separation distance. We believe the situation where both antennas would be oriented in such a way that the maximum white space signal would be in the main beam of a TV receive antenna is a low probability event.[57] Further, even if the TV receive antenna and the fixed white space device were pointed towards each other in substantially the same horizontal direction, we believe that the height disparity between TV transmit antennas and white space transmit antennas will still ensure some discrimination between the two signals at a TV receive antenna due to the TV receive antenna's vertical radiation pattern.[58] Second, contrary to NAB's assertion, we are requiring 40 milliwatt fixed devices to meet the same out-of-band emission as 40 milliwatt personal/portable devices.[59] These limits will reduce the likelihood of harmful interference to adjacent channel TV reception. In addition, the rules require white space devices to incorporate transmit power control and operate with the minimum power necessary to communicate.[60] This further reduces the likelihood of adjacent channel interference by, in many cases, reducing the level of the undesired white space device signal with respect to the desired television signal.[61] Finally, we note that because of the low power limit and antenna height restriction on white space devices, harmful interference would occur only at short distances making identification of a fixed device that may be causing harmful interference fairly straightforward since those devices' locations must be registered in the database.

(ii) Two contiguous vacant channels

32. *Background.* In the *Notice*, the Commission proposed to allow fixed devices to operate with a maximum power of four watts EIRP at locations where there are two contiguous vacant channels rather

[56] The current rules limit the power that can be supplied to the antenna input (*i.e.,* conducted power) of a fixed white space device to less than the maximum permissible radiated power (*i.e.*, power radiated from the transmitting antenna towards the receiving antenna) necessitating fixed white space devices to use directional antennas to attain the maximum permissible radiated power. Similarly, the rules we are adopting herein, *see infra* paras. 22-23, for lower power fixed operation place limits on the conducted output power of a white space device and allows for the use of an antenna with up to 6 dBi gain when operating with the maximum permissible conducted output power. Thus, the maximum EIRP for all fixed devices regardless of its radiated power is obtained only when using an antenna with at least a 6 dBi gain. When the maximum antenna gain exceeds 6 dBi, the conducted output power must be reduced by the amount the antenna gain exceeds 6 dBi.

[57] For example, OET 69 defines a UHF TV receive antenna pattern used in analyzing interference to TV reception. The 3 dB (half power) beamwidth of this pattern is approximately 45 degrees. Assuming that a white space device transmit antenna has a similar beamwidth since it is in the same frequency band, the probability of the transmit and receive antenna main beams overlapping is low.

[58] A TV receive antenna has directionality in the vertical plane. It receives the maximum signal in the horizontal plane (*i.e.,* level with the antenna), and has lower gain at angles below the horizontal plane (*i.e.,* when a transmitter is at a lower height than the antenna.) In addition, we note that TV transmits with horizontal polarization and that white space providers can take advantage of using vertical polarization to provide even more isolation between the signals. However the rules do not require white space devices to use vertical polarization.

[59] *See* NAB Comments at 6-7. The out-of-band emission limits that we are adopting for 40 milliwatt fixed devices are discussed in paragraph 42.

[60] *See* 47 C.F.R. § 15.709(a)(3). Transmit power control is a mechanism used to adjust the power of a radio transmitter to the minimum necessary to maintain its communication link at a certain level of quality. Transmit power control allows for more efficient spectrum use by minimizing interference to other devices, and allows for increased battery life in battery operated equipment.

[61] As discussed above, adjacent channel interference generally does not occur unless the adjacent channel signal level is at least 33 dB greater than the desired signal level. Some TV receivers may have even greater adjacent channel interference rejection capabilities. *See White Spaces Second R&O*, 23 FCC Rcd at 16869, para. 177.

than three.[62] Under this proposal, the signal of a white space device would be centered on the boundary between the two vacant television channels, effectively reducing the frequency separation to the white space signal from six to three megahertz on each side of the white space channel. Proponents of expanded opportunities for white space devices support this proposal while broadcasters and wireless microphone interests express opposition.[63] NAB expressed concern that operation at the four watt power level proposed in the *Notice* would cause harmful interference, while Shure expressed concern that this change would reduce the amount of adjacent channel spectrum available for wireless microphones.[64]

33. *Discussion*. We will allow fixed white space devices to operate with a maximum of 100 milliwatts EIRP at locations where there are at least two contiguous vacant TV channels and the white space device's signal occupies one or more six megahertz bands provided that there is at least three megahertz separating the white space emissions from the edge of lowest and highest vacant TV channels. For the case where the fixed white space device operates on two contiguous white space channels, this corresponds to the white space device operating with 50 milliwatts EIRP in a three megahertz segment of each TV channel, leaving a frequency separation of three megahertz between the white space device's operating frequency and the edges of the occupied adjacent TV channels. This action will allow fixed white space devices operating on the boundary of two vacant TV channels to transmit at a power level in each channel that is 1 dB above the maximum 40 milliwatt EIRP level we are allowing for fixed devices that operate wholly within an occupied adjacent TV channel.[65]

34. The current rules preclude fixed devices from operating unless there is a vacant TV channel above and below their channel. Such operation is inefficient as it requires three or more contiguous vacant TV channels in order for a fixed device to operate; a situation compounded in congested areas where there are few or no instances where three or more contiguous TV channels are vacant. This rule change will allow 100 milliwatt fixed devices to operate within the service contour of adjacent channel TV stations if their signals are three megahertz removed from the adjacent channel (*i.e.*, there is a three megahertz guard band between the white space signal and the edge of the adjacent TV channel). The White Space Alliance, Wi-Fi Alliance, and WISPA support this change arguing that it will expand their ability to deploy white space broadband systems by significantly increasing spectrum availability for fixed white space devices.[66]

35. The 100 milliwatt EIRP limit we are establishing for operation at the center of two vacant TV channels is based on the lower susceptibility of television receivers to harmful interference from a white space signal that is three megahertz away from the edge of an occupied television channel than they are to a white space signal with no frequency separation to the occupied TV channel. NAB, in opposing the Commission's proposal to allow four watt fixed operation spanning two channels, points to OET receiver study results showing that a one megahertz signal centered in an adjacent channel (*i.e.*, 2.5 megahertz away from the edge of an occupied TV channel) has the same interference potential as a wider band

[62] *See Notice*, 29 FCC Rcd at 12259, para. 37.

[63] *See* Alarm Industry Communications Committee Reply Comments at 5, Adaptrum Comments at 7, Google Comments at 43, Microsoft Comments at 45-46, NAB Comments at 8-9 (opposing proposal) Reply Comments at 5-6, Shure Comments at 27 (opposing proposal), White Space Alliance Comments at 10, Wi-Fi Alliance Comments at 12, and WISPA Comments at 8 Reply Comments at 7-9, xG Technology at 6.

[64] *See* NAB Comments at 8-9 and Reply Comments at 5-6, and Shure Comments at 27.

[65] The power spectral density rules require that a white space device spread its power evenly across the six megahertz TV channel. If a white space device at 100 milliwatts operates at the center of two channels, half the power or 50 milliwatts will fall in each channel. This increase in power in each channel represents a 1 dB increase over the 40 milliwatts currently permitted for operation on an occupied adjacent TV channel.

[66] *See* White Space Alliance Comments at 10, Wi-Fi Alliance Comments at 12, and WISPA Comments at 7.

signal immediately adjacent to an occupied TV channel.[67] We note, however, that a one megahertz signal in the center of an adjacent channel and at the same power as a digital television signal is not representative of a six megahertz white space signal that has been shifted 3 megahertz away from the channel edge. This is borne out by examining the Consumer Electronics Association (CEA) study submitted in GN Docket No. 12-268 and ET Docket No. 14-14, our proceeding on interservice interference between the broadcast television and wireless services. That study, *inter alia*, examined the interference rejection of digital television receivers to five megahertz LTE signals at various frequency separations from the TV channel edge. It indicated that the tested TV receivers were less susceptible to interference from an LTE signal with three megahertz frequency separation from a TV channel than an LTE signal immediately adjacent to a TV channel. The study showed that the reduced susceptibility to interference in this case ranged from 1.9 dB to 8.9 dB when the desired TV signal was very weak and from 2 dB to 12.4 dB when the desired TV signal was weak. On average a three megahertz separation provided an extra 3.9 dB margin for the very weak desired TV signal and 4.8 dB margin for the weak desired TV signal.[68] White space signals have noise-like characteristics[69] similar to LTE signals and can therefore be expected to pose similar potential for interference to television signals as LTE signals.[70] Based on CEA's study, we conclude that for the worst case receiver tested, the power of a fixed white space device operating in the center of two vacant TV channels, *i.e.*, three megahertz from each occupied adjacent TV channel, could be increased by as much as 1.9 dB over a signal that is at the edge of an adjacent channel and that most receivers have additional margin beyond that.

36. The 100 milliwatt white space power level we adopt for operation centered on the boundary of two vacant TV channels (*i.e.,* 50 milliwatts in a three megahertz segment of each channel) is 1 dB higher than the 40 milliwatt limit we are allowing for fixed devices operating with no frequency separation from occupied TV channels[71] and is therefore within the margin of additional interference provided by the three megahertz separation. We also observe that the out-of-band emissions limit for

[67] *See* OET Report FCC/OET 07-TR-1003, *Interference Rejection Thresholds of Consumer Digital Television Receivers Available in 2005 and 2006*, March 30, 2006, Figure 2-1 and Section 7.

[68] *See* Consumer Electronics Association, written *ex parte* presentation in *GN Docket No. 12-268* and *ET Docket 14-14* attachment "Recent Consumer DTV Receivers With Respect To TV & LTE Interference", Meintel, Sgrignoli and Wallace (Gary Sgrignoli), May 22, 2014, at Tables G-17 and G-19 (pp. 82-83).

[69] *See*, *e.g.*, Base signal spectrum analyzer measurements in test reports associated with Adaptrum certification application, FCC ID: A2UACRS20F and 6Harmonics certification application, FCC ID: 2AASTGWS-3000 showing noise-like characteristics exhibited by the white space devices.

[70] Tests conducted by our Laboratory showed that both LTE and DTV signals are "noise-like." *See* Office of Engineering and Technology Seeks Comment on Measurements of LTE into DTV Interference, Public Notice, GN Docket No. 12-268, ET Docket No. 14-14, 29 FCC Rcd 7415, 7433 (2014) (OET Measurements Report). In the interservice interference proceeding, the Commission found that the noise-like LTE signals have about the same potential for causing interference to digital television signals as digital television signals. White space devices, which are similar to digital television signals, have the same interference potential with respect to television service. However, the interference potential used to protect television service from white space devices (and from wireless operations at 600 MHz) are somewhat less restrictive than the DTV-to-DTV interference protection criteria in the rules because the white space and LTE/wireless interference standards are based on receiver studies which show that less protection than that provided in the rules is actually needed. *See Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television and Wireless Services*, ET Docket No. 14-14, Second Report and Further Notice of Proposed Rulemaking, 29 FCC Rcd 29 13071, 13093 (2014). *See also Unlicensed Operation in the TV Broadcast Bands*, ET Docket No. 04-186, Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd 16806, 16861 and 16864 (2008).

[71] Under the rules we are adopting in this Report and Order, a 40 milliwatt white space device could transmit in each of two adjacent vacant channels providing a total of 80 milliwatts across those two channels. *See* paragraph 29, *supra.* The increase to 100 milliwatts represents a 1 dB increase.

white space devices specifies a sharp roll-off that will serve to reduce the amount of out-of-band emissions that appear in the pass-band of a television receiver and further reduce the potential for interference. We find that the three megahertz of separation coupled with the white space emissions roll-off represents a conservative approach to allowing additional power for devices operating between two adjacent channels and will protect adjacent channel television stations from interference. However, to provide an additional measure of interference protection to TV reception, we are limiting such operation to antenna heights of 10 meters AGL or less. This is consistent with our decision above to limit 40 milliwatt fixed devices operating immediately adjacent to an occupied TV channel to antennas heights of 10 meters or less.[72] This rule change will enhance the opportunities for fixed white space devices and increase spectrum utilization without causing harmful interference.

37. We are not adopting a four watt EIRP limit as proposed for white space device operation at the center of two contiguous white space channels. NAB objects to that proposal stating that to satisfy the television adjacent channel -33 dB D/U interference criterion would require approximately 800 meters separation between a white space device and a television receiver under free space conditions.[73] However, by limiting the increase to 100 milliwatts, we calculate that under ideal free space conditions and without accounting for the sharp emissions roll-off of white space devices the required separation distance only increases by eleven meters over the separation distance needed to protect television from a 40 milliwatt white space devices.[74] In addition, the same factors that limit the interference potential of fixed white space devices on adjacent channels limit the interference potential in this case, including the 10 meter height limit and the directionality of the transmit and receive antennas.[75] Further, in the *Notice*, we observed that several studies appeared to indicate that operation between vacant channels at the higher four watt power level might not increase the potential for interference to television reception.[76] However, as pointed out by NAB, those studies examined interference issues to receivers in foreign television markets that use an analog transmission standard that is different from the U.S. television transmission standard. Thus, those studies cannot be relied upon to support a conclusion that white space device operation at powers up to four watts between occupied adjacent TV channels would not cause interference to television service in the U.S.[77] No additional information supporting the proposition that fixed white space devices could operate at those higher power levels in an adjacent TV channel was submitted in the record. We also are not aware of any studies or other information from other sources that would support a conclusion that fixed devices could operate at up to four watts on adjacent TV channels without causing interference to reception of television service. However, should new studies and information become available in the future showing that such operation is possible without causing interference to TV reception, we may revisit this issue in the future.

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[72] *See* para. 29, *supra.*

[73] *See* NAB Comments at 10-11. To calculate the separation distance, NAB assumed a DTV signal threshold of -83 dBm and a desired to undesired signal ratio (D/U) of -33. *See White Spaces Second R&O*, FCC Rcd 16867, para.171 specifying use of the adjacent channel -33 D/U as specified in ATSC Recommendation A/74. The ATSC provides recommended guidelines for DTV receiver performance in its document, "ATSC Recommended Practice: Receiver Performance Guidelines," ATSC Doc. A/74, 17 June 2004.

[74] The eleven meter increase was calculated by assuming a DTV signal threshold of -84 dBm (-84 dBm is the DTV signal threshold used throughout the white space proceeding); 1 dB more conservative than NAB's analysis. *See*, *e.g.*, *White Spaces Second R&O*, FCC Rcd 16843, paras.76-77.

[75] *See* para. 30-31, *supra.*

[76] *See Notice*, 29 FCC Rcd at 12259, para. 37.

[77] *See* NAB Comments at 9-10. NAB observes that these studies – one in South Africa and the other in Ghana – examined white space device operation on channels adjacent to 8 megahertz analog PAL system TV operations, not digital TV operations. Further, the South African study did find a potential for interference to television reception within 200 meters (or 656 feet) of the TVWS device.

38. The White Space Alliance and WISPA suggest that we also authorize similar "between channel" operations over three or more adjacent channels, which would allow at least 12 megahertz to be used over three channels, rather than six megahertz under the current rules.[78] WISPA submits that, for example, where there are four contiguous unoccupied TV channels, unlicensed use should be permitted on all but the upper and lower three megahertz of the block, enabling 18 megahertz – the middle two channels plus three megahertz from each of the outer two channels – to be available for unlicensed use. Such use is consistent with our decision below regarding channel aggregation whereby we are allowing white space devices to aggregate as many contiguous channels as available and transmit a wide signal across all of them to provide greater data rates.[79] Thus we will allow fixed white space devices to aggregate multiple available channels and transmit at a maximum of 100 milliwatts EIRP per channel so long as the white space signal occupies only three megahertz of the lowest and highest channel and the power spectral density requirements, the antenna AGL limit of 10 meters, and all separation criteria are met for each occupied channel. Where available, such operation will greatly increase the data rates available to white space device users.

39. We will not limit or otherwise restrict the ability for white space devices to operate across multiple available channels in order to preserve spectrum for wireless microphones as requested by Shure.[80] The rules we are adopting here and throughout this proceeding apply to the available spectrum to be shared by both wireless microphones and white space devices. Thus, we see no justification for restricting fixed white spaces from operating at the center of two adjacent TV channels to retain spectrum for the exclusive operation of wireless microphones.[81]

b. Operation at lower power levels

40. *Background*. The rules currently define three power levels for fixed and Mode I and Mode II personal/personal portable white space devices: 4000 milliwatts EIRP for fixed devices, 100 milliwatts EIRP for personal/portable devices outside the contour of adjacent channel TV stations, and 40 milliwatts EIRP for personal/portable devices inside the contour of adjacent channel TV stations.[82] However, the current table of separation distances in Section 15.712(a)(2) was calculated based solely on the fixed device maximum EIRP of 4000 milliwatts, which results in greater distances than necessary to protect TV reception from white space devices operating at lower power levels than the maximum allowed. Permitting shorter separation distances for white space devices operating at less than 4000 milliwatts EIRP can expand the locations at which they can operate without causing harmful interference.

41. In the *Notice,* the Commission proposed to provide flexibility for white space device users by defining a number of lower power levels for white space devices with correspondingly shorter separation distances than the current rules require. Specifically, the Commission proposed to define separation distances for fixed devices at EIRP levels of 40 milliwatts, 100 milliwatts, 250 milliwatts, 625 milliwatts and 1600 milliwatts (*i.e.,*16 dBm, 20 dBm, 24 dBm, 28 dBm and 32 dBm, respectively) in addition to the

[78] *See* Wi-Fi Alliance Comments at 10 and WISPA Comments at 8.

[79] *See* para. 48, *infra.*

[80] *See* Shure Comments at 27.

[81] We note that wireless microphones will have some exclusive spectrum on which to operate. In all cases, licensed wireless microphones will be able to operate in four megahertz of the duplex gap. In addition, unlicensed wireless microphones will be able to operate in portions of the guard band not available for white space devices including a portion of the three megahertz guard bands that may be on either side of channel 37 (if 84 megahertz of TV spectrum or more is recovered in the incentive auction). *See* paragraphs 153, 148 and 149, *infra*.

[82] *See* 47 C.F.R. § 15.709(a)(1)-(2). The rules also specify a maximum power limit of 50 milliwatts EIRP for personal/portable white space devices that rely on spectrum sensing. However, the Commission did not propose any changes to the technical requirements for these devices, and we are therefore not adopting any changes herein. *See* 47 C.F.R. § 15.717(b).

current separation distances at 4000 milliwatts (36 dBm).[83] It also proposed that a device be required to indicate to the white space database the power at which it will operate when it requests a list of available channels.[84] In addition, the Commission proposed conducted power, PSD and adjacent channel emission limits for fixed devices operating at the lower power levels.[85] It further proposed that when a device operates between two defined power levels, it must comply with the separation distances and adjacent channel emission limits for the higher power level, while the conducted power and PSD limits must be linearly interpolated between the defined values.[86] In addition, the Commission proposed that when the maximum gain of a fixed device antenna exceeds 6 dBi, the maximum conducted power, PSD and adjacent channel emission limits for each EIRP level be reduced by the amount in dB that the maximum antenna gain exceeds 6 dBi.[87]

42. *Discussion.* The record supports defining additional power levels for fixed devices with shorter separation distances from TV service contours.[88] Thus, we are defining EIRP, conducted power, PSD and adjacent channel emission limits for fixed devices as proposed in the *Notice* and as shown in the following table.[89]

EIRP limit (6 MHz)	Conducted power limit (6 MHz)	PSD limit (100 kHz)	Adjacent channel emission limit (100 kHz)
16 dBm (40 mW)	10 dBm (10 mW)	-7.4 dBm	-62.8 dBm
20 dBm (100 mW)	14 dBm (25 mW)	-3.4 dBm	-58.8 dBm
24 dBm (250 mW)	18 dBm (63 mW)	0.6 dBm	-54.8 dBm
28 dBm (625 mW)	22 dBm (158 mW)	4.6 dBm	-50.8 dBm
32 dBm (1600 mW)	26 dBm (400 mW)	8.6 dBm	-46.8 dBm
36 dBm (4000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm

43. We are adopting the proposed requirement to adjust these conducted power limits when higher gain antennas (greater than 6 dBi) are used to limit the maximum radiated emissions. Specifically,

[83] *See Notice*, 29 FCC Rcd at 12260, para. 40.

[84] *Id.*

[85] *See Notice*, 29 FCC Rcd at 12261, 12266, paras. 42, 59.

[86] *See Notice*, 29 FCC Rcd at 12260, 12266, paras. 41, 59.

[87] *See Notice*, 29 FCC Rcd at 12260-12261, 12266, paras. 41, 61.

[88] *See* Alarm Industry Communications Committee Reply Comments at 6, Anant Sahai Comments at 1, Dynamic Spectrum Alliance Comments at 5, Google Comments at 45, Microsoft Comments at 45, Motorola Comments at 4, Runcom Technologies Comments at 1, Spectrum Bridge Comments at 4, White Space Alliance Comments at 11, Wi-Fi Alliance Comments at 12, and WISPA Comments at 10. NAB does not oppose a graduated scale for intermediate power levels, provided the power levels are determined automatically and cannot be changed by a user. *See* NAB Comments at 13. Shure does not object to allowing white space devices to operate at lower power levels as long as the current minimum distance separations to wireless microphones are maintained. *See* Shure Comments at 27.

[89] The EIRP (effective or equivalent isotropically radiated power) is a characterization of the power radiated from an antenna. All else being equal, an increase in the EIRP will increase the signal propagation distance. The conducted power is the power from the transmitter into the antenna input. For a given antenna, the EIRP will increase or decrease by the same amount as the power conducted into the antenna. The power spectral density (PSD) is a characterization of how the energy from a transmitter is spread across the operating channel. The white space PSD limits were designed to ensure that the energy from a transmitter is spread uniformly across most of a channel, while allowing for roll-off near the channel edges to comply with the adjacent channel emission limits. *See White Spaces Third MO&O*, 27 FCC Rcd at 3703-3704, para. 30.

we will require that when the maximum gain of a fixed device antenna exceeds 6 dBi, the maximum conducted power, PSD and adjacent channel emission limits for each EIRP level be reduced by the amount in dB that the maximum antenna gain exceeds 6 dBi. This requirement is consistent with the current white space rules and is necessary to limit the maximum radiated power from white space devices.[90] We are also adopting the proposed requirement that when a white space device operates between defined EIRP levels, the conducted power and PSD limits must be linearly interpolated between the defined values.[91] This requirement provides flexibility to operate at precise power levels appropriate for an application while taking advantage of a 6 dBi gain antenna. We are also adopting the proposed requirement that when a white space device operates between two defined power levels, it comply with the adjacent channel emission limit for the higher power level.[92] This requirement is consistent with the adjacent channel emission limits adopted in the *White Spaces Third MO&O*.[93] In that proceeding, the Commission established adjacent channel emission limits based on the maximum operating power for a white space device, and did not require any reduction in the limits for a device operating at less than the maximum power. We are adopting a similar approach in this case, except that when the operating power of a device is reduced by at least 4 dB, it must then comply with an adjacent channel emission limit that is 4 dB lower. We find that this difference is appropriate because white space devices operating at lower power levels will now be permitted to operate closer to authorized services on adjacent channels, so there is a need to reduce the adjacent channel emission limits for lower power devices to reduce the potential for harmful interference. We do not believe that this reduction in adjacent channel emission limits will significantly affect equipment costs because the lower emission limits apply only to equipment operating at lower power levels, so there is no increase in the amount of attenuation required to comply with the limits (*i.e.,* the difference between the in-band and adjacent channel power levels).

44. We will require that fixed white space devices supply their geographic coordinates and antenna height above ground when querying a database for the list of available channels at their location. The database will supply the list of available channels and the maximum power level for each channel. This approach is supported in the record.[94] We believe that this approach is more efficient than requiring devices to specify a power level in advance because it will allow devices to obtain a list of all available channels at a location along with the maximum permissible power levels in a single query.[95] We will also require that white space devices do not contain an interface that would allow users to select higher power levels than the database indicates are available for a channel at a given location.

45. We decline to define power levels and establish separation distances for white space devices at 12 dBm (16 milliwatts) and 8 dBm (6.3 milliwatts) as requested by the Wi-Fi Alliance.[96] The required co-channel separation distances would not be significantly less than those required for 40 milliwatt

[90] *See* 47 C.F.R. § 15.709(a)(1) and (a)(5).

[91] For example, if a fixed device operates at a power level of 34 dBm EIRP (2 dB below the defined level of 36 dBm EIRP), then the conducted power and PSD limits must also be reduced by 2 dB below the defined levels for a 36 dBm EIRP fixed device.

[92] For example, if a fixed white space device operates with a power level greater than 28 dBm EIRP but no greater than 32 dBm EIRP, it must comply with the adjacent channel emission limit for a 32 dBm EIRP device.

[93] *See White Spaces Third MO&O,* 27 FCC Rcd at 3703, para. 29.

[94] *See* Anant Sahai Comments at 1, Google Comments at 45, Motorola Comments at 4, WISPA Comments at 11and xG Technology Comments at 7.

[95] For example, there may not be any channels available at a particular location that can be used at four watts EIRP, but there may be some available at lower power levels. If a device queries the database for channels available at four watts, it will receive a response that there are none available. It will then have to query the database again requesting channels at lower power levels.

[96] *See* Wi-Fi Alliance Comments at 12.

devices (1300 meters), so this change would add additional complexity to the rules without making a significant amount of additional spectrum available for white space devices.[97]

c. Channel bonding

46. We adopt our proposals to allow white space devices to use multiple contiguous and non-contiguous channels (channel "bonding" or "aggregation").

47. *Background.* White space devices must comply with a two part out-of-band emission limit in most of the TV bands.[98] First, they must comply with a power limit (conducted for fixed devices and EIRP for portable devices) in the six megahertz television channels immediately adjacent to the channel in which the device operates.[99] Second, they must comply with the Section 15.209 radiated emission limits at frequencies beyond the six megahertz television channels immediately adjacent to the channel in which the white space device operates.[100] The current out-of-band emission rules were written as though a white space device would transmit on only a single six-megahertz TV channel and meet the appropriate out-of-band emission limits at all frequencies outside of this single channel. However, a white space device could be designed to use two or more channels simultaneously to increase its transmission bandwidth and maximum data rate. A device could use multiple non-contiguous channels, *i.e.* channel aggregation, or could use multiple contiguous channels, *i.e.* channel bonding.[101] Because the rules do not consider cases where a white space device transmits on multiple channels simultaneously, the Commission proposed in the *Notice* to modify the rules so that users could better make use of the efficiencies associated with channel aggregation and channel bonding.[102] A number of parties supported the proposed changes, while no parties opposed them.[103]

48. *Discussion.* We are making several rule changes that will enable manufacturers to incorporate channel bonding and aggregation into white space devices if they choose. These changes will permit the development of devices that transmit at higher data rates, thus making higher speed equipment available to consumers. With respect to channel bonding, we are modifying Section 15.709 and incorporating this change into section 15.709(d)(1) to specify that the adjacent channel emissions limits do not apply within an adjacent channel that is being used by the same white space device, since in such cases there would be no TV station or other authorized service to protect on the adjacent channel.[104] Instead, we will require that white space devices must meet these limits within the six megahertz bands immediately above and below the edges of the band of contiguous channels used by the white space device. We are also modifying the rules to require that a white space device must meet the Section 15.209 limits at

[97] Adjacent channel separation distances would not be required at these power levels.

[98] White space devices must comply with more stringent out-of-band emission limits on channels 36 through 38 than in the rest of the TV bands. *See* 47 C.F.R. § 15.709(c)(4). This issue is addressed below in the discussion of operation on channel 37.

[99] *See* 47 C.F.R. § 15.709(c)(1).

[100] *See* 47 C.F.R. § 15.709(c)(3).

[101] There is no specific prohibition in the current rules on the use of multiple channels by a white space device. In fact, the rules specify the maximum power limits per six megahertz of bandwidth, implying that a device could use multiple six megahertz channels. *See* 47 C.F.R. §§ 15.709(a)(1) and (2).

[102] *See Notice*, 29 FCC Rcd at 12265-12266, para. 56-57.

[103] *See* Adaptrum Comments at 8, Dynamic Spectrum Alliance Comments at 6, Google Comments at 45-46, Microsoft Comments at 43, Motorola Comments at 7, Runcom Technologies Comments at 1, Spectrum Bridge Comments at 4, White Space Alliance Comments at 14, Wi-Fi Alliance Comments at 19, and WISPA Reply Comments at 9.

[104] To operate on two adjacent channels, a white space device would need to receive a message from a white space database indicating that both channels are available at its location.

frequencies more than six megahertz above and below the edges of the highest and lowest channels used in the device, except when the device uses multiple non-contiguous channels as discussed below.[105] These requirements will also apply to fixed devices that operate centered on the boundary of two channels as discussed above, since that is a form of channel bonding. With respect to channel aggregation, the modified rules in Section 15.709(d)(1) require that when a white space device transmits on multiple non-contiguous channels simultaneously, it must comply with the adjacent channel emission limits in the six megahertz bands above and below each of the single channels or channel groups used by the white space device, and with the Section 15.209 limits beyond these six megahertz bands.

d. Operation in less congested areas

49. *Background*. Fixed white space devices must currently comply with a maximum four watt EIRP radiated power limit and a 30 meter AGL limit in all circumstances. In adopting these limits for fixed white space devices, the Commission recognized that there would be advantages such as reduced infrastructure costs and increased service range to allowing white space devices to operate at higher power levels.[106] Regarding antenna height, a higher AGL can improve signal propagation by raising the antenna above obstacles such as trees and buildings, but can also negatively impact spectrum sharing among white space devices in congested areas where there are few available channels. Thus, the Commission decided not to allow fixed white space devices to operate at power levels above four watts EIRP or antenna heights above 30 meters AGL due to concerns that it could increase the risk of interference to TV in congested areas and negatively impact the ability of white space device to share spectrum.[107]

50. In the *Notice*, the Commission sought comment on ways to provide more flexibility to white space device operators in rural areas. It sought comment on the definition of "rural" areas as it related to white space devices and suggested that it be defined as areas where at least half of the television channels are unused for broadcast services and available for white space use. The Commission also requested comment on whether to allow fixed white space devices to transmit using antennas mounted more than 30 meters AGL in rural areas and if so, the maximum height that should be allowed and whether it should also consider increasing the HAAT limit. The Commission also requested comment on whether to allow fixed white space devices in rural areas to operate with up to ten watts EIRP using higher gain antennas, *i.e.*, with gain up to 10 dBi, and as an alternative, or in addition to higher antennas, transmitter conducted power greater than one watt. The Commission further asked whether the power limit for personal/portable white space devices in rural areas should be increased. Proponents of white space devices, including manufacturers, users, and database system administrators are in favor of allowing additional flexibility for fixed white space devices in rural areas.[108] Wireless microphone manufacturers oppose expanding the operational limits for fixed white space devices in such areas.[109]

51. *Discussion*. We are modifying the rules to allow fixed white space device operators in less congested areas to radiate at levels beyond the current 4 watt EIRP limit up to 10 watts EIRP to increase their service range. This power increase will provide increased opportunities for white space operators to serve more distant customers at less cost and provide point to point backhaul services, while at the same time protecting authorized operations from harmful interference and avoiding any adverse effect on the

[105] *See* §15.709(d)(2) of the rules in Appendix A.

[106] *See White Spaces Second Report and Order,* 23 FCC Rcd at 16847, para. 106.

[107] *See White Spaces Second Report and Order,* 23 FCC Rcd at 16847, para. 106 and at 16886, para. 228.

[108] *See* Adaptrum Comments at 5, Anant Sahai Comments at 1-3, Deere & Company Comments 3-4, Dynamic Spectrum Alliance Comments at 6-7, Google Comments at 46, Microsoft Comments at 41, Motorola Comments at 5-6, Spectrum Bridge Comments at 4, White Space Alliance Comments at 12-14, Wi-Fi Alliance Comments 15-17, WISPA Comments at 13-16, and xG Technologies Comments at 7.

[109] *See* Audio-Technica Comments at 13-15, Sennheiser Comments at 11, and Shure Comments at 28-29.

ability of white space devices to successfully share spectrum among themselves.[110] As an initial matter, we are using the term "less congested" in place of "rural" to describe the areas where fixed white space devices can take advantage of these rules. We find this term more descriptive in this case as it relates to areas where television spectrum is largely available to white space devices rather than relying on a population based metric which may not correlate to the same areas.[111] In the TV bands, fixed white space devices will be allowed to operate in the low VHF, high VHF, and UHF bands under this new higher power limit in "less congested" locations where within the band of intended operation at least half the allocated television channels are unused for broadcast services and available for white space use and the fixed white space devices are sufficiently separated from protected operations to avoid causing interference to them.

52. We are also allowing operation at up to 10 watts in the 600 MHz service band in areas where licensees have not yet commenced operation. As this band will have been repurposed from the current television band, it will be similar in propagation characteristics to the UHF television band. Thus, we are defining "less congested" areas in this band to be the same areas that are available in the newly repacked UHF television band. In addition, fixed white space devices in the 600 MHz service band will need to adhere to the separation distances provided below to protect new mobile broadband services.[112]

53. We are not, however, modifying the rule limiting transmitter conducted power to one watt, which necessitates the use of high gain antennas to achieve radiated power levels up to 10 watts in less congested areas. We also are not altering the rules limiting antenna AGL or HAAT to 30 meters and 250 meters respectively. To ensure that television stations, 600 MHz service licensees, and other protected operations are protected from interference due to a fixed white space device operating at more than 4 watts EIRP, we are changing the rules to increase the minimum separation distances between those services and the locations where fixed white space devices can operate. Finally, we are not increasing the allowable power for personal/portable white space devices.

54. We define less congested areas with respect to each frequency band where we are allowing higher power operations. For each TV band – low VHF (channels 2-6; 54-88 MHz); high VHF (channels 7-13; 174-216 MHz); UHF (channel 14 and above; beginning at 470 MHz) – less congested areas are locations where at least half of the TV channels for the bands that will continue to be allocated and assigned only for broadcast service are unused for broadcast and other protected services (*i.e.,* available for white space use). For example, for a white space device that will operate in the UHF-TV band (*e.g*., on channel 24), a less congested area will be determined based only on usage of the UHF-TV band and for a white space device that will operate in the high VHF-TV band (*e.g.,* channel 9) that determination will be based only on the usage of the high VHF-TV band (*i.e*., channels 7-13). As there are many services that use the TV broadcast band, we clarify this definition here. For purposes of calculating less congested areas, we include as "broadcast services" broadcast TV, including full power, Class A, low power television, and TV booster stations. In addition, we include the registered protected receive sites of broadcast auxiliary, TV translator, and Multi-channel Video Programming Distributor (MVPD)

[110] *See* Adaptrum Comments at 5, Microsoft Comments at 46-47, and White Space Alliance Comments at 13. The Wi-Fi Alliance and White Space Alliance submit that increasing the power limit to 10 watts EIRP will improve broadband service coverage in rural areas and will result in more efficient spectrum use since the power from the higher gain antenna will be concentrated in a narrower beamwidth. *See* Wi-Fi Alliance Comments at 15, White Space Alliance Comments at 13; *see also* Adaprtum Comments at 5, Microsoft Comments at 46, Motorola Comments at 5, and xG Technologies at 7.

[111] Several commenters state that we should not preclude fixed white space devices from operating at higher power levels in areas where population density exceeds that of a rural area. *See* Deere & company Reply Comments at 4, Sennheiser Comments at 11, and Shure Comments at 29.

[112] *See* para. 173, *infra*.

services.[113] We do not include land mobile operations in the 11 metropolitan areas where such use is permitted under section 90.303 of our rules, nor any areas where such operations are permitted by waiver.[114] Such use is conducted under a Land Mobile allocation and is not a broadcasting service. Similarly, we do not include offshore radio service, channel 37, or channel 17 in Hawaii as those too are not broadcast services.[115] We are not including licensed low power auxiliary devices (wireless microphones, etc.) in our definition of "broadcast service" for this limited purpose because such equipment typically is used on a transient basis and, thus is not licensed to a specific transmitter site. Prospectively, white space databases will determine whether a location is a less congested area based on whether at least half the total number of TV channels in the band of intended operation in an area are unused for broadcast services and available for fixed devices operating with 40 milliwatts at 3 meters HAAT.[116] This will provide the greatest opportunity for operation at the higher power levels. White space devices also will need to meet the separation distances from protected operations to avoid causing interference to them.

55. To ensure that new 600 MHz service licensees are similarly protected from interference, we define less congested areas as those same areas that are defined as less congested for the UHF-TV band. In all cases, white space devices will also need to meet the separation distances we are defining for 10 watt operation from the contour of the outer edge of the 600 MHz service licensee's facilities. We have included these distances in the co-channel and adjacent channel separation distance tables provided below.[117] Because white space device operations are controlled by the white space database in all bands, white space devices will be able to continue operating at higher power in less congested areas that will be allocated and assigned for 600 MHz service after the incentive auction, during and after the post-auction transition period. The database will be updated to include the required separation distances from base stations or other radio facilities deployed by the 600 MHz service licensees, and, after the licensees provide the polygonal shape encompassing those facilities, the database will be able to determine whether frequencies in the 600 MHz service band are available for white space use at the device's location. As television stations are repacked and 600 MHz service licensees commence operations, there may be a change in which areas are "less congested" and on which channels in those areas white space devices are permitted to operate with higher power, but those changes are transparent to the users.

56. We are not persuaded that the power limit should be increased to 16 watts EIRP, as requested by WISPA and xG Technologies.[118] We are concerned that at power levels above 10 watts EIRP, the

[113] Many stations in or related to the broadcast service are not listed in any Commission database. These services receive protection by registering their location in one of the white space databases. *See* 47 C.F.R. § 15.712 for a description of the protected areas for these services.

[114] *See* 47 C.F.R. §§ 2.106 and 90.303.

[115] *See* 47 C.F.R. §2.106 to see the allocation status of these services. Rules for the Offshore Radio Service can be found in 47 C.F.R. Part 22, Subpart I and a description of the geographic areas where stations in this service may operate can be found in 47 C.F.R. § 74.709(e). In Hawaii, 488-494 MHz (channel 17) is used for point-to-point communications pursuant to 47 C.F.R. § 22.603.

[116] For example, the current UHF-TV spectrum occupies channels 14-51 for a total of 37 broadcast channels (channel 37 is not counted for this purpose). If in a given area, there are two channels used for land mobile operations and there is a cable headend, three BAS receive sites, and a TV translator receive site, then the calculation would be based on 35 total TV channels (37 channels less the two land mobile channels). Thus if more than 17 channels in that area are available for use by a 40 milliwatt white space device operating at a 3 meter HAAT, then it would meet our definition of a less congested area and be available for operations at up to 10 watts EIRP.

[117] *See* Tables after para. 176, *infra.*

[118] *See* WISPA Comments at 13-16. xG Technologies also supports allowing operation at 16 dBi EIRP at locations where there are large areas of geography. *See* xG Technologies Comments at 7.

increased propagation distance would make it difficult to identify signal sources if any interference were to occur. We also disagree with WISPA that 10 watts EIRP is not substantial enough to provide a significant improvement in coverage in less congested areas as the 4 dB increase in radiated power will provide roughly a 1.5 times increase in range.[119]

57. We will not increase the allowable conducted transmitter power or antenna height limits for white space devices operating in less congested areas, as suggested by a number of the proponents of white space operation.[120] As stated, our preference is to enable the increase in power through a more highly directional antenna. We recognize that allowing fixed white space devices in less congested areas to operate with additional conducted transmitter power could provide more coverage over increased range. However, this raises the same concerns articulated above regarding a higher overall power limit; namely an increase in interference potential and a more difficult task to identify the source of such interference if it were to occur. It also reduces opportunities to share spectrum. For example, a fixed device operating with 10 watts EIRP using more than 1 watt of transmitter power and antenna with less than 10 dB gain to serve a fixed location would spread a significant portion of its signal energy to the side of its main beam and, thus, over areas it did not intend to reach. That signal energy to the side of the main beam would increase the background energy with which other white space devices would have to contend to provide service. For similar reasons, as well as our belief that it is generally not necessary to mount an antenna at heights greater than 30 meters (100 feet) AGL to avoid shadowing by trees and other obstructions in rural areas,[121] we are not increasing the antenna height in less congested areas beyond the current 30 meter AGL limit. We also are not increasing the power or antenna gain authorized for personal/portable white space devices. There is no support in the record for making such a change.

58. Anant Sahai comments that, for higher power operation, we correspondingly need to increase the separation distances between protected operations and television service contours to avoid interference.[122] The interference potential of fixed white space devices operating at EIRP levels up to the new 10 watt limit will extend somewhat farther than that of fixed devices operating at the four watt EIRP level. Thus, we are adding provisions referenced to the new 10 watt EIRP limit in section 15.712 of the rules which contains the protection criteria and separation distances for each of the other services operating in the TV bands. For protection of television service, the new minimum distance standards are:

Fixed Device Antenna HAAT for Operation between 4 and 10 Watts EIRP	Required minimum distance (km) from TV protected contour	
	Co-channel	Adjacent Channel
Less than 3 meters	4.5	0.2
3-Less than 10 meters	8.5	0.4
10-Less than 30 meters	13.9	0.6
30-Less than 50 meters	19.1	0.8

[119] Under free space conditions distance increases proportionally to the square root of the power. An increase from 4 watts EIRP to 10 watts EIRP is a 2.5 times increase resulting in a $\sqrt{2.5}$ = 1.6 times increase in distance.

[120] *See* Adaptrum Comments at 5, Anant Sahai Comments at 1, Google Comments at 46, Microsoft Comments at 46, Motorola Comments at 5-6, and Wi-Fi Alliance Comments at 15.

[121] A map by the National Aeronautics and Space Administration showing tree height data collected by satellite indicates that while some tree canopies can reach as high as 131 feet, most canopies range in height from 66 to 88 feet. *See* http://www.nasa.gov/topics/earth/features/forest-height-map.html.

[122] *See* Anant Sahai Comments at 3.

50-Less than 75 meters	23.8	0.9
75-Less than 100 meters	27.2	1.1
100-Less than 150 meters	32.3	1.3
150-Less than 200 meters	36.4	1.5
200-250 meters	39.5	1.7

The distances in the above table were calculated using the same method that we used in calculating the existing standards for minimum separations between white space fixed devices and television contours in Section 15.712(a)(2).[123]

59. Private land mobile radio services (PLMRS), including public safety, and commercial mobile radio service operations operate on TV channels 14-20 in 11 major markets and in some additional areas under waivers of the rules.[124] These PLMRS operations are protected from interference from white space devices through a circular exclusion zone extending from the center of each market out to 134 kilometers in radius for co-channel operations and 131 kilometers in radius for adjacent channel operations.[125] These exclusion zones are based on the Commission's finding in the *Second Report and Order* to require a fixed white space device operating with four watts EIRP and an antenna height of 30 meters to protect PLMRS/CMRS operations using the same criteria that are applied to TV translator, low power TV and Class A TV stations in Part 74 of the rules.[126] The PLMRS base stations operating outside the 11 metropolitan areas under waivers are protected from interference from white space devices by a 54 kilometer radius co-channel zone and 51 kilometer radius adjacent channel zone extending from the location of the base station. Using the same methodology to determine the protection zones, we find that fixed white space devices operating at 10 watts EIRP in less congested areas must not operate within a circular exclusion zone of 136 kilometers co-channel and 131.5 kilometers adjacent channel of the 11 major markets where PLMRS stations are permitted to operate and within 56 kilometers co-channel and 51.5 kilometers adjacent channel of PLMRS base stations operating outside the 11 major markets under a waiver.

60. The rules also protect the receive sites of broadcast auxiliary service (BAS) facilities, TV translators, low power TV stations, Class A TV stations and multichannel video program distributors (MVPDs) by prohibiting white space devices from operating within a keyhole shaped exclusion zone with the long end of the keyhole aligned between the protected receiver and its associated transmitter.[127] Specifically, white space devices are prohibited from operating co-channel and adjacent channel to the TV channel(s) being received by these facilities over an arc of ±30 degrees from a line between the receive site and each associated transmitter(s) (often a TV station(s)). The protection zone extends to a

[123] *See White Spaces Second R&O,* 23 FCC Rcd 16870-16871, para. 179-181; methodology revised in *White Spaces Third MO&O,* 27 FCC Rcd at 3698-3699, para. 16.

[124] See 47 C.F.R. § 90.305 and 47 C.F.R. § 22.625

[125] *See* 47 C.F.R. § 15.712(d).

[126] *See White Spaces Second R&O*, FCC Rcd 16873-16875, para.190-193; *see also* 47 C.F.R. 74.709. The protections for PLMRS from white space devices are based on a determination that the field strength from a TV band device on a co- or adjacent channel should not be permitted to exceed 52 dBμV or 76 dBμV, respectively, at the 130 km protected radius of the PLMRS/CMRS metropolitan area. Using these criteria, the FCC F(50,10) curves in Section 73.699 of the rules and assuming a fixed white space device operating at 4 watts EIRP and 30 meters AGL, it was determined that a white space device needed to be 4 km co-channel and 1 km adjacent channel beyond the PLMRS protected contour.

[127] The interference protection provisions for broadcast auxiliary facilities, TV translators, low power TV stations, Class A TV stations and multichannel video program distributors (MVPDs) from are in Sections 15.712(b) and (c). *See* 47 C.R.R. § 15.712(b) and (c).

maximum distance of 80 kilometers from the protected receiver toward its associated transmitter for co-channel operations and to 20 kilometers for adjacent channel operation.[128] In addition, to prevent interference from white space device signals outside the main beam of the protected receive antenna, white space devices are prohibited from operating within a circular area of 8 kilometers co-channel and 2 kilometers adjacent channel from the receive sites in all directions off the ±30 degree arc. We believe the 80 kilometer co-channel and 20 kilometer adjacent channel ranges of the wedge-shaped portion of the keyhole is large enough to sufficiently protect these protected receive sites from interference from fixed devices operating at 10 watts EIRP. By keeping the antenna height limit at 30 meters AGL, we observe that a receiver would have to be mounted at 200 meters above ground 80 kilometers away to achieve line of sight distance. Given the limited geographic arc within which the 80 kilometer separation distance applies, we believe this situation unlikely to occur. In addition, because these higher power devices must meet the same out-of-band emissions limits as four watt devices, it is not necessary to adjust the 20 kilometer adjacent channel separation distance. However, to protect these sites from white space devices that are located outside the main beam, we believe a modest increase in distance is necessary. We are therefore adjusting those distances to prohibit fixed devices operating at 10 watts EIRP from operating within 10.2 kilometers co-channel and 2.5 kilometers adjacent channel from the protected received site.[129]

61. Finally, to protect sensitive radioastronomy operations and safety-of-life wireless medical telemetry devices that use channel 37, we are not allowing fixed devices to operate with EIRP higher than four watts on channel 37 nor on the adjacent channels 36 and 38 at any locations.

2. Calculating white space device separation distances from a TV station contour

a. Fixed and personal/portable devices

62. *Background*. White space devices must protect defined service contours of analog and digital full service and low power television stations.[130] These contours are calculated using the methodology in Section 73.684 of the rules and the F(50,50) and F(50,90) curves contained in Section 73.699.[131] Under the current rules, fixed white space devices must operate outside the contours of co-channel and adjacent channel TV stations at the distances specified in the table in Section 15.712(a)(2). This table provides co-channel and adjacent channel separation distances for nine ranges of fixed device HAAT, up to a maximum of 250 meters.[132] As discussed above, the separation distances were calculated assuming a white space device EIRP of 4000 milliwatts.[133] Personal/portable devices that operate with an EIRP

[128] The specification for this keyhole protection zone was recommended by the National Translator Association. *See* National Translator Association Comments in response to the *Unlicensed Operation in the TV Bands*, First Report and Order and Further Notice of Proposed Rulemaking, ET Docket Nos. 02-380 and 04-186, 21 FCC Rcd 12266 (2006).

[129] These adjustments were derived as follows. A white space device operating at four watts EIRP and an antenna height of 30 meters will have a signal strength of 42.8 dBu at eight kilometers and 67.2 dBu at two kilometers as determined using the FCC F(50,10) curves. To have those same signal strength levels when operating with 10 watts EIRP and the same 30 meters antenna height, the respective distances are 10.2 kilometers and 2.5 kilometers .

[130] *See* 47 C.F.R. § 15.712(a)(1).

[131] *Id.* The F(50,50) and F(50,90) curves are statistical models that the Commission uses to determine the distance from a transmit antenna to a specific field strength contour when the radiated transmit power and the antenna height above average terrain are known. They represent the statistical percentage of locations and times at which a signal will be at or above a specific level. For example, a signal level determined from the F(50,50) curves will be exceeded at 50% of locations 50% of the time.

[132] Fixed devices may not operate at locations where their HAAT would exceed 250 meters.

[133] The assumptions used by the Commission to calculate these distances are described in the *Notice. See Notice*, 29 FCC Rcd at 12268, para. 64.

greater than 40 milliwatts, up to the maximum of 100 milliwatts, must comply with the co-channel and adjacent channel separation distances at the lowest HAAT in the table (*i.e.*, less than three meters).[134] Personal/portable devices operating at 40 milliwatts or less only need to comply with the co-channel separation distance at the lowest HAAT listed in the table.[135]

63. In the *Notice*, the Commission proposed to amend the table of separation distances in Section 15.712(a)(2) to reflect a range of fixed device power levels below four watts EIRP. The Commission also proposed to apply the separation distances for fixed devices at 40 milliwatts and 100 milliwatts EIRP, at the lowest antenna HAAT, to personal/portable devices. It also proposed to specify separate tables for co-channel and adjacent channel separation distances due to the increase in the total number of entries, and to add entries showing which separation distances apply to personal/portable devices.

64. *Discussion.* We are adopting the proposed tables of separation distances which are shown below. The record supports specifying minimum separation distances for a number of different power levels, and parties generally argue that the separation distances proposed in the *Notice* are conservative.

Antenna height above average terrain of unlicensed device	**Required separation distances in kilometers from co-channel digital or analog TV (full service or low power) protected contour**					
	16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
Personal/portable	1.3	1.7	N/A	N/A	N/A	N/A
Less than 3 meters	1.3	1.7	2.1	2.7	3.3	4.0
3-Less than 10 meters	2.4	3.1	3.8	4.8	6.1	7.3
10-Less than 30 meters	4.2	5.1	6.0	7.1	8.9	11.1
30-Less than 50 meters	5.4	6.5	7.7	9.2	11.5	14.3
50-Less than 75 meters	6.6	7.9	9.4	11.1	13.9	18.0
75-Less than 100 meters	7.7	9.2	10.9	12.8	17.2	21.1
100-Less than 150 meters	9.4	11.1	13.2	16.5	21.4	25.3
150-Less than 200 meters	10.9	12.7	15.8	19.5	24.7	28.5
200-250 meters	12.1	14.3	18.2	22.0	27.3	31.2

Antenna height above average terrain of unlicensed device	**Required separation distances in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour**				
	20 dBm (100 mW)	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
Personal/portable	0.1	N/A	N/A	N/A	N/A
Less than 3 meters	0.1	0.1	0.1	0.1	0.2
3-Less than 10 meters	0.1	0.2	0.2	0.2	0.3
10-Less than 30 meters	0.2	0.3	0.3	0.4	0.5
30-Less than 50 meters	0.3	0.3	0.4	0.5	0.7
50-Less than 75 meters	0.3	0.4	0.5	0.7	0.8

[134] *See* 47 C.F.R. § 15.712(a)(1).

[135] *Id.*

75-Less than 100 meters	0.4	0.5	0.6	0.8	1.0
100-Less than 150 meters	0.5	0.6	0.8	0.9	1.2
150-Less than 200 meters	0.5	0.7	0.9	1.1	1.4
200-250 meters	0.6	0.8	1.0	1.2	1.5

65. The changes we are adopting will permit fixed white space devices to operate in more locations than the current rules allow without causing harmful interference, *i.e.*, closer to a television station service contour, since to minimize complexity the current separation distances were based on the assumption that a fixed device always operates at the maximum power level of four watts.[136] In addition, since the separation distances for personal/portable devices were also based on an EIRP of four watts, they are greater than necessary since personal/portable devices may operate with a maximum EIRP of 100 milliwatts, or 40 milliwatts if they are on a channel adjacent to an occupied channel. Thus, these changes will also permit personal/portable devices to operate in more locations.

66. We decline to allow the use of the Longley-Rice methodology or other alternative methodologies for determining white space channel availability as a number of parties requested.[137] In the *Notice*, we did not propose any change in the use of the F(50,50) and F(50,90) curves for calculating the protected contours of TV stations, and we explained our belief that the use of the Longley-Rice methodology was not appropriate for determining whether a white space device would cause harmful interference to TV reception as it is computationally intensive and would significantly slow the ongoing real-time determination of available TV channels by the white space databases.[138] With respect to other methodologies for determining white space channel availability, no parties provided technical analyses showing how these methodologies could be used or what impact they would have on white space channel availability.

67. We also decline to allow white space device operators and databases to consider the directivity of fixed white space device antennas in determining channel availability. A number of parties support considering antenna directivity.[139] However, we find that there is not sufficient information in the record to show how to enable the use of antenna directivity without causing harmful interference to authorized services. For example, there is no consensus on the format for antenna patterns (*e.g.,* generic or actual, number of azimuths specified) and no information on how to ensure that accurate antenna orientation information is obtained by the antenna installer and entered into the white space databases. We could consider this issue again in the future if parties are able to develop a standard to address implementation and as we gain experience with the more flexible, but more complex, rules we are adopting herein.

b. Mode I operation

68. *Background.* The current white space rules provide for two types of personal/portable devices: Mode II and Mode I. Mode II devices, like fixed devices, incorporate geo-location and database

[136] *See White Spaces Second Report and Order,* 23 FCC Rcd at 16870-16871, para. 181.

[137] Adaptrum and Dynamic Spectrum Alliance support the use of the Longley-Rice methodology. *See* Adaptrum Comments at 9 and Dynamic Spectrum Alliance Comments at 4. The White Space Alliance suggested the use of the Shuttle Radar Topography Mission (SRTM-2002) model, while the Wi-Fi Alliance opposed the use of the TM-91-1 model but did not suggest an alternative. *See* White Space Alliance Comments at 17 and Wi-Fi Alliance Comments at 22.

[138] *See Notice,* 29 FCC Rcd at 12270, para. 71.

[139] *See* Adaptrum Comments at 5, Microsoft Comments at 47, Motorola Comments at 8, Spectrum Bridge Comments at 5, White Space Alliance Comments at 17, Wi-Fi Alliance Comments at 21 and WISPA Comments at 11.

access capabilities which facilitate their ability to meet the required separation distances at their operating location. Mode I devices contain neither geo-location capability nor database access[140] and instead obtain a list of available operating channels from a fixed or Mode II personal/portable white space device that is within their transmission range. Mode I devices may only operate so long as they can receive a controlling signal from a fixed or Mode II device.[141] Therefore, the actual location of a Mode I device is different from the location of the device from which it receives a list of available channels. However, because Mode I devices are limited to a maximum EIRP of 100 milliwatts, or 40 milliwatts EIRP if they are adjacent to an occupied TV channel, they must operate relatively close to the controlling device.[142]

69. As discussed above, the Commission originally developed the minimum separation distance rules for white space devices using the maximum fixed device power level of four watts EIRP.[143] For personal/portable devices, this resulted in very conservative separation distances that were greater than necessary to prevent harmful interference to TV reception (four kilometers co-channel). Large separation distance also serves as an extra buffer to guard against Mode I devices causing harmful interference since their exact location is unknown. With respect to fixed devices, the rules prohibit fixed devices with an HAAT greater than 106 meters from providing lists of available channels to Mode I devices in order to limit the range at which they can communicate, and therefore limit the uncertainty in their location.[144]

70. The Commission sought comment in the *Notice* on whether we should increase the required separation distances for Mode I devices to offset the uncertainty in the devices' locations, and Motorola supported this approach.[145] In its comments, Google recognizes that the location uncertainty of Mode I devices could lead to potential interference on channel 37 to WMTS systems or RAS locations. It states that the Commission's rules can ensure that Mode I devices do not cause interference to WMTS or RAS in channel 37 by mandating that white space databases establish an exclusion zone calculated as follows: the protection radius surrounding the incumbent's facility, plus the location uncertainty associated with the Mode II master device, plus the operating range of the Mode I client device.[146]

71. *Discussion.* We find that our decision to allow lower power white space devices to operate at closer distances to TV station contours necessitates some modifications to the rules for Mode I devices. By adopting more realistic separation distances based on a range of operating power, the separation distance for lower power operations become shorter than those currently in the rules, and thus, the location uncertainty inherent in a Mode I device becomes more significant. That is, because their controlling station may now operate closer to TV contours, than under current rules, the Mode I device could locate such that it is even closer to those same TV contours increasing its potential to cause harmful interference to TV reception. We will therefore require that a fixed or Mode II device that provides a list of available channels to a Mode I device comply with slightly greater separation distances from the TV contours of stations on the channel or channels that it indicates are available to the Mode I device.

72. We agree with Google about the need to protect WMTS and RAS systems from potential interference from Mode I personal/portable devices, but recognize that such protection needs to be

[140] *See* 47 C.F.R. § 15.703(e)-(f).

[141] *See* 47 C.F.R. § 15.711(b)(iv)(D).

[142] *See* 47 C.F.R. § 15.709(a)(2).

[143] *See* para. 40, *supra.*

[144] *See* 47 C.F.R. § 15.711(b)(3)(iv)(C).

[145] *See Notice,* 29 FCC Rcd at 12273, 12280 and 12287, para. 80, 101 and 132; and Motorola Comments at 4, footnote 6. Motorola argues that the location errors of Mode I devices could be addressed by increasing the required separation distances from protected services by the amount of the location error minus the required 50 meter location accuracy.

[146] *See* Google Comments at 33.

provided throughout the TV and 600 MHz band. Accordingly, we craft rules of general applicability to both fixed and Mode II white space devices that control Mode I white space devices in both the TV and 600 MHz band as well as on channel 37. We are not however, establishing classes for different types of Mode I and Mode II devices to provide a range of distances as suggested by Google.[147] We believe such a system would be confusing and administratively burdensome for white space database providers. Instead, we opt for a simpler approach outlined below.

73. As stated above, the rules require white space devices to operate with the minimum power necessary for communications. Under this condition, to have a balanced link, we assume that Mode I devices communicating with Mode II devices will operate at similar power levels. Thus, the necessary separation to protect TV reception from a Mode I device will be identical to the necessary separation for the controlling Mode II device. Given the location uncertainty of a Mode I device, we can ensure that it complies with the separation distance rules by requiring the Mode II controlling device to operate at twice the required distance in the table for a personal/portable white space device at the allowed power levels.[148] In this manner, a Mode I device operating at its maximum range from a controlling Mode II device should still comply with the minimum distance separation required to protect TV reception. By way of example, when a Mode II personal/portable white space device is communicating with another Mode II device or a fixed device, it may operate 1.3 kilometers from a co-channel TV contour when its EIRP is 40 milliwatts and 1.7 kilometers from a co-channel TV contour when its EIRP is 100 milliwatts. However, when a Mode II personal/portable white space device is controlling (*i.e.*, providing a list of available channels) to a Mode I device, then it must double the separation distance to 2.6 kilometers and 3.4 kilometers when its EIRP is 40 milliwatts and 100 milliwatts, respectively. This action will ensure that Mode I devices operate sufficiently far outside the protected contours of co-channel TV stations to prevent harmful interference. We similarly will require Mode II personal/portable white space devices to double the adjacent channel separation distance to 0.2 kilometers when operating at 100 milliwatts and serving Mode I devices. We will modify the table in section 15.712(a)(2) accordingly.

74. Fixed devices pose a slightly different challenge. Once installed, they have no ability to increase their distance from co and adjacent channel TV contours. As an initial matter, we find that increasing the separation distance from a co-channel protected TV contour by a factor of two for a fixed device controlling a Mode I personal/portable white space device would be overly protective since Mode I devices are portable and would operate at low antenna heights, thus limiting the range at which they could communicate with a fixed device. Rather than doubling the required separation distances, we will increase the separation distances that a fixed device must meet on channels provided to a Mode I device by the same amount as added for a controlling Mode II device, *i.e.,* 1.7 kilometers greater for 100 milliwatt Mode I devices and 1.3 kilometers greater for 40 milliwatt Mode I devices. Thus, to serve Mode I white space devices, fixed devices must exceed the co-channel separation distances in the table in section 15.712(a)(2) by this amount. Similarly, we will require such fixed devices to also exceed the adjacent channel separation distances specified in the table by 0.1 kilometers. We will modify the rule accordingly to specify this requirement. Finally, we are not changing the current requirement that only fixed devices with a HAAT of 106 meters or less may provide lists of available channels to Mode I devices.

c. Location accuracy

75. *Background*. In the *Notice*, the Commission sought comment on whether there are other location methods besides GPS that can determine a white space device's location to within ±50 meters.[149] The Commission also sought comment on a number of other issues related to geo-location accuracy,

[147] *See* Google Comments at 32-33.

[148] *See* Google Comments at 33 (suggesting that the controlling Mode II device should be a distance from a protected station by the distance required by the rules "plus the operating range of the Mode I client device.").

[149] *See Notice*, 29 FCC Rcd at 12271, para. 76.

including whether we should allow white space devices to use geo-location methods that are less accurate than the current rules require, the level of accuracy that should be required, how to determine the accuracy of other geo-location technologies, and how to assure that devices do not cause harmful interference to authorized services.[150]

76. Commenters generally point out that GPS often does not work indoors or in areas where there may be significant shielding from the satellites and that other technologies are available to assist in providing location information.[151] Google points out that the Commission's Communications Security, Reliability, and Interoperability Council (CSRIC) has looked into this issue. It states that CSRIC noted that in addition to cellular network-based technologies, devices could rely on Wi-Fi and/or Bluetooth-based positioning, RF pattern matching (which uses a database to correlate location with unique RF patterns), or beacons deployed at known locations.[152] Google asserts that a rigid mandate for a particular location accuracy is not necessary to ensure that white space devices are excluded from geographic areas where they might cause interference.[153] Similarly, Microsoft comments that a Mode II personal/portable white space device can incorporate one or more technologies that allow it to report back to the white space databases where it believes its current position to be, as well as an estimate of the uncertainty of its position and that the databases will then use the estimated location error when they return a list of available channels.[154] Spectrum Bridge also endorses such an approach noting that it is similar to the requirement defined by the ETSI EN 301 598 specification.[155] Google adds that Ofcom recently adopted a rule implementing this ETSI standard for unlicensed devices operating in television bands in the United Kingdom, and the Internet Engineering Task Force's Protocol to Access White Space Databases, which establishes the protocol for communications between databases and unlicensed devices in the broadcast bands and repurposed 600 MHz band, already accommodates device location accuracy as a parameter.[156] In addition, Shure does not oppose relaxing the location accuracy requirement, so long as the protection zones for wireless microphones are increased proportionally.[157]

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[150] *See Notice*, 29 FCC Rcd at 12272, para. 77.

[151] *See* Anant Sahai Comments at 2, Broadcom Comments at 27, Dynamic Spectrum Alliance Comments at 12, Google Comments at 41, Microsoft Comments at 41, Motorola Comments at 4, Spectrum Bridge Comments at 6, White Space Alliance Comments at 19, and Wi-Fi Alliance Comments at 23. Sennheiser and Shure state that any decrease in location accuracy should be offset by a corresponding increase in the protection distance between white space devices and wireless microphones. *See* Sennheiser Comments at 11 and Shure Comments at 27.

[152] *See* Google Comments at 40-41 citing CISRIC Working Group 1, Final Report: Specification for Indoor Location Accuracy Test Bed (June 2014), available at http://transition.fcc.gov/pshs/advisory/csric4/CSRIC_IV_WG-1_Subgroup3_061814.pdf.

[153] *See* Google Comments at 39-40.

[154] *See* Microsoft Comments at 42.

[155] *See* Spectrum Bridge Comments at 6. The harmonized European standard, ETSI EN 301 598, sets methods and principles for the operation of TV white space devices in the band 470 MHz to 790 MHz. Section 4.2.8.3 includes the requirements for the geo-location capability, along with requirements for a white space device to report its coordinates and its geo-location uncertainty (in meters) with a confidence level of 95%. *See* ETSI EN 301 598 as section 4.2.8.3, page 24; available at: http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf.

[156] *See* Google *ex parte* filing dated July 9, 2015 at 2. *See also*, Ofcom, Implementing TV White Spaces , Statement, § 5.14, Feb. 12, 2015, available at http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/statement/tvws-statement.pdf; and Internet Engineering Task Force, Protocol to Access White-Space (PAWS) Databases, RFC7545, available *at* https://datatracker.ietf.org/doc/rfc7545/. We note that while the ETSI standard mandates that the location uncertainty be provided with a 95% confidence interval, the PAWS standard states that the default confidence level is 95, but that any range from 0 to 100 may be provided.

[157] *See* Shure Comments at 28.

77. *Discussion.* We will allow fixed and Mode II personal/portable devices to use location technologies that have a lower degree of accuracy than ±50 meters. We agree with commenters that this change will expand the areas in which white space devices may operate, without causing harmful interference to licensed services, by permitting their use at indoor or other locations where a GPS signal that can provide location information to ±50 meters is not available. We will require fixed and Mode II devices to inform the database of their location uncertainty with a 95% confidence level when requesting a list of available channels, and require that the database consider this uncertainty in determining the list of available channels at the device's location. This is consistent with the standard adopted for use across Europe and implemented by Ofcom in the United Kingdom. We anticipate that our adoption of the same requirement will lead to harmonized devices and lower equipment costs for consumers.

78. To implement this requirement, the databases will increase the minimum separation distances from all protected services by the amount that the location uncertainty exceeds ±50 meters. For example, no increase in separation distances will be required for a device that meets the ±50 meter level of accuracy, while an adjustment of 50 meters would be required for a device with an accuracy of ±100 meters. In such a case, because the protection zones will get larger, either the same channel list or a smaller channel list will be returned from the white space databases to the white space device. We expect the differences between the default list and the list for a less accurate device to be more pronounced for urban areas as compared to more rural areas due to the presence of more protected services in urban areas. We will work with the white space database administrators as needed to ensure that the separation distances are calculated appropriately. We will require that applicants for certification of fixed and Mode II devices provide details regarding the technologies used by the device to determine its location and how, in the case of technologies other than GPS, the location uncertainty is calculated with a 95% confidence level. Finally, as part of the certification process, we will test to ensure that these parameters are correctly transmitted to the databases.

3. Frequencies of operation for white space devices

79. *Background*. White space devices are currently permitted to operate on unused TV channels within the range of 2-51, excluding channels 3, 4 and 37.[158] Fixed devices may operate on any available channel within that range, while personal/portable devices may operate only on channels 21-51, excluding channel 37.[159] The Commission prohibited all white space device operations on channel 37 to protect the RAS and WMTS.[160] It established the prohibition on the use of channels 3 and 4 to prevent direct pickup interference to TV interface devices with signal outputs on channels 3 or 4, such as VCRs, DVRs, and cable and satellite converter boxes.[161] In adopting this restriction, the Commission also expressed concern that TV receivers to which TV interface devices are connected could receive direct pickup interference on channels 3 and 4.[162] The Commission established the prohibition on personal/portable devices operation on channels 14-20 to protect the Private Land Mobile Radio Service and Commercial Mobile Radio Service ("PLMRS/CMRS") that operate on those channels in certain cities.[163]

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[158] *See* 47 C.F.R. § 15.701.

[159] *See* 47 C.F.R. § 15.703(i).

[160] *See First Report and Order and Further Notice of Proposed Rulemaking* in ET Docket Nos. 02-380 and 04-186, 21 FCC Rcd 12266, 12275 (2006) at para. 21.

[161] *See Second Report and Order and Memorandum Opinion and Order* ("*White Spaces Second R&O*") in ET Docket Nos. 02-380 and 04-186, 23 FCC Rcd 16807, 16860 (2008), para. 149-150.

[162] *Id.*

[163] *See Unlicensed Operation in the TV Broadcast Bands*, ET Docket No. 04-186, *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, *First Report and Order and Further Notice of Proposed Rulemaking*, 21 FCC Rcd 12266, 12275, para. 21 (2006).

80. The Commission decided in the *Incentive Auction R&O* that white space devices may continue to operate under the Part 15 rules—the current rules and any changes to those rules that we may adopt in this proceeding—in the spectrum that remains allocated and assigned for TV broadcast services following the incentive auction.[164] The Commission also decided to propose modifications to its rules regarding white space device and wireless microphone access to unused TV channels.

81. In the *Notice*, the Commission proposed to permit fixed white space devices to operate on channels 3 and 4, providing an additional 12 megahertz of contiguous spectrum for their use in areas where they are not occupied by authorized users. The Commission observed that limiting the use of these channels to fixed white space devices will reduce the likelihood of direct pickup interference to TV interface devices and TV receivers that continue use these frequencies, since a fixed white space device is less likely to be used in close proximity to a TV receiver than a portable device.

82. The Commission also proposed to remove the prohibition on personal/portable white space device operation on channels 14-20, making 42 megahertz of spectrum potentially available in locations where the spectrum is not used for the PLMRS/CMRS or other authorized services. It also sought comment on whether to permit personal/portable devices to operate below channel 14.

83. In the *Incentive Auction R&O,* the Commission decided that it would no longer continue to designate up to two unused television channels in any area exclusively for wireless microphone operations.[165] The Commission stated that in a separate proceeding, it would seek comment on ways it could update the rules for white space databases to provide for more immediate reservation of unused and available channels in the television bands to help ensure that licensed wireless microphone operators can obtain access to available television channels without receiving harmful interference from white space devices. It decided that it would continue to prohibit white space devices from operating on the first two vacant TV channels above and below channel 37 until such time as revised Commission rules are in effect to provide for more immediate interference protection. After that time, any available TV channel could be used by either wireless microphones or white space devices. In the *Notice*, the Commission proposed to eliminate the prohibition on white space device operation on these two channels and make them available for use by white space devices when the rules we proposed in the *Notice* became effective.

84. *Fixed devices on channels 3 and 4*. We modify our Part 15 rules to permit fixed white space devices to operate on TV channels 3 and 4. This action makes available an additional 12 megahertz of contiguous spectrum for their use in areas where they are not occupied by authorized users. Because this spectrum is immediately adjacent to channel 2, this rule change provides an opportunity for fixed devices to use the lower VHF band at maximum permitted power in areas where all three channels are not occupied. No commenters opposed adoption of this proposal.[166]

85. As we observed in the *Notice*, the Commission established this prohibition to protect TV interface devices and TV receivers from direct pickup interference on channels 3 and 4.[167] The Commission did not have detailed data on the susceptibility of TV interface devices and TV receivers to direct pickup interference on channels 3 and 4, but decided to take a cautious approach due to the expected large number of TV interface devices with outputs on those channels.[168] The number of these devices has been declining since 2008.[169] The transition from analog to digital TV in 2009 spurred many

[164] *See Incentive Auction R&O,* 29 FCC Rcd at 6842-6843, para. 677.

[165] *See Incentive Auction R&O,* 29 FCC Rcd at 6845, para. 684.

[166] *See, e.g.*, Alarm Industry Communications Committee Reply Comments at 4; Microsoft Comments at 46; Wi-Fi Alliance Comments at 8; WISPA Comments at 7.

[167] *See Notice,* 29 FCC Rcd at 12255, para. 22.

[168] *See White Spaces Second R&O,* 23 FCC Rcd at 16860, para. 150.

[169] See NAB Comments at 13.

consumers to replace their old analog TV receivers with digital receivers that have multiple inputs that allow the connection of external devices without requiring the use of a channel 3 or 4 input signal, including HDMI, component video and composite video inputs.[170] Further, the price of new TV receivers has dropped significantly since that time, resulting in many more consumers replacing their old analog TV receivers. TV receivers also have been required to come equipped with digital TV tuners for a number of years, thus eliminating the need to use an external converter box to receive over-the-air signals. While we recognize that some consumers continue to use older analog TV sets with a converter box or other TV interface devices with a channel 3 or 4 output, we believe that number is significantly less than in 2008, and will continue to drop over time.

86. Finally, we disagree with NAB that, although it does not oppose opening these bands to fixed devices, the new rule should not be effective for three years.[171] We believe it is unnecessary to specify a specific future date because, as WISPA notes, use of these channels by fixed devices will not occur immediately and will be delayed until manufacturers design and market equipment for use on these newly available VHF frequencies.[172]

87. *Personal/portable devices on channels 14-20*. We modify our Part 15 rules to permit personal/portable white space devices to operate on TV channels 14-20, but we do not permit them to operate below TV channel 14. This decision will make 42 megahertz of spectrum potentially available for personal/portable devices.

88. Unlicensed proponents support the proposal to allow personal/portable devices to operate on TV channels 14-20 as well as below channel 14,[173] whereas microphone proponents opposed permitting any such use below channel 21.[174] In adopting the prohibition on personal/portable white space devices on TV channels 14-20, the Commission explained that its approach was "conservative" and that it "anticipate[d] that channels 21-51 will provide adequate spectrum resources" for personal/portable white space devices.[175] In light of the repurposing of the TV bands, this conclusion is no longer valid.[176] Moreover, we conclude that continuing the prohibition on personal/portable device use on channels 14-20 is not necessary to protect PLMRS/CMRS operations. As we observed in the *Notice*, several white space databases have become operational over the past few years. The locations where the PLMRS/CMRS is used, both in eleven cities and in other areas where it is authorized under waiver, are already in the databases since that information is used to protect those operations from fixed white space operations.[177]

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[170] HDMI (High Definition Multimedia Interface) is a digital interface that carries video and audio signals. Component video is an analog interface that uses three cables to carry a video signal. Composite video uses a single cable to carry an analog video signal. Component and composite video cables are used in conjunction with cables that carry an analog audio signal.

[171] NAB Comments at 13.

[172] WISPA Reply Comments at 6-7.

[173] *See, e.g.*, Dynamic Spectrum Alliance Comments at 2; Google Comments at 39; Motorola Comments at 3; OPI/PK Reply Comments at 18; Spectrum Bridge Comments at 3; Wi-Fi Alliance Comments at 9.

[174] Sennheiser Comments at 10; Shure Comments at 23, 26.

[175] *White Spaces Second R&O*, 23 FCC Rcd at 16861, para. 152.

[176] *See* Google Comments at 38.

[177] Section 90.303(b) of the rules lists thirteen urban areas where the PLMRS/CMRS may operate on certain channels in the range of 14-20: 1) Boston, MA; 2) Chicago, IL; 3) Cleveland, OH; 4) Dallas/Ft. Worth, TX; 5) Detroit, MI; 6) Houston, TX; 7) Los Angeles, CA; 8) Miami, FL; 9) New York, NY/Northeast NJ; 10) Philadelphia, PA; 11) Pittsburgh, PA; 12) San Francisco/Oakland CA; and 13) Washington DC/MD/VA. PLMRS/CMRS operation under these provisions is currently not permitted in Cleveland, OH and Detroit, MI. *See* 47 C.F.R. § 90.303(b), footnotes 2 and 3.

Personal/portable devices rely on database access to determine their list of available channels, so they can protect the PLMRS/CMRS in the same manner as fixed devices.[178]

89. Sennheiser and Shure oppose permitting personal/portable white space device on channels 14-20, arguing that UHF spectrum is important for many wireless microphone applications and that channels 14-20 provide an opportunity for wireless microphones to operate without risk of interference from unlicensed mobile white space devices.[179] Shure notes that access to these channels is especially important for unlicensed wireless microphones users that are not eligible for a Part 74 license and may not be permitted to reserve vacant TV channels for their use, as do licensed wireless microphone users.[180] We recognize that, after the incentive auction and repacking, fewer channels may be available in the lower UHF frequencies for both white space device and wireless microphone users. Licensed wireless microphone users will be able to reserve vacant TV channels in the white space databases, as they do today, and the introduction of personal/portable devices on these channels will not impair their access. Unlicensed wireless microphones and unlicensed white space devices will have equal opportunity to access vacant channels on these and other TV channels and, after the incentive auction, spectrum in the 600 MHz guard bands and duplex gap as well.

90. We will not permit at this time personal/portable white space devices to operate below channel 14, including channels 3 and 4, as requested by many unlicensed proponents.[181] We believe that it is better to maintain the current overall scheme, which limits the frequencies where both personal/portable and fixed white space devices may operate, with personal/portable devices operating in higher frequency channels than fixed devices. As noted by the White Space Alliance, devices that operate at the lower frequencies typically require larger antennas that are better suited for use by fixed white space devices than personal/portable devices; thus there is no clear advantage to permitting personal/portable devices below channel 14.[182] Google recognizes the challenges cited by the White Space Alliance in using the lower VHF channels for personal/portable devices, but it and other commenters (*e.g.*, Alarm Industry Communications Committee) want the opportunity to explore new opportunities at these lower frequencies which have longer radio wavelengths.[183] We believe the Commission's Part 5 experimental radio rules provide such an opportunity for companies to conduct research on personal/portable devices in the lower VHF band.

91. *White space devices on channels above and below channel 37*. We will permit white space devices to operate on the vacant channels above and below channel 37 that are now available only for wireless microphone use 18 months after the effective date of this rule but no later than release of the *Channel Reassignment PN* at the conclusion of the incentive auction. Before this rule change becomes effective, we will have implemented the revised procedures for the immediate reservation and notification of wireless microphone use of vacant channels that we adopt in this proceeding.[184] This will ensure that licensed wireless microphone users, particularly broadcasters and others who cover breaking news events, will have a procedure in place that will enable them to get immediate access to needed spectrum.

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[178] *See* Google Comments at 38.

[179] Sennheiser Comments at 10; Shure Comments at 23-26.

[180] Shure Comments at 24.

[181] *See, e.g.,* Alarm Industry Communications Committee Reply Comments at 4; Google Comments at 39; Microsoft Comments at 40; Motorola Comments at 4; xG Technology Comments at 6.

[182] The White Space Alliance notes that the antenna size, power and receiver sensitivity for personal/portable devices are better satisfied at higher frequencies, and the lower frequencies should be made available only for longer range fixed devices. *See* White Space Alliance Comments at 9-10.

[183] *See* Alarm Industry Communications Committee Reply Comments at 4; Google Comments at 39.

[184] *See* para. 273, i*nfra*.

92. The Commission decided in the *Incentive Auction R&O* to permit unlicensed white space devices to operate on these two vacant channels, and proposed in the *Notice* to permit such use when it adopted new procedures for the immediate reservation and notification of wireless microphone use on vacant TV channels. Few commenters addressed the proposal in the *Notice.* Google and Wi-Fi Alliance generally support the Commission's proposal, arguing that revised procedures would permit wireless microphone users to rely on the white space databases for immediate access to vacant channels.[185] CP Communications and Shure argue against the Commission's decision in the *Incentive Auction R&O* to no longer hold out two vacant channels exclusively for wireless microphone use either before or after the incentive auction.[186] NAB suggests that two vacant channels should be available only for wireless microphone use until alternative spectrum is identified and available for licensed microphone use, whether in the duplex gap or elsewhere.[187]

93. We recently adopted the *Incentive Auction Reconsideration Order*, in which we denied the requests by wireless microphone proponents to retain two televisions channels for exclusive for wireless microphone use.[188] We do not revisit that decision here. In this proceeding, we address when the channels currently designated exclusively for wireless microphone operations will become available for unlicensed white space device use as well. NAB's suggestion that we hold out two vacant TV channels until the end of the transition period is not practical. Although two vacant TV channels above and below channel 37 are easily identifiable prior to the incentive auction, we will not know until after the incentive auction how much spectrum will be repurposed and which frequency bands will remain allocated to broadcasting services. The transition from broadcasting to wireless services will occur market by market over a period of time, and the now vacant TV channels for microphone use will be phased out as markets transition. This makes it impossible to identify channels in each market for exclusive microphone use after broadcasting facilities transition out of a market and new wireless licensees plan to introduce new services. We conclude that it is better to modify the procedures for microphone users to reserve vacant TV channels for immediate use, see discussion below,[189] because such a procedure is adaptable to the changing circumstances across the TV bands and the 600 MHz band during the post-auction transition period.

4. Unlicensed Wireless Microphones

94. *Background.* In the 2010 *TV Bands Wireless Microphones R&O and Further NPRM*, the Commission granted a waiver to permit unlicensed wireless microphones to operate in the television bands (channels 2-51, except channel 37) under Part 15 pursuant to certain technical rules.[190] The Commission stated that this waiver would remain in place until such time as it established final rules for their operations. It also proposed specific Part 15 rules for unlicensed wireless microphone operations in the TV bands.[191] In the *Notice*, the Commission decided to modify the 2010 proposals in a number of

[185] *See* Google Comments at 36; Wi-Fi Alliance Comments at 7.

[186] *See* CP Communications Reply Comments at 4; Shure Comments at 11. These commenters argue that two vacant channels should remain for wireless microphone use only, and do not address the proposal in the *Notice* as to *when* unlicensed white space devices should be permitted to operate on the vacant channels.

[187] *See* NAB *ex parte* filing dated June 30, 2015, at 1.

[188] *See Incentive Auction Second Order on Reconsideration,* 30 FCC Rcd at 6801-6805, para. 122-128.

[189] *See* para. 273, *infra.*

[190] *See TV Bands Wireless Microphones R&O and FNPRM*, 25 FCC Rcd at 669, para. 52. The Commission waived Section 15.201 which requires intentional radiators operating under Part 15 to be certified for operation under this rule part, and Section 15.209 (a) which prohibits operation of Part 15 devices in the TV bands and at field strengths greater than specified in the table unless specifically permitted elsewhere in Part 15. 47 C.F.R. §§ 15.201(b), 15.209(a).

[191] *See TV Bands Wireless Microphones R&O and FNPRM*, 25 FCC Rcd at 692-696, paras. 109-123.

ways. In particular, it proposed a different methodology for determining the minimum separation distances between wireless microphones and co-channel TV stations, tighter out-of-band emission limits to enable more efficient spectrum use, and a different definition of unlicensed wireless microphones.[192]

95. *Definition of unlicensed wireless microphones in Part 15.* We adopt our proposed definition of wireless microphone as a device that converts sound into electrical audio signals that are transmitted using radio signals to a receiver which converts the radio signals back into audio signals that are sent through a sound recording or amplifying system. We also adopt our proposals that wireless microphones may be used for cue and control communications and synchronization of TV camera signals as defined in section 74.801or our rules, and that the definition of wireless microphone does not include auditory assistance devices as defined in section 15.3(a) of our rules. Sennheiser supported the proposed definition.[193] This definition encompasses the types of wireless microphones that currently operate within the TV bands, but is not so broad as to encompass other types of unlicensed devices that already have provisions in Part 15 for operation outside the TV bands.

96. We disagree with the Nuclear Energy Institute and Utilities Telecom Council that the definition of unlicensed wireless microphone be expanded to specifically include wireless headsets used at nuclear power plants for bi-directional audio communications between and among personnel.[194] To the extent that a party wishes to use wireless microphones for specialized uses that would not be acceptable under this definition, such uses would be more appropriately authorized through a waiver rather than by adopting a broader definition of wireless microphone.

97. *Permissible frequencies of operation.* As proposed, we will allow unlicensed wireless microphones to operate in the TV spectrum on channels 2-51, excluding channel 37 in all locations and channel 17 in Hawaii, which is allocated for non-broadcast purposes. This action will make the maximum number of TV channels available for unlicensed wireless microphones. We are also adding an advisory to the rules indicating that the highest channel available for unlicensed wireless microphones will ultimately be determined by the outcome of the incentive auction, and the rules will be modified consistent with the auction results. Consistent with the rules for wireless microphones licensed under Part 74, we will require unlicensed wireless microphones to operate at least four kilometers outside the following protected service contours of co-channel TV stations.[195]

Type of station	Protected contour		
	Channel	Contour (dBu)	Propagation curve
Analog: Class A TV, LPTV, translator and booster	Low VHF (2-6)	47	F(50,50)
	High VHF (7-13)	56	F(50,50)
	UHF (14-51)	64	F(50,50)
Digital: Full service TV, Class A TV, LPTV, translator and booster	Low VHF (2-6)	28	F(50,90)
	High VHF (7-13)	36	F(50,90)
	UHF (14-51)	41	F(50,90)

98. We disagree with Motorola that we should prohibit the operation of wireless microphones on channels 14-20 to protect the Private Land Mobile Radio and Commercial Mobile Radio Services (PLMRS/CMRS).[196] As CP Communications and Sennheiser noted, both licensed and unlicensed

[192] *See Notice*, 29 FCC Rcd at 12292-12295, para 148-157.

[193] *See* Sennheiser Comments at 13.

[194] *See* Nuclear Energy Institute and Utilities Telecom Council Comments at 11.

[195] *See Incentive Auction R&O,* 29 FCC Rcd at 6698-6699, para. 305.

[196] *See* Motorola Comments at 9.

wireless microphones have operated on these channels for years without interference to the PLRMS/CMRS.[197] We also decline to allow the use of spectrum sensing to determine channel availability for wireless microphones as requested by Sennheiser.[198] The Commission did not propose to allow spectrum sensing as an alternative to the four kilometer separation distance, and no other party made a similar proposal or responded to Sennheiser's comments on the issue. Therefore, there is not sufficient information in the record for us to determine whether Sennheiser's proposal would adequately protect co-channel TV stations.

99. *Technical requirements for unlicensed wireless microphones.* Consistent with the current technical rules that apply to unlicensed wireless microphones under the existing Part 15 waiver and as supported in the record, we will permit wireless microphones to operate with a power level of up to 50 milliwatts EIRP in both the VHF and UHF TV bands.[199] We are specifying the power limit in terms of EIRP, which we base on the proposed 50 milliwatt conducted power limit and an assumed antenna gain of 0 dBi. We expect that this power level is appropriate for most users, particularly because parties using Part 15 wireless microphones will commonly be entities operating in smaller venues that do not require the longer range operation that higher power allows.[200] As suggested by Shure, we are specifying the power limit in terms of EIRP.[201] We are specifying EIRP rather than conducted power as proposed in the *Notice* for several reasons.[202] First, specifying the power limit in terms of EIRP ensures uniformity in the maximum radiated power for all unlicensed wireless microphones.[203] If we were to specify a conducted power limit without any antenna gain requirement, different devices operating at the same conducted power level could in fact be radiating at higher or lower power levels depending on their antenna gain.[204] Specifying the power limit in terms of EIRP will be particularly beneficial in the VHF band, where the efficiency of antennas is lower due to the longer radio wavelengths, since this approach will allow manufacturers to adjust the radiated power to partially compensate for low antenna efficiency. Also, specifying EIRP is consistent with other Part 15 rules, which generally specify radiated emission limits in a form that considers both power and antenna gain, *e.g.,* field strength, EIRP, or a combination of conducted power and antenna gain.[205] To reduce the compliance burden on wireless microphone operators, we are specifying power limits for these devices only in terms of EIRP, rather than allowing the use of either EIRP or conducted measurements as Shure suggests.[206]

100. As proposed in the *Notice* and supported by the record,[207] we will require unlicensed

[197] *See* CP Communications Reply at 6; Sennheiser Comments at 14.

[198] *See* Sennheiser Comments at 13.

[199] *See* Shure Comments at 20.

[200] Licensed Part 74 wireless microphones may operate with a power level of up to 250 milliwatts in the UHF TV band. *See* 47 C.F.R. § 74.861(e)(1)(ii).

[201] *See* Shure Comments at 20.

[202] *See Notice,* 29 FCC Rcd at 12293, para. 151. The Commission sought comment on whether the power should be expressed as EIRP rather than conducted power.

[203] *See, e.g.,* Shure Comments at 20.

[204] For example, a device with a 50 milliwatt conducted power output into an antenna with a gain of 0 dBi would have an EIRP of 50 milliwatts, while if the same device had an antenna with a gain of -3 dB, the EIRP would be 25 milliwatts, and if it had an antenna with a gain of 3 dB, the EIRP would be 100 milliwatts.

[205] For example, spread spectrum and fixed white space device limits are specified in terms of maximum conducted power and antenna gain. *See* 47 C.F.R. §§ 15.247(b) and 15.709(a)(1). Personal/portable white space devices, vehicular radar, and ultra-wideband device limits are specified in terms of EIRP. *See* 47 C.F.R. §§ 15.709(a)(2), 15.252(b), and 15.509-15.119.

[206] *See* Shure Reply Comments in GN Docket No. 14-166 at 31.

[207] *See* Microsoft Comments at 34; Sennheiser Comments at 13; Wi-Fi Alliance Comments 37.

wireless microphones to comply with the same channelization, frequency stability, and bandwidth requirements as Part 74 wireless microphones.[208] Specifically, we will require that operation be offset from the upper or lower channel edge by 25 kHz or an integral multiple thereof and that the operating frequency tolerance be 0.005 percent. We will permit the combination of multiple adjacent 25 kHz segments within a TV channel to form an operating channel with a maximum bandwidth not to exceed 200 kHz. Consistent with the measurement requirements for other Part 15 transmitters, we will require that the frequency tolerance be maintained over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage, for a variation in the supply voltage from 85 percent to 115 percent of the rated supply voltage at a temperature of 20 degrees C, and that battery operated equipment be tested using a new battery.[209] The 25 kHz offset requirement will prevent wireless microphones from operating at the edge of a TV channel where they could interfere with TV stations on adjacent channels, and the frequency tolerance requirement will ensure that devices do not drift from the designated frequencies. The limit on the bandwidth that a wireless microphone may occupy will leave room for the operation of multiple microphones within a TV channel.

101. We will also require that unlicensed wireless microphones comply with the same emission mask as licensed Part 74 wireless microphones. The record supports this result.[210] Specifically, we will require that emissions from analog and digital unlicensed wireless microphones comply with the emission masks in Section 8.3 of ETSI EN 300 422-1 v1.4.2 (2011-08), *Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 1: Technical characteristics and methods of measurement.*[211] Requiring wireless microphones to meet these tighter emission requirements will protect authorized services in adjacent bands from harmful interference, and will improve spectrum sharing by wireless microphones. Outside of the frequency range where the ETSI masks are defined (one megahertz above and below the wireless microphone carrier frequency), we will require that emissions comply with same limit as the edge of the ETSI masks, specifically, 90 dB below the level of the unmodulated carrier. We are incorporating the ETSI EN 300 422-1 standard into the Part 15 rules by reference and adding it to the list of measurement procedures in Sections 15.31 and 15.38.[212]

B. 600 MHz Guard Bands and Duplex Gap

102. We will allow fixed and personal/portable white space devices to operate in the 600 MHz guard bands between the wireless downlink band and the TV band with a power level of 40 milliwatts EIRP and a bandwidth of six megahertz when the guard band is sufficiently large (nine or 11 megahertz) to allow at least three megahertz frequency separation from wireless downlink spectrum. We will also allow white space devices to operate in a seven megahertz guard band at 40 milliwatts EIRP provided it narrows its bandwidth to four megahertz to maintain the required three megahertz frequency separation from wireless downlink spectrum. White space devices will not be permitted to operate in the guard bands immediately above and below channel 37, which would be adjacent to wireless downlink spectrum, thus not providing any frequency separation. We will allow unlicensed wireless microphones—which are narrow-band devices—to operate at 20 milliwatts EIRP in guard bands of any size, including three

[208] *See Notice,* 29 FCC Rcd at 12293, para. 152.

[209] *See id.* §§ 15.225(e), 15.229(d) and 15.231(d).

[210] *See* Microsoft Comments at 34; Motorola Comments at 9; Sennheiser Comments at 13; Shure Comments at 25; Wi-Fi Alliance Comments at 38.

[211] This standard is available at www.etsi.org.

[212] *See* 47 C.F.R. §§ 15.31 and 15.38. Section 15.31 lists the various measurement procedures that are used to determine compliance with the Part 15 rules. Section 15.38 lists the materials that have been incorporated into the rules by reference.

megahertz guard bands, provided they leave at least a one megahertz frequency separation from wireless downlink spectrum.

103. In the 600 MHz duplex gap, we require that unlicensed wireless microphones and white space devices operate at the same power limits as permitted in the 600 MHz guard bands, and that licensed wireless microphones operate at the same power limit as unlicensed wireless microphones. Also, we apportion the band to permit white space devices and unlicensed wireless microphones to operate in the upper six megahertz segment of the duplex gap and licensed wireless microphones in the four megahertz segment below that, with a one megahertz buffer at the lower end of the duplex gap adjacent to wireless downlink spectrum (1-4-6 split). White space devices and unlicensed wireless microphones operating in the guard bands and duplex gap will be required to rely on a database to identify the guard band frequencies available at their location.[213]

104. In the discussion that follows, we first address unlicensed white space device and wireless microphone operation in the guard bands between TV and wireless downlink bands, and subsequently address operations in the duplex gap between wireless downlink and wireless uplink bands. The guard band discussion separately addresses requirements to protect adjacent TV bands and adjacent wireless downlink bands. Because the duplex gap also is adjacent to wireless downlink bands, the requirements we address in the guard band section on this topic apply equally to the duplex gap and are addressed there, rather than in the duplex gap section. The duplex gap section addresses protection of wireless uplink bands as well as the apportionment of the duplex gap among unlicensed white space devices, unlicensed wireless microphones, and licensed wireless microphones.

105. Finally, we require unlicensed wireless microphones and white space devices that operate in these bands to meet many of the requirements that apply to their operation in the TV bands.[214] For example, we apply the same definition of wireless microphone to provide a uniform definition for unlicensed wireless microphones across all bands. We will also require that unlicensed wireless microphones operating in the guard bands and duplex gap comply with the same channelization, bandwidth, frequency stability, and emission mask requirements that apply to wireless microphones operating in the TV bands. These requirements are necessary to prevent harmful interference to authorized services outside the bands where wireless microphones operate. Similarly, we require white space devices that operate in the guard bands and duplex gap to meet the same bandwidth, emission mask, and database access requirements that apply to their operation in the TV bands.

1. Guard Bands

106. *Background*. The 600 MHz band includes a guard band between the wireless downlink services band and the TV band that will vary in size and frequency depending on the amount of spectrum recovered in the auction. There are three possibilities for the size of this guard band: 11 megahertz, nine megahertz, and seven megahertz. There will be a single three megahertz guard band above channel 37 if 84 megahertz of spectrum is recovered, and a three megahertz guard band on each side of channel 37 if more than 84 megahertz of spectrum is recovered. If less than 84 megahertz of spectrum is recovered, there will not be any guard bands adjacent to channel 37. In the *Notice*, the Commission observed that if exactly 84 megahertz of spectrum is recovered in the auction, channel 37 plus the three megahertz guard band that protects the WMTS and RAS on channel 37 from wireless downlink services would serve as the

[213] Graphic representations of the 600 MHz guard band options and of the 600 MHz duplex gap are provided after paragraphs 146 and 153, respectively.

[214] The Commission proposed that unlicensed wireless microphones operating in the guard bands, including the duplex gap, meet many of the same technical requirements that it proposed for unlicensed wireless microphones operating in the TV bands—for example, the definition of wireless microphone, channelization, bandwidth, frequency stability, and emission mask requirements. *See Notice*, 29 FCC Rcd at 12295, para. 158. In the *Notice*, the Commission also proposed to modify the Part 15 rules to refer to "white space device" so that the rules would apply equally to the 600 MHz band. *See Notice*, 29 FCC Rcd at 12253, para 14.

guard band between wireless downlink services and the TV band. The purpose of the three megahertz guard band is primarily to protect the WMTS and RAS on channel 37 from interference from wireless downlink services, but it also would protect wireless downlink services from harmful interference from white space devices operating on channel 37.[215] The Commission sought comment on whether white space devices could make use of any portion of these three megahertz guard bands. It also sought comment on whether any types of low power, narrowband devices could use these guard bands without causing harmful interference to licensed services in the adjacent bands.[216]

107. In the *Notice*, the Commission proposed to allow white space devices to operate in a six megahertz frequency band within the guard bands at a power level of 40 milliwatts EIRP, provided there would be a frequency separation of at least three megahertz from wireless downlink spectrum.[217] This proposal would allow white space device operation in guard bands of nine or eleven megahertz.[218] The Commission sought comment on whether to allow white space device operation at lower power or in narrower bandwidths within guard bands of seven or three megahertz.[219] The Commission also proposed to allow both fixed and personal/portable white space devices to operate in the guard bands.[220] It sought comment on whether to allow Mode I personal/portable white space devices (without geo-location) to operate in the guard bands, or limit operation to only fixed and Mode II white space devices (with geo-location).[221]

108. The Commission also proposed to allow unlicensed wireless microphones to operate across the guard band between television and wireless downlink spectrum, with the exception of a one megahertz segment at the upper end that would act as a buffer between unlicensed wireless microphone operations and wireless downlink services.[222] In the three megahertz guard bands adjacent to channel 37, the Commission proposed to allow unlicensed wireless microphones to operate in the two megahertz segment closest to channel 37, leaving a one megahertz buffer to protect wireless downlink services adjacent to these guard bands.[223] The Commission also proposed that unlicensed wireless microphones operating in the guard bands and duplex gap, and licensed wireless microphones operating in the duplex gap, operate with a maximum conducted power output of 20 milliwatts to the antenna—which is less than the 50 milliwatt power level proposed for unlicensed wireless microphones in the TV bands and the 250 milliwatt power permitted for licensed wireless microphones—to protect licensed wireless services outside these frequency bands.[224]

a. Protecting adjacent TV bands

109. *White space devices*. We are adopting our proposal to allow fixed and personal/portable white space devices to operate at 40 milliwatts EIRP in a six megahertz frequency band within the guard

[215] *See Notice*, 29 FCC Rcd at 12276, para. 90. In the *Notice*, the Commission also proposed to permit unlicensed fixed and personal/portable white space device operations on channel 37. If more than 84 megahertz is recovered and the Commission decides to permit white space devices to operate on channel 37, there could be a contiguous block of nine or 12 megahertz of spectrum for white space operation. *See Notice*, 29 FCC Rcd at 12285, para. 125.

[216] *Id.* at 12276, 12285, paras. 90 and 125.

[217] *Id.* at 12273, 12275, para. 82, 86.

[218] *Id.* at 12275, para. 87-88.

[219] *Id.* at 12276, para. 89-90.

[220] *Id.* at 12273, para. 80.

[221] *Id.*

[222] *Id*. at 12295, para. 159.

[223] *Id.*

[224] *Id.* at 12296, para. 160.

bands and duplex gap.[225] The record shows that this power level and bandwidth will be useful for unlicensed devices,[226] and our analysis shows that operation at this power level will not cause harmful interference to television services in adjacent bands.[227] As discussed above, we find that fixed white space devices can operate in the TV bands with a power level of 40 milliwatts EIRP and an antenna height of 10 meters AGL on channels immediately adjacent to occupied TV channels.[228] We will therefore also allow fixed white space devices to operate in the guard band adjacent to the remaining TV spectrum at the same power level and antenna height that we are allowing in the TV bands.

110. We will allow white space devices to operate in the 600 MHz guard bands under the technical requirements that we are adopting herein. In the event that market variation necessitates placing TV stations in the guard bands in some markets, we will require that white space devices operating in the guard bands comply with the same requirements (*e.g.,* minimum separation distances) that apply to white space devices operating in the TV bands.

111. *Wireless microphones*. As discussed below, we will allow wireless microphones to operate in the guard bands and duplex gap with a maximum power of 20 milliwatts EIRP. Consistent with our treatment of unlicensed wireless microphones in the TV bands,[229] we are specifying the power limit in terms of EIRP rather than conducted power, as proposed in the *Notice*.[230] Shure supports specifying the microphone power in terms of EIRP. It comments that by doing so, the Commission will ensure that wireless microphones, which have compact omni-directional antennas, can still achieve the full power permitted under the rules.[231] However, wireless microphone power limits in the guard bands will be lower than the levels permitted under the current Part 74 rules (50 milliwatts in the VHF TV band and 250 milliwatts in the UHF TV band) or under the Part 15 waiver (50 milliwatts in both the VHF and UHF TV bands).[232] As discussed below, this is necessary to protect adjacent band wireless downlink services from harmful interference. Where the guard band is immediately adjacent to TV spectrum, we predict that wireless microphones operating at 20 milliwatts EIRP or less will not cause harmful interference to TV reception because they already operate in such a manner (*i.e.,* with no frequency separation) at the higher 50 milliwatt power level without causing interference.

b. Protecting adjacent wireless downlink bands

(i) White Space Devices.

112. *Background.* In the *Notice*, the Commission proposed to allow both fixed and personal/portable white space devices to operate in the guard bands.[233] To protect wireless handsets, the *Notice* proposed to limit the power of white space devices in the guard bands and require a buffer between the edge of the channel used by a white space device and wireless downlink services.[234] Specifically, the

[225] *Id.* at 12275, para. 86.

[226] *See* Adaptrum Comments at 6, Dynamic Spectrum Alliance Comments at 8, Google Comments at 16, Microsoft Comments at 5, Motorola Comments at 9, and OTI/ PK Reply Comments at 5.

[227] *See* paras. 121-135, *infra.*

[228] *See* para. 29, *supra.*

[229] *See* para. 99, *supra.*

[230] *See Notice,* 29 FCC Rcd at 12296, para. 160.

[231] *See* Shure Comments at 20-21.

[232] *See* 47 C.F.R. § 74.861(e)(1) and *TV Bands Wireless Microphones R&O and Further NPRM*, 25 FCC Rcd at 684, para. 84.

[233] *See Notice,* 29 FCC Rcd at 12273, para. 80. The Commission sought comment on whether personal/portable operation should be limited to only Mode II devices, which include a geo-location capability.

[234] *Id.* at 12273, para. 81.

Commission proposed that white space devices could operate at 40 milliwatts EIRP in a six megahertz frequency band within the guard bands with at least a three megahertz frequency separation from wireless downlink spectrum. The Commission stated that this proposed approach would maximize spectrum use while preventing harmful interference to licensed services.[235]

113. A number of parties strongly support the Commission's proposal to allow white space device operation in the guard bands at 40 milliwatts.[236] Several of these parties argue that a 40 milliwatt power limit is overly conservative,[237] and that this limit could be increased to 100 milliwatts or greater without causing harmful interference to wireless downlink services.[238]

114. Other parties argued that operation in the guard bands at 40 milliwatts and three megahertz frequency separation, as proposed in the *Notice,* will result in harmful interference to wireless downlink services at significant distances.[239] All of these parties argue that emission limits for unlicensed devices should protect licensed services when licensed and unlicensed devices are separated by a distance of one meter.[240] CTIA and Qualcomm submitted reports that purport to show the impact of unlicensed devices on licensed wireless equipment.[241] Both parties assert that harmful interference to licensed wireless equipment should be defined as a one dB rise in the receiver noise floor.[242] CTIA and AT&T argue that out-of-band emission limits for white space devices must be significantly reduced below 40 milliwatts to prevent harmful interference to wireless downlink services.[243] These parties also argue that the minimum frequency separation between white space devices and wireless downlink spectrum should be at least five megahertz, and that even at that frequency separation, a power level of less than 40 milliwatts is necessary to prevent harmful interference.[244]

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[235] *Id.* at 12273-74, para. 82.

[236] *See* Broadcom Comments at 2, Dynamic Spectrum Alliance Comments at 9, Google Comments at 5, Microsoft Comments at 14, Motorola Comments at 8, OTI/PK Reply Comments at 5, White Space Alliance Comments at 20, and Wi-Fi Alliance Comments at 23.

[237] For example, Broadcom states that it tested three of the most popular handheld wireless devices and found that they exceed the 3GPP minimum performance specifications for rejecting adjacent channel signals by more than 20 dB. *See* Broadcom Comments at 13.

[238] *See* Broadcom Comments at 9 (power limit could be 112.5 milliwatts), Google Comments at 11 (power limit could be 302 milliwatts), Microsoft Comments at 14 (power limit in 11 megahertz guard band should be 100 milliwatts) and Motorola Comments at 8 (power limit should be 100 milliwatts).

[239] *See* AT&T Reply Comments at 5, CTIA Comments at 11, Qualcomm Comments at 4, and TIA Comments at 4.

[240] *See* AT&T Reply Comments at 4 (footnote 8), CTIA Comments at 29, Qualcomm Comments at 6 n.9 and TIA Comments at 6.

[241] *See* CTIA Comments at Appendices A through C (V-COMM measurement reports) and Qualcomm Comments at Appendix.

[242] *See* CTIA Comments at 10 and Qualcomm Comments at 9.

[243] The current adjacent channel emission limit for 40 milliwatt personal/portable white space devices is -56.8 dBm/100 kHz EIRP. *See* 47 C.F.R. § 15.709(c)(1)(i). The Commission did not propose any change to this limit for personal/portable devices, but proposed to allow fixed devices to operate at 40 milliwatts, subject to effectively the same adjacent channel emission limit (-62.8 dBm/100 kHz conducted power, plus an antenna gain of 6 dBi). *See Notice,* 29 FCC Rcd at 12266, para. 59. CTIA and AT&T request that the out-of-band emission limit be reduced to -89 dBm/100 kHz EIRP, which is a reduction of 32.2 dB. *See* CTIA Comments at 13 and AT&T Reply Comments at 5.

[244] *See* CTIA Comments at 25 and AT&T Comments at 8. These parties recommend a power limit of 6.6 dBm (5 milliwatts) for white space devices operating with a five megahertz frequency separation from wireless downlink spectrum.

115. *Discussion.* We are adopting our proposal to require that white space devices operating at 40 milliwatts EIRP in a six megahertz frequency band within the guard bands provide at least a three megahertz frequency separation from wireless downlink spectrum. We are selecting three megahertz as the minimum frequency separation because filter attenuation increases beyond a three megahertz frequency separation, thus reducing the potential for white space devices to cause harmful interference to wireless downlink services.[245] In addition, the out-of-band emissions from white space devices, which are a potential source of harmful interference to wireless handsets, tend to fall further below the limits required by our rules[246] as the frequency separation from the white space device increases.[247] Thus, a frequency separation of three megahertz will reduce the likelihood of a wireless handset receiving harmful interference.

116. As an initial matter, we noted above that the requirements that apply to the guard band apply equally to the duplex gap. CTIA disagrees with this approach stating that the licensed band edge near the guard band does not have the duplex filtering as is present in the duplex gap.[248] It believes performance and/or interference rejection at the licensed band edge of the guard band will not be as strong as that at the edge of the duplex gap. CTIA further states that V-COMM's testing indicates that the frequency buffers necessary for the guard band to protect licensed 600 MHz operations are generally larger than those required in the duplex gap.[249] As indicated in the sections that follow, our analysis uses the LTE 3GPP standard which specifies a minimum adjacent channel selectivity of 33 dB[250] as a starting point, but in some cases deviates as the record indicates real devices perform at levels better than those specified in the standard. Based on that, we found that having a buffer of at least three megahertz is sufficient to protect 600 MHz band wireless downlinks. CTIA asserts that the filtering in the duplex gap is better than that for the guard band. In most cases, as is here, the duplex gap is generally wider than any guard bands which provides additional bandwidth over which the filter can reject undesirable signals. In any event, the 33 dB adjacent channel selectivity specification must be met in all cases, including when the wireless channel is adjacent to a guard band or the duplex gap. Thus, 600 MHz band wireless downlinks will be protected when adjacent to a guard band and should enjoy a larger margin of protection when operating adjacent to the duplex gap given the larger five megahertz frequency separation as opposed to the three megahertz minimum.[251]

117. We disagree with parties who argue that operation of unlicensed white space devices in the guard bands at a level of 40 milliwatts EIRP in a six megahertz bandwidth with a three megahertz frequency separation from wireless downlink spectrum will cause harmful interference to wireless downlink services.[252] As explained below, we believe the rules we are adopting create an environment where the potential for white space devices to cause harmful interference to adjacent wireless downlink

[245] *See* Broadcom Comments at 10-11 and n.315, *infra*.

[246] *See* Appendix A, Final Rules at section 15.709(d).

[247] *See*, *e.g.*, Adaptrum certification application, FCC ID: A2UACRS20F and 6Harmonics certification application, FCC ID: 2AASTGWS-3000.

[248] Duplexers are pairs of filters, one transmit and one receive, that function together to reduce the potential for interference between a transmitter and a receiver in the same piece of equipment.

[249] *See* CTIA Comments at 21.

[250] *See 3GPP TS 36.101, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception.* ("3GPP TS 36.101") at section 7.5.1.

[251] We note that the three megahertz minimum separation will only occur if the guard band is seven or nine megahertz wide. For the eleven megahertz wide case, the separation between a white space device and the wireless downlink band is five megahertz; the same as in the duplex gap. *See* illustration after para. 146, *infra.*

[252] *See* CTIA Comments at 15, AT&T Reply Comments at 7, Qualcomm Comments at 4, and TIA Comments 4.

bands is low. Accordingly, we find no basis to adopt significantly tighter out-of-band emission limits, lower power levels, or a five megahertz frequency buffer to protect wireless downlink receivers from harmful interference from white space devices, as advocated by CTIA and AT&T.

118. Below, we assess the potential for harmful interference from 40 milliwatt white space devices to wireless downlink services in adjacent bands. Because there are neither 600 MHz band wireless devices nor portable white space devices currently available, our analyses are based on the predicted performance of such equipment. Our analyses also rely on predictions of other factors, including propagation and body losses,[253] which affect whether harmful inference will occur. These losses can vary significantly in practice, so we must make reasonable assumptions concerning these factors based on our experience. The purpose of the analyses is to determine whether the rules we are adopting comply with the Spectrum Act's requirement that the Commission not permit any use of a guard band that it determines would cause harmful interference to licensed services.[254] Harmful interference is defined by the Commission's rules as "interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Regulations."[255] We find it appropriate to use the Commission's existing definition of harmful interference. Applying the existing definition of harmful interference to the Spectrum Act, we find that we may not permit any use of the guard bands that we determine would cause serious degradation, obstruction, or repeated interruption to new 600 MHz service. We further find that we need not set technical rules so restrictive as to prevent all instances of interference, as opposed to harmful interference. Determining *ex ante* when operations in one band will seriously degrade, obstruct, or repeatedly interrupt operations in another band necessarily involves the Commission examining the particular interference scenario that is likely to arise and exercising its predictive judgment. In this similar circumstance, we establish technical rules for whites space devices and microphones that will permit their use without causing harmful interference (although not necessarily eliminating all interference) to new 600 MHz service licensees.

119. The analyses presented below build on the same analyses described in the *Notice* and are refined based on the record in this proceeding. Qualcomm states that the *Notice* completely overlooked CEA's technical study filed in the incentive auction proceeding that examined potential inter-service interference scenarios in the 600 MHz band, including between LTE equipment and unlicensed TV white space devices.[256] Qualcomm asserts that this study found unlicensed white space device operations in the duplex gap and guard band to present a significant and unresolvable interference risk to licensed mobile operations. Google counters that the CEA study cannot be relied upon because it ignores body loss and other significant sources of propagation loss, and fails to take into account spectral separation between the unlicensed channel and LTE downlink.[257] CEA states that an option to mitigate potential interference is

[253] Radio signals can experience many types of loss as they travel from transmitter to receiver. Among these are propagation loss (or path loss) and body loss. Propagation loss is any loss in the strength of a signal traveling from one point to another. Such losses may be due to absorption, scattering, dispersion, or the like. *See* http://www.dictionaryofengineering.com/definition/propagation-loss.html. Body loss is the loss generated due to signal blocking and absorption when a terminal antenna is close to the body. *See* http://www.teletopix.org/4g-lte/calculation-for-body-loss-and-feeder-loss-for-lte/.

[254] *See* 47 U.S.C. § 1454(e). The Part 15 rules are consistent with the Spectrum Act in that unlicensed operations are permitted only if they do not cause harmful interference to authorized services. *See* 47 C.F.R. § 15.5(b).

[255] *See* 47 C.F.R. § 2.1. In particular, we note that the Spectrum Act requires that the Commission not permit any use of a guard band that it determines would cause harmful interference to licensed services. This is analogous to the Part 15 rules, which provide that unlicensed operations are permitted only if they do not cause harmful interference to authorized services. *See* 47 U.S.C. § 1454(e) and 47 C.F.R. § 15.5(b).

[256] *See* Qualcomm Comments at 14 citing CEA *ex parte c*omments in GN Docket No. 12-268 filed December, 16, 2013 (CEA Study).

[257] *See* Google Comments at 16, n.44.

to add frequency separation within the protective band and suggests that three to four MHz separating the unlicensed operation from the licensed service may be enough to allow for some attenuation (roll-off) and account for the worst of the filter bandpass instabilities.[258] CEA also states that the criteria used in its analyses are intentionally conservative and that other assumptions could be considered in individual cases.[259] The record in this proceeding supports assumptions more conservative that those used by CEA. For example, CEA assumed antenna gain of 6 dBi for a whitespace device and 0 dBi for an LTE handset,[260] whereas the record in this proceeding supports -6 dBi antenna gain for personal/portable white space devices and LTE handsets.[261] In addition, as noted by Google, CEA did not consider several other sources of loss. For these reasons, we disagree with Qualcomm and do not rely on the CEA Study in making our decision in this proceeding. However, we note that we are providing at least three megahertz frequency separation between white space devices and 600 MHz service downlink spectrum which is consistent with CEA's suggestion regarding mitigating potential interference.

120. Our analyses show little potential for harmful interference to wireless handsets from portable white space devices. We believe that this represents the worst case for harmful interference because these types of devices would operate in the closest proximity to each other. By contrast, we expect that white space devices used in fixed applications, such as access points or for providing point-to-point communications, would typically have a greater physical separation distance from licensed wireless handsets, thus posing even less risk of harmful interference. We first considered the impact of out-of-band emissions from white space devices into the frequency bands that are received by wireless handsets. As commenters note, out-of-band emissions from a transmitter in an adjacent band appear as co-channel emissions within the band of a service potentially receiving harmful interference.[262] Second, we consider the effect of "blocking" from a white space transmitter to wireless receivers in the adjacent wireless downlink band. Blocking interference occurs because a receiver has limits on the level of adjacent channel emissions it can tolerate due to the selectivity of its internal filters.[263]

121. *Out-of-band emission interference.* With respect to harmful interference to wireless handsets from white space device out-of-band emissions, we make several assumptions which are detailed below. First, we started by considering the reference sensitivity of the handset receiver, for which we use -97 dBm at the antenna input as specified the applicable 3GPP standard.[264] This is the weakest signal level at which a receiver can meet a minimum specified throughput. CTIA states that for the devices tested, their testing shows a -105.1 dBm LTE receive sensitivity on average.[265] TIA notes that the 3GPP

[258] *See* CEA Study at 6.

[259] *Id.* at 5.

[260] *Id.* at 33-34.

[261] *See* para. 121, *infra.*

[262] *See* CTIA Comments at 12.

[263] We note that we do not consider intermodulation interference as commenters indicate that such interference is less of a concern than out-of-band or blocking interference. *See* CTIA Comments at 11 (stating that the V-COMM tests showed that "…out of band emissions and receiver blocking were the predominant causes for the required frequency separation and power control, …), Broadcom Comments at 16 (stating that its testing "… demonstrated conclusively that third-order intermodulation interference is of even less concern than blocking or out-of-band emissions from white space devices, …").

[264] The reference sensitivity power level is defined as the minimum mean power received at the antenna connector at which a throughput requirement shall be met for a specified reference measurement channel. The -97 dBm reference sensitivity is consistent with the specifications for a 700 MHz LTE transmitting over a five megahertz channel in bands 12, 13, and 17. *See 3GPP TS 36.101, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception.* ("3GPP TS 36.101").

[265] *See* CTIA Comments at Appendix B, pages 14 and 98.

standard is band specific when defining sensitivity levels and that specific specifications for the 600 MHz band have not been adopted. It states, however, that -97 dBm may be a reasonable assumption for a 5 MHz LTE channel size, particularly since that is the current specification for nearby bands.[266] We reject CTIA's assertion that we should use their measured -105.1 dBm level as the basis for developing our rules. First, we note that the 3GPP standard states that the test requirement for sensitivity is intended for conformance testing only and does not necessarily reflect the operational conditions of the network.[267] Additionally, as Google points out, we observe that data provided by CTIA shows that very few handsets operate at or near the maximum power of 23 dBm allowed by the rules, which correspondingly indicates that those handsets typically operate above their reference sensitivity level.[268] CTIA's data show that 95 percent of LTE handsets are operated at power levels of 10 dBm or less and that 65 percent are operated at power levels of 0 dBm or less. To save battery power, handsets incorporate power control to use the least amount of power necessary to ensure a good communications link; a lower handset transmit power corresponds to a higher received power level and a higher received power level corresponds to operation above the handset sensitivity level. We conclude from this data that in real-world operation, handsets rarely operate at levels approaching their sensitivity level or the reference sensitivity level specified in the 3GPP standard. In particular, we note that while we assumed a -97 dBm receive level for wireless handsets, LTE receivers commonly operate with a higher receive level because wireless carriers design their networks to provide better coverage than the minimum signal levels at which equipment is expected to operate. It is not unreasonable to assume that a handset will typically operate at a level that is at least 10 dB higher than the minimum.[269] Thus, we believe that using the -97 dBm reference sensitivity specified in the 3GPP standard is conservative.

122. An LTE handset will typically use an antenna with a gain of less than 0 dBi due to size and efficiency constraints, so we assume an antenna gain of -6 dBi. This assumption is consistent with Broadcom's, Google's, and Microsoft's comments.[270] Qualcomm conducted several tests to show interference potential between white space devices and LTE handsets and presented its results based on a -7 dBi antenna gain.[271] CTIA, in contrast, cites the 3GPP standard and argues that the industry standard for LTE device antenna gain is 0 dBi.[272] It claims that Qualcomm, in assuming -7 dBi antenna gain, was accounting for other losses, such as body loss, polarization mismatch, and other miscellaneous losses.[273] Qualcomm argues that Broadcom overestimates loss conditions because Broadcom's calculations include 3 dB of loss for antenna polarization mismatch, which Qualcomm contends is already accounted for in using -6 dBi antenna gain for the LTE device.[274] We disagree with CTIA and Qualcomm. Typical link

[266] *See* TIA Comments at 13.

[267] *See* 3GPP TS 36.101 at Note following Table 7.3.1-1.

[268] *See* Google *ex parte* comments filed May 22, 2015 at 5 citing CTIA *ex parte* comments filed May 8, 2015 at 6-7.

[269] When wireless licensees deploy their networks, they design them to achieve reliable service with a robust wireless signal, with propagation statistics of 90 percent or greater. *See e.g.* TIA Bulletin TSB-88-B. This increases the planned wireless signal strength over the median value by 10 dB or more and helps to maintain the reliability of mobile operations. Reliability prediction margins for wireless communications systems performance planning are derived based on location percentages of 90%, 95%, or 97%, and a time percentage of 100%.

[270] *See* Broadcom Comments at 4-5 finding that the following assumptions, common to both unlicensed access points and client devices, are reasonable and consistent with its understanding of their performance: Antenna polarization and mismatch – 3 dB; Shadowing loss – 3 dB; LTE antenna gain - -6 dB; LTE body loss – 3 dB totaling 15 dB of loss. *See also* Google Comments at 6 and Microsoft Comments at 6.

[271] *See* Qualcomm Comments at 10-12.

[272] *See* CTIA Comments at 9. *See also,* CTIA *ex parte* comments filed May 8, 2015 at 7.

[273] *See* CTIA *ex parte* comments filed May 8, 2015 at 7-8.

[274] *See* Qualcomm Reply Comments at 7 n.13.

budget calculations include separate entries for antenna gain and various losses, such as body loss, polarization mismatch, etc.[275] Thus we continue to believe that treating these as separate values does not double count or overestimate system losses. With respect to the antenna gain itself, we acknowledge that the 3GPP standard references a 0 dBi antenna. However, it states that this is a reference antenna,[276] which is an antenna with known performance, built to exacting specifications, and normally used to calibrate systems. By assuming a 0 dBi reference antenna, the standard can provide a bound on LTE device performance for testing and conformance purposes. However, antennas built into deployed equipment will perform worse than a reference antenna for a variety of reasons. First, they are often mass produced and do not conform to the same exacting specification as the reference antenna. Qualcomm acknowledges this in assuming a 3 dB loss for production variation.[277] Second, embedded handset antennas can experience several dBs of loss because they are not one hundred percent efficient.[278] In addition, antennas may also experience some loss due to impedance mismatch.[279] Finally, the radiation pattern of an antenna is not uniform in all directions and will have less than the maximum gain (or loss) in many directions. For these reasons, we believe that assuming -6 dBi of antenna gain for our analysis represents a realistic representation of the embedded antenna that will be installed on LTE handsets in the 600 MHz band.

123. Because the separation distances between unlicensed and licensed devices we are considering are short (*i.e.,* on the order of several meters maximum), a free space signal propagation model, rather than the TM-91-1 model as used in the *Notice*, is appropriate.[280] Free space path loss is the propagation loss that results from a line of sight path through space (*e.g*., the air). When the transmitter and receiver are very close together, there is a high probability that they have a clear line of sight, and free space path loss provides a bound on the loss of the transmission system. We also note that there is unanimous support in the record to use free space propagation for the analysis of interference from personal/portable white space devices to wireless handsets.[281]

124. In reality, other losses beyond free space path loss, such as those due to the human body, the transmission line, the antenna, polarization mismatch, etc. must also be considered. We assume several factors will attenuate the signal transmitted from the unlicensed device. First, we assume that there will be 2 dB signal loss due to polarization mismatch between transmit and receive antennas. Several parties support the use of 3 dB for this factor.[282] Qualcomm and TIA state that polarization

[275] *See*, *e.g.*, The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008) and http://www.radio-electronics.com/info/propagation/path-loss/link-budget-calculation-formula-equation.php.

[276] *See* 3GPP TS 36.101 at sections 6.1 and 7.1.

[277] *See* Qualcomm Comments at 10-11.

[278] Antenna efficiency is a measure of the power supplied to the antenna, including any reflection loss that is actually radiated by the antenna. The efficiency of small antennas that are tightly integrated into a small product can be affected substantially. Nearby grounded conductors and dielectric materials (like a typical plastic housing) will constrain and absorb the near-fields of the antenna and cause significant losses. Typical embedded antennas can range from 40% to 75% efficient which translates from more than 1 dB to over 3 dB of loss. *See* AT&T Antenna Fundamentals Technical Brief available at: http://www.att.com/edo/en_US/pdf/AntennaFundamentals.pdf.

[279] Impedance mismatch results in power reflected back from the antenna terminals into the antenna. *Id.*

[280] The free space path loss at 615 MHz is 28.23 dB at one meter and 34.25 dB at two meters. We note that free space path loss only considers the distance between a transmitter and a receiver and is independent of their height above ground. Thus, in contrast to the use of the TM-91-1 propagation model presented in the *Notice* (*See* 29 FCC Rcd at 12274, para. 84), antenna height parameters are not used here.

[281] *See e.g.,* Broadcom Comments at 5, Google Comments at 8, Microsoft Comments at 5-6, and CTIA *ex parte* comments filed May 8, 2015 at 8.

[282] *See* Broadcom Comments at 5, Google Comments at 6, Microsoft Comments at 5-6, and CTIA Comments at 9.

mismatch is already accounted for by Broadcom and others in the use of -6 dBi antenna gain and thus has been double counted.[283] TIA states that a likely use scenario is a white space device operating in close proximity to an LTE handset where polarization mismatch could possibly be 0.[284] Antenna polarization mismatch occurs due to the orientation of transmit and receive antennas not being in the same plane. Thus, as stated above, this is a separate loss factor and should be treated independent of the antenna gain factor.[285] Because two devices rarely have their antennas perfectly aligned, a polarization mismatch loss factor is appropriate to use. In theory, the polarization mismatch between a vertically and a horizontally polarized antenna is infinite. In reality, there may only be slight misalignment, and we believe we should use 2 dB loss here. We note that this is 1 dB more conservative than some parties advocate, but we believe, based on Commission precedent,[286] that this value is appropriate.

125. Second, we assume that there will be 3 dB body loss at both the unlicensed transmitter and at the LTE handset since our analysis considers portable devices that are typically held in the hand or carried on a person. Several commenters support the use of 3 dB body loss for white space devices and LTE handsets.[287] Google submits that 6 dB of body loss is a more reasonable assumption for an LTE handset.[288] In contrast, Qualcomm argues that no such loss exists for a portable white space device that could be located less than a meter away from an LTE device.[289] TIA states that devices other than handsets might be used in the 600 MHz band and that a tablet, for example, will have little head or body loss compared to a handset.[290] We disagree with Qualcomm and TIA. While devices may operate in close proximity to each other, they will generally be held in the hand or placed on a lap. Thus, some degree of body loss will be experienced. In the case where a device may be placed on a table and not held, other losses, such as absorption and reflection from the table, often in excess of the 6 dB assumed here (3 dB each for the white space device and the LTE device) substitute for body loss.[291] As with polarization mismatch, there is record support and Commission precedent for using 3 dB or more of body loss for handheld and personal/portable devices.[292] Thus, we will use the conservative value of 3 dB in our analyses.

126. Third, we assume that there will typically be 3.5 dB or more in propagation losses due to multipath and shadowing from nearby walls, objects or persons in the room.[293] Regarding multipath, in

[283] *See* Qualcomm Reply Comments at 7 n.13, and TIA Reply Comments at 6.

[284] *See* TIA Comments at 12

[285] *See* para. 122, *supra.*

[286] *See*, *e.g.*, The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008).

[287] *See e.g.,* Broadcom Comments at 5, Microsoft Comments at 5-6, and CTIA Comments at 9.

[288] *See* Google Comments at 6.

[289] *See* Qualcomm Reply Comments at 7 n.13.

[290] *See* TIA Comments at 12.

[291] *See, e.g.,* Google *ex parte* comments filed May 22, 2015 at 3-4 claiming that a tabletop could impart up to 16 dB of loss.

[292] *See e.g.,* Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands, *Report and Order*, WT Docket No. 12-357, 28 FCC Rcd 9483 (2013) at para. 147 ("In previous Commission analyses of mobile-to-mobile interference, however, the user scenario has been for voice use; that is, in prior Commission analysis, the total losses attributable to head and body losses have been in the range of as much as 6 to 10 dB for each device (both the transmitting and receiving device"). *See also,* FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008).

[293] These values are consistent with those specified by Broadcom in their comments, except that we conservatively add 0.5 dB due to multipath in addition to the shadowing loss. *See* n. 270, *supra*.

almost all cases, there will be some radiofrequency (RF) energy that reaches the receiver indirectly after bouncing off a wall or other object. This reflected signal could negatively interact with the desired signal and impart some loss. Therefore, consistent with past Commission precedent, we assume a modest 0.5 dB here.[294] Shadowing loss, which occurs due to objects in the path of an RF signal also imparts loss to the system. Broadcom, Google, and Microsoft agree with our assumption of 3 dB.[295] CTIA and Qualcomm argue that it is not appropriate to use shadowing loss for devices in close proximity.[296] We acknowledge that in the case cited by CTIA and Qualcomm, shadowing may not exist.[297] However, as described above, in any use case, the devices will either be held and exhibit body loss or placed on a table and experience reflections and absorption losses (and if there are objects on the table, some shadowing losses too). Taken together, the losses described in this and the preceding paragraphs will be present to varying degrees and in most cases at values above the conservative values we have chosen for our analysis purposes. We recognize that in real world situations, some of the assumptions we used will vary because no analysis can address every possible configuration or use case. For example, the assumed body losses could be either lower or significantly higher, depending on how a white space device or wireless handset is carried on the body or held in the hand. We believe that on the whole our analysis is extremely conservative and that harmful interference to wireless downlink services is unlikely to occur. Thus, we believe it is appropriate to use these values throughout our analyses and note that interference analyses of portable or handheld devices typically include each of these factors at values consistent with those used here.[298]

127. In addition, to account for the reduction in emissions level of white space devices in the LTE channel, we conservatively assume a 3 dB slope loss. We note that the white space out-of-band emission mask requires the emissions to attenuate to the Section 15.209 levels within six megahertz of the channel on which it is operating.[299] Therefore, these emissions will attenuate over the three to five megahertz buffer provided by the guard bands and duplex gap below the Commission's limit of -56.8 dBm/100 kHz before reaching the edge of the LTE channel. To meet the Section 15.209 limit of approximately -79 dBm beyond the adjacent six megahertz, the out-of-band emissions from the white space device must employ aggressive filtering. For example, if a white space device's out-of-band emissions were to decrease linearly to the limits required by the rules, they would decrease by 3.7 dB per megahertz or 11.1 dB over the first three megahertz and 18.5 dB over the first five megahertz.[300] Therefore, we reasonably assume that because the closest edge of a white space device's channel will be from three to five megahertz removed from the LTE downlink band, the out-of-band emissions from a

[294] *See*, *e.g.*, The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008).

[295] *See* Broadcom Comments at 4-5, Google Comments at 6, Microsoft Comments at 5-6, and Google *ex parte* comments filed May 22, 2015 at 2-3.

[296] *See* CTIA *ex parte* comments filed May 8, 2015 at 8; Qualcomm Reply Comments at 7 n.13.

[297] As Google explains, Qualcomm and CTIA urge us to develop interference protection standards based on the unrealistic assumption that "an LTE device and an unlicensed device will commonly operate one meter apart from each other, suspended in air, with no obstructions in between them." Google *ex parte* comments filed May 22, 2015 at 3.

[298] *See*, *e.g.*, The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008).

[299] *See* 47 C.F.R. § 15.209. Section 15.209 contains the general radiated emission limits that, unless otherwise specified, all Part 15 devices must meet. The limits in that rule section specify that radiated emissions from unlicensed devices in the 600 MHz band must not exceed an electric field strength level of 200 microvolts/meter measured at 3 meters (equivalent to approximately -79 dBm).

[300] There is a 22.2 dB difference from the -56.8 dBm out-of-band limit and the -79 dBm level that must be met six megahertz away. Thus, with linear attenuation, the emissions would decrease 3.7 dB per megahertz.

white space device will be at least 10 dB below the limit specified in the rules. Given the need to continue to roll-off at 3.7 dB per megahertz into the LTE channel, we believe the use of 3 dB slope loss is appropriate. Further, we note that test reports for already certified white space equipment indicate that their emissions roll-off are consistent with our description here.[301] Although the current equipment is all fixed, personal/portable equipment will have to meet the same section 15.209 limits six megahertz away from its channel. Thus, we expect those devices to have similar out-of-band emissions profiles as currently certified devices.

128. CTIA and Qualcomm argue that the interference threshold should be a 1 dB desensitization level (or 1 dB rise in the LTE receiver noise floor).[302] CTIA states that using a 1 dB desensitization threshold will ensure that the forward link budget of affected LTE systems is maintained and performance is not degraded.[303] Google argues that using a 1 dB threshold is too conservative, citing Commission precedent.[304] We agree that a 1 dB threshold is very conservative. The Commission stated in the H Block Order that a 1 dB desensitization criterion is too restrictive for modern cellular systems.[305] The Commission further noted that the 3GPP standard for UMTS and LTE devices specifies an in-band blocking requirement that sets the interfering signal level 6 dB or more above the reference sensitivity level.[306] In that proceeding, for determining mobile interference, the Commission found that the 3 dB desensitization level is a more appropriate metric for determining the presence of harmful interference.[307] For the same reasons articulated in that proceeding, we believe that using a 3 dB desensitization level here is more appropriate than the 1 dB level.

129. Based on the foregoing assumptions, and using the out-of-band emission limits for 40 milliwatt white space devices (-56.8 dBm/100 kHz, or -39.8 dBm/5 MHz), we calculate that for a 3 dB desensitization level, interference could begin to occur at 0.8 meters.[308] In the interest of completeness, we note that this distance rises to 1.7 meters for a 1 dB desensitization level. Thus, we believe using even the more stringent 1 dB desensitization criterion, the probability of harmful interference occurring would be an extremely unlikely event due to a variety of factors that would need to occur simultaneously. For example, a wireless device would have to be receiving in a frequency block immediately adjacent to the guard band or duplex gap, the received wireless signal would have to be at an extremely low level, a

[301] *See*, *e.g.*, Adaptrum certification application, FCC ID: A2UACRS20F and 6Harmonics certification application, FCC ID: 2AASTGWS-3000.

[302] *See* CTIA Comments at 10 and Qualcomm Comments at 9. A 1 dB desensitization level is defined as the level of interference at which the effective noise floor of the system will rise by 1 dB, that is, the receiver sensitivity will be reduced by 1 dB. This occurs when the interfering signal level is 6 dB below the noise floor of the receiver. Similarly, 3 dB desensitization occurs when the level of interference is equal to the level of the receiver's system noise.

[303] *See* CTIA Comments at 10-11.

[304] *See* Google Reply Comments at 8. Google cites the Commission's H Block Order in which the Commission stated that LTE systems are designed to operate in a strong interference environment. *See* Service Rules for Advanced Wireless Services H Block - Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands, WT Dkt. No. 12-357, *Report and Order*, 28 FCC Rcd 9493, 9548 (2013) at para. 144.

[305] *See* H Block Report and Order, 9548 at para. 145.

[306] *See* 3rd Generation Partnership Project (3GPP), Technical Specification Group Radio Access Network, Evolved Universal Terrestrial Radio Access (E-UTRA), Base Station (BS) Radio Transmission and Reception (Release 11), Requirement 7.6.1.1 (TS 36.101 V10.7.0, June 2012).

[307] *See* H Block Report and Order, 9548-9549 at para. 145.

[308] The received power = white space device OOBE power – filter slope loss – free space path loss – polarization mismatch – transmitter body loss – receiver body loss – shadowing/multipath loss – OOBE slope loss + antenna gain.

white space device would have to be located in very close proximity to a wireless device, the antenna patterns of both the transmitter and receiver would have to be closely aligned to maximize the white space device signal at the receiver, and there would have to be very low body and other propagation losses. While situations like this could occur, we believe that the probability is very low. Even in such situations, there are other mitigating factors that could prevent harmful interference from occurring. For example, white space devices must incorporate transmit power control, so they often operate below the maximum allowable power, and wireless networks manage operating channels and handset power in noisy conditions to ensure the best possible quality of service. Thus, we believe that the criteria we are adopting for white space devices will protect the 600 MHz service from harmful interference.

130. *Blocking interference.* With respect to blocking interference, we also consider interference between portable devices. As noted above, blocking interference results from limitations on a receiver's ability to reject signals in an adjacent band. We once again started by assuming a reference sensitivity for the LTE receiver of -97 dBm/5 MHz. We also begin by considering the 3GPP standard which specifies a minimum receiver adjacent channel selectivity of 33 dB.[309] We further assumed, consistent with the *Notice*, an additional 10 dB for adjacent channel selectivity[310] beyond the edge of the channel in which a white space device operates (three to five megahertz removed from the edge of the wireless downlink band). The record is mixed on this point. Broadcom, Google, and Microsoft support this assumption.[311] Broadcom states that, because LTE handsets are subject to stringent carrier requirements, they generally exceed 3GPP performance standards. It further states that its empirical results show that LTE handsets exceed 3GPP blocking performance standards by 20 dB.[312] CTIA opposes this view stating that assuming an additional 10 dB for adjacent channel selectivity is inconsistent the 3GPP standard. CTIA avers that V-COMM's testing took into account the actual rejection levels for the devices, making the addition of 10 dB in losses unnecessary.[313] TIA states that over the first three megahertz of frequency separation, an attenuation value of 0 dB or, if supported by filter vendor characterization data, at most, 1-2 dB is an appropriate assumption for filter attenuation because the filters in wireless handset receivers typically have relatively little attenuation at smaller frequency separations than this.[314] However, as evidenced by Broadcom's measurements of receive filters, filter attenuation exceeds that value, thus reducing the potential for white space devices to cause harmful interference to wireless downlink services.[315] We note that CTIA criticizes Broadcom's study because it claims

[309] *See* 3GPP TS 36.101 at Table 7.5.1-1.

[310] *See, Notice*, 29 FCC Rcd at 12274, para. 84. While this is 10 dB greater than the 3GPP standard, information in the record of the Incentive Auction proceeding indicates that this is a reasonable assumption. *See* Broadcom March 4, 2014 *ex parte* filing in GN Docket No. 12-268, attachment at 2.

[311] *See* Broadcom Comments at 13-14, Google Comments at 13-14, and Microsoft Comments at 7-8.

[312] *See* Broadcom Comments at 13-14.

[313] *See* CTIA Comments at 29. This view is also shared by Qualcomm and TIA. *See* Qualcomm Comments at 12 and TIA Comments at 10-11.

[314] *See*, *e.g.*, TIA Comments at 12.

[315] *See* Broadcom Comments at 10-11. Based on the LTE receiver filter curves shown in Broadcom's comments, the worst case filter would have approximately 8 dB attenuation at a separation of three megahertz from wireless downlink spectrum, 18 dB at a separation of six megahertz (the middle of the band where white space devices would operate), and 26 dB at a separation of nine megahertz (the edge of the band where white space devices would operate. Their curves for a typical filter show an attenuation ranging from approximately 15 dB to over 45 dB at a frequency separation of three to nine megahertz. In contrast, in the *Incentive Auction Report and Order*, the Commission assumed, without testing, a very conservative LTE receiver filter. That filter had no attenuation until three megahertz frequency separation and an attenuation ranging from 0 dB to 50 dB at a frequency separation from 3 to 11 megahertz. *See Incentive Auction R&O* at Appendix C, para. 21.

Broadcom's small sample of devices is not indicative of the over 1500 devices in the marketplace.[316] Yet, we observe that V-COMM's testing included only 10 devices; that too is a small sample of devices. Moreover, in conducting their bench testing, V-COMM did not actually characterize the receiver filters, but simply accounted for various communication system losses (3 dB each for transmit and receive antennas to account for being held by a hand, and 3 dB for polarization mismatch and miscellaneous losses). As described above, we believe it is reasonable to include several additional losses in the analysis, which V-COMM did not do. Had it accounted for these additional losses, its results would have shown a low probability of blocking interference. Additionally, because Broadcom characterized the actual performance of LTE receive filters, we believe it is appropriate to use that data in our analysis. Thus, we believe that allowing for an additional 10 dB over the 3GPP standard for receiver selectivity is a reasonable assumption.

131. As noted, we make many of the same assumptions as in our out-of-band emission interference analysis, including the use of a free space propagation model, 2 dB for antenna polarization mismatch, 3 dB body loss at both the white space device and the wireless handset, 3.5 dB loss for shadowing and multipath, 3 dB for OOBE slope loss, and a receiver antenna gain of -6 dBi. Consistent with the analysis above, we also assumed that real-world devices would operate with a 10 dB stronger signal than the minimum in the 3GPP standard. For this reason, using a 3 dB desensitization criterion, we assume that interference will begin to occur to a handset at a level greater than -54 dBm (the reference sensitivity plus the adjacent channel selectivity plus 10 dB). We calculate that an LTE handset would receive an adjacent channel signal level of -54 dBm at a distance of 3.4 meters.[317] For a 1 dB desensitization level, this distance would increase to 6.8 meters. This result requires some context. First, the 3GPP standard defines blocking as the point at which throughput falls below 95% of the maximum throughput.[318] As Google showed in their measurements, variations of greater than 5% throughput typically occur under normal usage conditions.[319] This can be due to a variety of reasons, such as movement of a handset and a continuously changing electromagnetic environment.[320] Therefore, even though an LTE handset may experience some blocking interference from a white space device as close as 3.4 meters (or even 6.8 meters), we do not believe this rises to the level of harmful interference as the LTE handset will continue to function, just at a slightly slower data rate, which we believe in the vast majority of instances would not be perceptible to the user as that user would likely experience similar fluctuations in data rates under normal usage conditions.

132. In sum, we find that the likelihood of harmful interference from 40 milliwatt white space devices to wireless downlink services is extremely low. It is not possible to ensure that harmful interference will never occur, as wireless interests apparently request. The Part 15 rules recognize this fact, indicating that the limits in Part 15 will not prevent harmful interference under all circumstances and

[316] *See* CTIA Comments at 29.

[317] The received power = white space device OOBE power – free space path loss – polarization mismatch – transmitter body loss – receiver body loss – shadowing/multipath loss – OOBE slope loss + antenna gain – receive filter attenuation.

[318] *See* 3GPP TS 36.101 at Section 7.65.1.1.

[319] *See* Google *ex parte* comments filed May 22, 2015 at A19-A21. Google submitted an evaluation of the impact of radiated emissions on LTE performance. This evaluation, conducted in a suburban basement, measured throughput of an LTE device in the presence of an interferer, purports to show that the LTE device was very robust. While Google's results are not reproducible due to lack of testing in a controlled environment, they are instructive in showing the variation in data rates that occurs under normal use conditions. Its measurement show that even without an interfering signal present, data rates varied from 3 Mbps to 1 Mbps equivalent to a drop of 67%.

[320] Fading of a radio signal is usually modelled as a random process and may vary with time and geographic position.

that it is the obligation of the unlicensed device to eliminate the interference or cease operations.[321] Nevertheless, as described above, we find that actual harmful interference from white space devices to wireless systems at the technical limits we are adopting would be an extremely unlikely event due to a variety of factors that would need to occur simultaneously.[322] For example, one factor noted above is that white space devices must incorporate transmit power control, so they often operate below the maximum allowable power. Qualcomm comments that unlicensed vendors have claimed that the proposed 40 mW transmit power level already is the lowest level that can support successful communications and thus is unlikely to be reduced.[323] However, Qualcomm does not cite to these purported vendor claims and we are unable to verify them. In any event, we believe that Qualcomm mischaracterizes the record. For example, OTI/PK claims that the emergence of a mass market for unlicensed chips, devices and services in this unique low-band spectrum is wholly dependent on access to three or more 40 mW, 6 MHz channels in every market nationwide.[324] This does not imply that devices will not transmit at power levels below 40 milliwatts, only that device users need the option to transmit at that level in circumstances when it is needed. Indeed, we note that devices generally operate at the lowest power necessary for successful communications to conserve battery power. We do not believe it is appropriate to establish technical requirements for white space devices based on the absolute worst case situation which will happen only rarely in the real world.

133. While our technical analysis shows that there is a low probability that unlicensed devices will cause harmful interference to licensed wireless services, we nonetheless remind parties that our rules prohibit unlicensed devices from causing harmful interference. This is true even for unlicensed devices that comply with our technical rules. In the event white space devices cause harmful interference to licensed wireless services, there are steps that we could take to eliminate the interference. As discussed above, before transmitting, white space devices must check a database to determine what channels are available for use at their location. They also must periodically re-check the database to ensure that a channel being used continues to remain available.[325] Moreover, if a licensed wireless service provider believes that an unlicensed device is causing harmful interference to its licensed service, we require all relevant parties to work collaboratively and in good faith to address those concerns in a timely manner. Our hope is that any such concerns can be addressed by the relevant parties on a voluntary and expedited basis. To that end, we plan on providing guidance in the future about how a licensed wireless service provider can contact a party responsible for the unlicensed device to discuss interference concerns. In addition, a licensed wireless provider can ask the FCC to adjudicate any claims of harmful interference and the FCC can take immediate corrective action upon determining that there is harmful interference, including by directing the database administrator(s) to deny the offending device(s) access to spectrum.[326]

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[321] *See* 47 C.F.R. § 15.15(c). ("Parties responsible for equipment compliance should note that the limits specified in this part will not prevent harmful interference under all circumstances. Since the operators of Part 15 devices are required to cease operation should harmful interference occur to authorized users of the radio frequency spectrum, the parties responsible for equipment compliance are encouraged to employ the minimum field strength necessary for communications, to provide greater attenuation of unwanted emissions than required by these regulations, and to advise the user as to how to resolve harmful interference problems."). *See also* 47 C.F.R. § 15.5.

[322] *See* para. 129, *supra.*

[323] *See* Qualcomm Comments at 3, 5, and 13. *See also*, Qualcomm Reply Comments at 3 and 7.

[324] *See* OTI/PK Reply Comments at 1.

[325] *See* para. 12, *supra.*

[326] *See* 47 C.F.R. § 15.715(k). All types of white space devices (fixed, Mode I and Mode II) must provide their FCC identifier when requesting a list of available channels, and the database must verify that the FCC identifier is valid before returning a list of available channels. A Mode I device passes its FCC identifier to the database through the fixed or Mode II device with which it communicates. *See* 47 C.F.R. § 15.711(b)(3)(iv)(A), 15.711(f)(3), 15.713(a)(1) and (5), and 15.713(g).

134. Finally, we conclude that because our analysis shows that out-of-band emissions from white space devices have a low probability of causing harmful interference to wireless services, we find no need for tighter out-of-band emissions from white space devices requested by Qualcomm, CTIA and AT&T.[327] Additionally, we observe that the out-of-band emission limits that licensed wireless handsets must meet are higher than the out-of-band emission limits we are requiring white space devices to meet. The 3GPP standard requires LTE handsets to meet out-of-band emission levels of -25 dBm/MHz (-15 dBm/100 kHz) up to 10 megahertz removed from its channel for a five megahertz LTE signal and -13 dBm/MHz (-3 dBm/100 kHz) up to 10 megahertz removed from its channel for a 10 megahertz LTE signal and -25 dBm/MHz beyond that.[328] Even accounting for performance better than the 3GPP standard, the emission levels across the duplex gap from transmitting LTE handsets that will be received by LTE handsets in the downlink band are still much higher than the -56.8 dBm/100 kHz out-of-band requirement for white space devices. No party has addressed the inconsistency of why these higher out-of-band emission limits from handsets are not problematic while white space device emissions will allegedly cause harmful interference. Therefore, we find it both unnecessary and inequitable to require white space devices to meet even tighter out-of-band emission limits.

135. We further conclude that based on our analysis, we need not designate any 600 MHz service spectrum blocks as "impaired" due to the potential presence of unlicensed white space devices operating in the guard bands or duplex gap. CTIA argues that the Commission should designate as "impaired" those licenses subject to interference caused by adjacent-channel unlicensed operations, consistent with the incentive auction inter-service interference (ISIX) approach.[329] Similarly, Qualcomm argues that the spectrum blocks adjacent to the guard bands and duplex gap would be impaired when compared to the non-adjacent spectrum blocks and that the Commission would have to value them less than the non-adjacent spectrum blocks. It continues that this would not allow the Commission to offer generic fungible spectrum blocks in the forward auction.[330] AT&T agrees stating that the rules the FCC is adopting will frustrate its stated goal of offering spectrum blocks that are technically and functionally interchangeable.[331] The analysis provided above shows that we do not believe 600 MHz service licensees will experience harmful interference due to the presence of unlicensed devices operating in the guard bands or duplex gap. Thus, we do not need to take any action as requested by CTIA, Qualcomm, or AT&T to designate the spectrum blocks adjacent to those bands as impaired. We believe licensees operating on those bands will enjoy a similar spectrum environment as 600 MHz service licensees operating on non-adjacent spectrum blocks and be able to deliver competitive broadband service to the U.S. public free from harmful interference.

[327] *See* Qualcomm Comments at 11, CTIA Comments at 12, and AT&T Reply Comments at 5.

[328] *See* 3GPP TS 36.101 at Table 6.6.2.1.1-1.

[329] *See* CTIA's May 8 ex parte letter at 10-11. In the *Incentive Auction R&O*, the Commission adopted a flexible band where in some instances broadcast stations may remain on spectrum in the 600 MHz service band (market variation). *See Incentive Auction R&O,* 29 FCC Rcd 6567, 6604-07 at paras. 81-87. In October 2014, the *ISIX Report and Order* addressed potential interference between digital television (DTV) stations and wireless service when co-channel or adjacent channel in areas with market variation. This *ISIX Report and Order* adopted a methodology for predicting inter-service interference during the incentive auction to determine impairments to the wireless licenses to be auctioned in the forward auction. *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions,* GN Docket No. 12-268, ET Docket No. 13-26, ET Docket No. 14-14, Second Report and Order and Further Notice of Proposed Rulemaking, 29 FCC Rcd 13071 (2014) (ISIX Report and Order).

[330] *See* Qualcomm Comments at 15-16.

[331] *See* AT&T Reply Comments at 5.

(ii) Wireless microphones.

136. *Background.* In the *Notice,* the Commission proposed to allow unlicensed wireless microphones to operate in the guard band between television and wireless downlink spectrum, with the exception of a one megahertz segment at the upper end that would act as a buffer between unlicensed wireless microphone operations and wireless downlink services.[332] If the guard band is 11 megahertz wide, unlicensed wireless microphones would be allowed to operate in the lower ten megahertz segment of the band; if the guard band is nine megahertz wide, unlicensed wireless microphones would be allowed to operate in the lower eight megahertz segment; and if the guard band is seven megahertz wide, unlicensed wireless microphones would be allowed to operate in the lower six megahertz segment. The Commission also proposed that unlicensed wireless microphones operating in the guard bands and duplex gap operate with a maximum conducted power output of 20 milliwatts to the antenna.[333] It believed that this power limit for wireless microphones is necessary in the guard bands and duplex gap to protect licensed wireless services outside these frequency bands, and to help enable coexistence between unlicensed wireless microphones and white space devices by making both types of devices operate at more comparable power levels.

137. Several parties express concern that operation of wireless microphones in the guard bands and duplex gap would cause harmful interference to wireless downlink services.[334] AT&T and CTIA argue that the out-of-band emission limits for wireless microphones need to be reduced to prevent harmful interference.[335] These parties also argue that the frequency buffer between wireless microphones and wireless downlink spectrum should be increased to five megahertz in the duplex gap and nine megahertz in the guard band.[336]

138. Wireless microphone interests argue that the proposed 20 milliwatt power limit in the guard bands and duplex gap is insufficient due to the noise level in these bands, and does not need to be that low to protect wireless handsets from harmful interference.[337] Sennheiser and Shure argue that only a 100 kHz frequency separation is needed at the lower end of the duplex gap (*i.e.,* adjacent to wireless downlink spectrum) if wireless microphones meet the ETSI emission mask.[338]

139. *Discussion.* We will allow unlicensed wireless microphones to operate in the guard bands with a maximum power of 20 milliwatts EIRP and at least a one megahertz frequency separation from wireless downlink spectrum. This power level will be useful for wireless microphone operators because many wireless microphones operate at power levels between 10 and 20 milliwatts. We find that this power limit for wireless microphones is necessary in the guard bands and duplex gap to protect licensed wireless services outside these frequency bands.[339] In addition, because we are allowing white space devices to operate in the guard bands and duplex gap at power levels of 40 milliwatts EIRP, limiting the power of unlicensed wireless microphones can help enable coexistence between unlicensed wireless microphones and white space devices by making both types of devices operate at more

[332] *See Notice,* 29 FCC Rcd at 12296, para. 159.

[333] *See Notice,* 29 FCC Rcd at 12296, para. 160.

[334] *See* AT&T Reply Comments at 6, CEA Comments at 5, CTIA Comments at 11, and Qualcomm Comments at 8.

[335] *See* AT&T Reply Comments at 6 and CTIA Comments at 12.

[336] *See* CTIA Comments at 5 and AT&T Reply Comments at 7.

[337] *See* Audio-Technica Comments at 10, CP Communications Comments at 4, Sennheiser Comments at 15, and Shure Reply Comments at 22.

[338] *See* Sennheiser Comments at 14-15; Shure Comments at 15.

[339] The guard band is adjacent to wireless downlink services (on the upper end), and the duplex gap is between wireless downlink and wireless uplink services.

comparable power levels.[340] The fact that we are specifying wireless microphone power in terms of EIRP, rather than conducted power as proposed in the *Notice,* will benefit wireless microphone manufacturers by ensuring that they can design equipment that operates with a maximum radiated power of 20 milliwatts, even if the design of a device requires the use of a less efficient antenna.[341]

140. We disagree with AT&T and CTIA that a nine megahertz frequency buffer is necessary to protect wireless downlink spectrum from wireless microphones. We are requiring a one megahertz buffer because the ETSI out-of-band emission limits that we are requiring wireless microphones to meet specifies that out-of-band emissions roll off over a one megahertz frequency span.[342] Thus, a one megahertz buffer ensures that wireless microphone out-of-band emissions will be at or below the ETSI limits in the wireless downlink band. We performed analyses on the interference potential of wireless microphones to wireless downlinks that are similar to those for white space devices.[343] Specifically, we considered both interference from out-of-band emissions as well as blocking interference.

141. *Out-of-band emissions interference.* With respect to harmful interference to wireless handsets from wireless microphone out-of-band emissions, we start by using many of the same assumptions we used in our analysis of white space device emissions into the wireless downlink band. Specifically, we use a handset receiver reference sensitivity of -97 dBm at the antenna input and assume a handset antenna gain of -6 dBi. We also use a free space signal propagation model and assume that several factors will act to attenuate the signal transmitted from the wireless microphone, including a 2 dB signal loss due to polarization mismatch between the transmit and receive antennas, 3.5 dB in propagation losses due to multipath and shadowing from nearby walls, objects or nearby people, and 3 dB of body loss at the wireless handset. Based on information Shure submitted into the record regarding wireless microphone body loss, we assume a larger body loss for a wireless microphone (8 dB for a body worn wireless microphone and 18 dB for a handheld wireless microphone)[344] than we assume for a white space device (3 dB). In addition, a wireless microphone's frequency band of operation will be at least one megahertz removed from the LTE downlink band where emissions are at the ETSI limit. We expect that wireless microphone emissions will continue to roll-off beyond the ETSI limit as frequency separation continues. However, because current wireless microphones are not yet required to meet that standard, the measurement data submitted to the Commission during the equipment certification process is not required to show the emission levels at frequency separations up to or beyond one megahertz. Thus, because the equipment certification measurement reports do not contain this data, we are not assuming a 3 dB slope

[340] Since white space devices are designed for broadband data applications and operate within six megahertz channels, only one can operate within a six megahertz band at a given location, whereas multiple wireless microphones can operate within a six megahertz band due to their narrower (200 kHz) bandwidth. Thus, two or more wireless microphones may operate within the same amount of spectrum as one white space device.

[341] *See* para. 99, *supra.*

[342] The ETSI emission mask requires the emissions from analog wireless microphones operating with a 200 kHz bandwidth to roll-off as follows: to -20 dBc at 70 kilohertz from the wireless microphone operating frequency, to -60 dBc at 100 kilohertz from the wireless microphone operating frequency, to -80 dBc at 200 kilohertz from the wireless microphone operating frequency, and to -90 dBc at 1 megahertz from the wireless microphone operating frequency. For digital wireless microphones, the ETSI standard requires the emissions from wireless microphones operating with a 200 kHz bandwidth to roll-off as follows: to -30 dBc at 100 kilohertz from the wireless microphone operating frequency, to -80 dBc at 350 kilohertz from the wireless microphone operating frequency, and to -90 dBc at 1 megahertz from the wireless microphone operating frequency. dBc is the amount in dB the emissions are reduced from the peak microphone power. All parameters are referenced to a one kilohertz bandwidth. Thus, for a 20 milliwatt wireless microphone with a 200 kilohertz bandwidth, the peak emissions translate to 0.1 milliwatt per one kilohertz or -10 dBm per one kilohertz. So -90 dBc at one megahertz is equivalent to -100 dBm per one kilohertz or –63 dBm per five megahertz. *See* ETSI EN 300 422-1 v1.4.2 (2011-08), Section 8.3.

[343] *See* para. 121-135, *supra.*

[344] *See* Shure *ex parte* filing dated April 13, 2015 at slide 17.

loss in our analysis here as we do for white space devices.[345] Finally, as with white space devices, we base our analysis on an interference criterion of a 3 dB rise in the noise floor.[346]

142. Based on the foregoing assumptions, and using the ETSI -90 dBc out-of-band emission limits for a 20 milliwatt (13 dBm) 200 kilohertz wireless microphone at a frequency separation of one megahertz and greater, we calculate that distance beyond which the interference criterion is exceeded.[347] The results are presented in the following table:[348]

Out-of-Band Interference		
Interference Criterion (rise in noise floor)	Body Worn Microphone (meters)	Hand Held Microphone (meters)
3 dB	0.09	0.03
1 dB	0.05	0.02

These distances are so short, that we believe OOBE interference from wireless microphones poses little risk of causing harmful interference to 600 MHz service downlinks even when multiple wireless microphones are used in close proximity. Because the necessary separation distances are so short, it is unlikely that multiple wireless microphones could be used in such close proximity to a 600 MHz service band handset. And even if several microphones were to be used near a wireless handset, they could not all use the same frequency in order to avoid causing interference to other wireless microphones. As wireless microphones spread throughout the guard bands and duplex gap, they will use frequencies farther from wireless downlink spectrum and we predict that out-of-band emissions from those additional wireless microphones will decline as the emission levels roll-off due to increased frequency separation.

143. *Blocking interference.* With respect to blocking interference from wireless microphones, we again assume a reference sensitivity for the LTE receiver of -97 dBm. We also assume an adjacent channel selectivity of 33 dB.[349] Because we are allowing wireless microphones to operate at a closer frequency separation than white space devices (one megahertz instead of three megahertz), we are

[345] We observe, however, based on the test reports of several current Commission certificated wireless microphones, we would expect that they would meet and exceed the ETSI standard justifying use of the 3 dB slope loss parameter. *See, e.g.,* the test report associated with the Shure wireless microphone FCC ID: DD4PA411A which shows emissions at approximately -87 dBc per kilohertz 750 kilohertz removed from the microphone center frequency and the test report associated with the Sennheiser wireless microphone FCC ID: DMOSKM9000 which shows emissions ranging from approximately -65 dBc to -80 dBc per kilohertz 750 kilohertz removed from the microphone center frequency.

[346] For completeness in presentation, we present results both for a 3 dB rise and a 1 dB rise in the noise floor.

[347] The received power = wireless microphone OOBE power – free space path loss – polarization mismatch – transmitter body loss – receiver body loss – shadowing/multipath loss + antenna gain.

[348] As stated, we did not include any OOBE slope loss in our calculations. However, as we believe that the wireless microphone emissions will continue to roll off, we provide calculation results that do include an additional 3 dB for OOBE slope loss:

Out-of-Band Interference		
Interference Criterion (rise in noise floor)	Body Worn Microphone (meters)	Hand Held Microphone (meters)
3 dB	0.03	0.01
1 dB	0.07	0.02

[349] *See* 3GPP TS 36.101 at Table 7.5.1-1.

assuming a conservative handset receive filter rejection of 3 dB.[350] In addition, we make many of the same assumptions as in our out-of-band emission interference analysis for wireless microphones, including the use of a free space propagation mode, 3 dB body loss at the wireless handset, 8 dB of body loss for body worn wireless microphones and 18 dB of body loss for handheld wireless microphones, 3.5 dB loss for shadowing and multipath, and a receiver antenna gain of -6 dBi.[351] Consistent with the analyses above, we also assume that real world devices would operate with a 10 dB stronger signal than the minimum specified in the 3GPP standard. Also, we assume a 3 dB rise in the noise floor as the appropriate interference criterion. Based on these assumptions, the distances beyond which interference criterion may be exceeded are:[352]

Blocking Interference		
Interference Criterion (rise in noise floor)	Body Worn Microphone (meters)	Hand Held Microphone (meters)
3 dB	6.6	2.1
1 dB	13.2	4.2

144. As with white space devices, this result requires some context. We again point out that the 3GPP standard defines blocking as the point at which throughput falls below 95% of the maximum throughput[353] and as Google showed in their measurements, variations of greater than 5% throughput typically occur under normal usage conditions.[354] Therefore, even though an LTE handset may experience some blocking interference from a wireless microphone as close as 6.6 meters, we do not believe this rises to the level of harmful interference. Handsets will continue to function, albeit at a slightly slower data rate, which we believe would generally not be perceptible to the user as that user would likely experience similar fluctuations in data rates under normal usage conditions. In addition, we

[350] *See* Broadcom Comments at 11. Their curves show an attenuation at a one megahertz frequency separation of approximately 3 dB with the worst case filter, and approximately 5 dB with a typical filter. We note that in the *Incentive Auction R&O*, the Commission assumed an even more conservative filter that shows no attenuation at a one megahertz frequency separation. *See Incentive Auction R&O,* 29 FCC Rcd at 6969-6974, Appendix C para. 10-21. However, as Broadcom points out in its comments, the Commission's assumed filter is not indicative of real world filter performance. Thus, we choose to conduct our analysis based on Broadcom's depiction of a worst case real world filter.

[351] Here, as for the out-of-band interference analysis, we exclude the slope loss from our calculations.

[352] The received power = wireless microphone OOBE power – free space path loss – polarization mismatch – transmitter body loss – receiver body loss – shadowing/multipath loss + antenna gain – receive filter attenuation.

Also, as with the out-of-band interference analysis, we provide results that include the additional 3 dB slope loss which we believe is more indicative of a real device.

Out-of-Band Interference		
Interference Criterion (rise in noise floor)	Body Worn Microphone (meters)	Hand Held Microphone (meters)
3 dB	4.7	2.06
1 dB	9.3	4.15

[353] *See* 3GPP TS 36.101 at Section 7.65.1.1.

[354] *See* Google *ex parte* filed May 22, 2015 at A19-A21. Google submitted an evaluation of the impact of radiated emissions on LTE performance. This evaluation, conducted in a suburban basement, measured throughput of an LTE device in the presence of an interferer, purports to show that the LTE device was very robust. While Google's results are not reproducible due to lack of testing in a controlled environment, they are instructive in showing the variation in data rates that occurs under normal use conditions. Its measurement show that even without an interfering signal present, data rates varied from 3 Mbps to 1 Mbps equivalent to a drop of 67%.

do not believe that even with multiple microphones operating within a close area, 600 MHz service handsets would experience harmful interference. First, as already mentioned, the wireless microphones would themselves need to spread over many different frequencies to avoid interfering with each other. Thus, it is unlikely that more than one microphone would be operating at the frequency next to the one megahertz buffer in the guard bands or duplex gap within a given area. Second, to conserve battery power, wireless microphones, like white space devices and mobile handsets,[355] generally operate below the maximum allowable power which reduces the likelihood of interference. Third, as with our analysis for white space devices, the analysis here considers the worst case which is unlikely to actually occur. Aside from the analysis assuming the wireless microphone is operating at maximum power, inherent in the worst case situation is that the mobile handset is operating at the edge of coverage near its sensitivity level, on the frequency closest to the guard bands or duplex gap, the antenna patterns of both the wireless microphone and wireless receiver would have to be closely aligned to maximize the wireless microphone signal at the receiver, and there would have to be *de minimis* body and other propagation losses; a scenario that is not likely to occur often, if at all. Finally, we note that wireless microphones are generally used in specific places – theaters, arenas, churches, etc. and not likely to be found in all areas where mobile handsets are in heavy use. Even at breaking news events, where there may be a mix of mobile handsets and wireless microphones, we believe it unlikely that all the factors needed to cause interference would generally occur simultaneously. Thus, we find that the likelihood of wireless microphones in the guard bands and duplex gap causing harmful interference to 600 MHz wireless downlink service to be very low.

c. Frequencies of operation

145. *White space devices*. The amount of spectrum available for white space devices in the guard bands between TV and wireless downlink services depends on their six megahertz operating bandwidth, the size of the guard band, and the power limits and separation distances that we determine are necessary to protect adjacent TV and wireless downlink services. Depending on the results of the auction and the band plan that is implemented, six-megahertz bandwidth white space devices will be able to operate in nine and eleven megahertz guard bands if they are available. In the case of a nine megahertz guard band, a white space device with three megahertz separation from wireless downlink spectrum would be immediately adjacent to a TV channel. Such operation is consistent with our analysis, detailed above showing that a three megahertz guard band will protect wireless handsets from white space devices and that no guard band is needed to protect adjacent channel TV operations.[356] If the guard band is 11 megahertz, we will apportion the spectrum such that white space devices will be required to operate at the lower end of the guard band, immediately adjacent to TV spectrum and five megahertz from wireless handsets. This will correspondingly provide a contiguous four megahertz block of spectrum not shared with white space devices for wireless microphone use and a one megahertz guard band between wireless microphones and wireless handsets. Distributing usage across an 11 megahertz guard band reduces the burden on white space devices, which will always operate in the same portion of the guard band, thus making channel availability checks simpler than if white space devices could operate anywhere within the guard band where they maintain at least a three megahertz separation from wireless downlink spectrum. In addition, this decision maximizes use of the spectrum because it provides a contiguous four megahertz band of spectrum for exclusive use by wireless microphones, rather than dividing this four megahertz of spectrum into two smaller segments above and below the band where white space devices could operate.[357] Finally, as explained below this plan is consistent with the plan we are adopting for the 11 megahertz duplex gap. The figure below depicts the various options for the guard bands.

[355] As discussed above, wireless networks manage operating channels and handset power in noisy conditions to ensure the best possible quality of service, and wireless handsets are typically multi-band devices that can operate in another band in the event interference occurs. *See* para.129, *supra.*

[356] *See* paras. 29-31, *supra.*

[357] For example, we could have provided for a variety of choices such as

(continued….)

146. We are also adopting rules to allow white space device operation in a seven megahertz guard band. A seven megahertz guard band is too small to allow a six megahertz white space device to operate while maintaining a three megahertz frequency separation from wireless downlink spectrum. Broadcom asserts that a six megahertz white space device could operate at a reduced power of 9 milliwatts in a seven megahertz guard band. It states that this power level is not sufficient for many applications, but may be useful for future low power technologies.[358] Although there may be future use cases for very low power white space devices, we are concerned that reducing the separation from wireless downlink spectrum may not allow out-of-band emissions from such low power white space devices to roll-off sufficiently to prevent causing harmful interference. However, we wish to maximize opportunities for unlicensed use of the 600 MHz guard bands. Therefore, instead of adopting Broadcom's suggestion, we will permit 40 milliwatt white space devices to operate in the lower four megahertz portion of a seven megahertz guard band, *i.e.,* the portion immediately adjacent to television spectrum. This will leave a three megahertz frequency separation from wireless downlink spectrum above the guard band. We will require that white space devices operating under these provisions to comply with the same technical requirements as 40 milliwatt white space devices in nine or 11 megahertz guard bands, with the exception of the channel bandwidth and the PSD limit. The current PSD limit would prevent a white space device in a four megahertz channel from attaining the full 40 milliwatts EIRP because the power is concentrated in a narrower bandwidth than was used in establishing the limit. We will therefore allow such devices to comply with a slighter higher PSD limit that is calculated using the same procedure described in the *White Spaces Third MO&O*, but using a narrower channel bandwidth.[359] Specifically, we will require that a 40 milliwatt personal/portable white space devices operating in a four megahertz channel comply with a PSD limit of 0.6 dBm/100 kHz EIRP. We will also require that a 40 milliwatt fixed device operating in a four megahertz channel comply with a conducted PSD limit of -5.4 dBm, since the conducted power limit for fixed devices is 6 dB less than the EIRP limit. These limits are about 2 dB higher than the limits for white space devices in a six megahertz channel. Because the out-of-band emission limits are not being modified for this narrower white space channel, the total radiated power adjacent to TV remains at 40 milliwatts. We are also maintaining the three megahertz separation to 600 MHz band wireless downlinks. Thus, we do not believe such white space devices operating in a seven megahertz guard band will cause harmful interference to either television reception or wireless downlinks.

Possible Guard Band Options

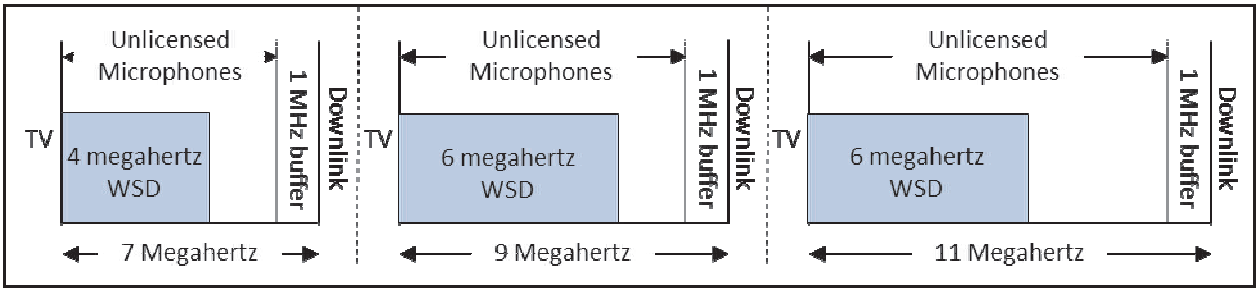
(Continued from previous page)

<table>
<tr><td colspan="6">←---------- 11 Megahertz Guard Band ----------→</td></tr>
<tr><td>Adopted</td><td colspan="3">Unlicensed Use</td><td colspan="1">Microphone</td><td>Guard Band</td></tr>
<tr><td>Option 1</td><td>Micro phone</td><td colspan="2">Unlicensed Use</td><td colspan="1">Microphone</td><td>Guard Band</td></tr>
<tr><td>Option 2</td><td colspan="2">Microphone</td><td colspan="2">Unlicensed Use</td><td>Microphone</td><td>Guard Band</td></tr>
</table>

However, under either Options 1 or 2, microphones would likely not be able to use the smaller slivers of spectrum as efficiently as the larger 4 megahertz portion being adopted.

[358] *See* Broadcom Comments at 20. Microsoft also endorses this position. *See* Microsoft Comments at 16-17.

[359] *See White Spaces Third MO&O*, 27 FCC Rcd at 3704, para. 30. In calculating the PSD, the Commission assumed that a white space device would occupy 500 kHz less than the maximum channel bandwidth due to the need for a roll-off to comply with the adjacent channel emission limits. In calculating the PSD for a four megahertz (4000 kHz) channel, we will therefore assume that the white space device occupies 3500 kHz of the channel. The PSD is then determined by dividing the power by the occupied bandwidth and specifying the result in terms of power per 100 kHz. Thus, the PSD is 40 mW / 3500 kHz = 1.143 mW/100 kHz, or 0.58 dBm/100 kHz.



147. We do not adopt rules to allow white space devices to operate in a three megahertz guard band adjacent to channel 37.[360] A guard band that size would be too small to permit white space device operation, because at least a three megahertz frequency separation is required to protect wireless downlink services.[361]

148. *Wireless microphones*. We will allow unlicensed wireless microphones to operate in certain segments of the guard bands. In the guard band between television and wireless downlink spectrum, we will allow unlicensed wireless microphones to operate across the guard band regardless of its eventual size (determined by the results of the auction) with the exception of a one megahertz segment at the upper end that would act as a buffer between unlicensed wireless microphone operations and wireless downlink services.[362] As with white space devices, the amount of spectrum available for wireless microphone operation in the guard band will depend on the size of the guard band and amount of frequency separation needed to protect wireless services from harmful interference. For example, if the guard band is 11 megahertz wide, unlicensed wireless microphones will be allowed to operate in the lower ten megahertz segment of the band; if the guard band is nine megahertz wide, unlicensed wireless microphones will be allowed to operate in the lower eight megahertz segment;[363] and if the guard band is seven megahertz wide, unlicensed wireless microphones will be allowed to operate in the lower six megahertz segment.[364]

149. In the three megahertz guard bands adjacent to channel 37, we will allow unlicensed wireless microphones to operate in the two megahertz segment closest to channel 37, leaving a one megahertz buffer to protect wireless downlink services adjacent to these guard bands. Today, wireless microphones operate on channels 36 and 38 at up to 250 milliwatts without causing harmful interference to WMTS and RAS operating on channel 37.[365] We thus conclude that we do not need any frequency separation between unlicensed wireless microphones operating in the guard bands and channel 37 because we are limiting the maximum permitted power in this spectrum to 20 milliwatts to protect wireless downlink services.

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[360] In the event that 84 megahertz or more is repurposed from TV to wireless services in the incentive auction, the incentive auction *Report and Order* established a three megahertz guard band around channel 37 to protect WMTS systems from harmful interference from 600 MHz band wireless downlinks. *See Incentive Auction R&O,* 29 FCC Rcd at 6692, para. 290.

[361] *See* para. 115, *supra*.

[362] This is consistent with our decision to provide one megahertz separation between licensed wireless microphones in the duplex gap and wireless downlink services. Because the technical parameters for licensed wireless microphones in the duplex gap are the same as those for unlicensed wireless microphones in the guard bands, the frequency separation needed to protect wireless downlinks is the same in both cases. *See* para. 151, *supra.*

[363] In both the 11 and nine megahertz guard band case, the lowest six megahertz will also be shared with white space devices.

[364] In this case, the lowest four megahertz will also be shared with white space devices.

[365] *See* 47 C.F.R. § 74.861(e)(1)(ii).

2. Duplex Gap

150. *Background*. The 600 MHz band includes a duplex gap of 11 megahertz between the wireless uplink and downlink services bands to prevent harmful interference between them.[366] The frequency range of this duplex gap will depend on the outcome of the incentive auction, but the size of the band will be the same nationwide, regardless of whether there is any market variation in the amount of spectrum recovered. Wireless downlink services will operate in the lower adjacent spectrum to the duplex gap, and wireless uplink services will operate in the upper adjacent spectrum to the duplex gap. In the *Incentive Auction R&O,* the Commission concluded that the public interest would be served by allowing broadcasters and cable programming networks to use wireless microphones on a licensed basis in a portion of the duplex gap and to obtain interference protection from unlicensed devices at specified times and locations, on an as-needed basis.[367] The Commission decided that in a separate proceeding it would examine how best to provide access to a portion of the duplex gap by licensed wireless microphone users, while also ensuring that unlicensed users of the duplex gap can make use of this spectrum to provide broadband services.[368] In the *Notice*, the Commission proposed to allow unlicensed operations, including both fixed and personal/portable white space devices and unlicensed microphones, to operate in the six megahertz band segment at the upper end of the duplex gap.[369] It also proposed to allow licensed wireless microphones to operate in the four megahertz band segment immediately below this six megahertz segment, and to use the remaining portion of the duplex gap spectrum to provide a one megahertz frequency separation between licensed wireless microphones and wireless downlinks in the spectrum below the duplex gap, thereby providing an additional margin of interference protection to mobile handsets.[370]

a. Protecting adjacent wireless downlink and uplink bands

151. As discussed above, we find that wireless downlink bands will be protected from harmful interference by requiring that unlicensed white space devices operate at 40 milliwatts EIRP with at least three megahertz frequency separation from wireless downlink bands and that wireless microphones operate at 20 milliwatts EIRP with at least one megahertz separation from wireless downlink bands. As proposed in the *Notice*, we will require that licensed wireless microphones operating in the duplex gap comply with the same technical requirements as unlicensed wireless microphones in the guard bands.[371] The split of the duplex gap that we describe below will provide for a one megahertz frequency separation between licensed wireless microphones and wireless downlink spectrum. It will also provide for a frequency separation of five megahertz, rather than three megahertz, from wireless downlink spectrum. Thus, wireless downlink services will be protected from harmful interference.

152. Regarding wireless uplink bands, we conclude that that it is not necessary to provide any frequency separation between white space devices and unlicensed wireless microphones and wireless uplink spectrum to prevent harmful interference to base station receivers.[372] First, base station antennas are generally mounted high on a tower, providing distance separation between them and white space

[366] The duplex gap is a guard band between 600 MHz uplink and downlink services.

[367] *See Incentive Auction R&O,* 29 FCC Rcd at 6703-6704, para. 314.

[368] *Id.*

[369] *See Notice*, 29 FCC Rcd at 12277, para. 93.

[370] *Id.*

[371] *See Notice*, 29 FCC Rcd at 12298, para. 165.

[372] No party alleged that white space devices or wireless microphones operating in the duplex gap would cause interference to wireless uplink spectrum.

devices and wireless microphones.[373] Further, base stations can take advantage of better receive filters to minimize the potential for adjacent channel interference. We believe these factors lead to very little risk of harmful interference to wireless base stations even when white space devices and unlicensed wireless microphones operate immediately adjacent to wireless uplink spectrum.

b. Frequencies of operation

153. We are adopting the proposed 1-4-6 split of the duplex gap. A six megahertz band for unlicensed devices, which will be used by both unlicensed white space devices and unlicensed wireless microphones, is supported by the record and is consistent with the current white space device rules.[374] Additionally, a four megahertz segment of the duplex gap is designated for licensed wireless microphones users only, thus enabling them to access spectrum for quick-breaking events without having to reserve channels in the white space databases.[375] Our plan maximizes the frequency separation between the six megahertz segment of the duplex gap for white space device use and wireless downlink spectrum, thereby reducing the risk of harmful interference to those adjacent band services as required by the Spectrum Act. The one megahertz buffer at the lower end of the duplex gap provides a margin of interference protection to wireless handsets from licensed wireless microphones. We will allow unlicensed wireless microphones to operate in the same six megahertz portion of the duplex gap as white space devices, and licensed wireless microphone use will be permitted in the four megahertz segment of the lower duplex gap designated for their operation.

Duplex gap with 1-4-6 megahertz split

154. This plan balances the spectrum needs of unlicensed white space and wireless microphone users. NAB argues that we should allow only licensed wireless microphones to operate within the duplex gap, that our plan favors white space devices over wireless microphones, and that allowing unlicensed use of the duplex gap is potentially wasteful if a market for unlicensed devices fails to develop.[376] OTI/PK suggests that we not allow licensed wireless microphones to operate in the duplex gap.[377] Shure argues that four megahertz for licensed wireless microphones does not adequately address users' needs for interference-free spectrum, and Sennheiser argues that six megahertz shared with unlicensed white space devices will be useful only for less critical wireless microphone uses.[378] In the *Second Order on Reconsideration,* we rejected the suggestion that only licensed wireless microphones be permitted in the duplex gap and "affirm[ed] the balanced approach we adopted in the *Incentive Auction R&O* to accommodate wireless microphone operations while also taking into account the interests of other users of the more limited spectrum … including the 600 MHz guard bands."[379] The purpose of the

[373] We also note that we are not limiting the antenna height of fixed white space devices to 10 meters as we do in the guard band between 600 MHz band wireless downlinks and TV. In that band, the height limit is intended to protect TV reception. *See* para. 109, *supra*. However, there are expected to be far fewer base stations than there are TV receivers reducing the likelihood of a white space device operating near a base station.

[374] *See* Adaptrum Comments at 6, Dynamic Spectrum Alliance Comments at 8, Google Comments at 16, Microsoft Comments at 5, Motorola Comments at 9, and OTI/PK Reply Comments at 5.

[375] The *Wireless Microphone R&O* addresses whether we should permit any licensed wireless microphone user to operate in the four megahertz segment of the duplex gap.

[376] *See* NAB Comments at 14; *see also* Shure Reply Comments at 12 (supporting NAB).

[377] *See* OTI/PK Reply Comments at 9.

[378] *See* Shure Reply Comments at 12, Sennheiser Comments at 8.

[379] *See Incentive Auction Second Order on Reconsideration*, 30 FCC Rcd at 6803, para. 126.

plan we adopt here for the duplex gap is to make spectrum available for both wireless microphones and white space devices, while minimizing the likelihood of harmful interference to licensed wireless services. Since wireless microphones use narrow channels (200 kilohertz) while white space devices use six megahertz channels, multiple licensed wireless microphones may operate at a given location in a four megahertz channel as opposed to a single white space device in a six megahertz channel.[380] Further, since we will allow unlicensed wireless microphones to operate in the same six megahertz portion of the duplex gap as white space devices, there will be ten megahertz of contiguous spectrum available for wireless microphones at locations where white space devices are not operating. We also reject Qualcomm's argument that the Spectrum Act permits only unlicensed operations in the duplex gap.[381] The Spectrum Act states that the Commission "may permit" unlicensed use of the guard bands, and requires only that we not permit "any use of a guard band that [we] determine would cause harmful interference to licensed services."[382] Nothing in the Spectrum Act prohibits licensed services in the duplex gap, provided they do not cause harmful interference.

155. We conclude that it is not necessary to provide a guard band between the four megahertz designated for licensed wireless microphones and the six megahertz designated for unlicensed white space devices and unlicensed wireless microphones. Recognizing that the rules require low emissions from white space devices outside their channel of operation, the record indicates that the risk of adjacent channel interference to licensed wireless microphones is low.[383] Wireless microphones currently operate adjacent to white space devices as well as full power television stations with no adverse effects as their narrow (no greater than 200 kilohertz) bandwidths and receiver selectivity [provide interference protection]. Thus, we believe that there is a low risk of unlicensed white space devices or unlicensed wireless microphones causing harmful interference to licensed wireless microphones in the adjacent band.

156. We disagree with parties requesting that we place a one megahertz buffer at the upper end of the duplex gap to protect white space devices from possible interference from wireless uplinks (handset transmitters) in the adjacent band.[384] These parties suggest that we eliminate a buffer between licensed wireless microphones and wireless downlink spectrum, or that we reduce the amount of spectrum available for licensed wireless microphones from four to three megahertz to provide an extra one megahertz buffer at the upper end of the duplex gap.[385] As discussed above, we find that a one megahertz frequency separation is necessary to protect licensed operations in wireless downlink spectrum (handset receivers) from wireless microphones operating in an adjacent frequency band, and thus we decline to eliminate this buffer from the lower end of the duplex gap.[386] To add a one megahertz buffer at the upper end of the duplex gap would reduce the spectrum available for licensed wireless microphones in order to maintain six megahertz for white space devices. Given our objective to balance the interests of different users, we are not reducing the amount of spectrum designated for licensed wireless microphones in the duplex gap. Although we recognize the argument of unlicensed advocates that a one megahertz buffer at

[380] Manufacturers have indicated that as many as 16 wireless microphones can operate in a six megahertz channel, and while we are allowing a smaller channel size here, manufacturers should still be able to get a substantial number of microphones to operate in it. *See Incentive Auction R&O,* 29 FCC Rcd at 6699, para. 306.

[381] *See* Qualcomm Comments at 18-19; CTIA Reply at 22.

[382] 47 U.S.C. § 1454(e).

[383] *See* CP Communications Reply Comments at 5; Sennheiser Comments at 9.

[384] *See* Dynamic Spectrum Alliance Comments at 8, Google Comments at 16-17, Microsoft Comments at 12, Motorola Comments at 9, OTI/PK Reply Comments at 9, and Wi-Fi Alliance Comments at 26-27.

[385] Motorola and Wi-Fi Alliance suggest allowing only three megahertz for licensed wireless microphones, while Dynamic Spectrum Alliance, Google, Microsoft and OTI/PK suggest eliminating the buffer at the lower end of the duplex gap.

[386] *See* para. 139, *supra.*

the upper end of the duplex gap could potentially reduce the level of adjacent channel emissions received from wireless systems within the six megahertz band used by white space devices, there are steps that manufacturers and users can take to mitigate the effects of adjacent channel wireless operations in the absence of a buffer. As noted in the record, white space device manufacturers must already design their receivers with good selectivity to operate immediately adjacent to high power television stations, and we expect that white space devices operating in the duplex gap would similarly be designed with good receiver selectivity.[387]

3. Database Access

157. *Background*. The Spectrum Act states that the Commission may permit unlicensed use of the guard bands,[388] and stipulates that (a) unlicensed use shall rely on a database or subsequent methodology as determined by the Commission, and (b) the Commission may not permit any use of a guard band that the Commission determines would cause harmful interference to licensed services.[389] The term "guard band" includes the duplex gap, and thus the Spectrum Act's requirements discussed here apply equally to the duplex gap.[390] Fixed and personal/portable white space devices clearly satisfy the Act's stipulation that "unlicensed use rely on a database" since our rules already require that these devices access a database over the Internet to identify vacant TV channels in their area that meet the interference avoidance requirements of our rules, and they may only operate on the vacant channels that the database identifies.[391] In the *Notice*, the Commission proposed that unlicensed wireless microphones that operate in the guard bands and duplex gap must "rely on a database" prior to operation to ensure that their intended operating frequencies are available for unlicensed wireless microphones at the location where they will be used.[392] The Commission sought comment on how unlicensed wireless microphones would comply with this requirement[393] With regard to licensed wireless microphone users in the duplex gap, the Commission did not propose to require those users to access a database before beginning operation and noted that as sophisticated users they could determine whether the duplex gap is available at their location.[394] Regarding the 600 MHz service band, in the *Notice* the Commission proposed separation distances for wireless microphone operation to protect new 600 MHz services from harmful interference and asked for comment on whether to require unlicensed wireless microphone users to check a database to ensure that they are outside a wireless licensee's service area, or whether the general non-interference requirements described in the *Incentive Auction R&O* are sufficient to protect 600 MHz service licensees.[395]

158. CTIA argues that Mode I personal/portable devices do not meet the Spectrum Act's requirements because they do not have database capabilities, and thus should not be permitted to operate in the guard bands and duplex gap.[396] The Wi-Fi Alliance argues that wireless microphones should meet

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[387] *See* White Space Alliance Comments at 21. For the same reasons, we reject Qualcomm's argument that we have ignored the potential for 600 MHz wireless handsets to cause interference to white space devices. *See* Qualcomm Comments at 7-8; Qualcomm Reply at 13-14.

[388] *See* 47 U.S.C. § 1454(c).

[389] *See* 47 U.S.C. § 1454(d) and (e).

[390] *See Incentive Auction R&O,* 29 FCC Rcd at 6613-6614, para. 97 & n. 322.

[391] Fixed and Mode II personal/portable devices must incorporate a mechanism to access the databases via the Internet, and Mode I personal/portable devices are permitted to operate only on channels identified for their use by either a fixed or Mode II personal/portable device. *See* 47 C.F.R. § 15.711(b)(3).

[392] *See Notice*, 29 FCC Rcd at 12297, para. 163.

[393] *See Notice*, 29 FCC Rcd at 12297, para. 164.

[394] *See Notice*, 29 FCC Rcd at 12298, para. 165.

[395] *See Notice*, 29 FCC Rcd at 12299, para. 169.

[396] *See* CTIA Reply Comments at 18-19.

the same database access requirements as white space devices and include an access mechanism to the databases via the Internet, and Microsoft asserts that the Spectrum Act requires a direct connection to the databases.[397] Audio-Technica, CP Communications, Sennheiser and Shure oppose database control of wireless microphone operations, claiming that implementing such a requirement is not practical and would be costly to develop.[398] Sennheiser argues that wireless microphones should be permitted to rely on manual database checks or sensing to satisfy the statutory requirement,[399] but Mobile Future believes that manual database checks are not a reliable means for avoiding harmful interference to licensed services as required by the Spectrum Act.[400]

159. *Discussion*. We will require that unlicensed white space devices and unlicensed wireless microphones operating in the 600 MHz guard bands, including the duplex gap, rely on database access to identify vacant channels for their use. This requirement is necessary because the Spectrum Act requires that unlicensed use of the guard bands "must rely on a database or subsequent methodology as determined by the Commission."[401] We conclude that this requirement is not unduly burdensome because there are several white space databases available, and unlicensed wireless microphone users will have an incentive to check a database to identify available frequencies for their use. We do not require that licensed wireless microphone users in the duplex gap rely on the white space databases to determine if those frequencies are available for their use at their location prior to operation.

160. The Spectrum Act does not define the terms "rely on a database" or "subsequent methodology." We conclude that the Spectrum Act gives us discretion to determine how unlicensed white space devices and unlicensed wireless microphone users should "rely on" the white space databases to identify available frequencies in the guard bands for their use. Unlicensed white space devices will rely on a database for identifying channels available for their use in the guard bands and duplex gap as they do now in the TV bands.[402] We reject CTIA's claim that Mode I personal/portable devices do not meet the Spectrum Act's database requirement.[403] Although Mode I personal/portable devices do not incorporate geo-location capability and do not directly query a white space database, they receive their channel assignments from either a fixed or Mode II personal/portable device which does include geo-location capability and which directly queries a white space database. Thus, Mode I devices "rely" on a database for their operation as required by the Spectrum Act.[404]

161. The Spectrum Act does not specify that unlicensed users must be capable of automatically, rather than manually, accessing a database. Because unlicensed wireless microphones and white space devices are used for different purposes and function differently,[405] the methods by which users of these devices rely on the databases need not be the same but, rather, should be appropriate for their use and function. Microsoft and OTI/PK argue that it is unrealistic to expect unlicensed wireless microphone users to query a database manually and that it would be better for wireless microphones to

[397] *See* Wi-Fi Alliance Comments at 39, Microsoft Comments at 36.

[398] *See* Audio-Technica Comments at 11-12, CP Communications Reply Comments at 4-5, Sennheiser Comments at 15, Shure Reply Comments at 21-22.

[399] *See* Sennheiser Reply Comments at 21.

[400] *See* Mobile Future Comments at 7-8.

[401] *See* 47 U.S.C. § 1454(d).

[402] *See* 47 C.F.R. § 15.711.

[403] *See* CTIA Reply Comments at 18-19.

[404] *See* Microsoft Comments at 37.

[405] Wireless microphones are used to amplify sound, *see* para. 95, *supra*, whereas white space devices are radiocommunication devices designed to provide telecommunications services, *see e.g.*, 47 C.F.R. § 15.703(b) (definition of fixed devices) and § 2.1 (definitions of radiocommunication service, telecommunication).

incorporate database communication capability to ensure protection to authorized users.[406] We are not persuaded that adding a database access mechanism to a wireless microphone is a practical solution. For example, microphones may be used at locations where an Internet connection is not easily available, and frequent channel availability checks or channel changes could interrupt their audio stream. Also, unlicensed wireless microphones must cease operating in the 600 MHz service band 39 months after release of the *Channel Reassignment PN*, and we are adopting rules in this proceeding that will cut off the marketing or operation of unlicensed microphones that can tune in the 600 MHz band after specified dates. At the end of this transition period, all unlicensed wireless microphones in the 600 MHz band will be certified to operate only in the guard bands and duplex gap, thus reducing the need for users to rely on database access to identify available channels for operation in this frequency range. Assuming it were feasible to include database communication capability in a wireless microphone, we have no evidence that manufacturers would be able to design and manufacture such devices before the end of the 39 month transition period when it would be most useful. We thus conclude that unlicensed wireless microphone users can satisfy the Spectrum Act's requirement to "rely on" a database by manually checking it via a separate Internet connection which can be done using a smart phone, laptop, or other similar telecommunications devices. We will require that unlicensed microphone users check the databases prior to beginning operation at a given location (*e.g.*, prior to beginning a performance). Because the databases will identify available channels based on the location where a microphone will be used (latitude and longitude), the user will need to re-check the databases for available channels if it moves from the earlier location.

162. We do not require licensed wireless microphone users of the four megahertz segment in the duplex gap to access a database before beginning operation. During the post-auction transition period while TV stations are in the process of vacating their channels in the 600 MHz band, a licensed wireless microphone user may need to determine whether the duplex gap is available in an area. After the end of this transition period, the duplex gap will generally be available nationwide, except possibly in a limited number of locations if the auction outcome necessitates repacking some TV stations into the duplex gap. We agree with Sennheiser that broadcasters and cable programming network entities that will be licensed to operate in the duplex gap are sophisticated users that are capable of determining whether the duplex gap is available at their location.[407] Thus, we do not believe it necessary to require licensed users of the four megahertz segment of the duplex gap to rely on a database to determine frequency availability.[408] Since we are limiting operation in this four megahertz segment to licensed users, the Spectrum Act's requirement that unlicensed devices rely on database access or a subsequent methodology as determined by the Commission does not apply.[409]

C. 600 MHz Service Band

163. We are adopting criteria to protect licensed wireless services operating in the 600 MHz service band from harmful interference from white space device operations. Specifically, we are adopting minimum separation distances from licensed wireless base stations that white space devices must meet to prevent harmful interference to wireless services in both the uplink and downlink bands. We are also adopting requirements to allow 600 MHz service licensees to provide to the white space database administrators—and for those administrators to enter and store in the databases—the locations where those licensees have commenced operation. Unlicensed white space devices are required to access these databases to ensure that they satisfy the required separation distances for co-channel and adjacent-channel operation to protect wireless services. We will require that both licensed and unlicensed wireless microphones operating in the 600 MHz service band during the post-auction transition period comply

[406] *See* Microsoft Comments at 37-38; OTI/PK Reply Comments at 13.

[407] *See* Sennheiser Comments at 9.

[408] Of course, licensed wireless microphone users may choose to manually check the database in a given area.

[409] *See* 47 U.S.C. § 1454(d).

with minimum separation distance requirements to prevent harmful interference to 600 MHz service licensees, and that unlicensed wireless microphones rely on the white space databases to ensure that their intended operating frequencies are available at the locations where they will be used.

1. White Space Devices

164. *Background.* The white space device rules contain protection requirements for a variety of services that operate in the TV bands, but they do not include protection requirements for licensed wireless broadband services because such wireless services did not operate in the TV bands at the time the Commission adopted those rules.[410] Therefore, the Commission proposed in the *Notice* to establish appropriate protection criteria, specifically, minimum distance separations, to protect these wireless services.[411] Protection criteria for wireless services are necessary for two reasons. First, the Commission decided to permit the continued operation of white space devices in repurposed spectrum, except in those areas in which a 600 MHz service licensee has commenced operations.[412] Because 600 MHz service licensees will be commencing operations at different places at different times depending on their business plans and other factors, some of the repurposed television spectrum may not be used for licensed wireless services in some areas immediately after the transition period and could continue to be used by white space devices. Second, the Commission decided to allow market variation in the 600 MHz Band Plan, so the same spectrum could be assigned for licensed wireless services in some areas and TV broadcasting in others.[413] White space devices could operate in locations where spectrum is assigned but not in use for TV broadcasting (*i.e.,* at locations that meet the minimum required separation distances from TV signal contours and other protected services).[414] Because these two factors would allow white space devices to operate in the same frequency bands as licensed wireless services in some instances, white space devices need to comply with minimum geographic separation distances from licensed wireless users to prevent harmful interference. Depending on the channel used by a white space device, the device could be in the same band as either wireless uplinks or downlinks.[415] Therefore, the Commission proposed separation distance requirements from both wireless uplinks and downlinks.[416]

165. The Commission proposed that the white space databases would use the proposed separation distances to ensure that unlicensed operations no longer occur on a channel in an area in which a licensee has commenced operations.[417] It also proposed that when a 600 MHz service licensee plans to commence operations on frequencies that includes spectrum available for unlicensed operations under the rules for white space devices, that licensee can notify any of the white space database administrators

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[410] *See* 47 C.F.R. § 15.712.

[411] *See Notice*, 29 FCC Rcd at 12288-12292, paras 133-144.

[412] *See Incentive Auction R&O,* 29 FCC Rcd at 6843-6844, para. 680. "Commence operations" has not yet been defined for the purpose of establishing when white space devices are to cease operations in a particular area. The Commission has sought comment on how to define the term "commence operations" in the context of the post-auction transition rules. *See Comment Sought on Defining Commencement of Operations in the 600 MHz Band*, GN Docket 12-268, Public Notice, 30 FCC Rcd 3200 (2015).

[413] *See Incentive Auction R&O,* 29 FCC Rcd at 6604-6605, para. 81-82.

[414] *See* 47 C.F.R. § 15.712.

[415] Wireless uplinks are transmissions from mobile devices to fixed base stations. The receivers of concern in developing protection criteria are those in fixed base stations. Wireless downlinks are transmissions from fixed base stations to mobile devices. The receivers of concern in developing protection criteria in the wireless downlink spectrum are mobile device receivers.

[416] *See Notice*, 29 FCC Rcd at 12288, para 133.

[417] *See Notice*, 29 FCC Rcd at 12287, para 131.

when and where it plans to commence operations.[418] The licensee would provide information to the white space databases to define a polygon representing the outer edge of its base station deployment.[419]

a. Permissible types of operation

166. We will allow fixed, Mode I and Mode II white space devices to operate in the 600 MHz service band under the same technical requirements (*e.g.,* power, antenna height, database access) that apply to operation in the TV bands. Additionally, we will require that white space devices comply with separation distances from the areas where a wireless licensee has commenced operations.

167. We disagree with TIA's argument that any white space operations in the 600 MHz service band should be limited to the same power level as the duplex gap (*i.e.,* 40 milliwatts) rather than four watts, as permitted for fixed white space devices in the TV bands.[420] We proposed different maximum power levels in these bands because the operational environments will differ significantly between the duplex gap and the 600 MHz service band. White space devices will be able to operate in the duplex gap in the same geographic areas where 600 MHz service licensees have commenced operation, but they will operate on frequencies adjacent to wireless uplink and downlink spectrum with small or no frequency separations and, potentially, at short physical separation distances (within a few meters) from wireless handsets. For these reasons, we are limiting white space device power to 40 milliwatts in the duplex gap to prevent harmful interference to licensed wireless services in adjacent bands. In contrast, white space devices will be allowed to operate in the 600 MHz service band only at locations where a wireless licensee has not commenced operations. Therefore, we can allow higher power levels for white space devices in the 600 MHz service band than in the duplex gap. These higher power levels require greater physical separation distances between white space devices and licensed wireless operations (both handsets and base stations). As discussed below, we are adopting minimum separation distances that white space devices in the 600 MHz service band must meet to protect licensed wireless services.

168. We do not address in this proceeding requests by AT&T, CTIA, Qualcomm and TIA to prohibit all unlicensed operations in a Partial Economic Area (PEA)[421] once a licensee has commenced operations in any part of that area.[422] In the *Incentive Auction R&O*, the Commission decided to allow continued operation of white space devices in the 600 MHz service band except in areas where a licensee has commenced operations.[423] The Commission noted that a 600 MHz service licensee can notify any of the white space database administrators when and where it plans to commence operations, and that the databases would be updated and would preclude unlicensed operations in those areas.[424] The Commission has sought comment separately on how to define the term "commence operations" in the context of the post-auction transition rules.[425] The *Notice* in this proceeding proposed rules to implement the decision in

[418] *See Notice*, 29 FCC Rcd at 12287, para 131.

[419] *See Notice*, 29 FCC Rcd at 12288, para 134.

[420] *See* TIA Comments at 15.

[421] The Commission defined Partial Economic Areas ("PEAs") as the service areas for 600 MHz band licenses. There are a total of 416 PEAs. *See Wireless Telecommunications Bureau Provides Details about Partial Economic Areas,* GN Docket No. 12-268, Public Notice, 29 FCC Rcd 6491 (2014) ("*PEAs PN"*).

[422] *See* AT&T Reply at 8, CTIA Comments at 38, Qualcomm Comments at 19, and TIA Comments at 16.

[423] *See Incentive Auction R&O,* 29 FCC Rcd at 6843-6844, para. 680. "Commence operations" has not yet been defined for the purpose of establishing when white space devices are to cease operations in a particular area. This issue will be decided during the pre-auction process. *See Incentive Auction R&O*, 29 FCC Rcd at 6840, para. 668 n.1861.

[424] *See Incentive Auction R&O,* 29 FCC Rcd at 6844, para. 680.

[425] *See Comment Sought on Defining Commencement of Operations in the 600 MHz Band*, GN Docket 12-268, Public Notice, 30 FCC Rcd 3200 (2015).

the *Incentive Auction R&O* by establishing minimum separation distances to protect licensed wireless services and procedures for including in the white space databases information on the locations where wireless licensees have commenced operations. The *Notice* did not reopen the issue of whether the Commission should permit unlicensed operation in the 600 MHz service band at locations where licensees have not yet commenced operation. Issues pertaining to the definition of "commence operations" will be addressed separately in response to the *Commence Operations PN*.

169. We also disagree with AT&T and Qualcomm that the Spectrum Act prohibits unlicensed use of the 600 MHz service band.[426] The Spectrum Act specifically permits unlicensed use of the guard bands, but does not contain any prohibition on continued unlicensed use of the 600 MHz service spectrum prior to a 600 MHz service licensee commencing operations.[427] Thus, we find that such operations are not prohibited by the Spectrum Act. Once a licensee notifies one of the white space databases that it has commenced operations in an area, unlicensed white space device use of that spectrum permanently ceases. Such an approach ensures that a licensee will have exclusive use of its spectrum when it commences operations and does not conflict with the Spectrum Act.

b. Protection criteria

(i) Wireless uplinks

170. *Background.* In the *Notice,* the Commission proposed co-channel and adjacent separation distances to protect wireless uplinks from harmful interference from white space devices.[428] Wireless uplinks are the transmissions from mobile devices to fixed base stations, so the receivers of concern in developing protection criteria are therefore those in fixed base stations. The Commission proposed that 600 MHz licensees provide information to the white space databases that defines a polygon representing the outer edge of their base station deployment, which the database would use to enforce the minimum required separation distances between white space devices and wireless base stations.[429] The Commission determined the proposed co-channel separation distances by assuming the situation where a white space device emission fully overlaps the receive band of a base station, but to ease the implementation burden, the Commission proposed that the co-channel separation distances apply for any amount of frequency overlap between a channel used by a white space device and a five megahertz spectrum block used by a Part 27 licensee.[430] The Commission also assumed that a typical base station operates at 30 meters or less above ground level and that a white space device can operate at various heights up to 250 meters above average terrain. It further assumed a base station receiver sensitivity level of the 3GPP standard of -101.5 dBm for wide area base stations.[431] Using these assumptions and the TM-91-1 propagation model, the Commission calculated separation distances to protect base station operations from harmful interference from co-channel white space devices.[432]

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[426] *See* AT&T Reply at 8 and Qualcomm Comments at 19.

[427] *See* 47 U.S.C. § 1454(c).

[428] *See Notice,* 29 FCC Rcd at 12288-12290, para. 134-139.

[429] *See Notice,* 29 FCC Rcd at 12288, para. 134.

[430] White space devices are designed to operate on six megahertz channels, whereas the 600 MHz Band Plan is based on five megahertz channels. Depending on which TV channel is being used by a white space device, its emissions could overlap the wireless channel by as little as one megahertz or fully overlap all five megahertz.

[431] We are relying on this assumption, rather than assuming actual operation at 10 dB or more above this level. *See* para. 121 and 143. Elsewhere in this Order, we protect adjacent channel operations in areas with typical wireless signal levels. Here, however, the Commission is protecting base stations at the outer edge of a 600 MHz band licensee's coverage area, where wireless signals are weaker. *See Notice,* 29 FCC Rcd at 12288, para. 135.

[432] TM-91-1 is consistent with Egli terrain model, which has range applicability up to 40 miles, as such TM-91-1 is used to calculate separation distances between white space devices and 600 MHz band base stations.

171. The Commission limited its proposed maximum co-channel separation distance to 60 kilometers, even in cases where the calculations showed greater distances.[433] It did so because the line-of-sight radio horizon for a 30 meter high base station antenna and a 250 meter high white space device antenna is 87 kilometers, so there was no reason for greater distances than this.[434] Further, the Commission predicted that the distances could be made even shorter than 87 kilometers because the line-of-sight radio horizon assumes perfect atmospheric conditions, and the absence of any obstructions such as buildings, mountains, trees or other ground clutter which further acts to reduce actual operating range.[435] In addition, the Commission noted that it developed the separation distances based on full overlap of the white space device's emissions with the base station receiver, but that there may be many cases where the overlap is less and these proposed distances will therefore provide additional protection.[436]

172. The Commission also proposed adjacent channel separation distances to protect wireless base stations from harmful interference from white space devices. It proposed to define adjacent channel operations as any overlap of a white space device's six megahertz operating channel with any portion of a five megahertz block directly adjacent to a five megahertz block that is being used by a 600 MHz base station.[437] It based the proposed separation distances on the situation where a white space device operates immediately adjacent to a five megahertz block used by a 600 MHz base station (*i.e.,* with a zero megahertz frequency offset), but recognized that in many cases, white space devices will operate with a greater frequency separation from 600 MHz base stations than used in the analysis, which will provide even greater protection.[438] In conducting the analysis to determine the necessary protection distances, the Commission assumed, similar to the analysis for handset protection, that the base station is operating 10 dB above its sensitivity level of -101.5 dBm.[439] It also assumed an adjacent channel selectivity of 43.5 dB and a wireless base station filter roll-off of 5.7 dB/MHz.[440]

173. *Discussion.* We adopt our proposed minimum separation distances that white space devices must meet when operating in spectrum that is also used for licensed 600 MHz wireless uplinks or downlinks. The record was mixed on the proposed separation distances, with some parties arguing the distances were too large and others arguing they are not sufficient.[441] After considering these comments, we find that the proposed separation distances are appropriate, as discussed further below. While these distances were calculated by determining the minimum separation from base stations that white space devices must meet to avoid causing harmful interference, consistent with the proposals in the *Notice* we are requiring that white space devices comply with these distances from any point along the edge of the polygon representing the outer edge of base station deployment, rather than from just the points that define the polygon in the database.[442] This requirement is necessary because the points defining a polygon could in some instances be farther apart than the protection distances we are adopting, thus possibly under-protecting base stations that are just inside the polygon and between the defined points.

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[433] *See Notice,* 29 FCC Rcd at 12289, para. 136.

[434] The radio horizon is an approximation of the maximum propagation distance for radio signals.

[435] *See Notice,* 29 FCC Rcd at 12289, para. 136.

[436] *See Notice,* 29 FCC Rcd at 12289, para. 136.

[437] *See Notice,* 29 FCC Rcd at 12289, para. 137.

[438] *Id.*

[439] *See Notice,* 29 FCC Rcd at 12289, para. 138.

[440] *Id.*

[441] *See* Motorola Comments at 11 and CTIA Comments at 31-33.

[442] *See Notice*, 29 FCC Rcd at 12288, para 134.

174. The co-channel and adjacent channel separation distances we adopt to protect wireless uplinks are listed in the tables below. These tables include a column for 10 watt fixed devices since, as discussed above, we will allow fixed device operation at this power level in the 600 MHz service band in addition to the TV bands in less congested areas.[443]

175. We are adopting the proposals in the *Notice* to define co-channel operation as any frequency overlap between a TV channel used by a white space device and a five megahertz spectrum block used by a 600 MHz service licensee, and adjacent channel operation as a frequency separation of zero to four megahertz between the edge of a channel used by a white space device and the edge of a five megahertz spectrum block used by a 600 MHz service licensee.[444] Consistent with the rules we are adopting for operation in the TV bands at various power levels, we are adding an entry to the tables to specify that personal/portable devices must meet the same separation distances as fixed devices with an HAAT of less than three meters.[445] Also, consistent with the rules we are adopting for operation in the duplex gap, we are not requiring adjacent channel separation distances to protect wireless uplink services from white space devices operating at 40 milliwatts since we determined that adjacent channel separation distances are not necessary in that case.[446] However, we are requiring adjacent channel separation distances for white space devices operating at higher power levels.

176. In addition, consistent with the rules for operation in the TV bands, we are requiring that a fixed or Mode II device that supplies a list of available channels to a Mode I device must comply with increased separation distances on any channels that are indicated as available to the Mode I device. As with operation in the TV bands, we will base the increases in separation distance on the minimum co-channel separation distances at 40 and 100 milliwatts. Therefore, if a Mode I device operates at greater than 40 milliwatts, the co-channel and adjacent channel separation distances must be increased by 6 kilometers and 0.14 kilometers, respectively. Similarly, if a Mode I device operates 40 milliwatts or less, the co-channel separation distance must be increased by 5 kilometers.

Antenna height above average terrain of unlicensed device	**600 MHz band wireless uplink spectrum Minimum co-channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment**						
	16 dBm (40mW)	**20 dBm (100 mW)**	**24 dBm (250mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**	**40 dBm (10 W)**
Personal/portable	5	6	N/A	N/A	N/A	N/A	N/A
Less than 3 meters	5	6	7	9	12	15	19
3-Less than 10 meters	9	11	14	17	22	27	34
10-Less than 30 meters	15	19	24	30	38	47	60
30-Less than 50 meters	20	24	31	38	49	60	60
50-Less than 75 meters	24	30	37	47	60	60	60

[443] *See* para. 52, *supra.*

[444] These definitions are necessary because TV stations use six megahertz channels, while licensed wireless spectrum will be auctioned in five megahertz blocks. Depending upon the final band plan and the TV channel used by a white space device, a wireless spectrum block could overlap a TV channel by anywhere from one to five megahertz. Likewise, a wireless spectrum block could overlap the five megahertz band adjacent to a TV channel by anywhere from one to five megahertz, which corresponds to frequency offset of zero to four megahertz from the edge of the TV channel used by the white space device.

[445] *See* para. 64, *supra.*

[446] *See* para. 152, *supra.*

75-Less than 100 meters	27	34	43	54	60	60	60
100-Less than 150 meters	33	42	53	60	60	60	60
150-Less than 200 meters	39	49	60	60	60	60	60
200-250 meters	43	54	60	60	60	60	60

Antenna height above average terrain of unlicensed device	**600 MHz band wireless uplink spectrum Minimum adjacent channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment**					
	20 dBm (100 mW)	**24 dBm (250mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**	**40 dBm (10 W)**
Personal/portable	0.1	N/A	N/A	N/A	N/A	N/A
Less than 3 meters	0.1	0.2	0.2	0.3	0.4	0.4
3-Less than 10 meters	0.3	0.3	0.4	0.5	0.6	0.8
10-Less than 30 meters	0.4	0.6	0.7	0.9	1.1	1.4
30-Less than 50 meters	0.6	0.7	0.9	1.2	1.4	1.8
50-Less than 75 meters	0.7	0.9	1.1	1.4	1.8	2.2
75-Less than 100 meters	0.8	1.0	1.3	1.6	2.0	2.6
100-Less than 150 meters	1.0	1.3	1.6	2.0	2.5	3.1
150-Less than 200 meters	1.2	1.4	1.8	2.3	2.9	3.6
200-250 meters	1.3	1.6	2.0	2.6	3.2	4.1

177. We reject CTIA's argument that use of the TM-91-1 model is inappropriate due to the range of distances and antenna heights over which it is defined. CTIA argues that the TM-91-1 model used by the Commission to determine the separation distances from base stations is not valid at the antenna heights and separation distances in the Commission's analysis.[447] Although the TM-91-1 model was developed to study a particular range of distances and antenna heights, it is based on the Egli model which has an applied range of up to 40 miles (64 kilometers) from the transmitter, a transmit antenna height of up to 5000 feet (1524 meters) and receive antenna height of up to 1000 feet (305 meters).[448] A comparison of the TM-91-1 model, equation 5, and Egli's model, equation 2 shows that they are identical when compared in the same units. Thus, while TM-91-1 was specifically developed for limited range, nevertheless by the virtue of the fact that it is identical to Egli's model, it has a broader range of application than stated in the report.

178. We disagree with CTIA that we should use the Longley-Rice model instead of the TM-91-1 model for consistency with the ISIX methodology.[449] The Longley-Rice methodology uses detailed, site specific terrain information and performs complex, computational intensive calculations to

[447] *See* CTIA Comments at 31-32.

[448] Egli, J.J.: "Radio Propagation Above 40 Mc Over Irregular Terrain"; Proceedings of the I.R.E., Vol. 45, October 1957.

[449] CTIA claims that the TM-91-1 model understates the potential for harmful interference to base stations as compared to the Longley-Rice model, and that the use of the Longley-Rice model would be consistent with the ISIX methodology. *See* CTIA Comments at 32.

determine signal coverage. In contrast, we are here developing a general table of separation distances that can be used by the white space databases to protect licensed wireless services in a wide variety of locations. We find that the simpler TM-91-1 model is more appropriate for this purpose.

179. We also disagree with CTIA that we should protect wireless base stations from white space devices at distances beyond 60 kilometers.[450] The Commission explained its rationale for proposing this distance in the *Notice*, stating that the line-of-sight radio horizon for a 250 meter high transmit antenna and a 30 meter high receive antenna is 87 kilometers, and that there are a number of factors that can reduce this range, including atmospheric conditions and obstructions such as buildings, mountains, trees or other ground clutter.[451] For these reasons, it proposed a 60 kilometer maximum separation distance and asked that commenters provide technical information and analysis if they believe the Commission should use different criteria. CTIA merely asserts that this distance is insufficient but does not suggest any larger distance as an alternative. Accordingly, we are adopting the proposed 60 kilometer separation distance.

180. We did not double count clutter by using the TM-91-1 model as CTIA asserts.[452] We agree that the TM-91-1 model effectively considers clutter; however, we did not include any additional clutter factor when using this model to calculate separation distances required to protect 600 MHz service band operations from harmful interference, with the exception of the largest co-channel separation distance (60 kilometers). In that case, we calculated the theoretical maximum line-of-site distance between a white space device and a wireless base station (87 kilometers) without considering clutter, then determined that a shorter distance is appropriate due to a number of factors including clutter.[453] Thus, we did not double count clutter in that case. We also disagree with CTIA that it is inconsistent to consider clutter in determining the white space device separation distances, but not in the ISIX methodology.[454] As discussed above, we are using different propagation models in these cases (TM-91-1 in this proceeding and Longley-Rice in the ISIX proceeding) for different purposes. The Commission considered whether to use clutter in the ISIX proceeding and determined that including an additional factor for clutter did not improve the accuracy of results obtained using the Longley-Rice methodology.[455] In contrast, the TM-91-1 model we are using in this proceeding considers clutter, but there is no way that its use can be excluded since it is built into the model and there is no separate clutter factor.

(ii) Wireless downlinks

181. *Background.* In the *Notice,* the Commission proposed co-channel and adjacent separation distances to protect wireless downlinks from harmful interference from white space devices.[456] Wireless downlinks are the transmissions from fixed base stations to mobile devices. The receivers of concern in developing protection criteria in the wireless downlink spectrum are therefore the mobile device's receivers. Because a database cannot track the constantly changing locations of mobile devices, the Commission based the protection criteria on base station location.[457] To determine the minimum required separation distances, the Commission first determined the minimum separation distance necessary to protect a mobile device from harmful interference from a white space device, then defined a maximum

[450] *See* CTIA Comments at 35.

[451] *See Notice,* 29 FCC Rcd at 12289, para. 136.

[452] *See* CTIA Comments at 33.

[453] The distance to the radio horizon in kilometers is 4.124 x sqrt(H1) + 4.124 x sqrt(H2) where H1 and H2 are the heights of the transmit and receive antennas in meters.

[454] *See* CTIA Comments at 34.

[455] *See ISIX Second Report and Order,* 29 FCC Rcd at 13089, para. 36.

[456] *See Notice,* 29 FCC Rcd at 12291-12292, para. 142-144.

[457] *See Notice,* 29 FCC Rcd at 12290, para. 140.

distance from base stations at which mobile devices would typically operate.[458] It proposed that the minimum required separation be the sum of these two distances.[459]

182. In determining the required separation distances from handsets, the Commission used the same assumptions as for the analysis for base stations, except for the receiver sensitivity and antenna. For those values it assumed a handset sensitivity of -97 dBm and antenna height of 1.5 meters above ground.[460] Based on those assumptions, it calculated a maximum co-channel separation distance of 4.2 kilometers for a four watt white space device at a 250 meter antenna height.[461] To reduce the compliance burden, the Commission proposed to use only this largest separation distance from handsets in determining the total required separation distance from base stations for white space devices at all power levels and antenna heights.[462] The Commission assumed that a wireless base station has a maximum range of 30 kilometers, so it proposed a co-channel separation distance of 35 kilometers between white space devices operating in wireless downlink spectrum and wireless base stations (*i.e.,* the sum of these two distances, rounded up to the next highest kilometer).[463]

183. To determine adjacent channel protection distances, the Commission used the same assumptions for handsets as used for interference analysis between wireless handsets in the duplex gap and white space devices, and assumed the worst case of no frequency separation between the edge of the handset receive band and the white space transmit band.[464] The Commission calculated a maximum separation distance of 353 meters for a four watt white space device at a 250 meter antenna height.[465] The Commission proposed an adjacent channel separation distance of 31 kilometers between white space devices operating in wireless downlink spectrum and wireless base stations (*i.e.,* the sum of these two distances, rounded up to the next highest kilometer).[466]

184. *Discussion.* We adopt the proposed minimum separation distances of 35 kilometers (co-channel) and 31 kilometers (adjacent channel) between white space devices operating in spectrum used by 600 MHz band wireless downlinks and the boundary of a polygon representing the outer edge of base station deployment. We also adopt the same definitions of co-channel and adjacent channel operation that apply with respect to wireless uplinks. The separation distances that we are adopting do not vary with EIRP or HAAT because the analysis in the *Notice* showed that increasing the EIRP or HAAT has only a small effect on the total required separation distance. Our analysis shows that these distances are also sufficient to provide protection from white space devices operating at 10 watts EIRP.[467]

185. As proposed in the *Notice,* we will require 40 milliwatt white space devices to meet adjacent channel separation distances from the service areas where a wireless licensee has commenced

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[458] *Id.*

[459] *Id.*

[460] *See Notice,* 29 FCC Rcd at 12290, para. 141.

[461] *See Notice,* 29 FCC Rcd at 12291, para. 142.

[462] *Id.*

[463] *Id.*

[464] *See Notice,* 29 FCC Rcd at 12291, para. 143.

[465] *Id.*

[466] *See Notice,* 29 FCC Rcd at 12291-12292, para. 144.

[467] For a 10 watt white space device operating in wireless downlink spectrum at an HAAT of 250 meters, the minimum required separation distances from handsets would be 4.3 kilometers (co-channel) and less than one kilometer (adjacent channel). Assuming a base station range of 30 kilometers, the minimum required separations from base stations rounded up to the next highest kilometer would be 35 kilometers (co-channel) and 31 kilometers (adjacent channel).

operations, at any frequency separation from zero to four megahertz from wireless downlink spectrum. This is because we are allowing fixed devices to operate with antenna heights of up to 250 meters HAAT, which increases their potential for causing harmful interference to wireless services.[468] As discussed above, we find that white space devices operating in the guard band adjacent to wireless downlink spectrum at low antenna heights (10 meters or less AGL) and a minimum frequency separation of three megahertz will not cause harmful interference to wireless handsets and thus do not specify a separation distance for such operations.[469] While we could allow for operation of such white space devices in the 600 MHz service band without an adjacent channel separation distance, we adopt a different approach in order to reduce the compliance burdens and provide for bright-line rules for the 600 MHz service band. Specifically, for the 600 MHz service band, we require all white space devices to comply with a single adjacent channel separation distance, independent of white space device power, antenna height or frequency offset. No party objected to this proposal.

186. We disagree with Motorola that we should decrease the minimum required separation distances to protect wireless downlinks, or that as an alternative we should allow information on the maximum operational range of base stations to be entered into the database.[470] Motorola argues that the maximum usable range of a cell site rarely exceeds 15 kilometers in practice, so the Commission's separation distances, which were based on the assumption that a base station could have a maximum range of 30 kilometers, should be reduced by 15 kilometers.[471] We recognize that the assumption of a 30 kilometer base station range is a very conservative approach to protecting wireless services. The Commission made this assumption to ensure that the calculated separation distances would adequately protect licensed wireless services, particularly in areas where base stations are farther apart, such as rural areas. However, no party responded to Motorola's analysis of the maximum range of a cell site, so there is limited information in the record that could justify a shorter distance. We are therefore adopting our proposed separation distances. With regard to Motorola's request to allow the database to include information on the maximum range of individual base stations, it did not provide a detailed description of how this approach would work. However, we believe that such an approach would complicate the process of protecting licensed wireless services. Licensees would be required to enter more information into the white space database because the maximum operational range is likely to be different for each base station. Further, this approach would be inconsistent with the method we adopt for using polygons to specify the outer limit of a licensees base station deployment since there would not be a single separation distance that could be applied uniformly outside the boundary of the polygon. Instead, it would be necessary for licensees to enter many more base stations into the database, each with its own protection distance.

2. Wireless Microphones

187. *Background.* In the *Incentive Auction R&O,* the Commission decided to permit wireless microphone users to continue to operate in the 600 MHz service band during the post-auction transition period subject to certain conditions. Specifically, wireless microphone users may continue to operate in this band, consistent with their secondary or unlicensed status, are not entitled to any interference protection from 600 MHz licensees' operations, and must cease operations if they cause harmful interference to any 600 MHz licensee's operations.[472] The Commission also decided that all wireless microphone operations must be transitioned out of the 600 MHz service band no later than the end of the

[468] *See Notice,* 29 FCC Rcd at 12289-12290, para. 138-139.

[469] *See* para. 109, *supra.*

[470] *See* Motorola Comments at 11.

[471] *Id.*

[472] *See Incentive Auction R&O*, 29 FCC Rcd at 6846, para. 687.

post-auction transition period, which will be 39 months after the issuance of the *Channel Reassignment PN*.[473]

188. In the *Notice*, the Commission proposed to protect 600 MHz service licensees from harmful interference from licensed and unlicensed wireless microphones using certain of the separation distances that it proposed to protect 600 MHz service licensees from harmful interference from white space devices.[474] Specifically, the Commission proposed to require that wireless microphones operate at the same distance outside a 600 MHz service licensee's service area as white space devices operating with a power of 4,000 milliwatts EIRP and an antenna height of three meters above average terrain.[475] The Commission also sought comment on how best to implement the proposed separation distances.[476] In particular, it sought comment on whether there is a need to require unlicensed wireless microphone users to check a database to ensure that they are outside a wireless licensee's service area, or whether the general non-interference requirements described in the *Incentive Auction R&O* are sufficient to protect 600 MHz service licensees.

189. Sennheiser supports the Commission's proposal that wireless microphones comply with a minimum separation distance requirement but believes that determining that distance by equating a group of microphones to a 4,000 milliwatt white space device yields an excessive and inaccurate result.[477] It argues that even ten "standard" 50 milliwatt wireless microphones in a six megahertz channel do not yield the same spectral density as a 4,000 milliwatt white space device.[478] Mobile Future argues that, even though the Spectrum Act requirement for database access does not apply to this spectrum, the Commission should require unlicensed wireless microphone users to check the white space databases to avoid causing harmful interference to new wireless services,[479] but Sennheiser believes that the general non-interference requirement adopted in the *Incentive Auction R&O* is sufficient.[480]

190. *Discussion.* We will require that licensed and unlicensed wireless microphones operating in the 600 MHz service band comply with minimum co-channel and adjacent channel separation distances from the areas where 600 MHz service licensees are operating. We find that this requirement is necessary to protect licensed wireless operations in the 600 MHz service band. However, we agree with Sennheiser that the separation distances proposed in the *Notice* are larger than necessary to protect licensed wireless services in some instances. As described below, we are reducing the separation for wireless microphones operating in the portion of the 600 MHz service band used for wireless uplinks, *i.e.,* base station receive frequencies. However, we are not reducing the proposed separation distances in the portion of the 600 MHz service band used for wireless downlinks (35 kilometers co-channel, 31 kilometers adjacent channel). The reason is that the primary component of those distances is an assumed base station communication radius of 30 kilometers, so the reduction in these separation distances would be relatively

[473] *Id.*

[474] *See Notice*, 29 FCC Rcd at 12298, para. 167.

[475] *See Notice*, 29 FCC Rcd at 12299, para. 168. The proposed approach in the *Notice* is similar to the approach the Commission used in the *Incentive Auction R&O* to determine the minimum separation distance between wireless microphones and the protected contour of co-channel television stations. In that case, the Commission based its determination on a power level significantly higher than a single wireless microphone since multiple wireless microphones can operate in a single six megahertz channel. It used the three meter antenna height above average terrain because that height is used in determining the separation distances for portable white space devices, and wireless microphones are also portable devices.

[476] *See Notice*, 29 FCC Rcd at 12299, para. 169.

[477] *See* Sennheiser Comments at 18.

[478] *Id.*

[479] *See* Mobile Future Comments at 7.

[480] *See* Sennheiser Comments at 18.

small if we recalculated them assuming a lower power for wireless microphones.[481] While we could allow for operation of wireless microphones in the repurposed 600 MHz downlink band without any adjacent channel separation distance in some cases similar to our actions in the guard bands and duplex gap, we adopt a different approach in order to reduce the compliance burdens and provide for bright-line rules for the 600 MHz service band. Specifically, for the 600 MHz service band, we require all wireless microphones to comply with the same adjacent channel separation distance as for white space devices.

191. With regard to protecting wireless uplinks, we will assume a lower total power for wireless microphones than 4,000 milliwatts. While licensed wireless microphones are permitted to operate with power levels of up to 250 milliwatts, most wireless microphones operate with a power level of less than 50 milliwatts.[482] Based on ten wireless microphones operating at 50 milliwatts as described by Sennheiser, the total power in a six megahertz channel would be less than 500 milliwatts. The actual EIRP that could affect a wireless system would be less than that for two reasons. First, wireless spectrum blocks are five megahertz wide, so depending on the overlap between a repurposed six megahertz TV channel and a wireless spectrum block, the maximum power that could fall into a five megahertz block would be 5/6 of the total, or 417 milliwatts. In most cases, a smaller overlap would occur and the power that could fall into a five megahertz block will be less than 417 milliwatts.[483] Second, the EIRP of an individual wireless microphone is often less than the 50 milliwatt conducted power limit due to antenna efficiency limitations, and because wireless microphones are often operated using less than the maximum allowable power to achieve greater battery life and spectral efficiency.[484] Because these two conditions are likely to create a situation where the overlapping power is much less than 417 milliwatts, we will base the separation distances that wireless microphones must meet to protect wireless uplinks on the nearest white space device power level that is less than 417 milliwatts, which is 250 milliwatts. The co-channel and adjacent channel separation distances that apply at that power level with a three meter antenna height are 7 kilometers and 0.2 kilometers. While we could allow for operation of wireless microphones in the repurposed 600 MHz uplink band without any adjacent channel separation distance in some cases similar to our actions in the duplex gap, we adopt a different approach in order to reduce the compliance burdens and provide for bright-line rules for the 600 MHz service band. Specifically, for the 600 MHz service band, we require all wireless microphones to comply with the same adjacent channel separation distance as for white space devices.

192. Licensed and unlicensed wireless microphones can continue to operate in the 600 MHz service band during the post-auction transition period, consistent with their secondary or unlicensed status, provided they do not cause harmful interference to incumbent TV services or new wireless services. However, they have a hard date by which they must cease operating in the band.[485] The white space databases will enable unlicensed wireless microphone users to determine whether their operating location is at least four kilometers outside the protected contour of TV stations that continue to operate in

[481] The Commission noted in the *Notice* that there would be little difference in the separation distances required to protect wireless downlinks from lower power and higher power white space devices. It therefore proposed a single co-channel and a single adjacent channel separation distance. *See Notice,* 29 FCC Rcd 12291-12292, para. 142 and 144.

[482] *See Incentive Auction R&O*, 29 FCC Rcd at 6699, para. 306.

[483] The power for a four megahertz overlap would be 333 milliwatts; for three megahertz would be 250 milliwatts; for two megahertz 167 milliwatts; and for one megahertz 83 milliwatts.

[484] As discussed above, we are setting the power limit for unlicensed wireless microphones at 50 milliwatts EIRP. However, all wireless microphones approved before the effective date of this change will have been certified for compliance based on a conducted power limit rather than an EIRP limit. Further, manufacturers are unlikely to certify many new wireless microphones for use in the repurposed 600 MHz band due to the operational cutoff after 39 months. Thus, we expect that mainly older wireless microphones that complied with the conducted power limit will continue to be used in the repurposed band through the 39 month transition period.

[485] *See* para. 17, *supra*.

that band and also to identify areas where 600 MHz service licensees are operating so they can avoid causing harmful interference to them. The 600 MHz service licensees rely on the deployment of multiple base stations to provide service, and expand the number and locations of base stations as they increase their service areas. This is a dynamic set of circumstances that necessitates periodic checking of the databases to identify the appropriate locations where wireless services are protected from harmful interference as required by the *Incentive Auction R&O*. We thus require that unlicensed wireless microphone users rely on the white space databases to ensure that their intended operating frequencies in the 600 MHz service band are available at the locations where they will be used. Operation in the 600 MHz service band requires that wireless microphone users check the databases more frequently than they would in the guard bands and duplex gap, *i.e*., always prior to beginning operation at a given location and not just if the microphone user moves from an earlier location.

D. Channel 37

193. Channel 37 (608-614 MHz) is currently used for the Wireless Medical Telemetry Service (WMTS)[486] and the Radio Astronomy Service (RAS).[487] Although, this channel sits in the middle of the UHF-TV band, the rules currently do not allow white space devices to operate there. In the *Incentive Auction R&O,* the Commission stated that authorizing the use of channel 37 for unlicensed operations would make additional spectrum available for unlicensed devices in areas of the country that are not in close proximity to hospitals or other medical facilities that use WMTS equipment, or to RAS sites.[488] It therefore decided to permit unlicensed operations on channel 37, subject to the development of the appropriate technical parameters for such operations to protect the WMTS and RAS from harmful interference.[489]

194. Consistent with the Commission's earlier decision, we will allow fixed and personal/portable white space devices to operate in channel 37 subject to rules specifying power and separation distances from health care facilities and radio astronomy sites.[490] In addition, we are removing

[486] The WMTS is used for remote monitoring of patients' vital signs and other important health parameters (*e.g.,* pulse and respiration rates) inside medical facilities. WMTS includes devices that transport the data via a radio link to a remote location, such as a nurses' station, which is equipped with a specialized radio receiver.

[487] RAS is a receive-only service that uses highly sensitive receivers to examine and study radio waves of cosmic origin. There are twelve RAS telescopes that have been using channel 37 or plan to use channel 37 in the near future. Of them, ten comprise the National Radio Astronomy Observatory's (NRAO's) Very Long Baseline Array (VLBA), which are distributed in several locations in the United States and its territories, and collect simultaneous observations that are combined to emulate a single telescope 5000 miles in diameter. The remaining two telescopes are single dish instruments. The Commission protects RAS from in-band harmful interference by imposing field strength limits on WMTS and requiring coordination of WMTS use within certain distances of RAS observatories.

[488] *See Incentive Auction R&O,* 29 FCC Rcd at 6687, para. 276.

[489] *See Incentive Auction R&O,* 29 FCC Rcd at 6686, para. 274. In their comments in response to the *Notice* in this proceeding, Sennheiser and Shure request that the Commission permit wireless microphones to operate on channel 37. *See* Sennheiser Comments at 9-10; Shure Reply Comments at 18. The *Notice* did not propose such operation and these requests are beyond the scope of this proceeding. We also observe that Sennheiser made this same request in a petition for reconsideration of the Commission's decision in the *Incentive Auction R&O* to permit unlicensed devices to operate on channel 37. The Commission denied Sennheiser's request, noting that it had never proposed to permit such use and the request on reconsideration was beyond the scope of that proceeding. *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Second Order on Reconsideration,* 30 FCC Rcd at 6804-6805, para. 128, n. 494.

[490] GE Healthcare and the WMTS Coalition, in *ex parte* comments raise a concern regarding the security of the white space access system including the database interface and the white space devices. *See* GE Healthcare and WMTS Coalition *ex parte* comments filed July 31, 2015. The parties request that the Commission institute more thorough and robust enforcement of its rules and cite a letter from NAB in which NAB claims it has found false device location information in the database. *See* Letter from Patrick McFadden, Vice President Spectrum Policy, National Association of Broadcasters, to Marlene H. Dortch, Secretary, Federal Communications Commission, RM-

(continued….)

the strict out-of-band limits from white space devices into channel 37 thus also opening up channels 36 and 38 for use by white space devices.[491] Finally, we discuss a process by which affected parties can mutually agree to adjust separation distances between white space devices and health care facilities.

1. Power limits and separation distances

a. General technical requirements and power limits

195. *Background.* In the *Notice*, the Commission sought comment on several approaches for accessing channel 37, including allowing fixed white space devices only, fixed and Mode II personal/portable devices, or also permitting Mode I personal/portable devices.[492] The Commission also proposed and sought comment on the appropriate power limits for white space devices operating on channel 37. In making these proposals, the *Notice* laid out various scenarios for the spectrum around channel 37 after the incentive auction and proposed a mix of limiting power to 40 milliwatts and operating up to 4 watts depending on the ultimate composition of the spectrum. In addition, the Commission asked if we should allow a higher power limit in rural areas.[493]

196. *Discussion.* There is support in the record for crafting rules that would provide the most flexibility for white space devices while also protecting incumbent WMTS and RAS. Motorola asserts that portable white space devices should be allowed to operate on channel 37 at up to 100 milliwatts EIRP, provided that they comply with minimum separation distances. Additionally, it comments that fixed devices should be allowed to operate on channel 37, so long as they meet minimum separation distances from WMTS and RAS users. Finally, Motorola contends that Mode I white space devices should be allowed to operate at increased separation distances over those proposed in the *Notice*.[494] Opposing this view, the WMTS Coalition and GE Healthcare state that at most, the Commission should initially only authorize fixed unlicensed devices to operate on channel 37, arguing that the Commission has no experience with personal/portable devices, and that interference from portable devices would be difficult to identify and correct.[495]

(Continued from previous page)
11745, ET Docket No. 14-165, Attachment at 1 (June 25, 2015). We note that NAB and the white space device manufacturers recently came to an agreement to address many of these concerns. *See* n.37, *supra.* In addition, the white space rules in Part 15 have several provisions regarding security of the device, the radio link, and the database. *See, e.g.,* Sections 15.709(f), 15.711(j), 15.713(a), and 15.713(l) in Appendix A – Final Rules. We believe the provisions in the rules are adequate to ensure security of the white space access system such that devices and databases will be protected from manipulation and thus protect WMTS systems. However, we note that Commission staff has been and will continues to collaborate with stakeholders to improve the databases.

[491] As stated in para. 91, *supra*., we are modifying the rules to permitting white space devices to operate on an equal basis with wireless microphones on the first vacant channel above and below channel 37. White space devices will be able to begin accessing these channels either 18 months after the effective date of this rule or no later than after the conclusion of the incentive auction when the *Channel Reassignment PN* is released.

[492] *See Notice*, 29 FCC Rcd at 12279-12280, paras. 101-103.

[493] *See Notice*, 29 FCC Rcd at 12280-12281, paras. 104-108.

[494] *See* Motorola Comments at 10. *See also,* Dynamic Spectrum Alliance Comments at 10 (stating that the Commission should allow use of Mode I, Mode II, and fixed devices on channel 37); Google Comments at 31 (asserting that both Mode I and Mode II personal/portable devices can operate safely on channel 37); Microsoft Comments at 26 (opining that the Commission should permit fixed and both Mode 1 and Mode II personal/portable devices to operate on channel 37).

[495] *See* WMTS Coalition Comments at 9. *See also*, GE Healthcare Comments at 28. GE bases its opposition to personal/portable devices based on questions regarding reliability and security of white space devices and the ability to disable errant devices. *See* GE Healthcare Comments at 28-29. We note in this regard that the white space rules require devices to have security features built in and for the databases to have the ability to shut down a device or class of devices if they are found to be causing harmful interference or otherwise in violation of the rules. *See* 47 C.F.R. §§ 15.709(a)(6), 15.715(k).

197. The rules for white space devices rely on geolocation and a database to protect a wide variety of services. We believe the same rules, as amended herein, can protect services on channel 37. The white space databases are well equipped to protect WMTS and RAS users from interference from fixed devices as well as Mode I and Mode II personal/portable white space devices. Further, we note that WMTS users argue that WMTS needs greater protection than TV because of health and safety concerns as well as the lack of spectrum resources and expertise as compared to broadcasters in identifying the cause of interference if any should occur. Our goal is to ensure that WMTS continues to provide health care facilities with reliable real-time patient data. Thus, as discussed further below, we are taking measures to ensure that the separation distances and procedures we adopt for white space devices operating on channel 37 are more than adequate to prevent harmful interference to the WMTS, and that we can quickly resolve any interference that occurs.[496] We are adopting distance separation requirements, consistent with our existing technical rules for white space devices along with additional procedures which allow all white space devices to operate on channel 37 without causing harmful interference to WMTS systems.

198. More specifically, we will allow fixed devices to operate on channel 37 at power levels up to 4 watts and with antennas ranging up to 250 meters HAAT. We will also allow both Mode I and Mode II personal/portable devices to operate at power levels up to 100 milliwatts. As with the rules we adopt above that require an adjustment in separation distance when fixed or Mode II devices are controlling a Mode I device, we will require the same here.[497] On this point, we note that the Wi-Fi Alliance comments that Mode I devices will continue to protect channel 37 operations in the same way they are protected against fixed and Mode II devices.[498]

199. Although we will allow fixed devices at up to four watts, the results of the incentive auction along with the interplay of all our white space rules provides a conservative approach to white space device usage on channel 37. If the incentive auction recovers exactly 84 megahertz of spectrum, there will be a three megahertz guard band above channel 37, and if more than 84 megahertz is recovered, there will be a three megahertz guard band on each side of channel 37. In either case, only that three megahertz guard band will separate white space devices operating on channel 37 from the mobile handset receive band. If this were to occur, then consistent with the rules we are adopting for the duplex gap and the guard bands, white space device operation on channel 37 would be limited to 40 milliwatts to ensure protection to those mobile handsets.[499] If the incentive auction recovers less than 84 megahertz, then channels 36 and 38 would remain available for TV. Our rules require the TV channel on either side of the white space channel to be vacant to operate a fixed station at power levels above 100 milliwatts. That would still be the case here: to operate at higher power on channel 37 would require channels 36 and 38 to both be free from TV operations.[500] Finally, we note that if channels 36 and/or 38 remain available for TV, we would, consistent with the rules being adopted herein, permit a white space device to operate at up to 100 milliwatts so long as it straddles channels 36 and 37 or channels 37 and 38 and it meets the separation distances being adopted for channel 37 as well as all other protection requirements specified in the rules. We will not permit, as requested by WISPA, white space devices operating in this manner to operate at power up to four watts[501] as we believe the risk of harmful interference to television reception is too great. Similarly, we will not permit, at this time, white space devices operating on channel 37 in rural

[496] *See* para. 220-221, *infra.*

[497] *See* para. 71-74, *supra.*

[498] *See* Wi-Fi Alliance Comments at 28.

[499] *See* para. 115, *supra.*

[500] *See* Comments of WISPA at 6 stating that the Commission should permit fixed white space devices on channel 37 to operate with an EIRP up to 4 watts where channels 36 and 38 are vacant.

[501] *See* Comments of WISPA at 6.

or areas where spectrum is not congested to operate with higher power than four watts. In such areas, there should already be sufficient spectrum available to operate at higher powers consistent with the rules we are adopting for less congested areas.[502] However, as we gain experience with higher power operations, we could revisit this issue and adjust the rules accordingly so long as WMTS and RAS are protected from harmful interference.

b. Determination of WMTS separation distances

200. *Background.* In the *Notice*, the Commission proposed a table of separation distances that white space devices must meet to protect WMTS systems based on white space device power and antenna height.[503] These separation distances were derived from assumptions found in the record in the incentive auction proceeding.[504] The proposed rules were the subject of much debate in the record in this proceeding and based on the comments, we are modifying some of the underlying assumptions and consequently adopting rules with adjusted separation distances from those proposed.

201. In the *Notice*, we based the determination of separation distance on the assumption that WMTS typically occupy a bandwidth of 10 kilohertz.[505] In addition, based on comments from GE, we assumed that to prevent harmful interference to WMTS receivers, the signal level at the perimeter of a registered WMTS facility should not exceed 10 microvolts per meter within a 100 kilohertz bandwidth on channel 37, or 20 millivolts per meter within a one megahertz bandwidth on channels 36 and 38.[506] However, in its comments, GE Healthcare states that receive sensitivity for a WMTS receiver is -95 dBm.[507] In an *ex parte* filing, the WMTS Coalition provides revised criteria for protection. Specifically, it states that the WMTS registration database shows many installations with equipment using a 12.5 kilohertz bandwidth and that an appropriately conservative value for receiver sensitivity to provide protection should be -100 dBm.[508]

202. *Discussion.* In consideration of the most recent information filed to the record and our goal to be conservative in our determination of protection distances to protect WMTS, we are basing our analysis on a -100 dBm receiver sensitivity level and a 12.5 kilohertz bandwidth. Using these criteria ensures that our analysis provides sufficient protection for WMTS devices produced by all manufacturers.

203. Throughout the Commission's various white space proceedings, we have used the TM-91-1 propagation model to determine protection distance between white space devices and receivers in other services.[509] Thus, we proposed to use this same model to calculate protection distance for WMTS devices. GE Healthcare objects to our use of the TM-91-1 propagation model, arguing that it is inappropriate and inconsistent with FCC precedent stating that free space propagation loss yields a more accurate estimate of the distance needed to prevent harmful interference under realistic worst-case line-of-

[502] *See* para. 51, *supra.*

[503] *See Notice,* 29 FCC Rcd at 12282, para. 112.

[504] *See* GE Healthcare Comments in GEN Docket No. 12-268.

[505] *Id.* at 39.

[506] *Id.* at 24.

[507] *See* GE Healthcare Comments, Appendix A at 5. We note that Google filed technical analysis showing calculated protection distances based on the -95 dBm criterion provided by GE Healthcare. *See* Google *ex parte* filing dated May 22, 2015 at 9.

[508] *See* WMTS Coalition *ex parte* filing dated June 12, 2015 at 4.

[509] *See*, *e.g.*, In the Matter of Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, *Third Memorandum and Order*, ET Docket No. 04-186; ET Docket No. 02-380, 27 FCC Rcd 3692, 3698 (2012) at ¶ 16.

sight propagation.[510] In addition, it argues that the TM-91-1 model is not valid at the antenna heights and distances used by the Commission, and that the TM-91-1 model calculates median field strength value which is not appropriate to use when predicting areas of harmful interference.[511] Broadcom, in their analysis applies the Winner+ Urban Micro propagation model.[512] GE Healthcare, in response, states that Broadcom's use of that model is flawed because it fails to represent a realistic worst case scenario.[513] While the Winner+ model is valid for the frequency range considered here, it was developed to model IMT advanced radio systems and has specific inputs depending on the scenario being modelled; *e.g.*, urban vs. suburban vs rural.[514] Our goal is to develop rules of general applicability that are easy to understand and implement, while also protecting WMTS systems from harmful interference. We believe using the Winner+ model would add significant complexity to the process as the inputs for each health care facility would need to be agreed upon in advance and provided to each database administrator so that each could produce the same protection zones. In addition to the added complexity, such a process could be so administratively cumbersome so as to prevent any sharing of the band. We do not believe this added complexity would provide much corresponding benefit. Instead, we believe that adopting rules that are crafted to protect the vast majority of health care facilities, along with additional procedures to ensure those that need additional protection also do not experience harmful interference, is less burdensome and provides the same result: low potential of harmful interference at health care facilities. Thus, we choose not to use that model here.

204. In its technical analysis, Google states that a variety of factors beyond simple free-space path loss are likely to cause additional losses between a TVWS device and a WMTS receiver, including ground clutter (such as trees, sidewalks, and roofs, even in line-of-sight conditions) and antenna polarization and pattern mismatch.[515] The WMTS Coalition agrees with Google's use of free space propagation loss but states that their inclusion of other loss factors is inappropriate.[516] To further bolster its argument, GE Healthcare cites to field tests which they proclaim show that white space devices can cause harmful interference to WMTS systems when operating consistent with the Commission's proposals.[517] Microsoft counters that the testing does not accurately represent real-world propagation loss, claiming that all WMTS receive antennas were placed near windows pointing at the simulated white space transmitter using a focused beam aimed directly at the hospital.[518]

205. In consideration of the foregoing arguments, we continue to believe that the TM-91-1 propagation model is the most appropriate model to use for determining the separation distances necessary to protect WMTS systems from white space devices at the various power/antenna height combinations permitted by the rules. The TM-91-1 model, which as stated above has been used previously to model white space interference potential, was developed for modelling propagation loss at relatively short distance to provide capability where the F curves are no longer appropriate.[519] We believe

[510] *See* GE Healthcare Comments at 10.

[511] *See* GE Healthcare Comments at 14-16.

[512] *See* Broadcom Comments at 23.

[513] *See* GE Healthcare Reply Comments at 7.

[514] *See* Celtic Telecommunications Solutions, "Winner+ Final Channel Models" available at: http://projects.celtic-initiative.org/winner+/WINNER+%20Deliverables/D5.3_v1.0.pdf.

[515] *See* Google *ex parte* filing dated May 22, 2015 at 11.

[516] *See* WMTS Coalition *ex parte* filing dated June 12, 2015 at 4.

[517] *See* GE Healthcare Comments at 25-26.

[518] *See* Microsoft Reply Comments at 22-24.

[519] For example, the F(50, 50) curve are undefined at distances less than 1.5 km. *See* 47 C.F.R. § 73.699, Figures 9, 9a, 10, 10a, 10b and 10c.

this model, which predicts propagation loss in excess of free space loss, is appropriate in this case as free space loss will under estimate actual signal loss. In addition, signals from white space devices will generally suffer from additional loss due to ground clutter, multipath effects and building penetration losses. To balance the use of this model and its loss predictions against the WMTS proponents' claim that health care facilities often have distributed antenna systems (DAS) installed near windows where there may be little building penetration loss, we have set the building penetration loss parameter of the model to 0.[520] To be sure, there will still be some building loss even for a DAS installed near clear windows. Nonetheless, we use zero here to ensure that our results are conservative and will protect WMTS systems from harmful interference. We believe that this is likely to be unrealistic in many cases, but given that this is the first time we are authorizing co-channel operation of unlicensed portable devices on channel 37, we elect this conservative approach. To the extent that this results in unreasonably large separation distances in individual cases, parties can seek a waiver, as discussed below. Finally, with respect to the TM-91-1 model, we note that it was developed based on suburban area data and that usage in urban areas with more densely packed buildings is likely to experience losses beyond those predicted here. And while the model in general may under predict losses for rural areas, our implementation, such as setting the building penetration loss parameter to 0 should offset the effects of some longer line-of-sight distances between white space devices and WMTS systems. Moreover, as indicated below, we take several steps to ensure that proper mechanisms are in place to minimize the potential for interference and for dealing with any interference that may occur.[521]

206. We also reject the argument that the TM-91-1 model is inappropriate to use because it is not valid at the antenna heights and distances under consideration here and returns results based on a median signal level. As an initial matter, we note that although the TM-91-1 model was developed to study a particular range of distances and antenna heights, it is based on the Egli model which has an applied range of up to 40 miles from the transmitter, transmit antenna height of 5000 feet and receive antenna height of 1000 feet.[522] A comparison of the TM-91-1 model, equation 5, and Egli's model, equation 2 shows that they are identical when compared in the same units. Thus, while TM-91-1 was specifically developed for limited range by the virtue of the fact that it is identical to Egli's model, it has a broader range of application than stated in the report. In addition, we believe the TM-91-1 model may actually overstate the interference potential somewhat because it does not account for terrain features, buildings, and land cover that have an effect on the strength of received signals, nor does it consider multipath effects. In particular, a comparison between predicted free space path loss and actual measured path loss for several test sites at two hospitals submitted by the WMTS coalition shows that in many cases the actual path loss is substantially more than the prediction and compares favorably with the predictions of the TM-91-1 model.[523]

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[520] WMTS systems employ distributed antenna system (DAS) infrastructure. The DAS combines received signals from many antennas distributed throughout the hospital. *See* GE Comments at 24.

[521] *See* para. 220-221, *infra*.

[522] Egli, J.J.: "Radio Propagation Above 40 Mc Over Irregular Terrain"; Proceedings of the I.R.E., Vol. 45, October 1957.

[523] *See* WMTS Coalition *ex parte* filing dated July 20, 2015. The *ex parte* comments include test reports for measurements at two hospitals in the Milwaukee area - Froedtert Community Memorial Hospital (Froedtert) and Wheaton Franciscan Healthcare – Franklin Hospital (Wheaton). For Froedtert, the measurements show actual path loss exceeds predicted free space path loss by 0.23 dB to 44.06 dB with the average and median difference being 17 dB and 15 dB, respectively. At Wheaton, the measured path loss exceeds predicted free space by a range of 12.85 dB to 30.47 dB with the average and median difference being 25 dB and 21 dB, respectively. In most cases, the predicted path loss from the TM-91-1 model compared favorably with the measured path loss. At Wheaton, assuming a 3 meter white space device antenna height and a 13 meter WMTS antenna height, the TM-91-1 model predicts less path loss that what was measured for all test sites. For example, the predicted free space path loss at test site #2, located 642 meters from the hospital, is 84.3 dB while the TM-91-1 model predicts propagation loss of 102 dB, and the measured data shows an actual path loss of 115 dB. The results for Freodtert are more mixed with

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207. Further, as already stated, we are taking additional measures to ensure conservative protection distances for WMTS receivers. We are using the lower receiver sensitivity value provided as well as the wider bandwidth. In addition, we have set the building loss parameter in the model to 0 and use several other conservative inputs to the model. We also note that there are many instances where median signal strength has been used to model interference between services, including safety of life services.[524]

208. Finally, with respect to the testing cited by GE Healthcare, we believe it over estimates the potential for interference to WMTS devices. We agree with Microsoft that the testing is not a representative case and instead represents the worst possible scenario because all WMTS receive antennas were placed near windows pointing at the simulated white space transmitter using a focused beam aimed directly at the hospital. This position is borne out by the results of the WMTS coalition testing where the interference distances where in almost all cases less than the distances calculated and adopted here.[525] To set protection limits based on the worst possible scenario presented by GE Healthcare, which we do not believe to be likely in actual deployments, could vastly over protect a large number of facilities to the detriment of efficient spectrum usage. Moreover, we note that in its testing, GE Healthcare states that the victim receivers were set at sensitivity levels of -85 dBm.[526] This is 15 dB higher than the -100 dBm level we are using in our model. Even accounting for the 10 dB between -85 dBm and the -95 dBm GE Healthcare recommends, we are still providing an additional 5 dB of protection as well as an additional 1 dB with the change from 10 kilohertz bandwidth to 12.5 kilohertz. Thus, we have added some margin to ensure that WMTS systems are protected from harmful interference by using assumptions that are even more conservative than those sought by GE Healthcare.

209. We calculated the minimum co-channel separation distances that would be required for white space devices to protect WMTS devices based on the assumptions already stated. That is, basing protection on receiver sensitivity of -100 dBm and a 12.5 kHz bandwidth. In addition, we set the frequency value to 611 MHz[527] - the center of the WMTS channel – which provides some margin over modelling the interference at the upper edge of the channel (614 MHz). We also assume an antenna aggregation gain of 3 dB to account for the possibility of multiple antennas receiving a WMTS signal.[528] To provide additional protection, we will not assume any additional building penetration loss for WMTS signals, using 0 dB. This is in addition to setting the building penetration loss variable in the model to 0. We will, however, assume an aggregate 2 dB of loss due to antenna mismatch, polarization effects, line loss, etc.[529] We believe this value to be reasonable for modelling WMTS protection and less than losses

(Continued from previous page)
the TM-91-1 model predicting less propagation loss for four test sites and more for five sites with the difference ranging from 1.7 dB to 20.2 dB.

[524] For example, the Commerce Spectrum Management Advisory Committee (CSMAC), which is comprised of spectrum policy experts from the government and the wireless industry, in studies by several Working Groups, used median propagation statistics when evaluating the interference environment between commercial wireless operations and federal operations. CSMAC approved reports by a number of Working Groups, one of which was Working Group 5 for aeronautical mobile operations, with SubWorking Group 5 which studied ACTS. *See* CSMAC WG5, ACTS SWG ACTS Final Report at 14 (Commerce Spectrum Management Advisory Committee Working Group 5, 1755-1850 MHz Airborne Operations, Air Combat Training System, Sub-Working Group Report).

[525] *See* n. 539, *infra.*

[526] *See* GE Healthcare Comments at 26.

[527] This is the same value used by GE Healthcare in its analyses of WMTS interference predictions in its comments to the incentive auction proceeding. *See* GE Healthcare Comments to GN Docket No. 12-268 at 51.

[528] GE Healthcare has stated that 3 dB is the appropriate value to use for antenna aggregation. *See* GE Healthcare Petition for Reconsideration in GN Docket No. 12-268 at 14.

[529] *See*, *e.g.*, The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests, DA 08-2245 (rel. Oct. 10, 2008).

likely to be experienced in actual system deployments. Finally, to protect, WMTS, we assume an I/N value of -6, providing for a 1 dB rise in the noise floor. We note that in the incentive auction proceeding, GE Healthcare, in its comments, provided analysis using the same I/N of -6 we use here.[530] Thus, we reject the WMTS Coalition's assertion to use an I/N of -8.4[531] as extremely conservative and with no basis for deviating from an already conservative -6 value.[532] Similarly, we reject Broadcom's recommendation to use an I/N of 0.[533] Although, this value is more conservative than its original recommendation to set I/N to 3,[534] it provides no justification for using 0. We used the TM-91-1 propagation model and white space device power levels that range from 40 milliwatts to 4,000 milliwatts in four dB steps.

210. For our analysis, we used the same range of HAAT currently specified in the rules for fixed white space devices and assumed that the WMTS receiver would be at a 10 meter height above ground.[535] The WMTS Coalition takes exception to use of this 10 meter antenna height, asserting that they have identified over 1600 hospitals with WMTS systems at greater heights.[536] It goes on to state that some WMTS systems are deployed on the 20th floor (70 meters above ground level) of a facility. GE Healthcare, also taking exception to our use of a 10 meter antenna height provides a histogram of WMTS system heights by floor counts, which it states shows that the majority of WMTS systems are located at heights AGL that exceed 10 meters.[537] We disagree with GE Healthcare's characterization of the data. First, the data only shows the total number of facilities of various heights with registered channel 37 WMTS systems. It does not show the distribution of WMTS devices among each floor. It is unreasonable to assume that every WMTS device at every facility is located on the top floor. We would expect devices to be located among several floors, many of which may be much lower than the uppermost floor of a facility. In addition, and also with respect to the WMTS Coalition that some WMTS deployments are deployed as high as the 20th floor, it is not unreasonable to assume that the taller facilities are more likely to be located in urban areas where losses due to shadowing and multipath will be greater and thus protected from harmful interference. Second, GE Healthcare's data reveals that of the 2381 WMTS facilities registered in the ASHE database 1176 or 49.4% are installed in facilities of three floors (approximately 10 meters) or less. These facts, when taken together, lead us to conclude that a large

[530] *See* GE Healthcare Comments to GN Docket No. 12-268 at 40.

[531] *See* WMTS Coalition *ex parte* filing dated June 12, 2015 at 5. The WMTS Coalition believes that the allowed power at the WMTS antenna should be assumed to be -81.6 dBm/6 MHz. Adjusting for a 12.5 kHz bandwidth, this equates to a protection level of -108.4 dBm/12.5 kHz.

[532] *See, e.g.,* Service Rules for Advanced Wireless Services H Block - Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands, WT Dkt. No. 12-357, *Report and Order*, 28 FCC Rcd 9493, 9538 (2013) at para. 114 (stating that the 3GPP2 standards allow for a 3 dB desensitization level). *See also*, *3GPP TS 36.101* at section 7.7.1.1 which provides for up to 6 dB of desensitization.

[533] *See* Broadcom Comments at 24.

[534] *See* Broadcom *ex parte* filing dated Jan. 17, 2014 in GN Dkt. 12-268 at 5-6.

[535] We note that GE Healthcare objects to the use of HAAT asserting that its use could lead to absurd results. *See* GE Healthcare Comments at 22-24. However, GE Healthcare does not offer any suggestions for alternative means of analysis. It states that because HAAT calculations do not begin for three meters from the transmitter, HAAT has no meaning over the distances being contemplated for protection of healthcare facilities. Further, GE Healthcare notes that the Commission's on-line Antenna Height above Average Terrain (HAAT) Calculator page (https://www.fcc.gov/encyclopedia/antenna-height-above-average-terrain-haat-calculator) states that Terrain variations within 3 km (2 miles) of the transmitter site usually do not have a great impact on station coverage. Thus, we point out that in these cases the HAAT and antenna height above ground level are the same and does not alter the analysis.

[536] *See* WMTS Coalition Comments at 14.

[537] *See* GE Healthcare Comments at 21-22.

number of WMTS devices using channel 37 WMTS are installed at or below the 10 meter value we used. To assume a greater height in our analysis would be unreasonable because it would produce greater separation distances than are needed to protect WMTS devices in many cases. Moreover, multipath and other reflections off the walls of a taller facility would result in more of the signal being reflected, which were not accounted for in our analysis. In light of this analysis and the test results submitted by the WMTS Coalition, we believe the separation distances we are adopting are reasonable and will protect WMTS systems from harmful interference. However, in instances where additional interference protection may be needed, we point out that we are putting procedures into place to ensure that such protection can be provided in an expeditious fashion. In addition, we note that the procedure outlined below whereby facilities must define their building perimeters can be adjusted to individualize the protection distances for each facility if needed.

211. The results of our analysis, which we are adopting and are shown in the table below provide for slightly longer separation distances than those proposed in the *Notice*. We believe these values represent a conservative evaluation of providing protection to WMTS and along with the procedures we adopt below provide opportunity for white space devices to deploy using channel 37.[538] We also observe that comparing the separation distances we are adopting to the WMTS test results for the Wheaton and Froedtert hospitals show that in all but one case tested, WMTS receivers would be protected from interference from white space devices.[539] The distances provided in the table will apply to fixed devices and Mode II personal/portable devices that are communicating with other fixed and/or Mode II devices. However, to account for some location uncertainty for Mode I devices, we will, consistent with our decision above for the duplex gap and guard bands require that these distances be doubled when the controlling device is a Mode II personal portable device and increased by 380 meters and 480 meters for fixed white space devices serving 40 milliwatts and 100 milliwatts personal/portable Mode I white spaced devices, respectively.[540]

Mode II Personal/Portable White Space Devices

Antenna height above average terrain of unlicensed device	**Required co-channel separation distances in kilometers from WMTS sites**					
	16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
Communicating with Mode II or Fixed device	0.38	0.48	N/A	N/A	N/A	N/A
Communicating with Mode I device	0.76	0.96	N/A	N/A	N/A	N/A

[538] We note that the WMTS Coalition based on their assumptions calculated separation distances ranging from 2.65 km (at 40 mW) to 23.7 km (at 4W). *See* WMTS Coalition *ex parte* filing dated June 12, 2015 at 6. In contrast Google submitted an analysis based on their assumptions stating that the required separation distances range from 187 meters to 1.9 km. *See* Google *ex parte* filing dated May 22, 2015 at 11.

[539] *See* WMTS Coalition *ex parte* filing dated July 20, 2015. For the two hospitals where measurements were taken, the results for a 16 dBm (40 mW) white space device show no interference to WMTS at distances ranging from 303 meters to 341 meters, well within the 380 meter distance calculated in our table. Similarly, the measured separation distances beyond which interference to WMTS would not occur is less than what we are adopting for the higher power levels too with one exception at Froedtert test site #13. That test report shows that the separation distance for a 36 dBm (4 watts) white space device must be at least 2006 meters from the hospital.

[540] *See* para. 71-74, *supra.*

Fixed White Space Devices

Antenna height above average terrain of unlicensed device	Required co-channel separation distances in kilometers from WMTS sites					
	16 dBm (40 mW)	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 watts)
Less than 3 meters	0.38	0.48	0.60	0.76	0.96	1.20
3-Less than 10 meters	0.70	0.88	1.10	1.38	1.74	2.20
10-Less than 30 meters	1.20	1.55	1.95	2.45	3.05	3.80
30-Less than 50 meters	1.55	2.00	2.50	3.15	3.95	4.95
50-Less than 75 meters	1.90	2.45	3.05	3.85	4.85	6.10
75-Less than 100 meters	2.20	2.80	3.55	4.45	5.60	7.05
100-Less than 150 meters	2.70	3.45	4.35	5.45	6.85	8.65
150-Less than 200 meters	3.15	3.95	5.00	6.30	7.90	9.95
200-250 meters	3.50	4.40	5.60	7.00	8.80	11.00

212. The Commission also proposed separation distances to protect WMTS systems from adjacent channel white space operations on channels 36 or 38 due to out-of-band interference or blocking (or overload) interference. The WMTS Coalition states that if unlicensed devices are authorized to operate in bands adjacent to channel 37, the protection distances and power limits utilized in channel 37 should apply equally to adjacent channels.[541] The Wi-Fi Alliance commented that it supports the Commission's proposal to base adjacent channel protection on the proposed variable power limits for white space devices.[542] We disagree with the WMTS Coalition as its approach to treat adjacent channel operations the same as co-channel operations would severely overprotect WMTS systems. Such an approach does not account for the roll-off of the white space transmit signal into the adjacent channel nor does it account for the WMTS receive filter which attenuates signals in the adjacent channel. Thus, we are basing the adjacent channel protection distances on analysis similar to that which we conducted to determine co-channel separation distance.

213. Our assumptions here are consistent with the co-channel analysis (10 meter WMTS antenna height, 3 dB antenna aggregation, 3 dB antenna mismatch, 0 dB building attenuation). Also, for the out-of-band interference analysis, we used the same -100 dBm/12.5 kHz receiver sensitivity and I/N protection criteria of -6. For the blocking interference analysis, because the white space device would be operating immediately adjacent to channel 37 we assumed 0 dB loss due to the receive filter and we used a blocking threshold of -37.8 dBm/MHz.[543] In the *Notice*, we calculated very small adjacent channel protection distances making free space loss appropriate model to use to calculate propagation loss. As in the *Notice*, our analysis showed that the protection distances to protect from blocking interference were larger than to protect from out-of-band interference. Thus, consistent with our proposal, we are basing the adjacent channel protection distances on the distances shown below, calculated to protect WMTS from blocking interference.

[541] *See* WMTS Coalition Comments at 25.

[542] *See* Wi-Fi Alliance Comments at 30.

[543] *See* GE Healthcare Comments to GN Dkt. 12-268 at 42.

Required adjacent channel separation distances in meters from WMTS sites					
16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
8	13	20	32	50	71

214. We adopt these adjacent channel protection distances for any antenna height for the given power level. We note that the free space model does not account for differences in antenna height between the transmitter and receiver as the TM-91-1 model does. However, because the distances are so short, we can assume that it is likely that the transmitter and receiver are both at approximately the same HAAT. Thus, under our assumed condition of the WMTS receiver being 10 meters above ground, if a white space device was operating at the maximum of 30 meters above ground allowed by our rules,[544] they would be at most 20 meters apart. We recognize that under these conditions, that separation distance is larger than necessary to provide protection (*e.g.*, the calculated protection value for a 40 milliwatt transmitter is only 8 meters). However, to reduce compliance burdens and to ensure that WMTS receivers are protected in all cases, such as when the antennas are closer in height above ground level, we adopt the calculated values for all instances at the various power levels.

215. Finally, as with co-channel separation distance, we are providing additional distance to be added to fixed and Mode II white space devices separation distances when they are controlling Mode I devices. When a Mode II or fixed white space device is providing channel lists for Mode I white space devices, they must comply with separation distances to 16 meters and 26 meters when serving 40 milliwatt and 100 milliwatt devices, respectively.

Mode II Personal/Portable White Space Devices

Antenna height above average terrain of unlicensed device	**Required adjacent channel separation distances in meters from WMTS sites**					
	16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
Communicating with Mode II or Fixed device	8	13	N/A	N/A	N/A	N/A
Communicating with Mode I device	16	26	N/A	N/A	N/A	N/A

216. The *Notice* sought comment on how best to apply the calculated separation distances.[545] We noted that WMTS systems often rely on use of distributed antenna systems that are often located near the perimeter of a facility. Google comments that separation distances should be measured from perimeters that account for actual line-of-sight information in the vicinity of a WMTS site.[546] Our goal is to provide protection from harmful interference to WMTS devices while providing flexibility for white space system operators to deploy devices. Thus, because the databases are already designed to provide for polygonal exclusion zones and a building perimeter is a polygon that can be defined as a series of

[544] *See* 15.712(a)(3).

[545] *See Notice,* 29 FCC Rcd at 12283, paras. 113-114.

[546] *See* Google Comments at 22.

latitude and longitude coordinates, these distances will apply from the perimeter of each health care facility containing channel 37 WMTS systems (or if several facilities containing channel 37 WMTS systems are clustered closely together, we will allow a them to be defined as a single entity).[547] We believe that obtaining the coordinates defining the perimeter of a facility will be a simple, straightforward process. In reaching this decision, we note Microsoft's support for an approach allowing users to register multiple points in the database to define a large facility.[548] We believe this procedure will provide an efficient mechanism for protecting health care facilities.

217. Several commenters suggested that a more nuanced approach may best balance the competing interests of health care facilities and white space proponents. GE Healthcare stated that terrain, surroundings or other factors could be used to determine a smaller distance than a strict separation distance.[549] GE Healthcare further states that it would support an interference mitigation approach that considers site-specific propagation conditions (including terrain and building features), provided it is based on whitespace device locations and WMTS deployments in three dimensions and uses realistic site-specific interference calculations.[550] Similarly, Google comments that separation distances should account for actual line-of-sight information in the vicinity of the WMTS site.[551] While we generally agree with these comments, we are concerned that lack of experience in using such methods to deploy white space devices on channel 37 while protecting WMTS systems could potentially result in interference. In that connection, we emphasize that the separation distance and protection procedures set out here is a default approach. We note that there is ongoing dialogue among the stakeholders and should those parties reach a consensus that differs from our approach, we invite those parties to submit an alternative approach for streamlined consideration by the Commission.[552] We will monitor the use of channel 37 and working with the stakeholders may adjust the distances as experience is gained. We also note that in particular instances, if parties believe a distance other than that provided in the rules either over or under protects WMTS systems, they may file waiver requests with the Commission to modify the distance for a particular facility or group of similarly situated facilities.[553] To ensure that WMTS systems are protected from the potential for harmful interference, the Commission will immediately require the database administrators to expand the separation distance for reasonable requests for a particular facility, until it has completed its analysis and can render a final decision on the waiver.[554] We commit to expeditiously resolving any such waiver request.

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[547] A requirement for healthcare facilities to register for protection in the white space databases is described in para. 246-247.

[548] *See* Microsoft Comments at 25.

[549] *See* GE Healthcare Comments at 27-28.

[550] *See* GE Healthcare Reply Comments at 15.

[551] *See* Google Comments at 22.

[552] While the WMTS Coalition recently request a delay in the Commission's consideration of Channel 37 technical rules, we note that no other stakeholder involved in the ongoing discussions support the request. *See* WMTS Coalition *ex parte* filing dated July 21, 2015. The technical rules adopted in this item will provide a useful framework for the parties to continue their discussions.

[553] Any provision of the rules may be waived by the Commission on its own motion or on petition if good cause therefor is shown. *See* 47 C.F.R. § 1.3. The Commission will waive its rules if it determines, after careful consideration of all pertinent factors, that such a grant would serve the public interest without undermining the policy which the rule in question is intended to serve. *See WAIT Radio v. FCC*, 418 F.2d 1153, 1159 (D.C. Cir. 1969) and *Northeast Cellular Telephone Co. v FCC,* 897 F.2d 1164 (D.C. Cir. 1990).

[554] For the WMTS community, we expect that any such filing will describe the good-faith steps taken to engage the unlicensed community and reach a consensus as to an appropriate and tailored approach to sharing. A request for an expanded protection zone of three times or less the separation distances provided by the rules will be considered presumptively reasonable. A request for an expanded separation distance will be dismissed in the absence of a

(continued….)

218. To implement the necessary protection, several parties are involved – the health care facility, the white space device operator, and the white space database administrator. Thus, we have strived to provide a procedure that is simple, straightforward, and easy to implement for all parties. First, the health care facility will register a representation of the perimeter the building to a white space database administrator.[555] That information will be entered into the database and shared with the other white space database administrators. White space system operators will then avoid operating within the protection zones of health care facilities through instructions from the database; *i.e.*, within the protection distance of a health care facility, the database will not show channel 37 as being available for use.

219. GE Healthcare comments that we should prohibit unlicensed device use on channel 37 in rural areas as those areas have greater chance of line-of-sight transmission to a WMTS receive antenna.[556] While we will not generally prohibit such operation, we recommend that unlicensed devices should only operate in channel 37 in areas where there are fewer than three channels available for unlicensed use between the UHF channels and the 600 MHz guard bands, including the duplex gap.[557] We have noted throughout this proceeding that we expect rural areas, where there are already plenty of channels available for white space devices, will continue to have channels available after the incentive auction. Thus, prioritizing the available channels in this manner will balance the interference protection needs of WMTS facilities against the needs of white space system operators to have sufficient spectrum on which to operate.

220. We note that the distances we are setting to protect WMTS systems will generally protect against harmful interference, but recognize that adjustments may be necessary based on the unique characteristics of the health care facility and path loss relative to the potential locations of the white space deployment. We take this opportunity to underscore for white space device operators that in all cases, they always have the obligation to protect WMTS systems from harmful interference and eliminate such interference if it should occur. As an added measure of protection, as discussed below, we will work with the interested parties to explore procedures whereby if interference to WMTS occurs, white space devices would be excluded from operating near that health care facility until such time as the interference has been fully resolved.[558]

221. Finally, we are providing an additional measure to ensure that the separation distances and procedures we adopt here will provide the intended protection to WMTS systems. We intend to limit initial deployment of white space devices using channel 37 to one or two areas. This is similar to the Commission's initial limited roll-out of white space devices in Wilmington, North Carolina in 2011.[559] By limiting initial roll-out to just a few areas, the Commission jointly with the FDA can work with white space device operators and health care facilities to validate and, if needed, adjust our approach so that critical WMTS systems do not experience harmful interference. Once the rules we are adopting here become effective and the deadline for health care facility registration has passed,[560] we encourage parties

(Continued from previous page)
substantiated showing and/or if the request does not otherwise meet the Commission's standards for a waiver of the rules.

[555] *See* para. 246-247.

[556] *See* GE Healthcare Reply Comments at 16.

[557] White space proponents have generally asserted that they need access to at least three usable channels. *See* Google *ex parte* filing dated July 9, 2015 at 1.

[558] *See* para. 249, *infra*.

[559] *See* Office of Engineering and Technology Announces the Approval of Spectrum Bridge, Inc.'s TV Bands Database System for Operation, *Public Notice*, DA 11-2043 (Dec. 22, 2011).

[560] *See* para. 247-248, *infra.* We will also entertain requests for testing in specific areas if white space device operators and healthcare facilities wish to conduct such a beta trial prior to the end of the registration period.

interested in deploying white space devices on channel 37 to contact OET to discuss the intended deployment and a test plan. At the successful conclusion of testing of these initial deployments, the Commission will issue a public notice to inform interested parties that they may deploy white space devices nationwide on channel 37.

c. Determination of RAS separation distances

222. *Background.* The *Notice* proposed different protection criteria for the ten very long baseline array (VLBA) stations[561] than for the two single dish radio astronomy observatories because of their differing potential to receive interference.[562] It noted that VLBA observations are less susceptible to interference than single dish observations because interfering signals do not correlate across the multiple receivers that comprise the array.[563] We proposed that white space devices operating on channel 37 comply with separation requirements based on their operating power to protect the ten VLBA observatories, and that they may not operate within defined exclusion zones around the two single dish observatories that receive on channel 37.

223. Our proposal for protection of the VLBA was based on existing requirements that protect those stations from WMTS stations operating on channel 37.[564] Using those requirements as a basis, we determined the minimum distance that a white space device must be from a VLBA site to provide the same level of protection as a WMTS transmitter. We proposed to calculate the separation distances between fixed white space devices and VLBA sites using a propagation model with a path loss exponent of 2.53 and noted that this model considers only the power of the white space device and not its antenna height above ground or average terrain. Based on this calculation, we proposed a various size exclusion zones ranging from 51 kilometers for a 40 milliwatt white space device to 314 kilometers for a 4 watt white space device.[565] We sought comment on whether those separation distances are greater than necessary to protect the VLBA as well as the methodology and assumptions used to calculate them, including whether a different propagation model should be used or different protection criteria.[566]

224. Most commenters stated that our proposals were too conservative because it provided a single separation value for all VLBA sites rather than taking into account terrain and antenna height. The National Radio Astronomy Observatory (NRAO) comments that it is likely that coordination distances could be fashioned to fit individual circumstances noting that in some cases larger separation distances might be needed. NRAO adds that protection cannot be decided on the basis of a single entry case and that aggregation must be considered.[567] The Committee on Radio Frequencies (CORF) recommends

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[561] Ten radio observatories comprise the National Radio Astronomy Observatory's (NRAO's) VLBA, which are distributed in several locations in the United States and its territories, and collect simultaneous observations that are combined to emulate a single telescope 5000 miles in diameter. These stations operate together as a large interferometer. Detailed information on the VLBA is available at: http://www.vlba.nrao.edu/astro/obstatus/current/node5.html. The VLBA telescopes are located in Mauna Kea, Hawaii, Owens Valley, California, Brewster, Washington, Kitt Peak, Arizona, Pie Town, New Mexico, Fort Davis, Texas, Los Alamos, New Mexico, North Liberty, Iowa, Hancock, New Hampshire, St. Croix, Virgin Islands. *See Notice,* 29 FCC Rcd at 12278, para. 98.

[562] *See Notice,* 29 FCC Rcd at 12283, para. 116.

[563] *See Incentive Auction R&O,* 29 FCC Rcd at 6694, para. 293, footnote 885.

[564] Section 95.1115(a) of the rules allows a maximum WMTS field strength on channel 37 of 200 millivolts per meter measured at a distance of three meters (this equates to an EIRP of approximately 12 mW). *See* 47 C.F.R. § 95.1115(a). Further, Section 95.1119(b) specifies that WMTS operations within 32 kilometers of the ten VLBA sites must coordinate with those sites. *See* 47 C.F.R. § 95.1119(b).

[565] *See Notice*, 29 FCC Rcd at 12284, para. 118

[566] *See Notice*, 29 FCC Rcd at 12284, para.120.

[567] *See* NRAO Comments at 2.

separation distances based on ITU Recommendation RA-769-2.[568] CORF provides a table of protection zones tailored to each VLBA site using the protection criteria of RA-769-2 and the Longley-Rice propagation model that are, in most cases larger than those proposed by the Commission.[569] Commenters generally agree with CORF that site specific modelling for each VLBA site is a good approach, but disagree with the methodology and size of the protection zones. For example, Google agrees with CORF that the Commission should use the Longley-Rice propagation model, but disagrees with CORF's recommendation to establish a single, fixed distance for each VLBA site, and instead argues for a combination of bearing-dependent separation distances and time coordination to make channel 37 available in many large population centers around the country, where its use would be precluded by constant-radius separation distances.[570] Similarly, the Dynamic Spectrum Alliance recommends that protection for radio astronomy be based on ITU Recommendation RA-769 and the Longley-Rice propagation model.[571] Motorola further argues that separation distance protection should be limited to a maximum of roughly the radio horizon.[572]

225. *Discussion.* We agree with commenters that a site specific terrain based protection criteria would be better than a single fixed distance for each site. These sites are often in rural areas and constructed to take advantage of terrain features to provide a very low noise environment for radio observations. We note that in response to our questions in the *Notice* seeking comment on different methodologies, commenters agree on a basic methodology for crafting protection zones – using a site specific, terrain dependent Longley-Rice analysis based on the protection criteria of ITU-R Recommendation 769-2. CORF provided such an analysis, but did not indicate the underlying assumptions and inputs to the model. Google, however, provided details of their analysis which also used the Longley-Rice propagation model and the protection criteria of ITU-R Recommendation RA.769-2 (*i.e.*, a radio astronomy operation must not experience received power above the specified level more than 2% of the time),[573] which equates to F(50,2) propagation.[574] Google then assumed a four watt EIRP white space device at 30 meters AGL operating 100% of the time. It argues that this analysis is conservative because white space devices must have power control and will generally operate at much lower power levels, some will be indoors, and the analysis does not account for clutter. Google shows that under these conditions, the calculated exclusion zones are much smaller than those proposed by the Commission.[575]

226. Based on those comments in the record, we are modifying our analysis consistent with the suggestions from CORF and Google. As they suggest, we will use a combination of the ITU Recommendation RA-769-2 and the Longley-Rice propagation model to determine the necessary protection distances for each VLBA site. To conduct our analysis, we used the Longley-Rice version 1.2.2 propagation model. To protect each VLBA receive site, we used the protection criteria of ITU-R

[568] *See* ITU-R RA.769-2 titled "Protection criteria used for radio astronomical measurements" available at: https://www.itu.int/dms_pubrec/itu-r/rec/ra/R-REC-RA.769-2-200305-I!!PDF-E.pdf.

[569] *See* CORF Comments at 6-8. CORF calculates shorter separation distances than those proposed by the Commission for the sites at Brewster, WA and Fort Davis, TX. It recommends larger distances at all other sites.

[570] *See* Google Reply Comments at 19-20.

[571] *See* DSA Comments at 10. Microsoft also agrees with such an approach. *See* Microsoft Reply Comments at 25-26.

[572] *See* Motorola Comments at 10.

[573] The timing criteria can be found in ITU-R Recommendation RA.1513-2, titled "Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy on a primary basis" available at : https://www.itu.int/dms_pubrec/itu-r/rec/ra/R-REC-RA.1513-2-201503-I!!PDF-E.pdf. This Recommendation is referenced in ITU-R RA.769-2.

[574] The signal level at 50% of the locations is not exceeded more than 2% of the time.

[575] *See* Google Comments at Appendix C.

RA-769-2 as recommended by CORF and Google (*i.e.*, -212 dB (W/m^2 Hz) which assuming an isotropic receive antenna equates to -131 dB (W/m^2 6 MHz) or a receiver interference threshold of 1.54 dBuV/m) along with F(50,2) propagation. For each VLBA receive site, we used the coordinates specified in section 15.713(h).[576] Neither CORF nor Google provided information regarding the radio astronomy receive antenna height. We used 27 meters above ground as the value for this model input.[577] To run the analysis, we placed white space transmitters with 40 milliwatts EIRP,[578] 3 meters above ground level , 611 MHz transmitter frequency, and an omni-directional transmit antenna pattern[579] every 2 kilometers along 72 radials spaced every 5^o extending from the Radio Astronomy (RA) receiver site out for 300 kilometers. We believe the difference between using 5^o radial spacing rather than the 1^o spacing recommended by Google[580] results in minimal loss of fidelity in determining exclusion zones and is a reasonable tradeoff compared to the number of points needing evaluation at the smaller spacing.[581] Using F(50,2)[582] propagation along the path from each white space transmitter to the radio astronomy site, we could determine, based on the terrain profile of each path,[583] which transmit sites produced a field strength above the protection criteria at the radio astronomy receiver. Those transmit sites are used to determine the site specific protection zone for each VLBA site. We believe that our use of the F(50,2) propagation statistics for this analysis provides a conservative determination of protection zones to ensure that VLBA sites do not receive interference from white space devices.

227. For each site, we provide a best fit polygon connecting the farthest points from each site beyond which the protection criteria is always satisfied. We are using this best fit polygon rather than

[576] *See* 47 C.F.R. § 15.713(h).

[577] Each VLBA dish is 25 meter (82 feet) in diameter, and when pointing straight up, the antenna is as high as a ten story building. *See* http://www.vlba.nrao.edu/php/sigpath/StaticHTML/intro_vlbaant.php. Thus, when pointed straight up, the receiving element of the dish can be as high at 130-140 feet (39.6-42.7 meters) above ground. We assumed the greatest potential for inference is when the dish is pointed towards the horizon which would lower the receiving element. We believe that in such a configuration the receiving element would be approximately 90 feet (27.4 meters) above ground level.

[578] As noted above, the outcome of the auction will determine the range of power levels available to white space devices operating on channel 37. If the auction repurposes 84 megahertz or more, then white space devices will be limited to no more than 40 milliwatts EIRP to protect new 600 MHz band handset receivers. If less than 84 megahertz is repurposed, then white space devices may operate with up to 4 watts EIRP, but only if channels 36 and 38 in the same area are unused for television. Otherwise, white space devices would be limited to a maximum of 100 milliwatts EIRP. *See* para. 33, *supra.* Because, white space devices will, in all cases, be able to operate with up to 40 milliwatts EIRP, but it will not be known until the conclusion of the auction whether they will be able to operate above that level, we only provide the protection distance for a 40 milliwatt white space transmitter here. If the result of the auction will allow for white space operation at higher power levels, we will perform this same analysis for the full range of power/antenna height combinations and solicit comments on those exclusion zones.

[579] The rules in 47 C.F.R. § 15.709(a)(9)(ii) limit the power spectral density of a 40 milliwatt personal/portable white space device to -1.4 dBm/100 kHz EIRP. An omnidirectional antenna is required to achieve this power level while using the full 6 megahertz channel.

[580] *See* Google Comments at Appendix C, page 6.

[581] Each radial contains 150 points to evaluate. Using 5^o spacing (72 radials) results in 10,700 propagation paths to be evaluated as compared to 54,000 for 1^o spacing (360 radials). In addition, we note that with 1^ospacing the points are only 0.17 kilometers apart when travelling 10 kilometers from the VLBA site and only 1.7 kilometers apart when travelling 100 kilometers from the VLBA site. Both these distances are within the initial 2 kilometer spacing we used and, in many cases would fall within the same grid cell, yielding identical results.

[582] F(50,10) is a statistical representation of the estimated field strength exceeded at 50 percent of the receiver locations 10 percent of the time.

[583] The analysis used on the 1 arc-second National Elevation Dataset available from the United States Geological Survey. *See* http://ned.usgs.gov/ for more information.

connecting a point along each radial to reduce the burdens in implementation. We do not believe that there would be much difference in available spectrum for white space devices if we were to create the polygons based on connecting a point on each radial (for a total of 72 points per polygon). A visual representation of the results for each site is provided in Appendix D. These plots show that each site receives protection due to terrain shielding and that this causes the protection distances to vary with direction. Therefore, to avoid overprotecting VLBA sites by prohibiting white space devices within a large circle centered on each site, we are instead requiring that white space devices be prohibited from transmitting within a polygon that encompasses only those areas that are predicted to have the potential to cause harmful interference. The polygon approach is not burdensome to implement, and white space databases already possess the capability to provide polygonal exclusion zones. The minimum and maximum protection distances for each site shown in the table below. In addition, Appendix D provides the coordinates defining each polygon.

Very Long Baseline Array (VLBA) Stations:	Minimum Protection Distance (km)	Bearing (degrees)*	Maximum Protection Distance (km)	Bearing (degrees)*
Pie Town, NM	74	130	142	255
Kitt Peak, AZ	52.4	174	284	40
Los Alamos, NM	42	110, 115	204	205
Ft. Davis, TX	8	15	26	155, 165
N Liberty, IA	64	60, 110	90	155
Brewster, WA	8	90, 105	36	350
Owens Valley, CA	26	125	88	345
St. Croix, VI	10	235	160	285
Hancock, NH	42	195, 200	140	15
Mauna Kea, Hi	2	335, 355	300	85-140

* Bearing is measured from true north relative to the VLBA station location.

228. We disagree with NRAO that we need to consider white space device signal aggregation when fashioning the separation distances. The VLBA is comprised of 25–meter dish antennas which have very high gain and very narrow beamwidth.[584] In addition, these antennas generally are aimed skyward. However, in the instance that an antenna is pointed towards the horizon, its antenna beam is still so narrow that it is unlikely that it will see more than a single white space device.

229. CORF asserts that since radio astronomy sites are generally located in rural areas, operation on channel 37 should be prohibited in those areas and in other areas where more than 10% of the TV channels are available for white space devices.[585] Google disagrees with this request stating that it

[584] The beamwidth is determined by the wavelength being observed divided by the diameter of the reflector. The equation used to determine beamwidth is: $\alpha = (206{,}265)\ \lambda / d$; where: α = smallest possible angle that can be resolved (in arcseconds), λ = wavelength observed (in meters), and d = diameter of reflector (in meters). *See* National Radio Astronomy Observatory 40-Foot Radio Telescope Operator's Manual available at http://www.gb.nrao.edu/epo/manual.pdf. For the VLBA 25-meter dish operating at 611 MHz ($\lambda = 0.49$ meters) which equates to a beamwidth of 4043 arcseconds or approximately 1.1 degrees.

[585] *See* CORF Comments at 6.

would yield little improvement in simplicity of implementation.[586] We already stated above that to add a measure of protection to rural WMTS facilities we are advising that white space systems only use channel 37 in areas where there are fewer UHF channels available for unlicensed devices than would meet that users spectrum requirements. Because most RAS sites are located in rural areas, we expect in most cases, white space device system operators will have access to sufficient spectrum so as to not need to use channel 37.

230. The *Notice* also sought comment on whether we should establish adjacent channel separation distances between white space devices operating on channels 36 and 38 and the ten VLBA observatories. Under the current rules, white space devices must operate at least 2.4 kilometers away from VLBA sites, so this requirement would apply to white space devices operating on channels 36 and 38.[587] CORF supports maintaining the 2.4 kilometer separation distance on all channels other than 37.[588] Thus, we will not alter this distance for operations on channels 36 and 38.

231. In its comments Adaptrum requests that permanent protection should be given only to RAS stations that make at least 40 hours of observations a week on channel 37.[589] Google, and the Open Technology Institute and Public Knowledge also comment that the Commission should adopt an approach to protecting RAS that takes time of operation into account.[590] We decline to adopt such a policy at this time. Because most of the RAS observatories are in remote areas, we believe that sufficient spectrum will be available in those areas within the exclusion zones we are adopting for white space devices after the incentive auction and repacking. However, after we gain more experience regarding the operations of white space devices, we may revisit this issue if it appears that the addition of expanding access to spectrum for white space devices in areas very close to the radio astronomy sites will provide sufficient benefits.

232. With respect to the two single dish RAS observatories that receive on channel 37 (Green Bank Telescope and Arecibo Observatory), the *Notice* pointed out that Section 1.924(a) requires parties planning to construct and operate a new or modified station at a permanent fixed location within a specified quiet zone around the National Radio Astronomy Observatory at Green Bank West Virginia to notify the observatory in writing of the technical details of the proposed operation.[591] Similarly, Section 1.924(d) requires parties planning to construct and operate a new station at a permanent fixed location on the islands of Puerto Rico, Desecheo, Mona, Vieques or Culebra to notify the Interference Office of the Arecibo Observatory in writing or electronically of the technical parameters of the planned operation.[592] Recognizing that it would be unreasonable for operators of white space devices to coordinate with the Green Bank and Arecibo Observatories, and because separation distances to protect these observatories would be extremely large, we proposed that white space devices not operate on channel 37 within the National Radio Quiet Zone around Green Bank or on the islands of Puerto Rico, Desecheo, Mona,

[586] *See* Google Reply Comments at 20.

[587] *See* 47 C.F.R. § 15.712(h)(3).

[588] CORF Comments at 11.

[589] *See* Adaptrum Comments at 6.

[590] *See* Google Comments at 26; Reply Comments at 19-20 and Open Technology Institute and Public Knowledge Reply Comments at 16-17.

[591] *See* 47 C.F.R. § 1.924(a). The area within which notifications must be provided is bounded by N 39°15′0.4″ on the north, W 78°29′59.0″ on the east, N 37°30′0.4″ on the south, and W 80°29′59.2″ on the west. The notification must include the geographic coordinates of the antenna location, the antenna height, antenna directivity (if any), the channel, the emission type and power.

[592] *See* 47 C.F.R. § 1.924(d). The notification must include the geographic coordinates of the antenna location, the antenna height, antenna directivity (if any), proposed channel and FCC rule part, type of emission, and EIRP.

Vieques or Culebra.[593] Commenters agreed with this approach and we will adopt rules prohibiting white space devices from operating within those areas.[594]

2. Guard bands adjacent to channel 37

233. *Background.* The *Notice* observed that under certain spectrum recovery scenarios, there will be a three megahertz guard band on one or both sides of channel 37, resulting in a contiguous block of nine or 12 megahertz of spectrum and sought comment on whether these guard bands could be combined with the six megahertz of channel 37 spectrum in areas where it is not being used for the RAS and WMTS to create a wider band for white space device use. Several commenters provided support for combining channel 37 with any guard bands to provide as much spectrum as necessary for white space devices. The White Space Alliance states that it fully supports to the ability to bond adjacent channels and including allowing channel 37 to be bonded with any guard bands.[595]

234. *Discussion.* We decline to provide the ability for white space devices to use the three megahertz guard bands that may be created adjacent to channel 37. We have decided in this proceeding that a three megahertz guard band is necessary to protect new 600 MHz mobile handsets from harmful interference from white space devices.[596] If spectrum is recovered in sufficient quantity to require the creation of these guard bands adjacent to channel 37, they will function to provide this protection. Thus, they will be unavailable for use by white space devices.

3. Out-of-band emission limits on channels 36-38

235. *Background.* The current white space rules require white space devices to comply with out-of-band emission limits on channels 36 through 38 in addition to the adjacent channel and Section 15.209 limits that white space devices must meet on other channels.[597] The white space device out-of-band emission limit on channel 37 is significantly more stringent (approximately 25 dB lower) than the Section 15.209 limit on this channel.[598] In the *Notice*, the Commission along with the proposal to allow white space devices to operate on channel 37 proposed to remove the out-of-band emission limits that apply on channels 36 through 38 and instead require white space devices to meet either the current adjacent channel or the Section 15.209 emission limits as appropriate.[599] We proposed that the devices access a database to ensure that they will operate sufficiently far from both WMTS and RAS sites to avoid causing harmful interference to these services. The database will enforce both co-channel and adjacent channel separation distances from the WMTS, which will ensure that emissions that fall within channel 37 do not cause harmful interference to the WMTS. Thus, the *Notice* stated that there will no longer be a need for the more stringent out-of-band emission limits on channels 36 through 38 and will eliminate the need for white space devices to incorporate additional filtering that blocks channel 37 and impacts the first and second adjacent channels, making channels 35, 36, 37, 38 and 39 useable by white space devices.

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[593] *See Notice,* 29 FCC Rcd at 12285, para. 123.

[594] *See*, *e.g.*, White Space Alliance Comments at 23.

[595] *See* White Space Alliance Comments at 23. The Wi-Fi Alliance and WISPA also express support. *See* Wi-Fi Alliance Comments at 32 and WISPA Comments at 7.

[596] As noted above, wireless microphones may operate in a portion of the channel 37 guard bands. *See* para. 149, *supra*.

[597] *See* 47 C.F.R. § 15.711(c)(4).

[598] The white space device out-of-band emission limit on channel 37 is 30 dB above a microvolt per meter measured at a one meter distance. The Section 15.209 limit on channel 37 is 200 microvolts per meter measured at a three meter distance, which is equivalent to 55.6 dB above a microvolt per meter measured at a one meter distance.

[599] *See Notice,* 29 FCC Rcd at 12286, para. 128.

236. Commenters generally support our proposal. Broadcom states that the stringent out-of-band limits on channels 36 and 38 handicap up to 30 megahertz across the country.[600] The Wi-Fi Alliance notes that the current out-of-band limits significantly increases the cost of chips because manufacturers mist incorporate an additional band-reject filter into the white space device to comply.[601] WISPA adds that the databases can enforce appropriate separation requirements from WMTS.[602] The WMTS Coalition states that the emission mask currently imposed in the adjacent channels can be eliminated so long as unlicensed devices operate with protection distances and power limits consistent with those in channel 37.[603]

237. *Discussion.* In light of the support for removing the strict emission mask into channel 37 which also hampers the ability to operate on channels 35, 36, 38, and 39, we are adopting our proposal. The rules will require all white space devices to meet the same emission mask for all channels in the TV and 600 megahertz band including channel 37. We have already determined the required separation distances for various power levels as shown above and thus reject the WMTS Coalition's position that the adjacent channels should have the same separation requirement as for co-channel operations on channel 37. This rule change which eliminates the need for additional filters to be incorporated into devices will reduce development and manufacturing costs and lead to lower prices to consumers.

E. White Space Databases

1. Expanding Location and Frequency Information

238. We are modifying our rules to specify the additional information that will be included in the white space databases so that the database administrators can provide white space devices with lists of available channels that will protect authorized users in the TV bands, the 600 MHz guard bands and duplex gap, the 600 MHz service band, and channel 37. The new 600 MHz service licensees and the healthcare facilities that operate WMTS networks on channel 37 will provide information on their operations directly to the white space database administrators that will, in turn, calculate the protection criteria for these services to identify available channels for white space use. Because these operations are entitled to interference protection under the Commission's rules, the database administrators will not be permitted to charge a fee for including this information in their databases. We also modify our rules to update information for services already included in the white space databases: Radio Astronomy Service, Canada and Mexico television stations, and Private Land Mobile Radio Service.

a. 600 MHz service band operations

239. *Background*. In the *Notice*, the Commission proposed to require that white space database administrators store information on the locations where 600 MHz service licensees commence operations.[604] Specifically, we proposed that the database administrators allow 600 MHz service licensees to enter the coordinates of at least eight points representing the corners of a polygon of the minimum size necessary to encompass all base stations within the area where a licensee is commencing operations, as well as the frequencies that a licensee will use in the specified area.[605] The white space databases will use this information along with specified protection criteria to ensure that white space devices operate at a sufficient distance outside the border of the defined polygon to prevent harmful interference to wireless services. The Commission also proposed that a 600 MHz service licensee enter the date it plans to

[600] *See* Broadcom Comments at 21.

[601] *See* Wi-Fi Alliance Comments at 33.

[602] *See* WISPA Comments at 6-7.

[603] *See* WMTS Coalition Comments at 25.

[604] *See Notice,* 29 FCC Rcd at 12302-12303, para. 178.

[605] Because the Commission is licensing the five megahertz blocks in pairs, there will always be at least one uplink and one downlink block in a service area.

commence operations when it registers a polygonal area and operating frequencies with the white space database.[606] The Commission also proposed that the white space database administrators provide to the other database administrators on a daily basis the data registered by 600 MHz service licensees, as they do for other services.[607]

240. *Discussion.* We are adopting the proposed requirements for entering and storing information on the locations where 600 MHz Band licensees have commenced operation in the white spaces database. Specifically, we are requiring that database administrators allow 600 MHz Band licensees to enter the coordinates of a minimum of eight points and a maximum of 120 points representing the corners of a polygon of the minimum size necessary to encompass all base stations or other radio facilities used to determine the area where a licensee is commencing operations consistent the Commission's decision in a separate future proceeding, as well as the frequencies that a licensee will use in that area. The white spaces databases will use this information along with the separation distances described above to ensure that white space devices operate at a sufficient distance outside the border of the defined polygon to prevent harmful interference to wireless services. The approach we are adopting will provide wireless licensees with sufficient flexibility to describe different areas of operation. For example, a licensee can enter the coordinates of multiple polygons in cases where it plans to commence service in multiple non-contiguous areas. A licensee can also specify shapes more complex than an eight-sided polygon to designate an area that includes irregular boundaries within a PEA or a PEA boundary so that the protected area in the database stops at the edge of a carrier's licensed area.

241. We will also require that a 600 MHz service licensee enter contact information (company name, contact person's name, address, phone number) and the date it plans to commence operations when it registers a polygonal area and operating frequencies with the white space database. Requiring the database to include this data will allow a licensee to define its operations area well in advance without limiting the ability of white space devices to operate until the actual date when the 600 MHz service wireless licensee commences operation. The database will disregard the registration information prior to the service commencement date when determining which channels are available for white space devices. Some licensees may not wish to make available details of their intended plans far in advance, and they could register their information closer to the actual date when they intend to commence operations.

242. As recommended by Spectrum Bridge, we will not require database administrators to provide a user interface to generate multi-sided polygons for 600 MHz license areas.[608] Instead, we will require only that database administrators make provisions to allow 600 MHz service licensees to upload the required registration information, including the polygon information which a licensee can generate using readily available software tools.[609] However, database administrators are free to develop a user interface if they choose. We will also require that white space database administrators provide a means to update or to remove and replace a previous registration when it needs to be updated or corrected. We will further require that database administrators share on a daily basis the data registered by 600 MHz licensees, as they do for other services.[610]

243. We disagree with CTIA, Qualcomm and TIA that the requirement for 600 MHz service licensees to notify the white space database of the areas where they are commencing operation is overly

[606] *See Notice,* 29 FCC Rcd at 12303, para. 181.

[607] *See* 47 C.F.R. § 15.715(l).

[608] *See* Spectrum Bridge Comments at 6.

[609] The polygon can be created in a standardized spatial format, such as ESRI shape-files or OGC formats, which Spectrum Bridge states are simple for databases to support and have few restrictions on the polygon complexity.

[610] *See* 47 C.F.R. § 15.715(l).

burdensome or complicated.[611] CTIA argues that if wireless licensees have to continually update their service areas in the white space databases, they would bear the burden of "staking a claim to their own assets."[612] The reporting procedure in no way diminishes a licensee's rights to provide service anywhere in its licensed areas. It is intended to ensure that licensees receive the interference protection to which they are entitled under the terms of their license. The method we are adopting requires the submission of only a minimal amount of information to the database (geographic coordinates, frequencies of operation, date of commencement of operation, and contact information), and this information is well known to licensees. We recognize that 600 MHz service licensees will need to update this information as they commence operations in additional areas, but this is something that they will need to do only when they increase their coverage area. No additional information will need to be submitted to the white space database if a licensee adds additional facilities within an area that is already registered with the database, since that entire area would already be protected. We will work with the database administrators as necessary to ensure that this registration process works in an efficient manner for all parties involved.

244. CTIA and AT&T are concerned that disclosure of planned 600 MHz service deployments to the white spaces data base administrators could expose competitively sensitive information.[613] In particular, AT&T points out that the "precise nature of carriers' service expansions has typically been closely held and treated confidentially. Allowing other carriers in the market access to anticipated 600 MHz deployments would provide an undue, and unwarranted, advantage in allowing them to respond to coverage-based competition."[614] We find that the safeguards associated with carriers' provision of this information address this concern. As stated above, 600 MHz service licensees may provide certain prescribed information – including geographic coordinates specifying their service area, frequencies of operation, date of commencement of operation, and contact information – to the white space database administrator in order to protect their operations from interference from white space devices.[615] The licensees exercise significant discretion as to when they make these disclosures, and may choose to do so directly before they commence operations. We also will direct the database administrators not to make information of the carriers' operational areas publicly available.[616] In addition, database administrators are

[611] *See* CTIA Comments at 37, Qualcomm Comments at 20, and TIA Comments at 17. CTIA's objection to this procedure is grounded in its belief that it conflicts with the exclusive rights purchased by wireless operators through auction. It argues that the Commission should determine that a white space device must cease operations when the wireless licensee has initiated service anywhere in its licensed area, thus rendering the reporting requirement to the databases unnecessary. *See* CTIA Comments at 37-38. The Commission will determine in a separate decision when a wireless licensee "commences operations."

[612] *See* CTIA Comments at 40. The Commission's rules permit "self-reporting" to the databases for other services. Although the white space databases download from Commission databases protection areas for most licensed stations entitled to protection, they also acquire information on the locations of receive sites entitled to protection from operators of such site, such as Multiple Video Program Distribution (MVPD) receive sites. *See* 47 C.F.R. § 15.713(b)(2).

[613] CTIA and AT&T raised these objections in response to the Commission's Public Notice seeking comment regarding the definition of "commencing operations" for purposes of the 600 MHz band service transition rules. *See* CTIA Comments, GN Docket No. 12-168, filed May 1, 2015 at 9; AT&T Reply Comments, GN Docket No. 12-168, filed May 18, 2015 at 11. *See also* "Comment Sought on Defining Commencement of Operations in the 600 MHz Band," Public Notice, FCC 15-38, GN Docket No. 12-268 (rel. March 26, 2015) (*Commencing Operations PN*).

[614] *See* AT&T Reply Comments, GN Docket No. 12-168, at 11.

[615] The parameters of the area where a wireless licensee has commenced operation are used by the database administrators solely to determine which frequencies are available at a geographic location for use by a white space device. The database will do this by calculating the required separation distances beyond the perimeter of the licensee's operations area. The carriers' service area is not disclosed to white space device users.

[616] The Commission previously considered and rejected a request that database administrators keep certain information submitted to them private, explaining that public examination of information that is required by the Commission's rules to be in the database allows for the detection of errors or falsely submitted data. *See White*

(continued….)

prohibited from "us[ing] their capacity as a database manager to engage in any discriminatory or anti-competitive practices or any practices that may compromise the privacy of users."[617] We find that the foregoing factors mitigate concern over the potential for anticompetitive use of 600 MHz service licensees' deployment information.

b. WMTS location information

245. *Background*. The Commission requires that authorized health care providers that use WMTS devices register the devices with a Commission-designated frequency coordinator prior to operation.[618] The registration program assists users in meeting their obligation to cooperate in selecting and using frequencies to reduce the potential for harmful interference with each other or co-primary RAS operations.[619] ASHE/AHA, the Commission-designated WMTS frequency coordinator,[620] has contracted with Comsearch to develop and maintain the WMTS database. Because the information in the WMTS database, *e.g*., the geographic coordinates of the transmitters operating on Channel 37, is the same type of information needed to protect the WMTS from harmful interference by white space devices operating on channel 37 and in the adjacent bands,[621] the Commission proposed to include in the white space databases the following information obtained from the WMTS database for each WMTS device registration on channel 37: (1) frequency of operation (*i.e*., channel 37); (2) geographic coordinates of transmitters, and (3) cross reference to the registration in the WMTS database (*e.g*., record number).[622] Because we only proposed to require the minimum information in the white space database necessary to determine if a device meets the required separation criteria from WMTS operating locations, we would need the cross reference to the more detailed information in the WMTS database if there are questions concerning data accuracy or if harmful interference occurs.[623]

246. *Discussion*. We decide in this proceeding that we will protect registered WMTS operations on channel 37 from harmful interference from white space devices operating on the same or

(Continued from previous page)
Spaces Second MO&O, 25 FCC Rcd at 18710, para. 119. Those concerns are not present here. Wireless carriers will be providing information about when and where they expect to commence operations, information which third parties likely would not be able to verify or correct. We conclude that the carriers' concerns about protecting competitively sensitive information outweigh the need to make this information publicly available.

[617] *See* In the Matter of Unlicensed Operations in the TV Broadcast Bands, *Order*, DA 11-131, ET Dkt. 04-186, *et al*. (rel. Jan. 26, 2011) at 7.

[618] *See* 47 C.F.R. § 95.1111(a).

[619] *See* 47 C.F.R. § 95.1115 (d)(4).

[620] ASHE/AHA and the Commission, under authority delegated to the Wireless Telecommunications Bureau, *see* 47 C.F.R. § 0.331, have a Memorandum of Understanding governing ASHE/AHA's obligations as the WMTS frequency coordinator. Memorandum of Understanding between The United States Government, The Federal Communications Commission, and the American Society of Health Care Engineering of the American Hospital Association Regarding Frequency Coordination for the Wireless Medical Telemetry Service.

[621] A WMTS registration request must include: 1) specific frequencies or frequency range(s) used, 2) modulation scheme used, 3) effective radiated power, 4) number of transmitters in use at the health care facility and the manufacturer name(s) and model numbers, 5) name of the authorized health care provider, 6) location of transmitter (coordinates, street address, building), and 7) contact information for the authorized health care provider. *See* 47 C.F.R. § 95.1111(a). We believe that it is not necessary for the white space database to include information on the modulation scheme, effective radiated power or the number of WMTS transmitters used at a location. The proposed protection criteria for the WMTS are minimum co-channel and adjacent channel separation distances, and the white space database does not need information on modulation and power to determine if a white space device meets the minimum separation distance requirements.

[622] *See* Notice, 29 FCC Rcd at 12300, para. 171.

[623] *Id.* at para. 172.

adjacent channels by requiring the unlicensed devices to comply with the default separation distances that we are adopting. The separation distances specified in the rules are from the perimeter of each health care facility or from the combined perimeter of several closely-spaced health care facilities.[624] We will permit only the health care facility that has registered with a white space database to update its record if any changes to the coordinates that define its perimeter are warranted.

247. To implement the protection criteria, we require that health care facilities that operate WMTS networks on channel 37 provide to a white space database the following information:

- Name and address of the health care facility
- Name, address, phone number and email address of a contact person
- Location of each facility where a WMTS network is installed (*i.e*., multiple latitude and longitude coordinates in NAD 83 that define the perimeter of the facility)

248. We conclude that we cannot rely on the information in the WMTS database to implement the methodology we adopt for separation distances because the WMTS database does not in all cases have the geographic location for each facility where a WMTS network is installed, nor does it have the coordinates that define the perimeter of each facility.[625] The Commission staff will work with the WMTS database coordinator and other parties as necessary to develop a plan for working with healthcare facilities to register their information with the white space databases.

249. In the event that harmful interference to WMTS operations occurs, WMTS Coalition requests that the Commission establish detailed procedures for the immediate suspension of operation by any unlicensed device that is suspected of causing harmful interference, until such time as the interference has been fully resolved.[626] Under the current white space rules, a database administrator does not function as a frequency coordinator and thus is not responsible for resolving interference claims. If there is a claim of harmful interference, a database administrator, upon request from the Commission, must provide the white space device's identifying information. If a device is found to be causing harmful interference, the Commission may then require that the party responsible for the unlicensed device take corrective actions or cease operating the device until the interference is resolved. In addition, if a representative of the Commission attempts and is unable to contact the person responsible for a device that is determined to be causing harmful interference, the Commission may require the white space database to return a message of "no channels available" to the device at its next scheduled re-check.[627] This will effectively shut down the device until contact is made with the responsible party so that the harmful interference can be resolved. The database administrator will rescind a "no channels available" status for that device only upon authorization by the Commission.[628] The Commission staff will work with the WMTS database coordinator and other parties as necessary to explore how these procedures may be modified so that a health care facility could notify the database administrators to immediately expand the protection zone around its facility, effectively suspending the operation of unlicensed devices closer to its facility that could be causing harmful interference, until such time as the interference has been fully resolved.

c. RAS location information

250. *Background*. The current white space rules list the locations of 14 radio astronomy sites and require that all white space devices operate at least 2.4 kilometers away from them.[629] The 12

[624] *See, e.g.,* Microsoft Comments at 25; Motorola Comments at 10.

[625] *See* Wi-Fi Alliance Comments at 44.

[626] See White Space Alliance Comments at 19.

[627] *See* 47 C.F.R. § 15.715(k).

[628] *See White Spaces Second R&O,* 23 FCC Rcd at 16880, para. 212.

[629] *See* 47 C.F.R. § 15.712(h)(3).

locations where the RAS receives on channel 37, specifically, the Arecibo Observatory, the Green Bank Telescope, and the ten sites that comprise the VLBA, are included in this list. The required 2.4 kilometer separation distance from these sites was based on the assumption that white space devices do not operate on channel 37, but in the *Notice* the Commission proposed to allow white space device operation on channel 37 and protection criteria for the RAS receive sites that receive channel 37 to protect them from harmful interference.[630] Based on our decision above to allow white space devices to operate on channel 37 subject to exclusion zones around each VLBA site, the white space database administrators will need to modify their systems: (a) to specify new separation distances from the ten VLBA sites, and (b) to include information on the quiet zones at Green Bank and the islands of Puerto Rico where white space devices may not operate. The *Notice* sought comment on changes to the white space database to account for protection of RAS receive sites from operation of white space devices on channel 37.[631]

251. *Discussion*. Commenters did not address the issue of any changes to the databases that would be necessary to protect radio astronomy sites to allow white space devices to operate on channel 37. However, given the current capabilities of the white space databases including the current requirement to impose an exclusion zone of 2.4 kilometer on all channels around the 10 VLBA sites, we believe they are well equipped to make the changes needed to implement our decisions. In fact, given that the databases already possess the capability to exclude white space devices from specific channels within a polygonal area to protect registered wireless microphone use, we believe adding similar polygonal areas, albeit over larger geographic areas than needed for microphones, to protect the 10 VLBA sites should be relatively easy to implement. Thus we will require the databases administrators to modify their databases to implement the polygonal exclusion areas on channel 37 specified above.[632] We believe that the database administrators will also be able to easily accommodate the requirement to protect the two single dish RAS observatories by excluding white space devices from operating within the National Radio Quiet Zone at Green Bank, WV and on the islands of Puerto Rico, Desecheo, Mona, Vieques and Culebra around the Arecibo observatory. We are adopting a requirement that the databases provide such protection. Finally, we delete from rule section 15.712 (h)(3), as proposed in the *Notice*, the Allen Telescope Array and the Very Large Array since they do not receive signals in the TV bands or the 600 MHz band.

d. Canadian and Mexican stations

252. *Background.* White space devices operate in the same frequency bands and on the same channels as TV stations in Canada and Mexico and need to avoid causing harmful interference to TV broadcast operations in those countries. Currently, the Commission receives from Canada information on Canadian TV stations in the border areas that need to be protected and passes it on to our white space database administrators who protect these locations.[633] The Commission sought comment on how best to have the Canadian and U.S. database administrators share information about stations in each country that need to be protected in the border areas, especially since some of these facilities may be receive sites that are not listed in Commission or Canadian government licensing databases.[634] The only commenter that addressed sharing of international information is Spectrum Bridge. It asserts that the Commission should remain the conduit for collection and distribution of international (Canada and Mexico) protected entity data. It states that this process works well today and provides consistency that would be difficult to maintain if the process were changed to a many-to-many relationship with foreign entities.[635]

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[630] *See Notice,* 29 FCC Rcd at 12279, 12283-12285, paras. 99-100, 116-124.

[631] *See Notice,* 29 FCC Rcd at 12301-12302, para. 175-176.

[632] *See* para. 247, *supra.*

[633] *See* 47 C.F.R. §§ 15.711 (a), 15.712 (g).

[634] *See Notice,* 29 FCC Rcd at 12304, para. 183.

[635] *See* Spectrum Bridge Comments at 7.

253. *Discussion.* We agree that this process works well today and we do not intend to make changes at this time. However, we also note that Canada has recently concluded its consultation finalizing white space device rules, but has not yet authorized their use as no databases have yet been approved.[636] Because we have rules that provide for registration and protection of certain operations that are not in a Commission database (*e.g*., cable headends, BAS receive sites, etc.), an efficient method for transferring this data to Canadian database administrators as well as passing such information from Canada to U.S. database administrators is needed to ensure that such stations continue to receive the protection to which they are entitled by the rules. We are unaware of any actions in Mexico at this time to implement a similar regime for white space devices in the TV bands. Since the Commission began working on rules for white space devices, it has engaged in discussions with our counterparts in Canada regarding operations along the common border. We will continue these discussions to develop the most efficient procedures to share registered entity information among various databases and provide information and procedures to the database administrators as agreements are reached.[637] At such time that Mexico develops white space device rules, we will engage with our counterparts there to work out similar arrangements.

e. Private Land Mobile Radio Service

254. *Background*. In the *Notice*, the Commission proposed to modify the information required to be included in the white space databases for PLMRS/CMRS base station operations located more than 80 kilometers from the geographic centers of the 13 metropolitan areas defined in Section 90.303(a) of the rules (*e.g.* , in accordance with a waiver).[638] These stations are protected to a distance of 54 kilometers from co-channel white space devices, and 51 kilometers from adjacent channel white space devices,[639] but the databases do not include the TV channel number on which the PLMRS/CMRS station operates, which is needed to determine when a station needs protection.[640] In addition, there does not appear to be any need to include the effective radiated power or antenna heights above ground and average terrain for each base station in the database because this information is not necessary for the database to calculate the separation distances. The Commission proposed to modify Section 15.713(h)(4) to require the white space database to include the TV channel number on which a PLMRS/CMRS base station operates, and to remove the requirement to include effective radiated power and antenna height information.[641]

255. *Discussion*. We are adopting our proposal to modify the information required to be included in the white space database to protect PLMRS/CMRS base stations in the TV bands that are located more than 80 kilometers from the geographic centers of the 13 metropolitan areas defined in Section 90.303(a) of the rules.[642] Specifically, we are modifying Section 15.713(h)(4) of the rules to require the white space databases to include the TV channel number on which a PLMRS/CMRS base

[636] *See* Industry Canada Radio Standards Specification for White Space Devices (RSS-222), Issue 1, February 2015 available at: https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/RSS-222-Issue1.pdf/$file/RSS-222-Issue1.pdf. *See also,* Industry Canada Client Procedures Circular on Application Procedures for White Space Database Administrators (CPC-4-1-01), Issue 1, February 2015 available at: https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/CPC-4-1-01-issue1.pdf/$file/CPC-4-1-01-issue1.pdf.

[637] One possibility might be to convene a workshop with database administrators on each side of the common border to work out a mutually agreeable solution.

[638] *See* 47 C.F.R. § 15.713(h)(4).

[639] *See* 47 C.F.R. § 15.712(d).

[640] Because the operating channel number is necessary to protect the PLMRS/CMRS, the white space database administrators already include this information in their databases even though it is not specifically required by the rules.

[641] *See Notice,* 29 FCC Rcd at 12303-12304, para. 182.

[642] *See* 47 C.F.R. § 15.713(h)(4).

station operates, and to remove the requirement for the white space databases to include the effective radiated power and antenna height information for each base station. One party supported the Commission's proposals and no parties opposed them.[643] We find that the proposed changes are needed to effectively protect the PLMRS/CMRS and to avoid the collection of unnecessary information in the white space databases, so we are adopting the proposed changes.

2. Changes to database procedures

256. We are modifying our white space database procedures to implement some of the decisions made in this proceeding. First, we require that fixed white space devices register with the database if they operate in the 600 MHz service band, the guard bands or duplex gap, and permit the white space database administrators to charge a fee for providing lists of available channels to white space devices and registering fixed white space in these bands. Second, we will no longer permit unlicensed wireless microphones to register their operating locations, channels and times in the white space databases to reserve channels for their use in the TV bands, the 600 MHz guard bands or duplex gap, and the 600 MHz service band. We will permit database administrators to charge a fee for providing unlicensed microphone users with information about available frequencies at the locations where they intend to operate and, to facilitate this, we will require that microphone users register with a database administrator. Third, to accommodate the needs of licensed wireless microphone users for immediate access to channels for late-breaking events, we will require that database administrators "push" information to white space devices in the area where the wireless microphones will be used, notifying them of changes in channel availability, rather than require all white space devices to re-check a database every twenty minutes.

a. White space device registration and fees

257. *Background*. Fixed white space devices must register with the white space databases, providing the geographic coordinates, antenna height and certain identifying information.[644] In the *Notice*, the Commission proposed to clarify our rules to ensure that fixed white space devices register with the databases if they would operate not only in TV bands but also in the 600 MHz service band, the guard bands and duplex gap, and Channel 37.[645] We also proposed to modify our rule that permits the white space database administrators to charge a fee for providing lists of available channels to white space devices and to register fixed white space devices to clearly state that this rule provision applies to white space devices that would operate in the TV bands, the 600 MHz service band, the 600 MHz guard bands, including the duplex gap, and Channel 37.[646] Regarding the registration of fixed white space devices in the white space databases, the Commission has stated that devices that do not check the database for three months to update their channel lists will be removed from the databases, but it did not codify this requirement.[647] Fixed devices that are re-registered later would be subject to a new registration fee. We sought comment on whether we should continue this requirement.[648]

258. *Discussion.* We are adopting our proposed requirement that fixed white space devices must register with the database if they operate in the 600 MHz service band, the guard bands duplex gap, or channel 37.[649] We are also modifying the rule that permits the white space database administrators to charge a fee for providing lists of available channels to white space devices and registering fixed white

[643] *See* White Space Alliance Comments at 24.

[644] *See* 47 C.F.R. §§ 15.713 (b)(2)(iii), (f)(3).

[645] *See Notice,* 29 FCC Rcd at 12308, para. 197.

[646] *See* 47 C.F.R. § 15.714(a) (fees may be charged for providing a list of available channels).

[647] *See White Spaces Second R&O*, 23 FCC Rcd at 16880, para. 211.

[648] *See Notice*, 29 FCC Rcd at 12308, para. 199.

[649] *See Notice*, 29 FCC Rcd at 12308, para. 197.

space devices to clearly state that this rule applies to white space devices that would operate in the TV bands, the 600 MHz service band, and the 600 MHz guard bands, including the duplex gap, and channel 37.[650] We are taking these actions for consistency with the current Part 15 rules which require that fixed white space devices operating in the TV bands must register with the white space databases.[651]

259. We are also modifying the rules to require that a fixed white space device registration will be removed from the white space databases if the device has not checked the database for at least three months to update its channel list. As discussed in the *Notice,* the Commission adopted this requirement in the *White Spaces Second R&O* but failed to codify it at the time.[652] This rule will help ensure the integrity of the white space databases by requiring the removal of entries for fixed devices that are registered but are no longer in operation. We are also clarifying that a database administrator may charge a new registration fee for a fixed white space device that is removed from the database under this provision but is later re-registered.

b. Unlicensed wireless microphone registration and fees

260. *Background*. Under the current rules, Part 74 licensees operating Low Power Auxiliary Service (LPAS) equipment, including wireless microphones, may register their operating locations, channels and times in the white space database.[653] The white space database protects these registered locations by requiring fixed devices to operate at least one kilometer from them and requiring personal/portable devices to operate at least 400 meters from them.[654] Licensees may register their information directly with any one of the designated white space database administrators, and the information is then shared with all the other database administrators. Parties operating large numbers of wireless microphones on an unlicensed basis are also allowed to register their operating locations in the white space database under certain circumstances.[655] These registered locations are given the same protection from white space devices as licensed LPAS operations. Registration of unlicensed wireless microphones is limited to venues of events and productions and shows that use large numbers of microphones that cannot be accommodated in the two reserved channels and other channels that are not available for use by white space devices at a specific location.[656]

261. In the *Notice*, the Commission proposed to eliminate the Part 15 rule that permits unlicensed wireless microphone users to register their operating locations, channels and times in the white space databases to protect their operations from possible interference from white space devices.[657] Thus,

[650] *See* 47 C.F.R. § 15.714(a) (fees may be charged for providing a list of available channels).

[651] *See* 47 C.F.R. §§ 15.713 (b)(2)(iii) and (f)(3).

[652] *See Notice,* 29 FCC Rcd at 12308, para. 199 and *White Spaces Second R&O*, 23 FCC Rcd at 16880, para. 211.

[653] *See* 47 C.F.R. § 15.713(h)(8).

[654] *See* 47 C.F.R. § 15.712(f).

[655] *See* 47 C.F.R. § 15.713(h)(9).

[656] Parties filing registration requests must certify that they are making use of all TV channels not available to white space devices and on which wireless microphones can practicably be used. As a benchmark, at least six to eight wireless microphones should be operating in each channel used at such venues. Sites of eligible event venues using unlicensed wireless microphones must be registered with the Commission at least 30 days in advance, and the Commission provides this information to the white space database administrators. In 2012, prior to adoption of the *Incentive Auction R&O*, public notices were issued to explain the registration process for reserving channels. *See* Office of Engineering and Technology and Wireless Telecommunications Bureau Announce the Initial Launch of Unlicensed Wireless Microphone Registration System, ET Docket No. 04-186, *Public Notice*, 27 FCC Rcd at 11163 (OET/WTB 2012); Office of Engineering and Technology and Wireless Telecommunications Bureau Announce Nationwide Launch of Unlicensed Wireless Microphone Registration System, ET Docket No. 04-186, *Public Notice*, 27 FCC Rcd at 15102 (OET/WTB 2012).

[657] *See Notice*, 29 FCC Rcd at 12305, para. 185.

unlicensed wireless microphones would no longer be permitted to register their operations in the TV bands, as well as in the 600 MHz guard bands or duplex gap. The Commission also proposed that, if it decided that unlicensed wireless microphones operating in the 600 MHz guard bands and duplex gap must contact the white space databases to identify operating frequencies available for their use, the database administrators may charge a fee for providing this information.[658] It sought comment on whether wireless microphone users should register their devices in the white space databases, whether database administrators should assess a fee for microphone registration, as they do with fixed white space devices, and whether a registration program would facilitate the assessment of fees for obtaining channel lists.[659]

262. *Discussion*. We will eliminate the Part 15 rule that permits unlicensed wireless microphone users to register their operating locations, channels and times in the white space databases to reserve channels for their use and to protect these operations from possible interference from white space devices. This rule will be effective 18 months after the effective date of this rule but in any event no later than the release of the *Channel Reassignment PN* after the conclusion of the incentive auction. Unlicensed wireless microphones will not be permitted to register channels for protection in the TV bands, the 600 MHz guard bands or duplex gap, and the 600 MHz service band.

263. As discussed above, we are requiring that unlicensed wireless microphones rely on the database to identify channels for their use in the 600 MHz guard bands and duplex gap, as required by the Spectrum Act, and we also are requiring their reliance on the database for their operation in the 600 MHz service band during the post-auction transition period. In order for the database administrators to provide unlicensed wireless microphone users with information about available frequencies and required separation distances at the location where they intend to operate, we require that microphone users register with a database administrator and provide their identifying information and locations. Database administrators will be permitted to charge a fee for providing unlicensed microphone users with information about available frequencies and required separation distances at the locations where they intend to operate.

264. We make these changes for the reasons given in the *Notice*.[660] First, in 2014 in the *Wireless Microphones Second R&O* we expanded eligibility for Part 74 LPAS licenses to include professional sound companies and the owners and operators of large venues that routinely use 50 or more wireless microphones.[661] We noted that the goal in both the *TV Bands Wireless Microphones Second R&O* and in 2010 in the *TV White Spaces Second MO&O*, in which the Commission adopted rules permitting unlicensed users to register in the white space database for protection in the TV bands, was to ensure that entities requiring a large number of wireless microphones are able to register in the white space database.[662]

265. We also make these changes because we are adopting new rules for unlicensed wireless microphones that are consistent with rules applicable to white space devices, as proposed in the *Notice.* Specifically, we are requiring that unlicensed microphones operate under similar technical rules (*e.g.*, power limits) as white space devices in the TV bands, the 600 MHz guard bands and duplex gap; we are

[658] *See Notice*, 29 FCC Rcd at 12308, para. 197.

[659] *See Notice*, 29 FCC Rcd at 12308, para. 198.

[660] *See Notice*, 29 FCC Rcd at 12305-12306, para. 186-187.

[661] *See TV Bands Wireless Microphones Second R&O*.

[662] *See Wireless Microphones Second R&O* at ¶ 21 (the revised eligibility "will enable the newly eligible entities, which generally are able to register for database protection [under the 2010 *TV White Spaces Second MO&O*] as unlicensed users, to obtain protection in the TV bands database in a more administratively efficient manner, through the Part 74 license process"). *See also* Unlicensed Operation in the TV Broadcast Bands and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz band, ET Docket Nos. 04-186 and 02-380, *Second Memorandum Opinion and Order*, 25 FCC Rcd 18661, 18674-75, para. 31-32.

applying the same general conditions of operation as white space devices (*i.e*., they may not cause interference to authorized services and must accept any interference received, including interference from other unlicensed devices);[663] and we are requiring that unlicensed wireless microphones operating in the 600 MHz guard bands and duplex gap must contact the white space databases prior to operation, as will white space devices, to ensure that their intended operating frequencies are available for unlicensed wireless microphones at the location where they will be used.

266. Sennheiser, Shure and many small theaters and schools argue that we should continue to permit unlicensed wireless microphone users to register channels in the white space database to get protection from white space devices.[664] They claim that many users—*e.g*., churches, schools, trade shows and conference centers—do not routinely use 50 or more microphones and are ineligible for a Part 74 license, but nonetheless require reliable, interference-free operation. Shure also argues that the proposed technical rules for microphone use in the guard bands and duplex gap do not put them on equal footing with white space devices.[665] When the Commission decided in the *TV White Spaces Second MO&O* to allow unlicensed wireless microphones operating under waivers of the Part 15 rules to register channel use in the databases, it limited such use to venues and productions that needed large numbers of microphones which could not be accommodated in vacant TV channels or channels not available for white space use,[666] and it sought comment on expanding Part 74 license eligibility for users of large numbers of microphones. The Commission subsequently modified its Part 74 rules to enable entities that used large numbers of microphones on a regular basis to obtain a license, thus enabling them to reserve channels for their use and providing them with interference protection from white space devices. Entities that did not meet the microphone threshold to qualify for a Part 74 license would continue to operate on an unlicensed basis. No party filed a petition for reconsideration of this decision. When the Commission proposed in this proceeding to eliminate the channel reservation process for unlicensed wireless microphones, it was balancing the interests between licensed and unlicensed entities' access to spectrum in a reconfigured TV bands that would have fewer vacant channels available. Because users of large numbers of wireless microphones would be eligible for a Part 74 license, the proposal was intended to level the playing field for unlicensed users of white space devices and wireless microphone who regularly use fewer devices and needed access to fewer vacant channels. We find that it would be inequitable to continue to provide interference protection to one unlicensed user over another and it would be unfair to licensed microphone users because it would effectively eliminate any distinction between licensed and unlicensed microphone users in gaining access to spectrum and interference protection.

267. We recognize that under the rules we adopted in the *Incentive Auction R&O* and in this proceeding, there will be fewer TV channels available for wireless microphone use and fewer channels available for white space devices. On the other hand, the Commission has decided that unlicensed wireless microphones will have access to spectrum in the 600 MHz guard bands and duplex gap, albeit on a shared basis with white space devices. Depending on the auction results and the final band plan, there likely will be spectrum segments that will accommodate wireless microphone use but not white space devices. For example, the three megahertz guard bands adjacent to channel 37 would be available for unlicensed wireless microphones but not white space devices, and in seven and nine megahertz guard bands, wireless microphones could use at least two megahertz on an exclusive basis, in addition to four or six megahertz, respectively, shared with white space devices.

268. Sennheiser, Shure and Wireless Microphone Alliance of America oppose requiring unlicensed wireless microphone users to pay a fee to access the databases to identify available spectrum

[663] *See* 47 C.F.R. § 15.5(b).

[664] *See* Sennheiser Comments at 19; Shure Comments at 30.

[665] *See* Shure Comments at 30.

[666] *See* 47 C.F.R. § 15.713(h) (9).

for their use.[667] Sennheiser claims this would be a cumbersome regulatory burden on users who would need to register with a database in order to pay fees. Shure argues that wireless microphones are incumbent services entitled to protection and thus should not be "singled out" out to pay fees to a database. The purpose of the database is two-fold: to protect authorized services and facilities that are entitled to interference protection under the Commission's rules, and to identify for unlicensed devices channels available for their use without causing harmful interference to authorized users. As Spectrum Bridge notes, the database administrators incur costs to not only maintain data but also to calculate and provide lists of available channels for unlicensed users.[668] Because both unlicensed white space devices and unlicensed wireless microphone users will benefit equally from the information provided by the databases, they should be equally responsible for supporting the ongoing operation of the databases. The database administrators may charge fees to register fixed unlicensed white space devices and to provide lists of available channels to white space devices.[669] Unlicensed wireless microphones will be equally treated.

269. To enable unlicensed wireless microphone users to register with a database, we will require that they provide a database administrator with the same information that they have provided to reserve a channel under current rule section 15.713(h)(9), namely: (a) name of the individual or business that owns the unlicensed wireless microphone; (b) an address for the contact person; (c) an email address for the contact person; (d) a phone number for the contact person; and (e) coordinates where the device will be used (latitude and longitude in NAD 83).

c. Frequency of white space device check times and databases sharing registration information

270. *Background*. Under current rules, white space devices are required to re-check the database at least once per day to obtain the list of available TV channels at the location where the device operates.[670] If a device is unable to make contact with the database on any given day, it may continue to operate until 11:59 PM on the following day, at which time it must cease operation until it re-establishes contact with the database.[671] The Commission established these timeframes because most protected services listed in its databases do not change on a frequent basis. Further, since the Commission provides updated data to the white space database administrators only once every weekday, there is generally no need for white space devices to recheck the database more frequently than once per day.

271. The only protected use for which database information generally changes more frequently than once daily is wireless microphones. A wireless microphone user may register with a single white space database, and that database must then share the registration information with the other databases at least once daily, or more often as appropriate.[672] The Commission established two reserved television channels where white space devices cannot operate to ensure that there would be spectrum available for wireless microphones used in applications such as electronic news gathering for which it is not possible to register the operating location in the database at least 24 hours in advance.

272. In the *Incentive Auction R&O*, the Commission decided to no longer designate two vacant television channels for wireless microphone use only. To ensure that wireless microphone users registering channels for their use receive protection in a timely manner, the Commission proposed two

[667] *See* Sennheiser Comments at 20; Shure Comments at 32-33; Wireless Microphone Alliance of America Reply Comments at 3.

[668] *See* Spectrum Bridge Comments at 8.

[669] *See* 47 C.F.R. § 15.714(a).

[670] *See* 47 C.F.R. § 15.711(b)(3)(i)-(ii).

[671] *See* 47 C.F.R. § 15.711(b)(3)(iii).

[672] *See* 47 C.F.R. § 15.715(d) and (l).

changes to its rules: (a) to amend Sections 15.711(b)(3)(i) and 15.711(b)(3)(ii) of the rules to require fixed and Mode II personal/portable white space devices to re-check the database at time intervals not to exceed 20 minutes, and (b) to eliminate Section 15.711(b)(3)(iii) which allows a white space device to continue operating until 11:59 PM on the following day if it cannot establish contact with the database. We also proposed to amend Section 15.715(l) of the rules to require database administrators to share wireless microphone registration information between databases within ten minutes. The effect of these proposals would be to ensure that a white space device cease operation on a channel used by a wireless microphone within 30 minutes after a new registration is entered into the database. We also sought comment on how a white space device should respond in the event that it cannot contact a database at the specified re-check interval, *e.g.*, should the device simply be required to cease transmitting, or should it be permitted to operate for a longer time so it can retry contacting the database.

273. *Discussion*. Based on a careful analysis of the concerns raised by both white space device and wireless microphone proponents, we are persuaded that requiring all white space devices to re-check a database for a list of available channels every twenty minutes would unnecessarily burden the database administrators and the white space device users and is not necessary to accomplish our objectives. We already have in place a procedure whereby licensed wireless microphone users can register with a database and reserve channels for their use well in advance of their intended date of operation. We expect licensed microphone users to continue to use this process so that they are ensured of having access to the spectrum they need for planned events. The issue that needs to be addressed is making channels available for licensed wireless microphone use for events that cannot be anticipated, such as late-breaking news events, within minutes or hours of when they occur. Today, broadcaster and others covering such events can rely on having access to the two vacant television channels above and below channel 37, which they can use without having to contact a database to register their use. When these two vacant channels are no longer available for their exclusive use, they will have to contact a database and request channels for immediate use. We conclude that for these occasions, we will require that database administrators "push" information to white space devices in the area where the licensed wireless microphones will be used, notifying them of changes in channel availability, rather than require all white space devices to re-check a database every twenty minutes. This approach balances the needs of both white space device and wireless microphone proponents. It satisfies the objective of our proposal to make spectrum available for licensed wireless microphone use for late-breaking events, but it does not burden all white space users with unnecessary frequent database re-checking in meeting this objective.

274. Specifically, when a database administrator receives a request for immediate access to channels for licensed wireless microphone use, we require that the database administrators share licensed wireless microphone's channel registration information among themselves within ten minutes, as proposed in the *Notice* and which no commenters opposed.[673] We require that the database administrators "push" information about changes in channel availability for fixed and Mode II personal/portable white space devices within 20 minutes of receiving it, identifying for the white space device other vacant channels that it could use instead. The database administrators need to push this information only to white space devices that are located within the separation distances, specified in rule section 15.712(f)(1),[674] from the location specified by the wireless microphone registrant. To provide the database administrators with sufficient time to modify their systems, we will require their compliance with these requirements 12 months after the effective date of these new rules.

275. Wireless microphone proponents supported the proposals in the *Notice* to require all white space devices to re-check channel availability at their location every 20 minutes to allow more immediate reservation of channels, and to eliminate the rule that now permits white space devices to

[673] *See* NAB Comments at 13; Sennheiser Comments at 20; Shure Comments at 33; Spectrum Bridge Comments at 7; WISPA Comments at 23.

[674] *See* 47 C.F.R. § 15.712(f)(1).

continue operating until 11:59 PM on the following day if it cannot establish contact with the database.[675] White space proponents uniformly opposed these proposals, citing numerous problems with the proposed approach. Alarm Industry Communications Committee and MELD Technology are concerned that the proposed rules would be disruptive of broadband operations and eliminate continuity of service.[676] Google, Microsoft and Spectrum Bridge argue that the proposal would be a 72 times increase in daily polling of the databases by each white space device in use, thus increasing the costs for managing the databases (*e.g.*, additional signaling, computation load, data retention storage) and decreasing the battery life of white space devices.[677] MELD and Spectrum Bridge point out that a 72 times increase in daily polling also will increase users' costs if they have metered data plans for Internet access, particularly if they rely on multiple white space devices.[678] NAB disputes Google's claims that more-frequent re-checking by the white space devices would increase the databases' administrative costs since each device sends small amounts of data with little or no incremental cost to the device; they also claim that Google's argument that the a device's battery life would be shortened is unsupported.[679] MELD, Spectrum Bridge, White Space Alliance and WISPA also request that we allow extra time for retry attempts since Internet connections get disrupted.[680]

276. Commenters suggested several alternative approaches: require database administrators to "push" information on wireless microphone registrations to white space devices;[681] designate a few "fast polling" channels and only those white space devices operating on these channels would be required to re-check the database every 20 minutes;[682] and allow the database administrators to assign to white space devices channels they may use for a specified amount of time, thus eliminating the need for frequent re-checking by the devices.[683] We conclude that requiring the database administrators to "push" information to white space devices is the most practical means to balance the concerns of the white space proponents with the immediate spectrum needs of microphone users, as needed. Also, our rules already permit, although they do not require, database administrators to "push" information to white space devices.[684]

277. We conclude that requiring all white space devices in the country to re-check channel availability in their area every twenty minutes would unnecessarily burden the white space databases, drive up costs for database management and white space devices users, and is overly-broad in satisfying the objective of the original proposal, *i.e.*, to ensure that white space devices clear a channel needed for licensed wireless microphone users for late-breaking events in a specific area. NAB's assertion that more frequent checking by each white space device would not increase the databases' administrative costs is based on a very small number of registered fixed white space devices as of February 2015, and is not a reliable measure for projecting costs in the future. We also reject the suggestion to designate a few "fast polling" channels because we could not determine until after the post-auction transition period which vacant channels will be available for wireless microphones and white space devices in any given area.

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[675] *See* NAB Comments at 13; Sennheiser Comments at 20; Shure Comments at 33.

[676] *See* Alarm Industry Communications Committee Reply Comments at 7; MELD Technology Comments at 2.

[677] *See* Google Comments at 47-48; Microsoft Comments at 49; Spectrum Bridge Comments at 7.

[678] *See* MELD Technology Comments at 3; Spectrum Bridge Comments at 7.

[679] *See* NAB Reply Comments at 7-8. NAB's estimates are based on the amount of data 560 white space devices would transmit to a white space database, citing the number of registered fixed devices as of February 19, 2015.

[680] *See* MELD Technology Comments at 2; Spectrum Bridge Comments at 7; White Space Alliance Comments at 25; WISPA Comments at 22-23.

[681] *See* White Space Alliance Comments at 25; WISPA Comments at 21-22.

[682] *See* Anant Sahai Comments at 2; Google Comments at 47.

[683] *See* Wi-Fi Alliance Comments at 41.

[684] *See* 47 C.F.R. §15.711(b)(3)(v).

Also, because only a few channels would be designated for "fast polling," this approach is less flexible in meeting the needs of wireless microphone users for immediate access to spectrum.[685] As for the suggestion that we schedule channels and operating times for white space devices, this approach is fundamentally different than the scheme underlying the current rules and may not allow wireless microphone users to immediately access spectrum, as needed.

278. By adopting a requirement for "push" notifications to white space devices of wireless microphone registrations to enable more immediate protection when reserving channels, such as for late-breaking events, we conclude that we do not need to eliminate Section 15.711(b)(3)(iii) which allows a white space device to continue operating until 11:59 PM on the following day if it cannot establish contact with the database. We will continue to require that white space devices re-check the database at least once per day to obtain the list of available TV channels at the location where the device operates. This way the channel lists they receive each day will include those channels that wireless microphone users reserve in advance, and they will be able to continue to operate on any of those available channels unless they receive a "push" notification. We emphasize that the "push" procedure should only be used by wireless microphone users when circumstances prevent them from reserving vacant channels in advance of their expected use, *e.g.*, breaking news events covered by broadcasters and similar entities. Unnecessary and frequent use of the "push" procedure would be disruptive to broadband services being provided by white space devices.

F. Equipment Certification and Marketing

279. The rule changes we are adopting give greater flexibility for white space device operation in the TV bands. The majority of these changes are permissive, meaning that manufacturers of approved white space devices are not required to incorporate them into their equipment. However, the requirement for white space devices to accept channel information pushed by a database will require changes to previously approved devices. In addition, we are adopting rules for unlicensed wireless microphones that operate in the TV bands and for unlicensed devices and for licensed and unlicensed wireless microphones that operate in the guard bands and duplex gap. These devices will be affected by the transition provisions adopted in the *Incentive Auction R&O.* We address certification, marketing and operational requirements for white space devices and unlicensed wireless microphones below.

1. White space devices

280. The changes we are adopting to require fixed and Mode II personal/portable devices to accept updated channel lists "pushed" by the database require changes to devices that were previously approved, since the method that a device uses to communicate with the database is a function of a device.[686] Based on our experience with certifying fixed white space devices and testing white space databases prior to permitting them to offer service, we believe that this change can be implemented through software updates and no hardware changes, so only a short transition time period is necessary. Also, we want these procedures in place well before white space devices gain access to the two vacant TV channels now reserved for wireless microphone use, to re-assure licensed microphone users requiring access to spectrum for late-breaking events. Accordingly, we are requiring that devices for which a certification application is filed beginning six months after the effective date of the rules comply with the new channel push requirements. We will also require that within nine months after the effective date of the rules, all white space devices imported and marketed within the United States must comply with these requirements, regardless of when they were certified. We will further require that white space devices that do not comply with the new channel push requirements must cease operating within one year of the effective date of the rules.

[685] NAB points out that broadcasters covering breaking news events could be using microphones that operate on channels other than those designated for "fast polling." NAB Reply Comments at 7.

[686] *See* para. 273, *supra.*

2. Wireless microphones

281. We adopt rules to establish cutoff dates for the certification, manufacturing and marketing of unlicensed wireless microphones in the TV bands, the guard bands (including the duplex gap), and the 600 MHz service band.[687] We will permit unlicensed wireless microphone users to operate Part 74 wireless microphones in the TV bands under the waivers already in place[688] and in the 600 MHz service band until they must cease those operations no later than 39 months after release of the *Channel Reassignment PN*. We will accept applications to certify wireless microphones under new Part 15 rules as soon as those rules are effective, and we will require applications to certify wireless microphones under new Part 15 rules nine months after the release of the *Channel Reassignment PN* or no later than 24 months after the effective date of the new rules, whichever occurs first. We will require that manufacturing and marketing of all wireless microphones that would not comply with the 600 MHz band cease 18 months after release of the *Channel Reassignment PN* or no later than 33 months after the effective date of the new rules, whichever occurs first.[689]

282. *Background.* All wireless microphones that now operate in the TV bands are certified as compliant with Part 74, Subpart H of the Commission's rules. The Commission decided in the *Incentive Auction R&O* that all wireless microphones that operate in the portion of the TV bands that will be repurposed for licensed wireless services may continue to operate in that spectrum during the post-auction transition period but must cease those operations no later than 39 months after release of the *Channel Reassignment PN*.[690] At the end of this post-auction transition period, licensed microphones will be permitted to operate in a portion of the duplex gap, and unlicensed wireless microphones will be permitted to operate in the guard bands and duplex gap. In the *Notice*, the Commission proposed to establish cutoff dates for the certification, manufacturing and marketing of wireless microphones in the 600 MHz band spectrum to ensure that manufacturers cease making and marketing equipment that cannot be legally used after a certain date.[691] Because similar technical requirements would apply to both licensed and unlicensed wireless microphones, the Commission proposed to apply to both the same transition rules for certification, manufacturing and marketing, and sought comment on aligning the transition period as closely as possible with the post-auction transition schedule.[692]

283. Currently, unlicensed wireless microphones operate in the TV bands under Part 15 of the Commission's rules pursuant to waivers.[693] In the *Notice*, the Commission proposed that to continue permitting users to operate Part 74 wireless microphones in the TV bands under the waivers already in place until they must cease those operations no later than 39 months after release of the *Channel Reassignment PN*. The Commission also proposed to accept applications to certify wireless microphones under new Part 15 rules as soon as those rules are effective, but not require such applications until after the incentive auction. The Commission proposed to require applications to certify wireless microphones under new Part 15 rules or modified Part 74 rules nine months after the release of the *Channel Reassignment PN* or no later than 24 months after the effective date of the new rules, whichever occurs first. It also proposed to require that manufacturing and marketing of all wireless microphones that would

[687] In the Wireless Microphones Report and Order, we are adopting rules for certification, manufacturing, and marketing of licensed wireless microphone devices under the Part 74 LPAS rules.

[688] *See TV Bands Wireless Microphones R&O and Further NPRM*, 25 FCC Rcd at 682-87, para. 81-90.

[689] These transition rules for unlicensed wireless microphones that we are adopting parallel the requirement that we are adopting for licensed wireless microphones under Part 74 in the Wireless Microphone Report and Order in GN Docket No. 14-166.

[690] *See Incentive Auction R&O,* 29 FCC Rcd at 6846, para. 687.

[691] *See Notice*, 29 FCC Rcd at 12309, para. 203.

[692] *See Notice*, 29 FCC Rcd at 12310, paras. 204-205.

[693] *See* para. 13, *supra*.

not comply with the 600 MHz band cease 18 months after release of the *Channel Reassignment PN* or no later than 33 months after the effective date of the new rules, whichever occurs first. The Commission acknowledged that a marketing and operating cutoff need not apply to wireless microphones certified to operate only in the guard bands and duplex gap, but it proposed that, if a wireless microphone is certified to operate in any portion of the 600 MHz service band, it may no longer be marketed or operated after the specified cutoff dates, even if it could be tuned to operate outside the 600 MHz service band. This approach will allow use of the FCC identification number to identify which wireless microphones may be legally marketed and operated, rather than having to determine the precise frequency to which a specific wireless microphone is tuned, which may not be indicated on the device.[694]

284. *Discussion.* We adopt transition rules for the TV bands, the guard bands (including the duplex gap), and the 600 MHz service band that will allow us to gradually phase out older microphones and introduce new ones that are compliant with the technical rules for unlicensed and licensed wireless microphones that we adopt in this proceeding and for licensed wireless microphone that we adopt in the Wireless Microphone R&O.[695] We are aligning the transition periods as closely as possible with the post-auction transition schedule because this will ensure compliance with the post-auction 600 MHz Band Plan and be less disruptive to wireless microphone manufacturers and users.

285. Regarding unlicensed wireless microphones, we will permit users of such equipment to operate Part 74 wireless microphones in the TV bands under the waivers already in place and in the 600 MHz service band until they must cease those operations no later than 39 months after release of the *Channel Reassignment PN*. The majority of commenters agree with this approach.[696] Although these microphones are certified as compliant with Part 74 rules, the waiver requires that they be operated consistent with the Part 15 rules which we are now adopting in this proceeding. Thus, their continued use in the TV bands and in the 600 MHz band during the post-auction transition period is unlikely to cause harmful interference to licensed services.

286. We will accept applications to certify wireless microphones under new Part 15 rules as soon as those rules are effective, and we will require applications to certify wireless microphones under new Part 15 rules nine months after the release of the *Channel Reassignment PN* or no later than 24 months after the effective date of the new rules, whichever occurs first. We will require that manufacturing and marketing of all wireless microphones that would not comply with the rules for operation in the 600 MHz band cease 18 months after release of the *Channel Reassignment PN* or no later than 33 months after the effective date of the new rules, whichever occurs first. If a wireless microphone is certified to operate in any portion of the 600 MHz service band, it may no longer be marketed or operated after the specified cutoff dates by an unlicensed wireless microphone user, even if it could be tuned to operate outside the 600 MHz service band.

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[694] Manufacturers commonly certify wireless microphones to operate over a relatively wide frequency range, then market units that operate over only a portion of the authorized frequency range. A wireless microphone must be labeled with an FCC identification number that allows us to locate its certification records, including the authorized frequency range, but there is no requirement to label each individual wireless microphone with the exact frequency range over which it is tuned. Thus, a visual inspection of a wireless microphone may not show whether it is tuned to operate in the repurposed 600 MHz band.

[695] The technical rules include the new emission mask for wireless microphones. *See* para. 99, *supra*.

[696] The Nuclear Energy Institute and Utilities Telecom Council request that they be permitted to operate under the terms of their modified waiver on all frequencies below 698 MHz beyond the 39 month transition period. *See* Nuclear Energy Institute and Utilities Telecom Council Comments at 8-11. We are addressing this request in the Wireless Microphone Report and Order that is being released concurrently with this Report and Order. *See* Wireless Microphone Report and Order at Section III.B.1.b.(i)(d) (other TV bands revisions).

287. Sennheiser generally supports the proposed cutoff dates for certification, manufacturing and marketing of wireless microphones.[697] CTIA and Mobile Future argue that no new wireless microphones should be certified that are inconsistent with the post-auction 600 MHz band as of the date of release of the *Channel Reassignment PN* and that manufacturing and marketing of older microphones should cease six months after release of the *Channel Reassignment PN*.[698] We recognize that it is important to provide manufacturers with sufficient time to design new products, obtain Commission certification, and commence manufacturing. It is equally important to allow manufacturers to sell existing devices that allow the public to continue providing service until new products are available in the marketplace. The cutoff dates that we adopt for certification, manufacturing and marketing of wireless microphones appropriately balance these two goals. Manufacturers will not know what band plan they need to design and manufacture to until after the incentive auction is concluded, and it would be unreasonable to require that only certification applications complying with the new rules be accepted at the time the *Channel Reassignment PN* is released. Broadcast stations will be vacating the 600 MHz band over a 39 month period after the release of the *Channel Reassignment PN*, and new wireless operations will be built out gradually as broadcast stations leave the band and most likely continuing beyond the 39 month transition period. It would be unreasonable to cut off manufacturing and marketing six months into the 39 month transition period since this would deny the public access to devices that would allow them to continue to provide service. We conclude that the cutoff dates we have chosen will encourage manufacturers to concentrate on developing wireless microphones that operate in compliance with new Part 74 and Part 15 rules and ensure that manufacturers cease making and marketing equipment that cannot be legally used after a certain date.[699]

288. Mobile Future agrees with the proposal that if a wireless microphone is certified to operate in any portion of the 600 MHz service band, it may no longer be marketed or operated after the specified cutoff dates, even if it could be tuned to operate outside the 600 MHz service band.[700] Sennheiser, Shure and Wireless Microphone Alliance of America disagree and argue that this approach would harm consumers by denying them the use of equipment that would otherwise have a long life and which users can re-tune to operate on permissible frequencies.[701] Sennheiser argues that the Commission did not impose a similar requirement on white space devices,[702] and Shure suggests that wireless microphone users should have access to the 600 MHz service band until commercial wireless services commence operations and that microphone users can check databases manually to determine when and where wireless services have begun.[703] We are adopting different transition rules for wireless microphones in the 600 MHz service band than for white space devices because in the *Incentive Auction R&O* the Commission decided that wireless microphones would have a hard date for ceasing operations in that band, but that white space devices could continue operating at locations where wireless licensees have not commenced operations. We understand that consumers may not understand the need to forego the use of equipment in the 600 MHz band that could otherwise be used for many years, but the Commission had to balance this harm to individual users against the need to protect new wireless services from harmful

[697] *See* Sennheiser Comments at 21.

[698] *See* CTIA Comments at 43-44, Mobile Future Comments at 7-8.

[699] CP Communications argues that wireless microphone users should be compensated for the cost of replacing their wireless microphone inventory when that equipment has more years of useful life. *See* CP Communications Reply Comments at 9-10. The Commission rejected this argument in the *Second Order on Reconsideration*. *See Second Order on Reconsideration*, 30 FCC Rcd at 6805, para. 130.

[700] *See* Mobile Future Comments at 8.

[701] *See* Sennheiser Comments at 21, Shure Comments at 41, Wireless Microphone Alliance of America Reply Comments at 3.

[702] *See* Sennheiser Reply Comments at 23-24.

[703] *See* Shure Comments at 39-41.

interference.

V. PROCEDURAL MATTERS

A. Final Regulatory Flexibility Analysis

289. The Final Regulatory Flexibility Analysis, required by the Regulatory Flexibility Act, *see* 5 U.S.C. § 604, is contained in Appendix C.

B. Paperwork Reduction Act

290. This document contains modified information collection requirements subject to the Paperwork Reduction Act of 1995 (PRA), Public Law 104-13. It will be submitted to the Office of Management and Budget (OMB) for review under Section 3507(d) of the PRA. OMB, the general public, and other Federal agencies are invited to comment on the new or modified information collection requirements contained in this proceeding. In addition, we note that pursuant to the Small Business Paperwork Relief Act of 2002, Public Law 107-198, *see* 44 U.S.C. 3506(c)(4), we previously sought specific comment on how the Commission might further reduce the information collection burden for small business concerns with fewer than 25 employees.

291. We have assessed the effects of the policies adopted in this Report and Order with regard to information collection burdens on small business concerns, and find that these policies will benefit many companies with fewer than 25 employees by providing unlicensed white space devices and unlicensed wireless microphones with access to spectrum in the television broadcasting band and the 600 MHz band, while at the same time protecting licensed users from harmful interference. In addition, we have described impacts that might affect small businesses, which includes most businesses with fewer than 25 employees, in the Final Regulatory Flexibility Analysis in Appendix C.

C. Congressional Review Act

292. The Commission will send a copy of this Report and Order to Congress and the Government Accountability Office pursuant to the Congressional Review Act.

D. Contact Persons

293. For additional information concerning this Report and Order, please contact Mr. Hugh L. Van Tuyl at (202) 418-7506, or Hugh.VanTuyl@fcc.gov.

VI. ORDERING CLAUSES

294. Accordingly, IT IS ORDERED that, pursuant to the authority contained in Sections 4(i), 302, 303(e), 303(f), and 307 of the Communications Act of 1934, as amended, and sections 6403 and 6407 of the Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, 126 Stat. 156, 47 U.S.C. §§ 154(i), 302, 303(e), 303(f), 307, 1452, and 1454, this Report and Order IS HEREBY ADOPTED.

295. IT IS FURTHER ORDERED that Parts 15, 27, 74 and 95 of the Commission's rules ARE AMENDED as specified in Appendix B, and such rule amendments WILL BECOME EFFECTIVE 30 days after the date of publication in the *Federal Register*, except for Sections 15.713(b)(2)(iv)-(v), 15.713(j)(4), 15.713(j)(10), 15.713(j)(11), 15.715(n), 15.715(o), 15.715(p), 15.715(q), 27.1302 and 95.1111(d) which contain new or modified information collection requirements that require approval by the OMB under the PRA and WILL BECOME EFFECTIVE after the Commission publishes a notice in the *Federal Register* announcing such approval and the relevant effective date.

296. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of the Report and Order, including the Final Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the U.S. Small Business Administration.

297. IT IS FURTHER ORDERED that the Commission SHALL SEND a copy of the Report and Order in a report to be sent to Congress and the Government Accountability Office pursuant to the Congressional Review Act, see 5 U.S.C. §801(a)(1)(A).

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

Appendix A

Final Rules

For the reasons set forth in the preamble, the Federal Communications Commission amends parts 2, 15, 27, 74, and 95 of Title 47 of the Code of Federal Regulations to read as follows:

1. The authority citation for part 2 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 302a, 303, and 336, unless otherwise noted

2. Section 2.106 is amended by revising footnote 246 to the table of allocations to read as follows:

§ 2.106 Table of Frequency Allocations.

* * * * *

US246 No station shall be authorized to transmit in the following bands: 73-74.6 MHz, 608-614 MHz, except for medical telemetry equipment[1] and white space devices,[2] 1400-1427 MHz, 1660.5-1668.4 MHz, 2690-2700 MHz, 4990-5000 MHz, 10.68-10.7 GHz, 15.35-15.4 GHz, 23.6-24 GHz, 31.3-31.8 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz, 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, 250-252 GHz.

[1]Medical telemetry equipment shall not cause harmful interference to radio astronomy operations in the band 608-614 MHz and shall be coordinated under the requirements found in 47 CFR 95.1119.

[2]White space devices shall not cause harmful interference to radio astronomy operations in the band 608-614 and shall not operate within the areas described in 47 CFR 15.712(h).

* * * * *

3. The authority citation for part 15 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 302, 303, 304, 307, 336, and 544A.

4. Section 15.37 is amended by adding new paragraphs (i) and (j) to read as follows:

§ 15.37 Transition provisions for compliance with the rules.

* * * * *

(i) Wireless microphones for which an application for certification is filed beginning nine months after the release of the *Channel Reassignment PN,* as defined in § 73.3700(a)(2) of this chapter, or no later than **[24 months after the effective date of the rules]**, whichever occurs first, must comply with the requirements of § 15.236. Manufacturing and marketing of wireless microphones that would not comply with the rules for operation in § 15.236 must cease 18 months after release of the *Channel Reassignment PN* or no later than **[33 months after the effective date of rules]**, whichever occurs first. A wireless microphone that is certified to operate in any portion of the 600 MHz service band as defined in § 15.236(a) may no longer be marketed or operated after the specified cutoff dates, even if it could be tuned to operate on frequencies outside of this band.

(j) White space devices for which a certification application is filed beginning **[six months after the effective date of the rules]** must comply with the channel push requirements in § 15.711(i) of this part. White space devices that are imported or marketed beginning **[nine months after the effective date of the rules]** must comply with this requirement. White space devices that do not comply with this requirement must cease operation no later than **[one year from the effective date of the rules].**

5. Section 15.38 is amended by adding a new paragraph (h) to read as follows:

§ 15.38 Incorporation by reference.

* * * * *

(h) The following document is available from the European Telecommunications Standards Institute, 650 Route des Lucioles, F-06921 Sophia Antipolis Cedex, France, or at *http://www.etsi.org/deliver/etsi_en/300400_300499/30042201/01.04.02_60/en_30042201v010402p.pdf*: ETSI EN 300 422-1 V1.4.2 (2011-08): "*Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 1: Technical characteristics and methods of measurement,*" August 8, 2011, IBR approved for § 15.236.

6. Section 15.205 amended by adding a new paragraph (d)(10) to read as follows:

§ 15.205 Restricted bands of operation.

* * * * *

(d) * * *

(10) White space devices operating under subpart H of this part are exempt from complying with the requirements of this section for the 608-614 MHz band.

* * * * *

7. A new Section 15.236 added to read as follows:

§ 15.236 Operation of wireless microphones in the bands 54-72 MHz, 76-88 MHz, 174-216 MHz, 470-608 MHz and 614-698 MHz.

(a) *Definitions*. The following definitions apply in this section.

(1) *Wireless Microphone*. An intentional radiator that converts sound into electrical audio signals that are transmitted using radio signals to a receiver which converts the radio signals back into audio signals that are sent through a sound recording or amplifying system. Wireless microphones may be used for cue and control communications and synchronization of TV camera signals as defined in § 74.801 of this chapter. Wireless microphones do not include auditory assistance devices as defined in § 15.3(a) of this part.

(2) *600 MHz duplex gap.* An 11 megahertz guard band that separates part 27 600 MHz service uplink and downlink frequencies, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(3) *600 MHz guard bands*. Designated frequency bands that prevent interference between licensed

services in the 600 MHz service band and either the television bands or channel 37, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(4) *600 MHz service band*. Frequencies that will be reallocated and assigned for 600 MHz services pursuant to part 27, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(5) *Spectrum Act*. Title VI of the Middle Class Tax Relief and Job Creation Act of 2012 (Pub. L. No. 112-96).

Note to paragraphs (2), (3) and (4): The specific frequencies will be determined in light of further proceedings pursuant to GN Docket No. 12-268 and the rules will be updated accordingly pursuant to a future public notice.

(b) Operation under this section is limited to wireless microphones as defined in this section.

(c) Operation is permitted in the following frequency bands.

(1) Channels allocated and assigned for the broadcast television service. The highest channel available will depend on the outcome of the incentive auction.

(2) Frequencies in the 600 MHz service band on which a 600 MHz service licensee has not commenced operations. Operation on these frequencies must cease no later than the end of the post-auction transition period as defined in § 27.4 of this chapter. Operation must cease immediately if harmful interference occurs to a 600 MHz service licensee.

(3) The upper six megahertz segment of the 600 MHz duplex gap.

(4) The 600 MHz guard band between television and 600 MHz service downlink services, excluding the upper one megahertz segment.

(5) The 600 MHz guard bands adjacent to channel 37, excluding the one megahertz segments furthest from channel 37.

(6) Prior to operation in the frequencies identified in paragraphs (c)(2)-(5) of this section, wireless microphone users shall rely on the white space databases in Part 15, Subpart H to determine that their intended operating frequencies are available for unlicensed wireless microphone operation at the location where they will be used. Wireless microphone users must register with and check a white space database to determine available channels prior to beginning operation at a given location. A user must re-check the database for available channels if it moves to another location.

(d) The maximum radiated power shall not exceed the following values:

(1) In the bands allocated and assigned for broadcast television and in the 600 MHz service band: 50 mW EIRP

(2) In the 600 MHz guard bands including the duplex gap: 20 mW EIRP

(e) Operation is limited to locations separated from licensed services by the following distances.

(1) Four kilometers outside the following protected service contours of co-channel TV stations.

Type of station	Protected contour		
	Channel	Contour (dBu)	Propagation curve
Analog: Class A TV, LPTV, translator and booster	Low VHF (2-6)	47	F(50,50)
	High VHF (7-13)	56	F(50,50)
	UHF (14-51)	64	F(50,50)
Digital: Full service TV, Class A TV, LPTV, translator and booster	Low VHF (2-6)	28	F(50,90)
	High VHF (7-13)	36	F(50,90)
	UHF (14-51)	41	F(50,90)

(2) The following distances outside of the area where a 600 MHz service licensee has commenced operation.

Type of station	Separation distance in kilometers	
	Co-channel	Adjacent channel
Base	7	0.2
Mobile	35	31

(f) The operating frequency within a permissible band of operation as defined in paragraph (c) must comply with the following requirements.

(1) The frequency selection shall be offset from the upper or lower band limits by 25 kHz or an integral multiple thereof.

(2) One or more adjacent 25 kHz segments within the assignable frequencies may be combined to form a channel whose maximum bandwidth shall not exceed 200 kHz. The operating bandwidth shall not exceed 200 kHz.

(3) The frequency tolerance of the carrier signal shall be maintained within +/- 0.005% of the operating frequency over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. Battery operated equipment shall be tested using a new battery.

(g) Emissions within the band from one megahertz below to one megahertz above the carrier frequency shall comply with the emission mask in Section 8.3 of ETSI EN 300 422-1 V1.4.2 (2011-08), *Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 1: Technical characteristics and methods of measurement.* Emissions outside this band shall comply with the limit specified at the edges of the ETSI mask.

8. Subpart H is revised to read as follows:

Subpart H—White Space Devices

Contents

§ 15.701 Scope.

This subpart sets forth the regulations for unlicensed white space devices. These devices are unlicensed intentional radiators that operate on available TV channels in the broadcast television frequency bands, the 600 MHz band (including the guard bands and duplex gap), and in 608-614 MHz (channel 37).

§ 15.703 Definitions.

(a) *600 MHz duplex gap.* An 11 megahertz frequency band that separates part 27 600 MHz service uplink and downlink frequencies, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(b) *600 MHz guard bands*. Designated frequency bands that prevent interference between licensed services in the 600 MHz service band and either the television bands or channel 37, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(c) *600 MHz service band*. Frequencies that will be reallocated and assigned for 600 MHz band services pursuant to part 27, in accordance with the terms and conditions established in GN Docket No. 12-268, pursuant to section 6403 of the Spectrum Act.

(d) *Available channel.* A channel which is not being used by an authorized service and is acceptable for use by the device at its geographic location under the provisions of this subpart.

(e) *Contact verification signal.* An encoded signal broadcast by a fixed or Mode II device for reception by Mode I devices to which the fixed or Mode II device has provided a list of available channels for operation. Such signal is for the purpose of establishing that the Mode I device is still within the reception range of the fixed or Mode II device for purposes of validating the list of available channels used by the Mode I device and shall be encoded to ensure that the signal originates from the device that provided the list of available channels. A Mode I device may respond only to a contact verification signal from the fixed or Mode II device that provided the list of available channels on which it operates. A fixed or Mode II device shall provide the information needed by a Mode I device to decode the contact verification signal at the same time it provides the list of available channels.

(f) *Fixed device.* A white space device that transmits and/or receives radiocommunication signals at a specified fixed location. A fixed device may select channels for operation from a list of available channels provided by a white space database, and initiate and operate a network by sending enabling signals to one or more fixed devices and/or personal/portable devices. Fixed devices may provide to a Mode I personal/portable device a list of available channels on which the Mode I device may operate, including channels on which the Mode I device but not the fixed device may operate.

(g) *Geo-location capability.* The capability of a white space device to determine its geographic coordinates and geo-location uncertainty. This capability is used with a white space database approved by the FCC to determine the availability of spectrum at a white space device's location.

(h) *Less congested area.* Geographic areas where at least half of the TV channels for the bands that will continue to be allocated and assigned only for broadcast service are unused for broadcast and other protected services and available for white space device use. Less congested areas in the UHF TV band are also considered to be less congested areas in the 600 MHz service band.

(i) *Mode I personal/portable device.* A personal/portable white space device that does not use an internal geo-location capability and access to a white space database to obtain a list of available channels. A Mode I device must obtain a list of available channels on which it may operate from either a fixed white space device or Mode II personal/portable white space device. A Mode I device may not initiate a network of fixed and/or personal/portable white space devices nor may it provide a list of available channels to another Mode I device for operation by such device.

(j) *Mode II personal/portable device*. A personal/portable device that uses an internal geo-location capability and access to a white space database, either through a direct connection to the Internet or through an indirect connection to the Internet by way of fixed device or another Mode II device, to obtain a list of available channels. A Mode II device may select a channel itself and initiate and operate as part of a network of white space devices, transmitting to and receiving from one or more fixed devices or personal/portable devices. A Mode II personal/portable device may provide its list of available channels to a Mode I personal/portable device for operation on by the Mode I device.

(k) *Network initiation.* The process by which a fixed or Mode II white space device sends control signals to one or more fixed white space devices or personal/portable white space devices and allows them to begin communications.

(l) *Operating channel.* An available channel used by a white space device for transmission and/or reception.

(m) *Personal/portable device.* A white space device that transmits and/or receives radiocommunication signals on available channels at unspecified locations that may change.

(n) *Receive site.* The location where the signal of a full service television station is received for rebroadcast by a television translator or low power TV station, including a Class A TV station, or for distribution by a Multiple Video Program Distributor (MVPD) as defined in 47 U.S.C. 602(13).

(o) *Sensing only device.* A personal/portable white space device that uses spectrum sensing to determine a list of available channels. Sensing only devices may transmit on any available channels in the frequency bands 512-608 MHz (TV channels 21-36) and 614-698 MHz (TV channels 38-51).

(p) *Spectrum Act*. Title VI of the Middle Class Tax Relief and Job Creation Act of 2012 (Pub. L. No. 112-96).

(q) *Spectrum sensing.* A process whereby a white space device monitors a television channel to detect whether the channel is occupied by a radio signal or signals from authorized services.

(r) *Television bands.* The portions of the broadcast television frequency bands at 54-72 MHz (TV channels 2-4), 76-88 MHz (TV channels 5-6), 174-216 MHz (TV channels 7-13), 470-608 MHz (channels 14-36) and 614-698 MHz (channels 38-51) that will be allocated and assigned to broadcast television licensees consistent with the outcome of the auction conducted pursuant to *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, GN Docket No. 12-268 (FCC 14-50) (rel. June 2, 2014). Channels 2-13 are in the VHF band, and channel 14-51 are in the UHF band.

(s) *White space database.* A database system approved by the Commission that maintains records on authorized services and provides lists of available channels to white space devices and unlicensed wireless microphone users.

Note to paragraphs (a), (b) and (c): The specific frequencies will be determined in light of further proceedings pursuant to GN Docket No. 12-268 and the rules will be updated accordingly pursuant to a future public notice.

§ 15.705 Cross reference.

(a) The provisions of subparts A, B, and C of this part apply to white space devices, except where specific provisions are contained in subpart H.

(b) The requirements of subpart H apply only to the radio transmitter contained in the white space device. Other aspects of the operation of a white space device may be subject to requirements contained elsewhere in this chapter. In particular, a white space device that includes a receiver that tunes within the frequency range specified in §15.101(b) and contains digital circuitry not directly associated with the radio transmitter is also subject to the requirements for unintentional radiators in subpart B.

§ 15.706 Information to the user.

(a) In addition to the labeling requirements contained in § 15.19, the instructions furnished to the user of a white space device shall include the following statement, placed in a prominent location in the text of the manual:

This equipment has been tested and found to comply with the rules for white space devices, pursuant to part 15 of the FCC rules. These rules are designed to provide reasonable protection against harmful interference. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

(1) Reorient or relocate the receiving antenna.
(2) Increase the separation between the equipment and receiver.
(3) Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
(4) Consult the manufacturer, dealer or an experienced radio/TV technician for help.

(b) In cases where the manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

§ 15.707 Permissible channels of operation.

(a)(1) All white space devices are permitted to operate on available channels in the frequency bands 470-698 MHz (TV channels 14-51), subject to the interference protection requirements in §§ 15.711 and 15.712, except as provided in paragraph (a)(2) of this section.

(2) White space devices are not permitted to operate on the first channel above and below TV channel 37 (608-614 MHz) that are available (*i.e.*, not occupied by an authorized service) until **[18**

months after the effective date of this rule] but no later than release of the Channel Reassignment Public Notice upon completion of the broadcast television spectrum incentive auction, as defined in § 73.3700 (a) of this chapter. If a channel is not available both above and below channel 37, operation is prohibited on the first two channels nearest to channel 37. These channels will be identified and protected in the white space database(s).

(3) *600 MHz guard band.* In the 600 MHz guard band between television and 600 MHz service downlink bands, white space devices may only operate immediately adjacent to the television band with a maximum bandwidth of 6 megahertz. White space devices are prohibited from operating in the three megahertz segment adjacent to the 600 MHz service band.

(4) *600 MHz duplex gap.* In the 600 MHz duplex gap, white space devices shall only operate in the 6 megahertz segment immediately adjacent to the 600 MHz service uplink band.

(5) *600 MHz service band*. White space devices may operate on frequencies in the 600 MHz service band in areas where 600 MHz band licensees have not commenced operations, as defined in part 27 of this chapter.

(6) *Channel 37 guard band*. White space devices are not permitted to operate in either three megahertz segment above or below channel 37 if that spectrum is adjacent to the 600 MHz service band.

(b) Only fixed white space devices that communicate only with other fixed white space devices may operate on available channels in the bands 54-72 MHz (TV channels 2-4), 76-88 MHz (TV channels 5 and 6), and 174-216 MHz (TV channels 7-13), subject to the interference protection requirements in §§ 15.711 and 15.712.

§ 15.709 General technical requirements.

(a) *Radiated power limits.* The maximum white space device EIRP per 6 MHz shall not exceed the limits of paragraphs (2), (3), and (4) of this paragraph.

(1) General requirements.

(i) White space devices may be required to operate with less power than the maximum permitted to meet the co-channel and adjacent channel separation requirements of § 15.712 of this part.

(ii) Mode I personal/portable devices are limited to 40 mW, if the white space device that controls it is limited to 40 mW.

(2) TV bands and 600 MHz service band.

(i) Fixed devices: Up to 4 W (36 dBm) EIRP, and up to 10 W (40 dBm) EIRP in less congested areas in the TV bands and 600 MHz service band at locations where they meet the co-channel and adjacent channel separation distances of §§ 15.712(a)(2) and 15.712(i) of this part, respectively. Operation in the 602-620 MHz band is limited to a maximum of 4 W (36 dBm) EIRP.

(ii) Personal/Portable devices: Up to 100 mW (20 dBm) EIRP.

(3) 608-614 MHz band (channel 37).

(i) Fixed devices: Up to 4 W (36 dBm) EIRP.

(ii) Personal/Portable devices: Up to 100 mW (20 dBm) EIRP.

(4) 600 MHz duplex gap and guard bands. Up to 40 mW (16 dBm) EIRP.

(b) *Technical limits.*

(1) Fixed white space devices.

(i) Technical limits for fixed white space devices are shown in the table and subject to the requirements of this section.

(ii) For operation at EIRP levels of 36 dBm (4000 mW) or less, fixed white space devices may operate at EIRP levels between the values shown in the table provided that the conducted power and the conducted power spectral density (PSD) limits are linearly interpolated between the values shown and the adjacent channel emission limit of the higher value shown in the table is met. Operation at EIRP levels above 36 dBm (4000 mW) shall follow the requirements for 40 dBm (10,000 mW).

EIRP (6 MHz)	Conducted power limit (6 MHz)	Conducted PSD limit[1] (100 kHz)	Conducted adjacent channel emission limit (100 kHz)
16 dBm (40 mW)	10 dBm (10 mW)	-7.4 dBm	-62.8 dBm
20 dBm (100 mW)	14 dBm (25 mW)	-3.4 dBm	-58.8 dBm
24 dBm (250 mW)	18 dBm (63 mW)	0.6 dBm	-54.8 dBm
28 dBm (625 mW)	22 dBm (158 mW)	4.6 dBm	-50.8 dBm
32 dBm (1600 mW)	26 dBm (400 mW)	8.6 dBm	-46.8 dBm
36 dBm (4000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm
40 dBm (10000 mW)	30 dBm (1000 mW)	12.6 dBm	-42.8 dBm

[1] The conducted power spectral density from a fixed white space device shall not be greater than the values shown in the table when measured in any 100 kHz band during any time interval of continuous transmission, except that a 40 mW fixed white space device operating in a four megahertz channel within a seven megahertz guard band must comply with a conducted power spectral density limit of -5.4 dBm.

(2) Personal/Portable white space devices. Technical limits for personal/portable white space devices are shown in the table and subject to the requirements of this section.

EIRP (6 MHz)	Radiated PSD limit EIRP[1] (100 kHz)	Radiated Adjacent channel emission limit EIRP (100 kHz)
16 dBm (40 mW)	-1.4 dBm	-56.8 dBm
20 dBm (100 mW)	2.6 dBm	-52.8 dBm

[1] The radiated power spectral density from a personal/portable white space device shall not be greater than the values shown in the table when measured in any 100 kHz band during any time interval of continuous transmission, except that a 40 mW white space device operating in a four megahertz channel within a seven megahertz guard band must comply with a radiated power spectral density limit of 0.6 dBm.

(3) Sensing-only devices. Sensing-only white space devices are limited to 17 dBm (50 mW) EIRP and are subject to the requirements of this paragraph and of § 15.717 of this part.

(i) Radiated PSD limit: -0.4 dBm EIRP.

(ii) Adjacent channel emission limit: -55.8 dBm EIRP.

(c) *Conducted power limits*.

(1) The conducted power, PSD and adjacent channel limits for fixed white space devices operating at up to 36 dBm (4000 milliwatts) EIRP shown in the table in paragraph (b)(1) of this section are based on a maximum transmitting antenna gain of 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the maximum conducted output power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(2) The conducted power, PSD and adjacent channel limits for fixed white space devices operating at greater than 36 dBm (4000 milliwatts) EIRP shown in the table in paragraph (b)(1) of this section are based on a maximum transmitting antenna gain of 10 dBi. If transmitting antennas of directional gain greater than 10 dBi are used, the maximum conducted output power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 10 dBi.

(3) Maximum conducted output power is the total transmit power over the occupied bandwidth delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (*e.g.*, alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) White space devices connected to the AC power line are required to comply with the conducted limits set forth in § 15.207.

(d) *Emission limits*.

(1) The adjacent channel emission limits shown in the tables in paragraphs (b)(1) and (b)(2) of this section apply in the six megahertz channel immediately adjacent to each white space channel or group of contiguous white space channels in which the white space device is operating.

(2) At frequencies beyond the six megahertz channel immediately adjacent to each white space channel or group of contiguous white space channels in which the white space device is operating the white space device shall meet the requirements of § 15.209.

(3) Emission measurements in the adjacent bands shall be performed using a minimum resolution bandwidth of 100 kHz with an average detector. A narrower resolution bandwidth may be employed near the band edge, when necessary, provided the measured energy is integrated to show the total power over 100 kHz.

(e) *Transmit power control.* White space devices shall incorporate transmit power control to limit their operating power to the minimum necessary for successful communication. Applicants for equipment certification shall include a description of the device's transmit power control feature mechanism.

(f) *Security*. White space devices shall incorporate adequate security measures to prevent the devices from accessing databases not approved by the FCC and to ensure that unauthorized parties cannot modify the device or configure its control features to operate in a manner inconsistent with the rules and protection criteria set forth in this subpart.

(g) *Antenna requirements.*

(1) *Fixed white space devices*.

(i) *Above ground level*. The transmit antenna height shall not exceed 30 meters above ground level, except that the antenna height may not exceed 10 meters above ground level for fixed white space devices operating in the TV bands or guard band at 40 mW EIRP or less or operating across multiple contiguous TV channels at 100 mW EIRP or less.

(ii) *Height above average terrain (HAAT)*. The transmit antenna shall not be located where the height above average terrain is more than 250 meters. The HAAT is to be calculated by the white space database using the methodology in § 73.684(d) of this chapter.

(2) Personal/portable devices shall have permanently attached transmit and receive antenna(s).

(3) Sensing-only white space devices operating under the provisions of § 15.717 of this subpart.

(i) The provisions of § 15.204(c)(4) do not apply to an antenna used for transmission and reception/spectrum sensing.

(ii) Compliance testing for white space devices that incorporate a separate sensing antenna shall be performed using the lowest gain antenna for each type of antenna to be certified.

(h) *Compliance with radio frequency exposure requirements*.

(1) *Fixed white space devices*. To ensure compliance with the Commission's radio frequency exposure requirements in §§ 1.1307(b), 2.1091 and 2.1093 of this chapter, fixed white space devices shall be accompanied by instructions on measures to take to ensure that persons maintain a distance of at least 40 cm from the device, as well as any necessary hardware that may be needed to implement that protection. These instructions shall be submitted with the application for certification.

(2) Personal/portable white space devices that meet the definition of portable devices under § 2.1093 of this chapter and that operate with a source-based time-averaged output of less than 20 mW will not be subject to routine evaluation for compliance with the radio frequency exposure guidelines in §§ 1.1307(b), 2.1091 and 2.1093 of this chapter, while devices that operate with a source-based time-average output power greater than 20 mW will be subject to the routine evaluation requirements.

§ 15.711 Interference avoidance methods.

Except as provided in § 15.717 of this part, channel availability for a white space device is determined based on the geo-location and database access method described in paragraphs (a) through (e) of this section.

(a) *Geo-location required.* White space devices shall rely on a geo-location capability and database access mechanism to protect the following authorized service in accordance with the interference protection requirements of § 15.712: digital television stations, digital and analog Class A, low power, translator and booster stations; translator receive operations; fixed broadcast auxiliary service links; private land mobile service/commercial radio service (PLMRS/CMRS) operations; offshore radiotelephone service; low power auxiliary services authorized pursuant to §§ 74.801 through 74.882 of this chapter, including licensed wireless microphones; MVPD receive sites; wireless medical telemetry service (WMTS); radio astronomy service (RAS); 600 MHz service band licensees where they have commenced operations; and unlicensed wireless microphones used by venues of large events and

productions/shows as provided under § 15.713(j)(9). In addition, protection shall be provided in border areas near Canada and Mexico in accordance with § 15.712(g).

(b) *Geo-location requirement.*

(1) *Accuracy*. Fixed white space devices that incorporate a geo-location capability and Mode II devices shall determine their location and their geo-location uncertainty (in meters), with a confidence level of 95%.

(2) *Reference datum*. All geographic coordinates shall be referenced to the North American Datum of 1983 (NAD 83).

(c) *Requirements for fixed white space devices*.

(1) The geographic coordinates and antenna height above ground level of a fixed white space device shall be determined at the time of installation and first activation from a power-off condition by either an incorporated geo-location capability or a professional installer. This information may be stored internally in the white space device. In the case of professional installation, the party who registers the fixed white space device in the database will be responsible for assuring the accuracy of the entered coordinates and antenna height. If a fixed white space device is moved to another location or if its stored coordinates become altered, the operator shall re-establish the device's:

(i) Geographic location and antenna height above ground level and store this information in the white space device either by means of the device's incorporated geo-location capability or through the services of a professional installer; and

(ii) Registration with the database based on the device's new coordinates and antenna height above ground level.

(2)(i) Each fixed white space device must access a white space database over the Internet to determine the available channels and the corresponding maximum permitted power for each available channel that is available at its geographic coordinates, taking into consideration the fixed device's antenna height above ground level and geo-location uncertainty, prior to its initial service transmission at a given location.

(ii) Operation is permitted only on channels and at power levels that are indicated in the database as being available for each white space device. Operation on a channel must cease immediately or power must be reduced to a permissible level if the database indicates that the channel is no longer available at the current operating level.

(iii) Each fixed white space devices shall access the database at least once a day to verify that the operating channels continue to remain available. Each fixed white space device must adjust its use of channels in accordance with channel availability schedule information provided by its database for the 48-hour period beginning at the time the device last accessed the database for a list of available channels.

(iv) *Fixed devices without a direct connection to the Internet.* A fixed white space device may not operate on channels provided by a white space database for another fixed device. A fixed white space device that has not yet been initialized and registered with a white space database consistent with § 15.713 of this part, but can receive the transmissions of another fixed white space device, may transmit to that other fixed white space device on either a channel that the other white space device has transmitted on or on a channel which the other white space device indicates is available for use to access the database to register its location and receive a list of channels that are available for it to use. Subsequently, the

newly registered fixed white space device must only use the channels that the database indicates are available for it to use.

(d) *Requirements for Mode II personal/portable white space devices.*

(1) The geographic coordinates of a Mode II personal/portable white space device shall be determined by an incorporated geo-location capability prior to its initial service transmission at a given location and each time the device is activated from a power-off condition to determine the available channels and the corresponding maximum permitted power for each available channel at its geographic coordinates, taking into consideration the device's geo-location uncertainty. The location must be checked at least once every 60 seconds while in operation, except while in sleep mode, *i.e.*, in a mode in which the device is inactive but is not powered-down.

(2) Each Mode II personal/portable white space device must access a white space database over the Internet to obtain a list of available channels for its location. The device must access the database for an updated available channel list if its location changes by more than 100 meters from the location at which it last established its available channel list.

(3) Operation is permitted only on channels and at power levels that are indicated in the database as being available for the Mode II personal/portable white space device. Operation on a channel must cease immediately or power must be reduced to a permissible level if the database indicates that the channel is no longer available at the current operating level.

(4) A Mode II personal/portable white space device that has been in a powered state shall re-check its location and access the database daily to verify that the operating channel(s) and corresponding power levels continue to be available. Mode II personal/portable devices must adjust their use of channels and power levels in accordance with channel availability schedule information provided by their database for the 48-hour period beginning at the time of the device last accessed the database for a list of available channels.

(5) A Mode II personal/portable device may load channel availability information for multiple locations, (*i.e.,* in the vicinity of its current location) and use that information to define a geographic area within which it can operate on the same available channels at all locations. For example a Mode II personal/portable white space device could calculate a bounded area in which a channel or channels are available at all locations within the area and operate on a mobile basis within that area. A Mode II white space device using such channel availability information for multiple locations must contact the database again if/when it moves beyond the boundary of the area where the channel availability data is valid.

(e) *Requirements for Mode I personal/portable white space devices.*

(1) A Mode I personal/portable white space device may only transmit upon receiving a list of available channels from a fixed or Mode II white space device. A fixed or Mode II white space device may provide a Mode I device with a list of available channels only after it contacts its database, provides the database the FCC Identifier (FCC ID) of the Mode I device requesting available channels, and receives verification that the FCC ID is valid for operation.

(2) A Mode II device must provide a list of channels to the Mode I device that is the same as the list of channels available to the Mode II device.

(3) A fixed device may provide a list of available channels to a Mode I device only if the fixed device HAAT as verified by the white space database does not exceed 106 meters. The fixed device must provide a list of available channels to the Mode I device that is the same as the list of channels available

to the fixed device, except that a Mode I device may operate only on those channels that are permissible for its use under § 15.707 of this part. A fixed device may also obtain from a white space database and provide to a Mode I personal/portable white space device, a separate list of available channels that includes adjacent channels available to a Mode I personal/portable white space device, but not a fixed white space device.

(4) To initiate contact with a fixed or Mode II device, a Mode I device may transmit on an available channel used by the fixed or Mode II white space device or on a channel the fixed or Mode II white space device indicates is available for use by a Mode I device. At least once every 60 seconds, except when in sleep mode (*i.e.,* a mode in which the device is inactive but is not powered-down), a Mode I device must either receive a contact verification signal from the Mode II or fixed white space device that provided its current list of available channels or contact a Mode II or fixed white space device to re-verify/re-establish channel availability. A Mode I device must cease operation immediately if it does not receive a contact verification signal or is not able to re-establish a list of available channels through contact with a fixed or Mode II device on this schedule. If a fixed or Mode II white space device loses power and obtains a new channel list, it must signal all Mode I devices it is serving to acquire and use a new channel list.

(f) *Display of available channels.* A white space device must incorporate the capability to display a list of identified available channels and its operating channels.

(g) *Identifying information.* Fixed white space devices shall transmit identifying information. The identification signal must conform to a standard established by a recognized industry standards setting organization. The identification signal shall carry sufficient information to identify the device and its geographic coordinates.

(h) *Continuing operation.* If a fixed or Mode II personal/portable white space device fails to successfully contact the white space database during any given day, it may continue to operate until 11:59 p.m. of the following day at which time it must cease operations until it re-establishes contact with the white space database and re-verifies its list of available channels.

(i) *Push notifications.* White space device manufacturers and database administrators must implement the push notification requirements of paragraphs (i)(1)-(2) of this section, and may also implement a system that pushes additional updated channel availability information from the database to white space devices.

(1) In response to a request for immediate access to a channel by a licensed wireless microphone user, white space database administrators are required to share the licensed microphone channel registration information to all other white space database administrators within 10 minutes of receiving each wireless microphone registration.

(2) White space database administrators shall push updated available channel lists to fixed and Mode II personal/portable white space devices within 20 minutes of receiving the notification required by paragraph (i)(1) of this section. The information need only be pushed to white space devices that are located within the separation distances, specified in § 15.712(f) of this part, for each licensed wireless microphone registration received.

(3) White space database administrators must update their systems to comply with these requirements no later than [**12 months after the effective date of the rules**].

(j) *Security.* (1) White space devices shall incorporate adequate security measures to ensure that they are capable of communicating for purposes of obtaining lists of available channels only with databases operated by administrators authorized by the Commission, and to ensure that communications

between white space devices and databases are secure to prevent corruption or unauthorized interception of data. This requirement includes implementing security for communications between Mode I personal portable devices and fixed or Mode II devices for purposes of providing lists of available channels. This requirement applies to communications of channel availability and other spectrum access information between the databases and fixed and Mode II devices (it is not necessary for white space devices to apply security coding to channel availability and channel access information where they are not the originating or terminating device and that they simply pass through).

(2) Communications between a Mode I device and a fixed or Mode II device for purposes of obtaining a list of available channels shall employ secure methods that ensure against corruption or unauthorized modification of the data. When a Mode I device makes a request to a fixed or Mode II device for a list of available channels, the receiving device shall check with the white space database that the Mode I device has a valid FCC Identifier before providing a list of available channels. Contact verification signals transmitted for Mode I devices are to be encoded with encryption to secure the identity of the transmitting device. Mode I devices using contact verification signals shall accept as valid for authorization only the signals of the device from which they obtained their list of available channels.

(3) A white space database shall be protected from unauthorized data input or alteration of stored data. To provide this protection, the white space database administrator shall establish communications authentication procedures that allow fixed and Mode II white space devices to be assured that the data they receive is from an authorized source.

(4) Applications for certification of white space devices shall include a high level operational description of the technologies and measures that are incorporated in the device to comply with the security requirements of this section. In addition, applications for certification of fixed and Mode II white space devices shall identify at least one of the white space databases operated by a designated white space database administrator that the device will access for channel availability and affirm that the device will conform to the communications security methods used by that database.

§ 15.712 Interference protection requirements.

The separation distances in this section apply to fixed and personal/portable white space devices with a location accuracy of ±50 meters. These distances must be increased by the amount that the location uncertainty of a white space device exceeds ±50 meters.

(a) *Digital television stations, and digital and analog Class A TV, low power TV, TV translator and TV booster stations*:

(1) *Protected contour.* White space devices must protect digital and analog TV services within the contours shown in the following table. These contours are calculated using the methodology in § 73.684 of this chapter and the R-6602 curves contained in § 73.699 of this chapter.

Type of station	Protected contour		
	Channel	Contour (dBu)	Propagation curve
Analog: Class A TV, LPTV, translator and booster	Low VHF (2-6)	47	F(50,50)
	High VHF (7-13)	56	F(50,50)
	UHF (14-69)	64	F(50,50)
Digital: Full service TV, Class A TV, LPTV, translator and booster	Low VHF (2-6)	28	F(50,90)
	High VHF (7-13)	36	F(50,90)
	UHF (14-51)	41	F(50,90)

(2) *Required separation distance.* White space devices must be located outside the contours indicated in paragraph (a)(1) of this section of co-channel and adjacent channel stations by at least the minimum distances specified in the following tables.

(i) If a device operates between two defined power levels, it must comply with the separation distances for the higher power level.

(ii) White space devices operating at 40 mW EIRP or less are not required to meet the adjacent channel separation distances.

(iii) Fixed white space devices operating at 100 mW EIRP or less per 6 megahertz across multiple contiguous TV channels with at least 3 megahertz separation between the frequency band occupied by the white space device and adjacent TV channels are not required to meet the adjacent channel separation distances.

(iv) Fixed white space devices may only operate above 4 W EIRP in less congested areas as defined in § 15.703(h).

Mode II Personal/Portable White Space Devices

	Required separation in kilometers from co-channel digital or analog TV (full service or low power) protected contour	
	16 dBm (40 mW)	20 dBm (100 mW)
Communicating with Mode II or Fixed device	1.3	1.7
Communicating with Mode I device	2.6	3.4

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from co-channel digital or analog TV (full service or low power) protected contour*						
	16 dBm (40 mW)	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)
Less than 3	1.3	1.7	2.1	2.7	3.3	4.0	4.5
3 - 10	2.4	3.1	3.8	4.8	6.1	7.3	8.5
10 - 30	4.2	5.1	6.0	7.1	8.9	11.1	13.9
30 - 50	5.4	6.5	7.7	9.2	11.5	14.3	19.1
50 - 75	6.6	7.9	9.4	11.1	13.9	18.0	23.8
75 - 100	7.7	9.2	10.9	12.8	17.2	21.1	27.2
100 - 150	9.4	11.1	13.2	16.5	21.4	25.3	32.3
150 - 200	10.9	12.7	15.8	19.5	24.7	28.5	36.4
200-250	12.1	14.3	18.2	22.0	27.3	31.2	39.5

* When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 1.3 kilometers if the Mode I device operates at power levels no more than 40 mW EIRP or 1.7 kilometers if the Mode I device operates at power levels above 40 mW EIRP.

Personal/Portable White Space Devices

	Required separation in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour
	20 dBm (100 mW)
Communicating with Mode II or Fixed device	0.1
Communicating with Mode I device	0.2

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	Required separation in kilometers from adjacent channel digital or analog TV (full service or low power) protected contour*					
	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 W)	40 dBm (10 W)
Less than 3	0.1	0.1	0.1	0.1	0.2	0.2
3 - 10	0.1	0.2	0.2	0.2	0.3	0.4
10 - 30	0.2	0.3	0.3	0.4	0.5	0.6
30 - 50	0.3	0.3	0.4	0.5	0.7	0.8
50 - 75	0.3	0.4	0.5	0.7	0.8	0.9
75 - 100	0.4	0.5	0.6	0.8	1.0	1.1
100 - 150	0.5	0.6	0.8	0.9	1.2	1.3
150 - 200	0.5	0.7	0.9	1.1	1.4	1.5
200-250	0.6	0.8	1.0	1.2	1.5	1.7

* When communicating with a Mode I personal/portable white space device that operates at power levels above 40 mW EIRP, the required separation distances must be increased beyond the specified distances by 0.1 kilometers.

(3) *Fixed white space device antenna height.* Fixed white space devices must comply with the requirements of § 15.709(g) of this part.

(b) *TV translator, Low Power TV (including Class A) and Multi-channel Video Programming Distributor (MVPD) receive sites.*

(1) MVPD, TV translator station and low power TV (including Class A) station receive sites located outside the protected contour of the TV station(s) being received may be registered in the white space database if they are no farther than 80 km outside the nearest edge of the relevant contour(s). Only channels received over the air and used by the MVPD, TV translator station or low power/Class A TV station may be registered.

(2) White space devices may not operate within an arc of ±30 degrees from a line between a registered receive site and the contour of the TV station being received in the direction of the station's transmitter at a distance of up to 80 km from the edge of the protected contour of the received TV station for co-channel operation and up to 20 km from the registered receive site for adjacent channel operation, except that the protection distance shall not exceed the distance from the receive site to the protected contour.

(3) Outside of the ±30 degree arc defined in paragraph (b)(2) of this section:

(i) White space devices operating at 4 watts EIRP or less may not operate within 8 km from the receive site for co-channel operation and 2 km from the receive site for adjacent channel operation.

(ii) White Space devices operating with more than 4 watts EIRP may not operate within 10.2 km from the receive site for co-channel operation and 2.5 km from the receive site for adjacent channel operation.

(iii) For purposes of this section, a TV station being received may include a full power TV station, TV translator station or low power TV/Class A TV station.

(c) *Fixed Broadcast Auxiliary Service (BAS) Links*.

(1) For permanent BAS receive sites appearing in the Commission's Universal Licensing System or temporary BAS receive sites registered in the white space database, white space devices may not operate within an arc of ±30 degrees from a line between the BAS receive site and its associated permanent transmitter within a distance of 80 km from the receive site for co-channel operation and 20 km for adjacent channel operation.

(2) Outside of the ±30 degree arc defined in paragraph (c)(1) of this section:

(i) White space devices operating at 4 watts EIRP or less may not operate within 8 km from the receive site for co-channel operation and 2 km from the receive site for adjacent channel operation.

(ii) White Space devices operating with more than 4 watts EIRP may not operate within 10.2 km from the receive site for co-channel operation and 2.5 km from the receive site for adjacent channel operation.

(d) *PLMRS/CMRS operations*

(1) White space devices may not operate at distances less than those specified in the table below from the coordinates of the metropolitan areas and on the channels listed in § 90.303(a) of this chapter.

White space device transmitter power	**Required separation in kilometers from areas specified in § 90.303(a) of this chapter**	
	Co-channel Operation	Adjacent Channel Operation
4 watts EIRP or less	134	131
Greater than 4 watts EIRP	136	131.5

(2) White space devices may not operate at distances less than those specified in the table below from PLMRS/CMRS operations authorized by waiver outside of the metropolitan areas listed in § 90.303(a) of this chapter.

White space device transmitter power	**Required separation in kilometers from areas specified in § 90.303(a) of this chapter**	
	Co-channel Operation	Adjacent Channel Operation
4 watts EIRP or less	54	51
Greater than 4 watts EIRP	56	51.5

(e) *Offshore Radiotelephone Service.* White space devices may not operate on channels used by the Offshore Radio Service within the geographic areas specified in § 74.709(e) of this chapter.

(f) *Low power auxiliary services, including wireless microphones*. Fixed white space devices are not permitted to operate within 1 km, and personal/portable white space devices will not be permitted to operate within 400 meters, of the coordinates of registered low power auxiliary station sites on the registered channels during the designated times they are used by low power auxiliary stations.

(g) *Border areas near Canada and Mexico:* Fixed and personal/portable white space devices shall comply with the required separation distances in § 15.712(a)(2) from the protected contours of TV stations in Canada and Mexico. White space devices are not required to comply with these separation

distances from portions of the protected contours of Canadian or Mexican TV stations that fall within the United States.

(h) *Radio astronomy services:*

(1) Operation of fixed and personal/portable white space devices is prohibited on all channels within 2.4 kilometers at the following locations.

(i) The Naval Radio Research Observatory in Sugar Grove, West Virginia at 38 30 58 N and 79 16 48 W.

(ii) The Table Mountain Radio Receiving Zone (TMRZ) at 40 08 02 N and 105 14 40 W.

(iii) The following facilities:

Observatory	Latitude (deg/min/sec)	Longitude (deg/min/sec)
Arecibo Observatory	18 20 37 N	066 45 11 W
Green Bank Telescope (GBT)	38 25 59 N	079 50 23 W
Very Long Baseline Array (VLBA) Stations:		
Pie Town, NM	34 18 04 N	108 07 09 W
Kitt Peak, AZ	31 57 23 N	111 36 45 W
Los Alamos, NM	35 46 30 N	106 14 44 W
Ft. Davis, TX	30 38 06 N	103 56 41 W
N. Liberty, IA	41 46 17 N	091 34 27 W
Brewster, WA	48 07 52 N	119 41 00 W
Owens Valley, CA	37 13 54 N	118 16 37 W
St. Croix, VI	17 45 24 N	064 35 01 W
Hancock, NH	42 56 01 N	071 59 12 W
Mauna Kea, HI	19 48 05 N	155 27 20 W

(2) Operation within the band 608-614 MHz is prohibited within the areas defined by the following coordinates: (all coordinates are NAD 83)

(i) Pie Town, NM

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
35	25	56.28	107	44	56.40
35	15	57.24	107	41	27.60
33	52	14.16	107	30	25.20
33	22	39.36	107	49	26.40
33	57	38.52	109	36	10.80
34	04	46.20	109	34	12.00
34	27	20.88	109	12	43.20
35	15	30.24	108	25	55.20

(ii) Kitt Peak, AZ

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
34	08	18.24	111	36	46.80
33	54	10.08	109	38	20.40
32	09	25.56	113	42	03.60
31	29	15.72	111	33	43.20
33	20	36.60	113	36	14.40
34	09	20.52	112	34	37.20

(iii) Los Alamos, NM

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
36	25	54.12	106	06	07.20
36	32	26.88	105	59	27.60
36	45	23.40	105	48	03.60
36	48	10.44	105	30	21.60
36	13	37.92	105	26	38.40
35	38	40.92	105	48	36.00
35	36	51.48	105	49	30.00
34	06	17.28	107	10	48.00
34	16	18.12	107	17	16.80
35	21	22.68	106	51	07.20

(iv) Ft. Davis, TX

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
30	42	16.92	103	55	22.80
30	35	49.92	103	41	52.80
30	32	35.88	103	43	04.80
30	25	20.64	103	49	48.00
30	24	30.24	103	52	30.00
30	26	14.28	103	57	54.00
30	33	03.60	104	09	10.80
30	40	03.36	104	05	9.60
30	43	11.28	103	58	48.00

(v) N. Liberty, IA

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
42	03	27.00	90	54	16.56
41	59	03.12	90	46	49.44
41	34	19.20	90	51	11.16
41	19	27.12	90	58	58.80
41	02	09.96	91	07	18.84
41	07	51.24	92	03	44.64
41	50	03.12	92	36	20.16
42	28	50.16	91	44	35.16

(vi) Brewster, WA

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
48	18	00.36	119	35	27.60
48	16	40.08	119	34	51.60
48	15	20.52	119	34	33.60
48	12	26.64	119	34	08.40
48	07	51.96	119	34	33.60
48	06	44.64	119	34	48.00
47	58	44.40	119	36	03.60
47	55	06.60	119	37	40.80
47	52	48.72	119	39	03.60
48	00	49.68	119	59	06.00
48	26	59.64	119	46	04.80
48	26	08.52	119	43	22.80

(vii) Owens Valley, CA

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
37	05	49.56	118	02	13.20
37	03	27.36	118	01	08.40
36	29	09.96	118	06	50.40
36	30	48.60	118	11	56.40
36	37	08.04	118	16	37.20
37	25	12.72	118	41	16.80
37	27	30.24	118	41	02.40
37	44	45.96	118	39	03.60
37	59	49.92	118	32	09.60
37	46	12.72	118	20	09.60

(viii) St. Croix, VI

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
18	29	15.36	64	22	38.28
18	06	51.12	64	08	03.84
18	04	31.44	64	06	12.24
18	02	02.76	64	04	33.96
17	59	26.52	64	03	09.36
17	56	43.80	64	01	59.52
17	53	56.04	64	01	04.80
17	51	03.96	64	00	25.56
17	48	09.72	64	00	02.16
17	42	19.08	63	58	57.36
17	39	07.92	63	58	15.96
17	42	10.44	64	39	37.44
17	43	57.00	64	50	46.32
18	07	24.24	66	02	36.96
18	16	13.80	65	44	56.04

(ix) Hancock, NH

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
44	08	59.64	71	32	01.68
43	46	24.60	71	18	57.60
42	58	41.88	71	15	14.04
42	29	25.08	71	52	51.96
42	34	05.88	72	07	08.76
42	34	41.52	72	09	41.76
42	55	47.28	72	55	03.72

(x) Mauna Kea, HI

North Latitude (deg/min/sec)			West Longitude (deg/min/sec)		
20	11	01.32	153	03	43.20
20	00	52.92	152	35	56.40
19	46	42.60	152	35	34.80
19	32	33.36	152	36	28.80
19	18	31.68	152	38	38.40
19	04	44.04	152	42	07.20
18	51	16.56	152	46	51.60
18	38	15.72	152	52	44.40
18	25	46.56	152	59	49.20
18	13	55.20	153	07	55.20
18	02	46.68	153	17	06.00
17	52	26.40	153	27	14.40
17	42	57.96	153	38	16.80
17	35	20.04	153	50	45.60
17	27	52.20	154	03	10.80
17	21	27.00	154	16	15.60
17	16	08.40	154	29	49.20
17	11	57.84	154	43	51.60
17	08	57.48	154	58	08.40
17	07	09.12	155	12	43.20
17	23	53.52	155	27	21.60
19	29	13.92	155	36	21.60
19	47	53.88	155	29	27.60
19	48	52.92	155	27	39.60
19	48	58.68	155	27	14.40

(3) Operation within the band 608-614 MHz is prohibited within the following areas:

(i) The National Radio Quiet Zone as defined in § 1.924(a)(1) of this chapter.

(ii) The islands of Puerto Rico, Desecheo, Mona, Vieques or Culebra

(i) *600 MHz service band*: Fixed and personal/portable devices operating in the 600 MHz Service Band must comply with the following co-channel and adjacent channel separation distances outside the defined polygonal area encompassing the base stations or other radio facilities deployed by a part 27 600 MHz Service Band licensee that has commenced operation.

(1) Fixed white space devices may only operate above 4 W EIRP in less congested areas as defined in § 15.703(h).

(2) If a device operates between two defined power levels, it must comply with the separation distances for the higher power level.

(3) For the purpose of this rule, co-channel means any frequency overlap between a channel used by a white space device and a five megahertz spectrum block used by a part 27 600 MHz band licensee, and adjacent channel means a frequency separation of zero to four megahertz between the edge of a channel used by a white space device and the edge of a five megahertz spectrum block used by a part 27 600 MHz band licensee.

(4) On frequencies used by wireless uplink services:

Mode II Personal/Portable White Space Devices

	600 MHz band wireless uplink spectrum Minimum co-channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment	
	16 dBm (40 mW)	**20 dBm (100 mW)**
Communicating with Mode II or Fixed device	5	6
Communicating with Mode I device	10	12

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	**600 MHz band wireless uplink spectrum Minimum co-channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment***						
	16 dBm (40mW)	**20 dBm (100 mW)**	**24 dBm (250mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**	**40 dBm (10 W)**
Less than 3	5	6	7	9	12	15	19
3 - 10	9	11	14	17	22	27	34
10 - 30	15	19	24	30	38	47	60
30 - 50	20	24	31	38	49	60	60
50 - 75	24	30	37	47	60	60	60
75 - 100	27	34	43	54	60	60	60
100 - 150	33	42	53	60	60	60	60
150 - 200	39	49	60	60	60	60	60
200-250	43	54	60	60	60	60	60

* When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 5 kilometers if the Mode I device operates at power levels no more than 40 mW EIRP or 6 kilometers if the Mode I device operates at power levels above 40 mW EIRP.

Personal/portable White Space Devices

	600 MHz band wireless uplink spectrum Minimum adjacent channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment
	20 dBm (100 mW)
Communicating with Mode II or Fixed device	0.1
Communicating with Mode I device	0.3

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	**600 MHz band wireless uplink spectrum Minimum adjacent channel separation distances in kilometers between white space devices and any point along the edge of a polygon representing the outer edge of base station or other radio facility deployment***					
	20 dBm (100 mW)	**24 dBm (250mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**	**40 dBm (10 W)**
Less than 3	0.1	0.2	0.2	0.3	0.4	0.4
3 - 10	0.3	0.3	0.4	0.5	0.6	0.8
10 - 30	0.4	0.6	0.7	0.9	1.1	1.4
30 - 50	0.6	0.7	0.9	1.2	1.4	1.8
50 - 75	0.7	0.9	1.1	1.4	1.8	2.2
75 - 100	0.8	1.0	1.3	1.6	2.0	2.6
100 - 150	1.0	1.3	1.6	2.0	2.5	3.1
150 - 200	1.2	1.4	1.8	2.3	2.9	3.6
200-250	1.3	1.6	2.0	2.6	3.2	4.1

***** When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 0.1 kilometers.

(5) On frequencies used by wireless downlink services: 35 kilometers for co-channel operation, and 31 kilometers for adjacent channel operation.

(j) *Wireless Medical Telemetry Service*:

(1) White space devices operating in the 608-614 MHz band (channel 37) are not permitted to operate within an area defined by the polygon described in § 15.713(j)(11) plus the distances specified in the tables below:

Mode II Personal/Portable White Space Devices

	Required co-channel separation distances in kilometers from WMTS sites	
	16 dBm (40 mW)	20 dBm (100 mW)
Communicating with Mode II or Fixed device	0.38	0.48
Communicating with Mode I device	0.76	0.96

Fixed White Space Devices

Antenna height above average terrain of unlicensed devices (meters)	Required co-channel separation distances in kilometers from WMTS sites*					
	16 dBm (40 mW)	20 dBm (100 mW)	24 dBm (250 mW)	28 dBm (625 mW)	32 dBm (1600 mW)	36 dBm (4 watts)
Less than 3	0.38	0.48	0.60	0.76	0.96	1.20
3 - 10	0.70	0.88	1.10	1.38	1.74	2.20
10 – 30	1.20	1.55	1.95	2.45	3.05	3.80
30 – 50	1.55	2.00	2.50	3.15	3.95	4.95
50 – 75	1.90	2.45	3.05	3.85	4.85	6.10
75 - 100	2.20	2.80	3.55	4.45	5.60	7.05
100 - 150	2.70	3.45	4.35	5.45	6.85	8.65
150 - 200	3.15	3.95	5.00	6.30	7.90	9.95
200-250	3.50	4.40	5.60	7.00	8.80	11.00

* When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 0.38 kilometers if the Mode I device operates at power levels no more than 40 mW EIRP, or 0.48 kilometers if the Mode I device operates at power levels above 40 mW EIRP.

(2) White space devices operating in the 602-608 MHz band (channel 36) and 614-620 MHz band (channel 38) are not permitted to operate within an area defined by the polygon described in § 15.713(j)(11) plus the distances specified in the tables below:

Mode II Personal/Portable White Space Devices

	Required adjacent channel separation distances in meters from WMTS sites	
	16 dBm (40 mW)	20 dBm (100 mW)
Communicating with Mode II or Fixed device	8	13
Communicating with Mode I device	16	26

Fixed White Space Devices

Required adjacent channel separation distances in meters from WMTS sites*					
16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 watts)**
8	13	20	32	50	71

* When communicating with Mode I personal/portable white space devices, the required separation distances must be increased beyond the specified distances by 8 meters if the Mode I device operates at power levels no more than 40 mW EIRP, or 13 meters if the Mode I device operates at power levels above 40 mW EIRP.

(k) White space devices are not permitted to operate in the 488-494 MHz band in Hawaii.

§ 15.713 White space database.

(a) *Purpose.* The white space database serves the following functions:

(1) To determine and provide to a white space device, upon request, the available channels at the white space device's location in the TV bands, the 600 MHz guard bands, the 600 MHz duplex gap, the 600 MHz service band, and channel 37. Available channels are determined based on the interference protection requirements in § 15.712. A database must provide fixed and Mode II personal portable white space devices with channel availability information that includes scheduled changes in channel availability over the course of the 48 hour period beginning at the time the white space devices make a re-check contact. In making lists of available channels available to a white space device, the white space database shall ensure that all communications and interactions between the white space database and the white space device include adequate security measures such that unauthorized parties cannot access or alter the white space database or the list of available channels sent to white space devices or otherwise affect the database system or white space devices in performing their intended functions or in providing adequate interference protections to authorized services operating in the TV bands. In addition, a white space database must also verify that the FCC identifier (FCC ID) of a device seeking access to its services is valid; under this requirement the white space database must also verify that the FCC ID of a Mode I device provided by a fixed or Mode II device is valid. A list of devices with valid FCC IDs and the FCC IDs of those devices is to be obtained from the Commission's Equipment Authorization System.

(2) To determine and provide to an unlicensed wireless microphone user, upon request, the available channels at the microphone user’s location in the 600 MHz guard bands, the 600 MHz duplex gap, and the 600 MHz service band. Available channels are determined based on the interference protection requirements in § 15.236.

(3) To register the identification information and location of fixed white space devices and unlicensed wireless microphone users.

(4) To register protected locations and channels as specified in paragraph (b)(2) of this section, that are not otherwise recorded in Commission licensing databases.

(b) *Information in the white space database.*

(1) Facilities already recorded in Commission databases. Identifying and location information will come from the official Commission database. These services include:

(i) Digital television stations.

(ii) Class A television stations.

(iii) Low power television stations.

(iv) Television translator and booster stations.

(v) Broadcast Auxiliary Service stations (including receive only sites), except low power auxiliary stations.

(vi) Private land mobile radio service stations.

(vii) Commercial mobile radio service stations.

(viii) Offshore radiotelephone service stations.

(ix) Class A television station receive sites.

(x) Low power television station receive sites.

(xi) Television translator station receive sites.

(2) Facilities that are not recorded in Commission databases. Identifying and location information will be entered into the white space database in accordance with the procedures established by the white space database administrator(s). These include:

(i) MVPD receive sites.

(ii) Sites where low power auxiliary stations, including wireless microphones and wireless assist video devices, are used and their schedule for operation.

(iii) Fixed white space device registrations.

(iv) 600 MHz service band operations in areas where the part 27 600 MHz service licensee has commenced operations.

(v) Locations of health care facilities that use WMTS equipment operating on channel 37 (608-614 MHz).

(c) *Restrictions on registration.*

(1) Television translator, low power TV and Class A station receive sites within the protected contour of the station being received are not eligible for registration in the database.

(2) MVPD receive sites within the protected contour or more than 80 kilometers from the nearest edge of the protected contour of a television station being received are not eligible to register that station's channel in the database.

(d) *Determination of available channels.* The white space database will determine the available channels at a location using the interference protection requirements of § 15.712, the location information supplied by a white space device, and the data for protected stations/locations in the database.

(e) *White space device initialization.* (1) Fixed and Mode II white space devices must provide their location and required identifying information to the white space database in accordance with the provisions of this subpart.

(2) Fixed and Mode II white space devices shall not transmit unless they receive, from the white space database, a list of available channels and may only transmit on the available channels on the list provided by the database.

(3) Fixed white space devices register and receive a list of available channels from the database by connecting to the Internet, either directly or through another fixed white space device that has a direct connection to the Internet.

(4) Mode II white space devices receive a list of available channels from the database by connecting to the Internet, either directly or through a fixed or Mode II white space device that has a direct connection to the Internet.

(5) A fixed or Mode II white space device that provides a list of available channels to a Mode I device shall notify the database of the FCC identifier of such Mode I device and receive verification that that FCC identifier is valid before providing the list of available channels to the Mode I device.

(6) A fixed device with an antenna height above ground that exceeds 30 meters or an antenna height above average terrain (HAAT) that exceeds 250 meters shall not be provided a list of available channels. The HAAT is to be calculated using computational software employing the methodology in § 73.684(d) of this chapter.

(f) *Unlicensed wireless microphone database access.* Unlicensed wireless microphone users in the 600 MHz band may register with and access the database manually via a separate Internet connection. Wireless microphone users must register with and check a white space database to determine available channels prior to beginning operation at a given location. A user must re-check the database for available channels if it moves to another location.

(g) *Fixed white space device registration.*

(1) Prior to operating for the first time or after changing location, a fixed white space device must register with the white space database by providing the information listed in paragraph (g)(3) of this section.

(2) The party responsible for a fixed white space device must ensure that the white space device registration database has the most current, up-to-date information for that device.

(3) The white space device registration database shall contain the following information for fixed white space devices:

(i) FCC identifier (FCC ID) of the device;

(ii) Manufacturer's serial number of the device;

(iii) Device's geographic coordinates (latitude and longitude (NAD 83));

(iv) Device's antenna height above ground level (meters);

(v) Name of the individual or business that owns the device;

(vi) Name of a contact person responsible for the device's operation;

(vii) Address for the contact person;

(viii) E-mail address for the contact person;

(ix) Phone number for the contact person.

(h) A personal/portable device operating in Mode II shall provide the database its FCC Identifier (as required by § 2.926 of this chapter), serial number as assigned by the manufacturer, and the device's geographic coordinates (latitude and longitude (NAD 83)).

(i) *Unlicensed wireless microphone registration*. Unlicensed wireless microphone users in the 600 MHz band shall register with the database prior to operation and include the following information:

(i) Name of the individual or business that owns the unlicensed wireless microphone

(ii) Address for the contact person

(iii) Email address for the contact person

(iv) Phone number for the contact person; and

(v) Coordinates where the device will be used (latitude and longitude in NAD 83).

(j) *White space database information.* The white space database shall contain the listed information for each of the following:

(1) Digital television stations, digital and analog Class A, low power, translator and booster stations, including stations in Canada and Mexico that are within the border coordination areas as specified in § 73.1650 of this chapter (a white space database is to include only TV station information from station license or license application records. In cases where a station has records for both a license application and a license, a white space database should include the information from the license application rather than the license. In cases where there are multiple license application records or license records for the same station, the database is to include the most recent records, and again with license applications taking precedence over licenses.):

(i) Transmitter coordinates (latitude and longitude in NAD 83);

(ii) Effective radiated power (ERP);

(iii) Height above average terrain of the transmitting antenna (HAAT);

(iv) Horizontal transmit antenna pattern (if the antenna is directional);

(v) Amount of electrical and mechanical beam tilt (degrees depression below horizontal) and orientation of mechanical beam tilt (degrees azimuth clockwise from true north);

(vi) Channel number; and

(vii) Station call sign.

(2) Broadcast Auxiliary Service.

(i) Transmitter coordinates (latitude and longitude in NAD 83).

(ii) Receiver coordinates (latitude and longitude in NAD 83).

(iii) Channel number.

(iv) Call sign.

(3) Metropolitan areas listed in § 90.303(a) of this chapter.

(i) Region name.

(ii) Channel(s) reserved for use in the region.

(iii) Geographic center of the region (latitude and longitude in NAD 83).

(iv) Call sign.

(4) PLMRS/CMRS base station operations located more than 80 km from the geographic centers of the 13 metropolitan areas defined in § 90.303(a) of this chapter (e.g., in accordance with a waiver).

(i) Transmitter location (latitude and longitude in NAD 83) or geographic area of operations.

(ii) TV channel of operation.

(iii) Call sign.

(5) Offshore Radiotelephone Service. For each of the four regions where the Offshore Radiotelephone Service operates.

(i) Geographic boundaries of the region (latitude and longitude in NAD 83 for each point defining the boundary of the region.

(ii) Channel(s) used by the service in that region.

(6) MVPD receive sites. Registration for receive sites is limited to channels that are received over-the-air and are used as part of the MVPD service.

(i) Name and address of MVPD company;

(ii) Location of the MVPD receive site (latitude and longitude in NAD 83, accurate to ±/− 50 m);

(iii) Channel number of each television channel received, subject to the following condition: channels for which the MVPD receive site is located within the protected contour of that channel's transmitting station are not eligible for registration in the database;

(iv) Call sign of each television channel received and eligible for registration;

(v) Location (latitude and longitude) of the transmitter of each television channel received;

(7) Television translator, low power TV and Class A TV station receive sites. Registration for television translator, low power TV and Class A receive sites is limited to channels that are received over-the-air and are used as part of the station's service.

(i) Call sign of the TV translator station;

(ii) Location of the TV translator receive site (latitude and longitude in NAD 83, accurate to ±/− 50 m);

(iii) Channel number of the re-transmitted television station, subject to the following condition: a channel for which the television translator receive site is located within the protected contour of that channel's transmitting station is not eligible for registration in the database;

(iv) Call sign of the retransmitted television station; and

(v) Location (latitude and longitude) of the transmitter of the retransmitted television station.

(8) Licensed low power auxiliary stations, including wireless microphones and wireless assist video devices. Use of licensed low power auxiliary stations at well-defined times and locations may be registered in the database. Multiple registrations that specify more than one point in the facility may be entered for very large sites. Registrations will be valid for no more than one year, after which they may be renewed. Registrations must include the following information:

(i) Name of the individual or business responsible for the low power auxiliary device(s);

(ii) An address for the contact person;

(iii) An email address for the contact person (optional);

(iv) A phone number for the contact person;

(v) Coordinates where the device(s) are used (latitude and longitude in NAD 83, accurate to ±/− 50 m);

(vi) Channels used by the low power auxiliary devices operated at the site;

(vii) Specific months, weeks, days of the week and times when the device(s) are used (on dates when microphones are not used the site will not be protected); and

(viii) The stations call sign.

(9) Unlicensed wireless microphones at venues of events and productions/shows that use large numbers of wireless microphones that cannot be accommodated in the two reserved channels and other channels that are not available for use by white space devices at that location. Prior to **[18 months after the effective date of this rule]** but no later than release of the Channel Reassignment Public Notice upon completion of the broadcast television spectrum incentive auction, as defined in § 73.3700(a) of this chapter, sites of large events and productions/shows with significant unlicensed wireless microphone use at well-defined times and locations may be registered in the database. Entities responsible for eligible event venues registering their site with a TV bands data base are required to first make use of the two reserved channels and other channels that are not available for use by white space devices at that location.

As a benchmark, at least 6-8 wireless microphones should be operating in each channel used at such venues (both licensed and unlicensed wireless microphones used at the event may be counted to comply with this benchmark). Multiple registrations that specify more than one point in the facility may be entered for very large sites. Sites of eligible event venues using unlicensed wireless microphones must be registered with the Commission at least 30 days in advance and the Commission will provide this information to the data base managers. Parties responsible for eligible event venues filing registration requests must certify that they are making use of all TV channels not available to white space devices and on which wireless microphones can practicably be used, including channels 7-51 (except channel 37). The Commission will make requests for registration of sites that use unlicensed wireless microphones public and will provide an opportunity for public comment or objections. Registrations will be valid for one year, after which they may be renewed. The Commission will take actions against parties that file inaccurate or incomplete information, such as denial of registration in the database, removal of information from the database pursuant to paragraph (i) of this section, or other sanctions as appropriate to ensure compliance with the rules. Registrations must include the following information:

(i) Name of the individual or business that owns the unlicensed wireless microphones;

(ii) An address for the contact person;

(iii) An e-mail address for the contact person (optional);

(iv) A phone number for the contact person;

(v) Coordinates where the device(s) are used (latitude and longitude in NAD 83, accurate to ±/− 50 m);

(vi) Channels used by the wireless microphones operated at the site and the number of wireless microphones used in each channel. As a benchmark, least 6-8 wireless microphones must be used in each channel. Registration requests that do not meet this criteria will not be registered in the TV bands data bases;

(vii) Specific months, weeks, days of the week and times when the device(s) are used (on dates when microphones are not used the site will not be protected); and

(viii) The name of the venue.

(10) 600 MHz service in areas where the part 27 600 MHz band licensee has commenced operations.

(i) Name of 600 MHz band licensee;

(ii) Name and address of the contact person;

(iii) An email address for the contact person (optional);

(iv) A phone number for the contact person;

(v) Area within a part 27 600 MHz band licensee's Partial Economic Areas (PEA), as defined in § 27.6 of this chapter, where it has commenced operation. This area must be delineated by at minimum of eight and a maximum of 120 geographic coordinates (latitude and longitude in NAD 83, accurate to +/- 50 m);

(vi) Date of commencement of operations;

(vii) Identification of the frequencies on which the part 27 600 MHz band licensee has commenced operations;

(viii) Call sign.

(11) Location of health care facilities operating WMTS networks on channel 37 (608-614 MHz)

(i) Name and address of the health care facility;

(ii) Name and address of a contact person;

(iii) Phone number of a contact person;

(iv) Email address of a contact person;

(v) Latitude and longitude coordinates referenced to North American Datum 1983 (NAD 83) that define the perimeter of each facility. If several health care facilities using 608-614 MHz wireless medical telemetry equipment are located in close proximity, it is permissible to register a perimeter to protect all facilities in that cluster.

(k) *Commission requests for data*.

(1) A white space database administrator must provide to the Commission, upon request, any information contained in the database.

(2) A white space database administrator must remove information from the database, upon direction, in writing, by the Commission.

(l) *Security.* The white space database shall employ protocols and procedures to ensure that all communications and interactions between the white space database and white space devices are accurate and secure and that unauthorized parties cannot access or alter the database or the list of available channels sent to a white space device.

(1) Communications between white space devices and white space databases, and between different white space databases, shall be secure to prevent corruption or unauthorized interception of data. A white space database shall be protected from unauthorized data input or alteration of stored data.

(2) A white space database shall verify that the FCC identification number supplied by a fixed or personal/portable white space device is for a certified device and may not provide service to an uncertified device.

(3) A white space database must not provide lists of available channels to uncertified white space devices for purposes of operation (it is acceptable for a white space database to distribute lists of available channels by means other than contact with white space devices to provide list of channels for operation). To implement this provision, a white space database administrator shall obtain a list of certified white space devices from the FCC Equipment Authorization System.

§ 15.714 White space database administration fees.

(a) A white space database administrator may charge a fee for provision of lists of available channels to fixed and personal/portable devices and for registering fixed devices. This provision applies to devices that operate in the TV bands, 600 MHz service band, and the 600 MHz guard bands and duplex gap.

(b) A white space database administrator may charge a fee for provision of lists of available channels to wireless microphone users.

(c) The Commission, upon request, will review the fees and can require changes in those fees if they are found to be excessive.

§ 15.715 White space database administrator.

The Commission will designate one or more entities to administer the white space database(s). The Commission may, at its discretion, permit the functions of a white space database, such as a data repository, registration, and query services, to be divided among multiple entities; however, it will designate specific entities to be a database administrator responsible for coordination of the overall functioning of a database and providing services to white space devices. Each database administrator designated by the Commission shall:

(a) Maintain a database that contains the information described in § 15.713.

(b) Establish a process for acquiring and storing in the database necessary and appropriate information from the Commission's databases and synchronizing the database with the current Commission databases at least once a week to include newly licensed facilities or any changes to licensed facilities.

(c) Establish a process for registering fixed white space devices and registering and including in the database facilities entitled to protection but not contained in a Commission database, including MVPD receive sites.

(d) Establish a process for registering facilities where part 74 low power auxiliary stations are used on a regular basis.

(e) Provide accurate lists of available channels and the corresponding maximum permitted power for each available channel to fixed and personal/portable white space devices that submit to it the information required under §§ 15.713(e), (g), and (h) based on their geographic location and provide accurate lists of available channels and the corresponding maximum permitted power for each available channel to fixed and Mode II devices requesting lists of available channels for Mode I devices. Database administrators may allow prospective operators of white space devices to query the database and determine whether there are vacant channels at a particular location.

(f) Establish protocols and procedures to ensure that all communications and interactions between the white space database and white space devices are accurate and secure and that unauthorized parties cannot access or alter the database or the list of available channels sent to a white space device consistent with the provisions of § 15.713(l).

(g) Make its services available to all unlicensed white space device users on a non-discriminatory basis.

(h) Provide service for a five-year term. This term can be renewed at the Commission's discretion.

(i) Respond in a timely manner to verify, correct and/or remove, as appropriate, data in the event that the Commission or a party brings claim of inaccuracies in the database to its attention. This requirement applies only to information that the Commission requires to be stored in the database.

(j) Transfer its database along with the IP addresses and URLs used to access the database and list of registered fixed white space devices, to another designated entity in the event it does not continue as the database administrator at the end of its term. It may charge a reasonable price for such conveyance.

(k) The database must have functionality such that upon request from the Commission it can indicate that no channels are available when queried by a specific white space device or model of white space devices.

(l) If more than one database is developed, the database administrators shall cooperate to develop a standardized process for providing on a daily basis or more often, as appropriate, the data collected for the facilities listed in § 15.713(b)(2) to all other white space databases to ensure consistency in the records of protected facilities.

(m) Provide a means to make publicly available all information the rules require the database to contain, including fixed white space device registrations and voluntarily submitted protected entity information, except the information provided by 600 MHz band licensees pursuant to § 15.713(j)(10)(v)-(vi) of this part shall not be made publicly available.

(n) Establish procedures to allow part 27 600 MHz service licensees to upload the registration information listed in § 15.713(j)(10) for areas where they have commenced operations and to allow the removal and replacement of registration information in the database when corrections or updates are necessary.

(o) Remove from the database the registrations of fixed white space devices that have not checked the database for at least three months to update their channel lists. A database administrator may charge a new registration fee for a fixed white space device that is removed from the database under this provision but is later re-registered.

(p) Establish procedures to allow health care facilities to register the locations of facilities where they operate WMTS networks on channel 37.

(q) Establish procedures to allow unlicensed wireless microphone users in the 600 MHz band to register with the database and to provide lists of channels available for wireless microphones at a given location.

§ 15.717 White space devices that rely on spectrum sensing.

(a) *Applications for certification.* Parties may submit applications for certification of white space devices that rely solely on spectrum sensing to identify available channels. Devices authorized under this section must demonstrate with an extremely high degree of confidence that they will not cause harmful interference to incumbent radio services.

(1) In addition to the procedures in subpart J of part 2 of this chapter, applicants shall comply with the following.

(i) The application must include a full explanation of how the device will protect incumbent authorized services against interference.

(ii) Applicants must submit a pre-production device, identical to the device expected to be marketed.

(2) The Commission will follow the procedures below for processing applications pursuant to this section.

(i) Applications will be placed on public notice for a minimum of 30 days for comments and 15 days for reply comments. Applicants may request that portions of their application remain confidential in accordance with § 0.459 of this chapter. This public notice will include proposed test procedures and methodologies.

(ii) The Commission will conduct laboratory and field tests of the pre-production device. This testing will be conducted to evaluate proof of performance of the device, including characterization of its sensing capability and its interference potential. The testing will be open to the public.

(iii) Subsequent to the completion of testing, the Commission will issue by public notice, a test report including recommendations. The public notice will specify a minimum of 30 days for comments and, if any objections are received, an additional 15 days for reply comments.

(b) *Power limit for devices that rely on sensing.* The white space device shall meet the requirements for personal/portable devices in this subpart except that it will be limited to a maximum EIRP of 50 mW per 6 megahertz of bandwidth on which the device operates and it does not have to comply with the requirements for geo-location and database access in § 15.711(b), (d), and (e). Compliance with the detection threshold for spectrum sensing in § 15.717(c), although required, is not necessarily sufficient for demonstrating reliable interference avoidance. Once a device is certified, additional devices that are identical in electrical characteristics and antenna systems may be certified under the procedures of Part 2, Subpart J of this chapter.

(c) *Sensing requirements*—(1) *Detection threshold.* (i) The required detection thresholds are:

(A) ATSC digital TV signals: -114 dBm, averaged over a 6 MHz bandwidth;

(B) NTSC analog TV signals: -114 dBm, averaged over a 100 kHz bandwidth;

(C) Low power auxiliary, including wireless microphone, signals: -107 dBm, averaged over a 200 kHz bandwidth.

(ii) The detection thresholds are referenced to an omnidirectional receive antenna with a gain of 0 dBi. If a receive antenna with a minimum directional gain of less than 0 dBi is used, the detection threshold shall be reduced by the amount in dB that the minimum directional gain of the antenna is less than 0 dBi. Minimum directional gain shall be defined as the antenna gain in the direction and at the frequency that exhibits the least gain. Alternative approaches for the sensing antenna are permitted, e.g., electronically rotatable antennas, provided the applicant for equipment authorization can demonstrate that its sensing antenna provides at least the same performance as an omnidirectional antenna with 0 dBi gain.

(2) *Channel availability check time.* A white space device may start operating on a TV channel if no TV, wireless microphone or other low power auxiliary device signals above the detection threshold are detected within a minimum time interval of 30 seconds.

(3) *In-service monitoring.* A white space device must perform in-service monitoring of an operating channel at least once every 60 seconds. There is no minimum channel availability check time for in-service monitoring.

(4) *Channel move time.* After a TV, wireless microphone or other low power auxiliary device signal is detected on a white space device operating channel, all transmissions by the white space device must cease within two seconds.

9. The authority citation for part 27 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 301, 302a, 303, 307, 309, 332, 336, 337, 1403, 1404, 1451, and 1452, unless otherwise noted.

10. A new Section 27.1320 is added to read as follows:

§ 27.1320 Notification to white space database administrators

To receive interference protection, 600 MHz licensees shall notify one of the white space database administrators of the areas where they have commenced operation pursuant to §§ 15.713(j)(10) and 15.715(n) of this chapter.

11. The authority citation for part 74 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 303, 307, 309, 336 and 554.

12. Section 74.802 is amended by revising paragraphs (a)(2), (c) and (f) to read as follows:

§ 74.802 Frequency assignment.

(a)(1) * * *

(2) The four megahertz segment from one to five megahertz above the lower edge of the 600 MHz duplex gap may be assigned for use by low power auxiliary stations.

Note to paragraph (a)(2): The specific frequencies for the 600 MHz duplex gap will be determined in light of further proceedings pursuant to GN Docket No. 12-268 and the rule will be updated accordingly pursuant to a future public notice.

* * * * *

(c) Specific frequency operation is required when operating within the 600 MHz duplex gap or the bands allocated for TV broadcasting.

(1) * * *

(2) * * *

Note to paragraph (c): The specific frequencies for the 600 MHz duplex gap will be determined in light of further proceedings pursuant to GN Docket No. 12-268 and the rule will be updated accordingly pursuant to a future public notice.

* * * * *

(f) *Operations in 600 MHz band assigned to wireless licensees under part 27 of this chapter.* A low power auxiliary station that operates on frequencies in the 600 MHz band assigned to wireless licensees under part 27 of this chapter must cease operations on those frequencies no later than the end of the post-auction transition period as defined in § 27.4 of this chapter. During the post-auction transition period, low power auxiliary stations will operate on a secondary basis to licensees of part 27 of this chapter, *i.e.,* they must not cause to and must accept harmful interference from these licensees, and must comply with the distance separations in § 15.236(e)(2) of this chapter outside the areas where a licensee has commenced operations as specified pursuant to § 15.713(j)(10).

13. Section 74.861 is amended by revising paragraphs (a) and (e) to read as follows:

§ 74.861 Technical requirements.

(a) Except as specified in paragraph (e) of this section, transmitter power is the power at the transmitter output terminals and delivered to the antenna, antenna transmission line, or any other impedance-matched, radio frequency load. For the purpose of this subpart, the transmitter power is the carrier power.

* * * * *

(e) For low power auxiliary stations operating in the 600 MHz duplex gap and the bands allocated for TV broadcasting, the following technical requirements apply:

(1) The power may not exceed the following values.

(i) * * *

(ii) * * *

(iii) 600 MHz duplex gap: 20 mW EIRP

* * * * *

14. The authority citation for part 95 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 301, 302(a), 303, and 307(e).

15. Section 95.1111 is revised by adding a new paragraph (d) to read as follows:

§ 95.1111 Frequency coordination.

* * * * *

(d) To receive interference protection, parties operating WMTS networks on channel 37 shall notify one of the white space database administrators of their operating location pursuant to §§ 15.713(j)(11) and 15.715(p) of this chapter.

Appendix B

List of Parties Filing Comments

Comments

1. Actors Theatre
2. Adaptrum, Inc.
3. All For One Theater
4. Alley Theatre
5. Alliance Theatre
6. Anant Sahai
7. Aquila Theatre
8. Arden Theatre Company
9. Arkansas State University - Jonesboro
10. Arvada Center for the Arts and Humanities
11. Asolo Repertory Theatre
12. Audio-Technica U.S., Inc.
13. Baltimore Symphony Orchestra
14. Bloomington High School South
15. BMCC Tribeca Performing Arts Center
16. Bonny Eagle High School
17. Broadcom Corporation
18. Center Theatre Group
19. Central High School
20. Central York High School
21. Centre Stage
22. Chaparral High School
23. Classic Stage Company
24. Cohen, Dippell and Everist, P.C.
25. Committee on Radio Frequencies
26. Consumer Electronics Association
27. Court Theatre
28. CP Communications, LLC
29. CTIA-The Wireless Association
30. Dad's Garage Theatre Company
31. Denver Center for the Performing Arts Theatre Company
32. Dynamic Spectrum Alliance
33. Fort Mason Center
34. Fort Worth Academy of Fine Arts
35. GE Healthcare
36. Goodspeed Musicals
37. Google Inc.
38. Greendale High School Theatre
39. Hangar Theatre
40. Heritage Christian School
41. Houston Symphony
42. Hubbard Street Dance Chicago
43. Indiana Repertory Theatre
44. J.P. Taravella High School
45. James E. Taylor High School
46. John Jay High School
47. Kansas City Repertory Theatre
48. Kentucky Shakespeare
49. La Jolla Playhouse
50. La Reina High School
51. Lake Nona Middle School
52. Lake Oswego High School
53. McCarter Theatre Center
54. Meeker High School
55. MELD
56. Microsoft Corporation
57. Milwaukee Repertory Theater
58. Mobile Future
59. Motorola Solutions, Inc.
60. Mountain Vista High School
61. Naperville North High School
62. National Association of Broadcasters
63. Nuclear Energy Institute and Utilities Telecom Council
64. Oregon Shakespeare Festival
65. Pacific Conservatory Theatre
66. Parkway School District
67. Performing Arts Wireless Microphone Working Group
68. QUALCOMM Incorporated
69. Runcom Technologies, Ltd.
70. San Francisco Playhouse
71. Scheck Hillel Community School
72. Sennheiser Electronic Corporation
73. Shakespeare Theatre Company
74. Shure Incorporated
75. Signature Theatre
76. Spectrum Bridge Inc.
77. Steppenwolf Theatre
78. Telecommunications Industry Association
79. The New York Musical Theatre Festival
80. The Public Theater
81. The Screen Actors Guild – American Federation of Television & Radio Artists
82. Theatrical Outfit
83. Tippecanoe High School
84. University of Miami's Jerry Herman Ring Theatre
85. Westcoast Black Theatre Troupe

86. Westside Theatre
87. WhiteSpace Alliance
88. Wi-Fi Alliance
89. Wireless Internet Service Providers Association
90. WMTS Coalition
91. xG Technology, Inc.
92. Yale School of Drama and Yale Repertory Theatre

Reply comments

1. Alarm Industry Communications Committee
2. AT&T
3. Cohen, Dippell and Everist, P.C.
4. Coleman Bazelon (on behalf of Qualcomm)
5. CP Communications, LLC
6. CTIA-The Wireless Association
7. Deere & Company
8. GE Healthcare
9. Google Inc.
10. Microsoft Corporation
11. National Association of Broadcasters
12. Open Technology Institute and Public Knowledge
13. QUALCOMM Incorporated
14. Sennheiser Electronic Corporation
15. Shure Incorporated
16. Telecommunications Industry Association
17. The Wireless Internet Service Providers Association
18. Wireless Microphone Alliance of America
19. WMTS Coalition
20. xG Technology, Inc.

Appendix C

Final Regulatory Flexibility Analysis

As required by the Regulatory Flexibility Act of 1980, as amended (RFA),[1] an Initial Regulatory Flexibility Analysis (IRFA) was incorporated in the *Notice of Proposed Rule Making* (NPRM).[2] The Commission sought written public comment on the proposals in the *NPRM*, including comment on the IRFA. This present Final Regulatory Flexibility Analysis (FRFA) conforms to the RFA.[3]

A. Need for, and Objectives of, the Report and Order

The Report and Order maximizes unlicensed white space devices' access to spectrum in the television broadcasting band and the 600 MHz band in a number of ways. It modifies the Part 15 rules to permit fixed and personal/portable devices to use TV channels previously unavailable to them while continuing to protect TV services from harmful interference by adjusting power limits, specifying separation distances, and specifying antenna heights. The Report and Order also adopts technical rules for white space device operations in the 600 MHz band—including the duplex gap, guard bands, repurposed 600 MHz band and channel 37—by establishing power limits and specifying frequency and distance separations as needed to protect authorized services in those bands from harmful interference. White space devices will continue to access the white space databases for channel assignments in the TV bands, as well as in the 600 MHz band and channel 37. The Report and Order also adopts rules for unlicensed wireless microphones operating in the TV bands, guard bands and duplex, and for licensed wireless microphones operating in the duplex gap.

B. Summary of Significant Issues Raised by Public Comments in Response to the IRFA

There were no comments filed that specifically addressed the rules and policies proposed in the IRFA.

C. Response to Comments by the Chief Counsel for Advocacy of the Small Business Administration

Pursuant to the Small Business Jobs Act of 2010, the Commission is required to respond to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration (SBA), and to provide a detailed statement of any change made to the proposed rules as a result of those comments. The Chief Counsel did not file any comments in response to the proposed rules in this proceeding.

D. Description and Estimate of the Number of Small Entities to Which the Rules Will Apply

The RFA directs agencies to provide a description of, and where feasible, an estimate of the number of small entities that may be affected by the proposed rules, if adopted.[4] The RFA generally

[1] *See* 5 U.S.C. § 603. The RFA, *see* 5 U.S.C. § 601 – 612, has been amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), Pub. L. No. 104-121, Title II, 110 Stat. 857 (1996).

[2] *See* Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap; ET Docket No. 14-165; Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268.

[3] *See* 5 U.S.C. § 604.

[4] *See* 5 U.S.C. § 603(b)(3).

defines the term "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[5] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[6] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the Small Business Administration (SBA).[7]

Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing. The Census Bureau defines this category as follows: "This industry comprises establishments primarily engaged in manufacturing radio and television broadcast and wireless communications equipment. Examples of products made by these establishments are: transmitting and receiving antennas, cable television equipment, GPS equipment, pagers, cellular phones, mobile communications equipment, and radio and television studio and broadcasting equipment."[8] The SBA has developed a small business size standard for Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing, which is: all such firms having 750 or fewer employees. According to Census Bureau data for 2007, there were a total of 939 establishments in this category that operated for part or all of the entire year. Of this total, 912 had less than 500 employees and 17 had more than 1000 employees.[9] Thus, under that size standard, the majority of firms can be considered small.

Television Broadcasting. This Economic Census category "comprises establishments primarily engaged in broadcasting images together with sound. These establishments operate television broadcasting studios and facilities for the programming and transmission of programs to the public."[10] The SBA has created the following small business size standard for Television Broadcasting firms: those having $38.5 million or less in annual receipts.[11] The Commission has estimated the number of licensed commercial television stations to be 1,388.[12] In addition, according to Commission staff review of the BIA Advisory Services, LLC's *Media Access Pro Television Database* on March 28, 2012, about 950 of an estimated 1,300 commercial television stations (or approximately 73 percent) had revenues of $14 million or less.[13] We therefore estimate that the majority of commercial television broadcasters are small entities.

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[5] *See* 5 U.S.C. § 601(6).

[6] *See* 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[7] *See* 15 U.S.C. § 632.

[8] The NAICS Code for this service 334220. *See* 13 C.F.R 121/201. *See also* http://factfinder.census.gov/servlet/IBQTable?_bm=y&-fds_name=EC0700A1&-geo_id=&-_skip=300&-ds_name=EC0731SG2&-_lang=en

[9] *See* http://factfinder.census.gov/servlet/IBQTable?_bm=y&-geo_id=&-fds_name=EC0700A1&-_skip=4500&-ds_name=EC0731SG3&-_lang=en

[10] U.S. Census Bureau, *2012 NAICS Definitions: 515120 Television Broadcasting*, (partial definition), http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=515120&search=2012 (last visited May 6, 2014).

[11] 13 C.F.R. § 121.201 (NAICS code 515120) (updated for inflation in 2010).

[12] *See FCC News Release*, Broadcast Station Totals as of December 31, 2013 (rel. January 8, 2014), http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db0108/DOC-325039A1.pdf.

[13] We recognize that BIA's estimate differs slightly from the FCC total given.

We note, however, that in assessing whether a business concern qualifies as small under the above definition, business (control) affiliations must be included.[14] Our estimate, therefore, likely overstates the number of small entities that might be affected by our action because the revenue figure on which it is based does not include or aggregate revenues from affiliated companies. In addition, an element of the definition of "small business" is that the entity not be dominant in its field of operation. We are unable at this time to define or quantify the criteria that would establish whether a specific television station is dominant in its field of operation. Accordingly, the estimate of small businesses to which rules may apply does not exclude any television station from the definition of a small business on this basis and is therefore possibly over-inclusive to that extent.

In addition, the Commission has estimated the number of licensed noncommercial educational (NCE) television stations to be 396.[15] These stations are non-profit, and therefore considered to be small entities.[16]

There are also 2,414 low power television stations, including Class A stations and 4,046 television translator stations.[17] Given the nature of these services, we will presume that all of these entities qualify as small entities under the above SBA small business size standard.

Manufacturers of unlicensed devices. In the context of this FRFA, manufacturers of Part 15 unlicensed devices that are operated in the UHF-TV band (channels 14-51) for wireless data transfer fall into the category of Radio and Television and Wireless Communications Equipment Manufacturing. The Census Bureau defines this category as follows: "This industry comprises establishments primarily engaged in manufacturing radio and television broadcast and wireless communication equipment. Examples of products made by these establishments are: transmitting and receiving antennas, cable television equipment, GPS equipment, pagers, cellular phones, mobile communications equipment, and radio and television studio and broadcasting equipment."[18] The SBA has developed the small business size standard for this category as firms having 750 or fewer employees.[19] According to Census Bureau data for 2007, there were a total of 939 establishments in this category that operated for the entire year.[20] Of this total, 912 had less than 500 employees and 17 had more than 1000 employees. Thus, under that size standard, the majority of firms can be considered small.

Radio Broadcasting. The SBA defines a radio broadcast station as a small business if such station has no more than $38.5 million in annual receipts.[21] Business concerns included in this industry are those "primarily engaged in broadcasting aural programs by radio to the public."[22] According to

[14] "[Business concerns] are affiliates of each other when one concern controls or has the power to control the other or a third party or parties controls or has to power to control both." 13 C.F.R. § 21.103(a)(1).

[15] *See FCC News Release*, Broadcast Station Totals as of December 31, 2013 (rel. January 8, 2014), http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db0108/DOC-325039A1.pdf.

[16] *See generally* 5 U.S.C. §§ 601(4), (6).

[17] *See FCC News Release*, Broadcast Station Totals as of December 31, 2013 (rel. January 8, 2014), http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db0108/DOC-325039A1.pdf.

[18] U.S. Census Bureau, *2012 NAICS Definitions: 334220 Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing*, http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=334220&search=2012 (last visited Mar. 6, 2014).

[19] 13 C.F.R § 121.201 (NAICS code 334220).

[20] U.S. Census Bureau, Table No. EC0731SG3, *Manufacturing: Summary Series: General Summary: Industry Statistics for Subsectors and Industries by Employment Size: 2007* (NAICS code 334220), http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2007_US_31SG3.

[21] 13 C.F.R § 121.201, 2012 NAICS code 515112.

[22] U.S. Census Bureau, *2012 NAICS Definitions: 515112 Radio Broadcasting*, http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=515112&search=2012 (last visited Mar. 6, 2014).

review of the BIA Publications, Inc. Master Access Radio Analyzer Database as of November 26, 2013, about 11,331 (or about 99.9 percent) of 11,341 commercial radio stations have revenues of $35.5 million or less and thus qualify as small entities under the SBA definition. The Commission notes, however, that, in assessing whether a business concern qualifies as small under the above definition, business (control) affiliations[23] must be included. This estimate, therefore, likely overstates the number of small entities that might be affected, because the revenue figure on which it is based does not include or aggregate revenues from affiliated companies.

In addition, an element of the definition of "small business" is that the entity not be dominant in its field of operation. The Commission is unable at this time to define or quantify the criteria that would establish whether a specific radio station is dominant in its field of operation. Accordingly, the estimate of small businesses to which rules may apply does not exclude any radio station from the definition of a small business on this basis and therefore may be over-inclusive to that extent. Also, as noted, an additional element of the definition of "small business" is that the entity must be independently owned and operated. The Commission notes that it is difficult at times to assess these criteria in the context of media entities and the estimates of small businesses to which they apply may be over-inclusive to this extent.

Radio, Television, and Other Electronics Stores. The Census Bureau defines this economic census category as follows: "This U.S. industry comprises: (1) establishments known as consumer electronics stores primarily engaged in retailing a general line of new consumer-type electronic products such as televisions, computers, and cameras; (2) establishments specializing in retailing a single line of consumer-type electronic products; (3) establishments primarily engaged in retailing these new electronic products in combination with repair and support services; (4) establishments primarily engaged in retailing new prepackaged computer software; and/or (5) establishments primarily engaged in retailing prerecorded audio and video media, such as CDs, DVDs, and tapes."[24] The SBA has developed a small business size standard for Electronic Stores, which is: all such firms having $32.5 million or less in annual receipts.[25] According to Census Bureau data for 2007, there were 11,358 firms in this category that operated for the entire year.[26] Of this total, 11,323 firms had annual receipts of under $25 million, and 35 firms had receipts of $25 million or more but less than $50 million.[27] Thus, the majority of firms in this category can be considered small.

E. Description of Projected Reporting, Recordkeeping, and Other Compliance Requirements for Small Entities

White space devices are unlicensed devices that operate in the TV bands at locations where frequencies are not in use by licensed services. These devices may be either fixed or portable. Fixed devices may operate at power levels up to four watts, and portable devices operate at up to 100 milliwatts

[23] *See* n.14.

[24] U.S. Census Bureau, *2012 NAICS Definitions, 443142 Electronics*, http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=443142&search=2012 NAICS Search (last visited May 6, 2014).

[25] 13 C.F.R. § 121.201, NAICS code 443142.

[26] U.S. Census Bureau, 2007 Economic Census, Subject Series: Retail Trade, Estab & Firm Size: Summary Statistics by Sales Size of Firms for the United States: 2007, NAICS code 443142 (released 2010), http://www2.census.gov/econ2007/EC/sector44/EC0744SSSZ4.zip (last visited May 7, 2014). Though the current small business size standard for electronic store receipts is $30 million or less in annual receipts, in 2007 the small business size standard was $9 million or less in annual receipts. In 2007, there were 11,214 firms in this category that operated for the entire year. Of this total, 10,963 firms had annual receipts of under $5 million, and 251 firms had receipts of $5 million or more but less than $10 million. *Id.*

[27] *Id*. An additional 33 firms had annual receipts of $50 million or more.

if they are outside the service contours of adjacent channel TV stations or 40 milliwatts within the service contour of an adjacent channel TV station. To prevent harmful interference to broadcast television stations and other authorized users of these bands, white space devices must obtain a list of available TV channels that may be used at their location from databases administered by private entities selected by the Commission.

Wireless microphones also operate in the TV bands. Certain entities may be issued licenses under Subpart H of Part 74 of the rules to operate low power auxiliary stations in the TV bands. The Commission also allows the operation of Part 74 certified wireless microphones in the VHF and UHF TV bands on an unlicensed basis under a waiver of the Part 15 rules granted in the 2010 *TV Bands Wireless Microphones R&O and Further NPRM*.

In the *Incentive Auction R&O*, the Commission decided to repurpose a portion of the UHF TV spectrum for licensed wireless services (the "600 MHz band"). The Commission's band plan provides for a guard band between television spectrum and 600 MHz downlink services, a guard band between 600 MHz uplink and downlink services (a duplex gap), and guard bands between 600 MHz downlink services and channel 37. In the TV bands that are repurposed for wireless services, the Commission decided to allow white space devices to continue operating indefinitely in areas where a 600 MHz band licensee has not commenced operations, and to allow wireless microphones to operate for 39 months after release of a public notice announcing channel reassignments as a result of the incentive auction.

Most RF transmitting equipment, including white space devices and wireless microphones, must be authorized through the certification procedure. Certification is an equipment authorization issued by the Commission or by a designated TCB based on an application and test data submitted by the responsible party (*e.g.,* the manufacturer or importer). The Report and Order does not change the authorization procedure for white space devices and wireless microphones. However, it establishes new and modified technical requirements for white space devices and wireless microphones, as well as certification, marketing and operational cutoff dates for certain equipment.

With regard to white space devices, the Report and Order permits their operation at lower power levels and closer separation distances to TV stations in all areas, and at higher power with a greater separation distance from TV stations in less congested areas. It also permits the operation of white space devices on additional channels and frequencies where operation is not currently permitted, including TV channels 3 and 4 (fixed devices), channels 14-20 (portable devices), channel 37 (fixed and portable devices), and the 600 MHz guard bands and duplex gap (fixed and portable devices). In addition, the Report and Order allows for the operation of devices with less precise geo-location capabilities. These changes are permissive, meaning that manufacturers of white space devices may implement them in their equipment, but are not required to do so.

The Report and Order requires that white space devices and databases incorporate a "push" feature that allows updated channel information to be sent to a white space device in the event that a previously available channel becomes reserved for use by a wireless microphone. White space devices for which a certification application is filed beginning six months after the effective date of the rules must comply with the new channel push requirement. The Report and Order also requires that within nine months after the effective date of the rules, all white space devices imported and marketed within the United States must comply with these requirements, regardless of when they were certified. It further requires that white space devices that do not comply with the new channel push requirements must cease operating within one year of the effective date of the rules.

With regard to unlicensed wireless microphones, the Report and Order establishes cutoff dates for the certification, manufacturing and marketing of unlicensed wireless microphones in the TV bands, the guard bands (including the duplex gap), and the 600 MHz service band. It permits unlicensed wireless microphone users to continue to operate Part 74 certified wireless microphones in the TV bands under waivers already in place and in the 600 MHz service band until they must cease those operations no later than 39 months after release of the *Channel Reassignment PN*. The Commission will accept applications to certify wireless microphones under new Part 15 rules as soon as those rules are effective, and will

require applicants to certify wireless microphones under new Part 15 rules nine months after the release of the *Channel Reassignment PN,* or no later than 24 months after the effective date of the new rules, whichever occurs first. The Report and Order also requires that manufacturing and marketing of all wireless microphones that would not comply with the 600 MHz band cease 18 months after release of the *Channel Reassignment PN* or no later than 33 months after the effective date of the new rules, whichever occurs first.

E. Steps Taken to Minimize the Significant Economic Impact on Small Entities, and Significant Alternatives Considered

The RFA requires an agency to describe any significant, specifically small business, alternatives that it has considered in reaching its proposed approach, which may include the following four alternatives (among others): "(1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance and reporting requirements under the rule for such small entities; (3) the use of performance rather than design standards; and (4) an exemption from coverage of the rule, or any part thereof, for such small entities."[28]

The rule changes adopted in the Report and Order give greater flexibility for fixed and personal/portable white space device operation in the TV bands. As noted above, the majority of these changes are permissive, meaning that manufacturers of white space devices are not required to incorporate them into previously approved equipment, with the exception of the channel "push" requirement. The Commission adopted this requirement as an alternative to its proposal in the *NPRM* to require that white space devices check the database every 20 minutes to determine which channels are available for use. The Commission determined that the push requirement would be less burdensome on equipment manufacturers, users, and white space database administrators than a 20 minute re-check interval. This change can be implemented in existing devices through a software update without hardware changes, so only a short transition time period is provided.

With regard to wireless microphones, unlicensed users may continue to use Part 74 certified wireless microphones under an existing waiver during the 39 month transition period rather than using Part 15 certified equipment. The Commission took this action since manufacturers need time to certify wireless microphones under the new Part 15 rules, and to permit users to continue using their existing equipment until the operational cutoff date previously established by the Commission.

Report to Congress: The Commission will send a copy of the Report and Order, including this FRFA, in a report to Congress pursuant to the Congressional Review Act.[29] In addition, the Commission will send a copy of the Report and Order, including this FRFA, to the Chief Counsel for Advocacy of the SBA. A copy of the Report and Order and FRFA (or summaries thereof) will also be published in the Federal Register.[30]

[28] *See* 5 U.S.C. § 603(c)(1) – (c)(4).

[29] *See* 5 U.S.C. § 801(a)(1)(A).

[30] *See* 5 U.S.C. § 604(b).

Appendix D

Channel 37 Radio Astronomy Protected Zones

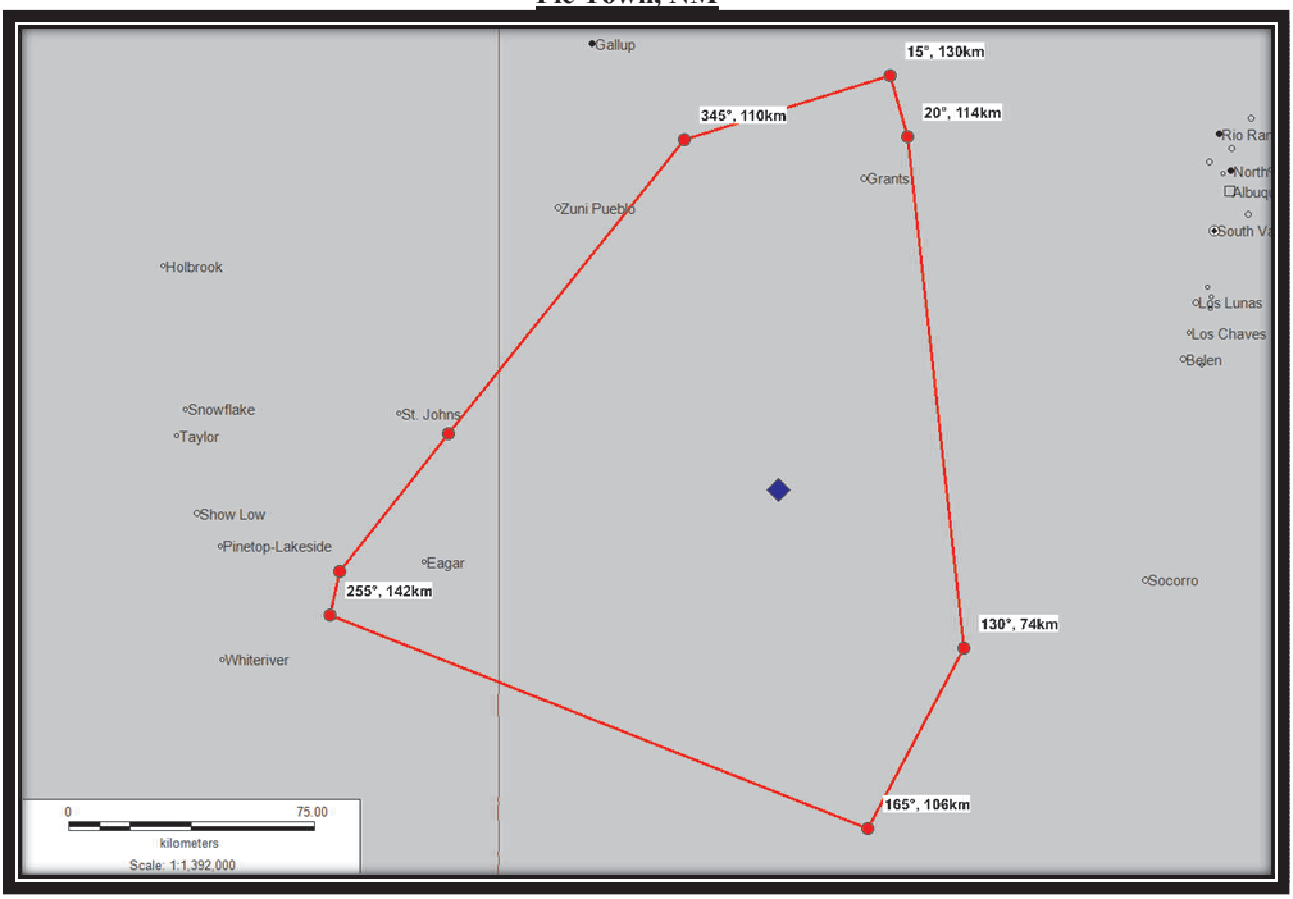
This appendix provides detailed depictions of the zones being implemented by this Report &Order to protect the ten Very Long Baseline Array (VLBA) sites throughout the United States. For each site, we provide an image of the protection zone superimposed upon a map as well as the coordinates that comprise each zone.

As explained in the text, these protection zones were developed using the Longley-Rice version 1.2.2 propagation model to calculate the field strength received at each VLBA from a 40 milliwatt white space transmitter spaced every two kilometers along radials spaced every five degrees. The white space transmitter was assumed to be three meters above ground level and the radio astronomy receiver was assumed to be 27 meters above ground level. The protection level specified in ITU-R RA.769-2 titled "Protection criteria used for radio astronomical measurements" along with the timing criteria in ITU-R Recommendation RA.1513-2, titled "Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy on a primary basis" were used as the basis of protection. To implement those parameters, F(50,2) propagation was used to protect a VLBA receiver interference threshold of 1.54 dBuV/m.

The protected areas shown below represent a best fit polygon connecting the farthest points from each site beyond which the protection criteria is always satisfied.

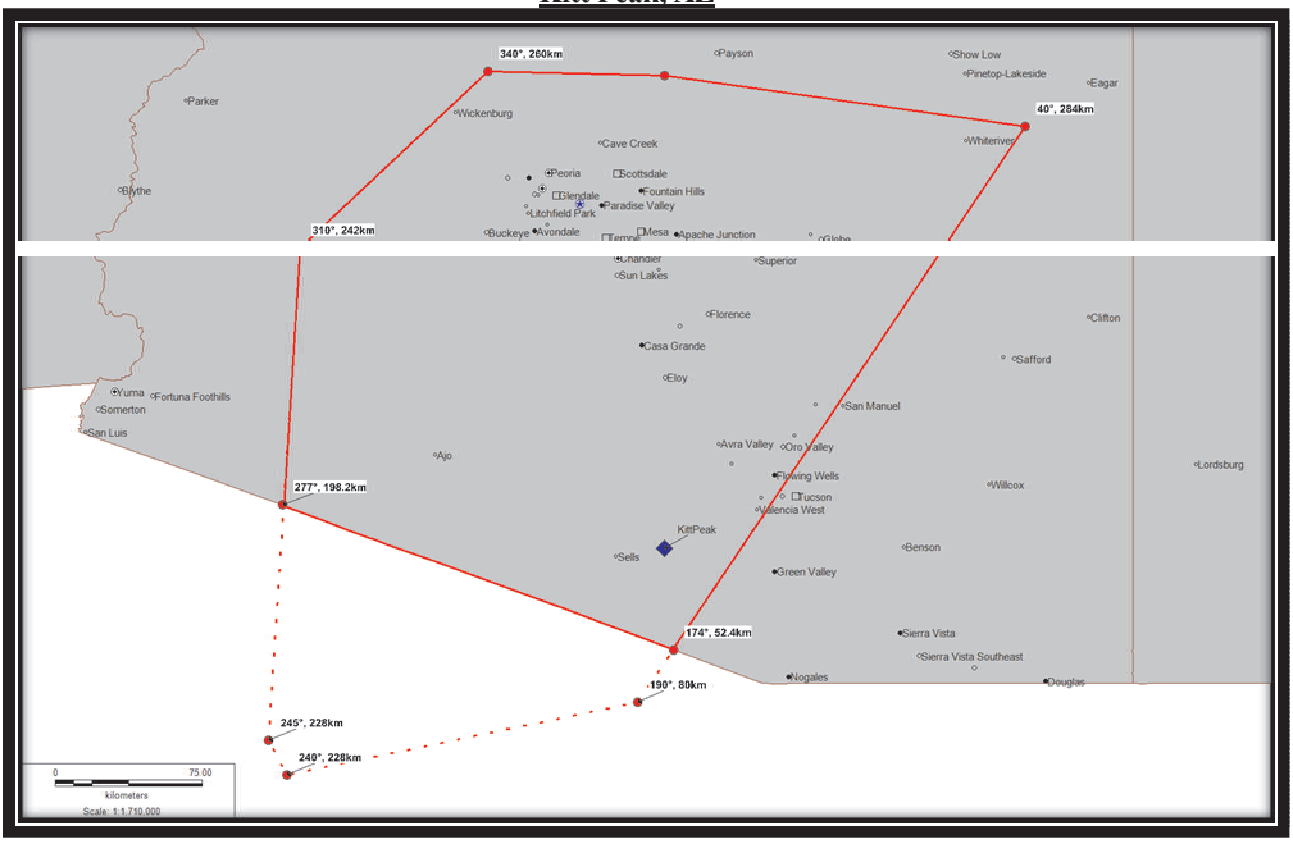
If the results of the incentive auction allow for higher power white space devices on channel 37, we will re-run this analysis to determine the protection zones corresponding to those higher power cases and solicit comments on the resulting protection zones.

Pie Town, NM



Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
15	130	35	25	56.28	107	44	56.40
20	114	35	15	57.24	107	41	27.60
130	74	33	52	14.16	107	30	25.20
165	106	33	22	39.36	107	49	26.40
255	142	33	57	38.52	109	36	10.80
260	136	34	04	46.20	109	34	12.00
280	102	34	27	20.88	109	12	43.20
345	110	35	15	30.24	108	25	55.20

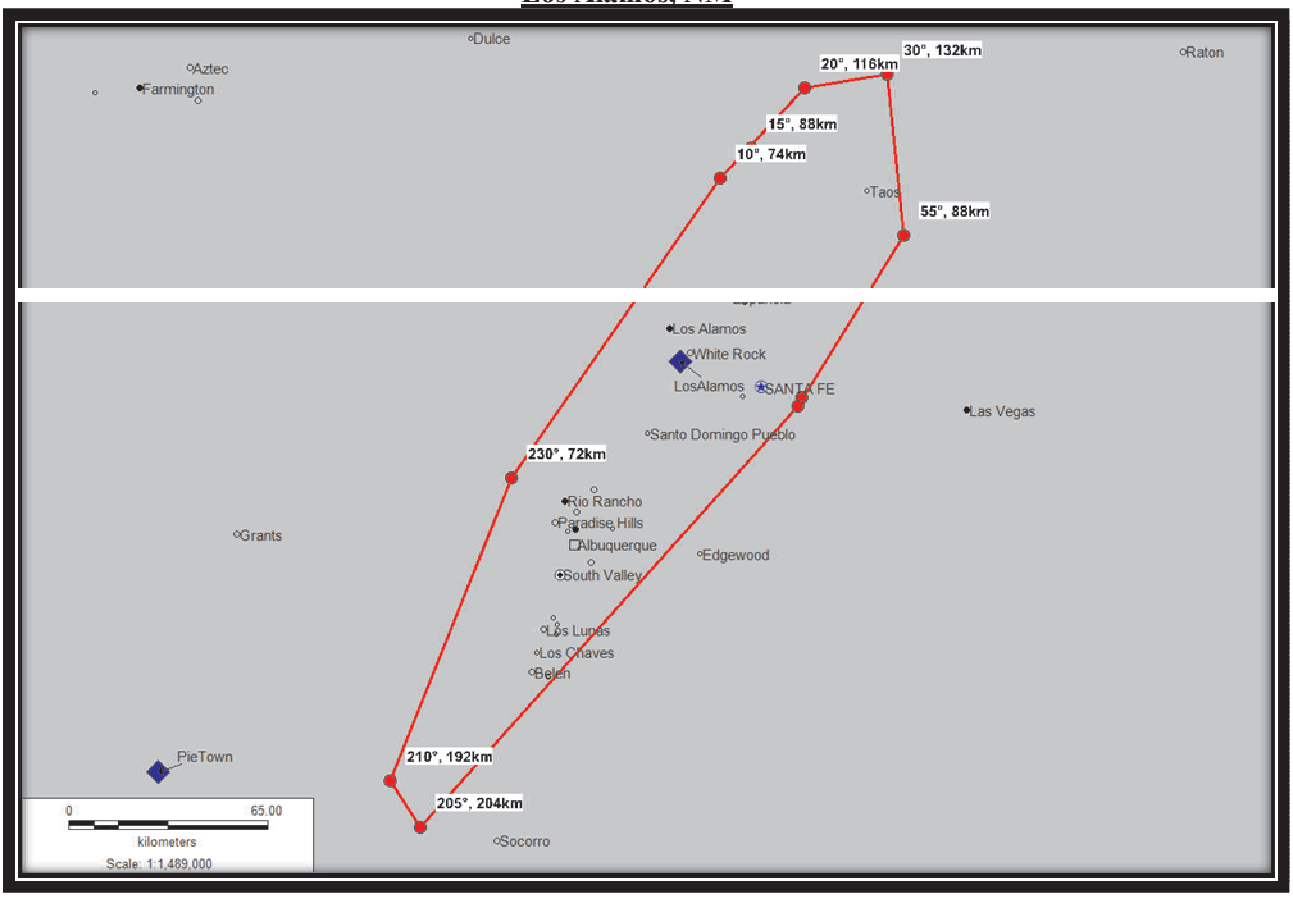
Kitt Peak, AZ



Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
0	242	34	08	18.24	111	36	46.80
40	284	33	54	10.08	109	38	20.40
174	52.4	32	09	25.56	113	42	03.60
277	198.2	31	29	15.72	111	33	43.20
310	242	33	20	36.60	113	36	14.40
340	260	34	09	20.52	112	34	37.20

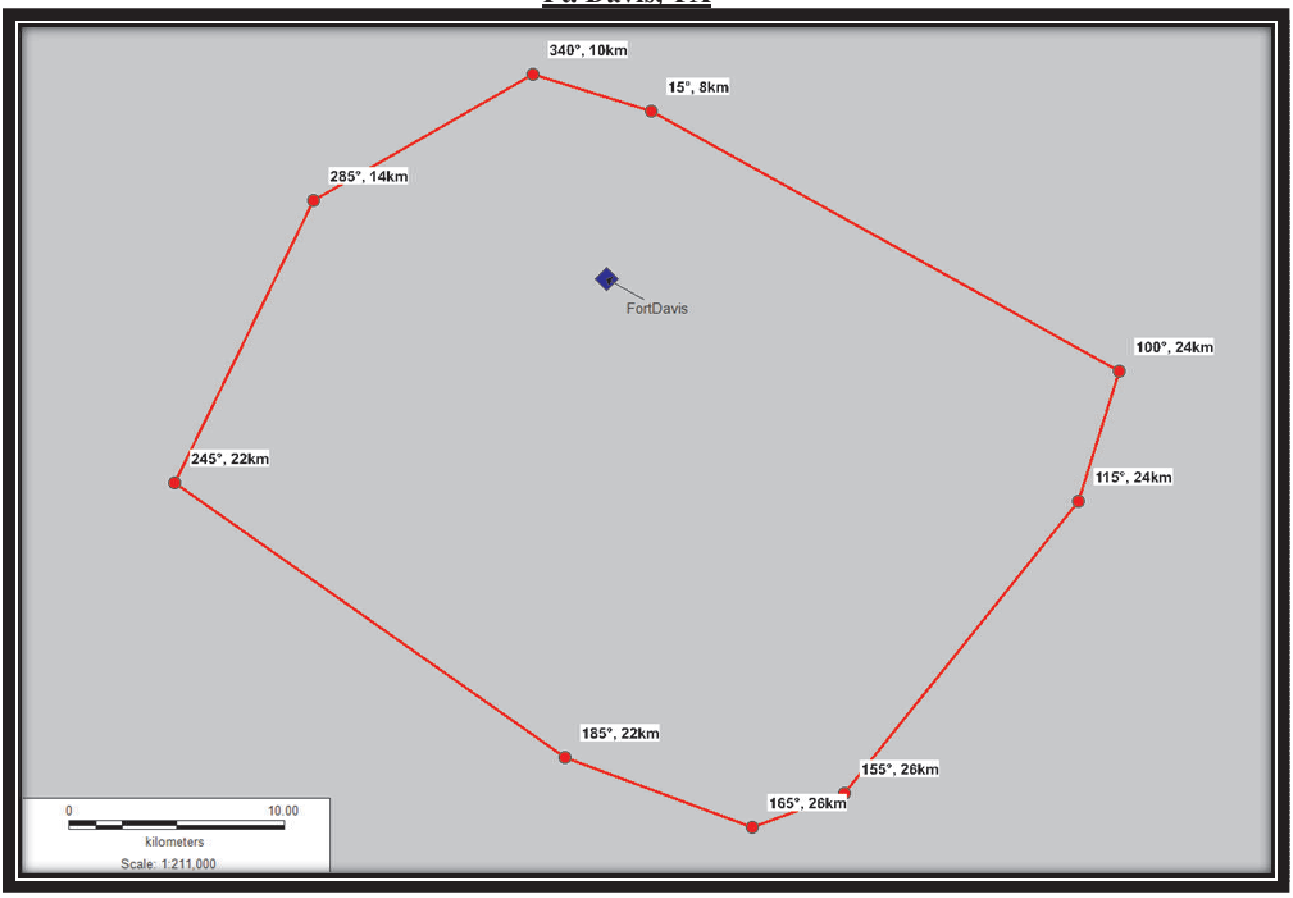
Note: The dotted lines to the south show the full protection zone which falls in Mexico. However, we are only extending the calculated zone to the U.S. border.

Los Alamos, NM



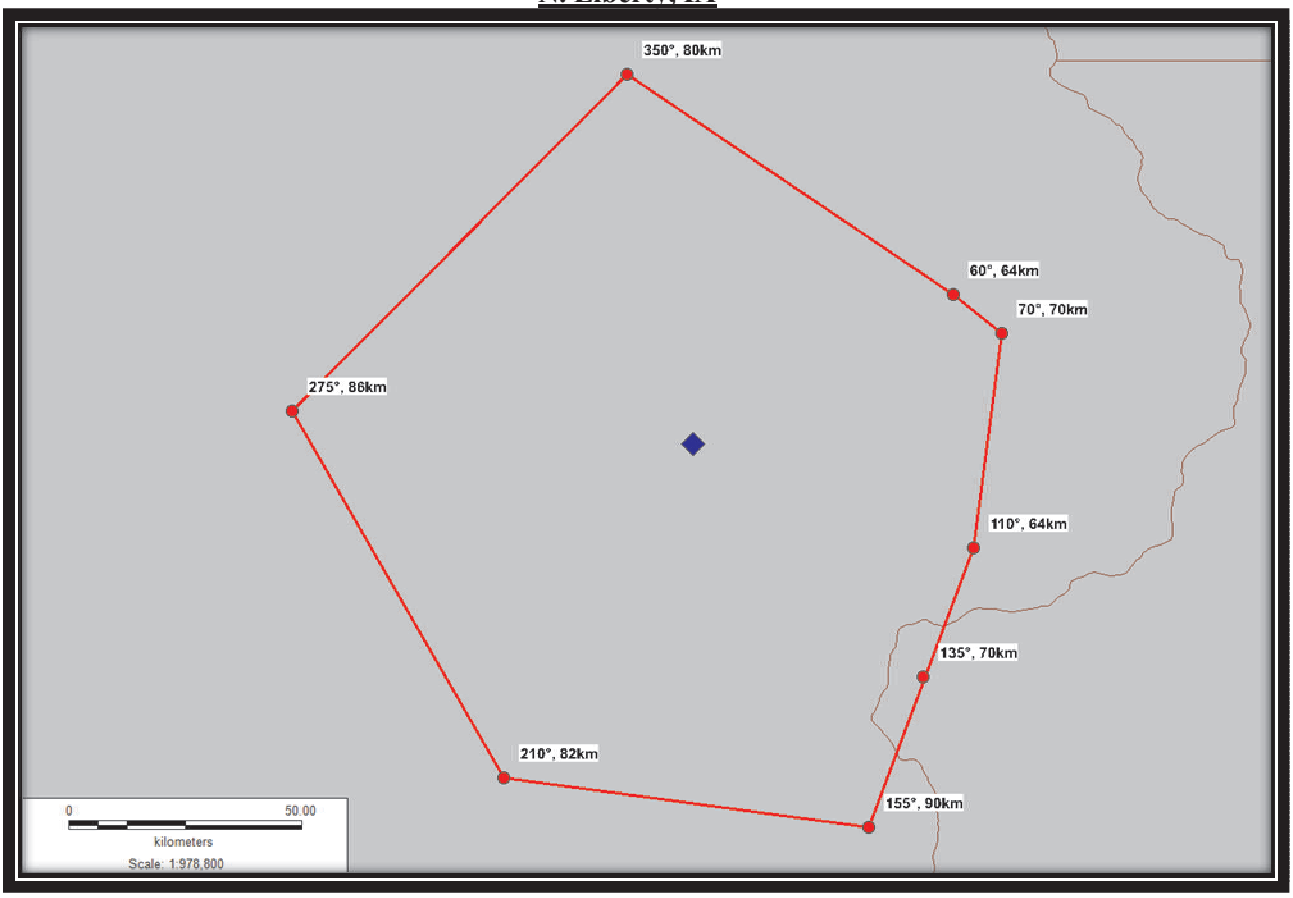
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
10	74	36	25	54.12	106	06	07.20
15	88	36	32	26.88	105	59	27.60
20	116	36	45	23.40	105	48	03.60
30	132	36	48	10.44	105	30	21.60
55	88	36	13	37.92	105	26	38.40
110	42	35	38	40.92	105	48	36.00
115	42	35	36	51.48	105	49	30.00
205	204	34	06	17.28	107	10	48.00
210	192	34	16	18.12	107	17	16.80
230	72	35	21	22.68	106	51	07.20

Ft. Davis, TX



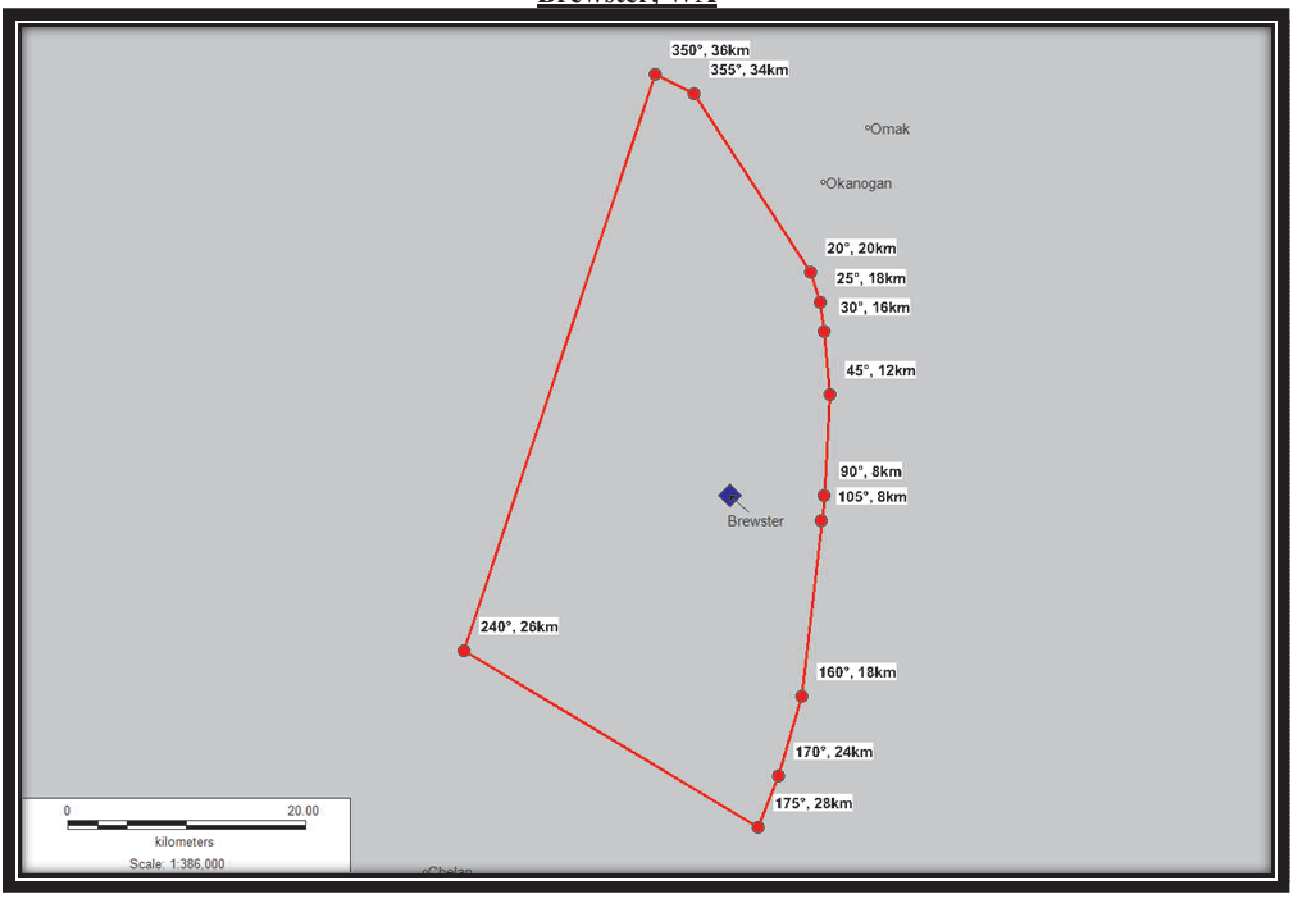
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
15	8	30	42	16.92	103	55	22.80
100	24	30	35	49.92	103	41	52.80
115	24	30	32	35.88	103	43	04.80
155	26	30	25	20.64	103	49	48.00
165	26	30	24	30.24	103	52	30.00
185	22	30	26	14.28	103	57	54.00
245	22	30	33	03.60	104	09	10.80
285	14	30	40	03.36	104	05	09.60
340	10	30	43	11.28	103	58	48.00

N. Liberty, IA



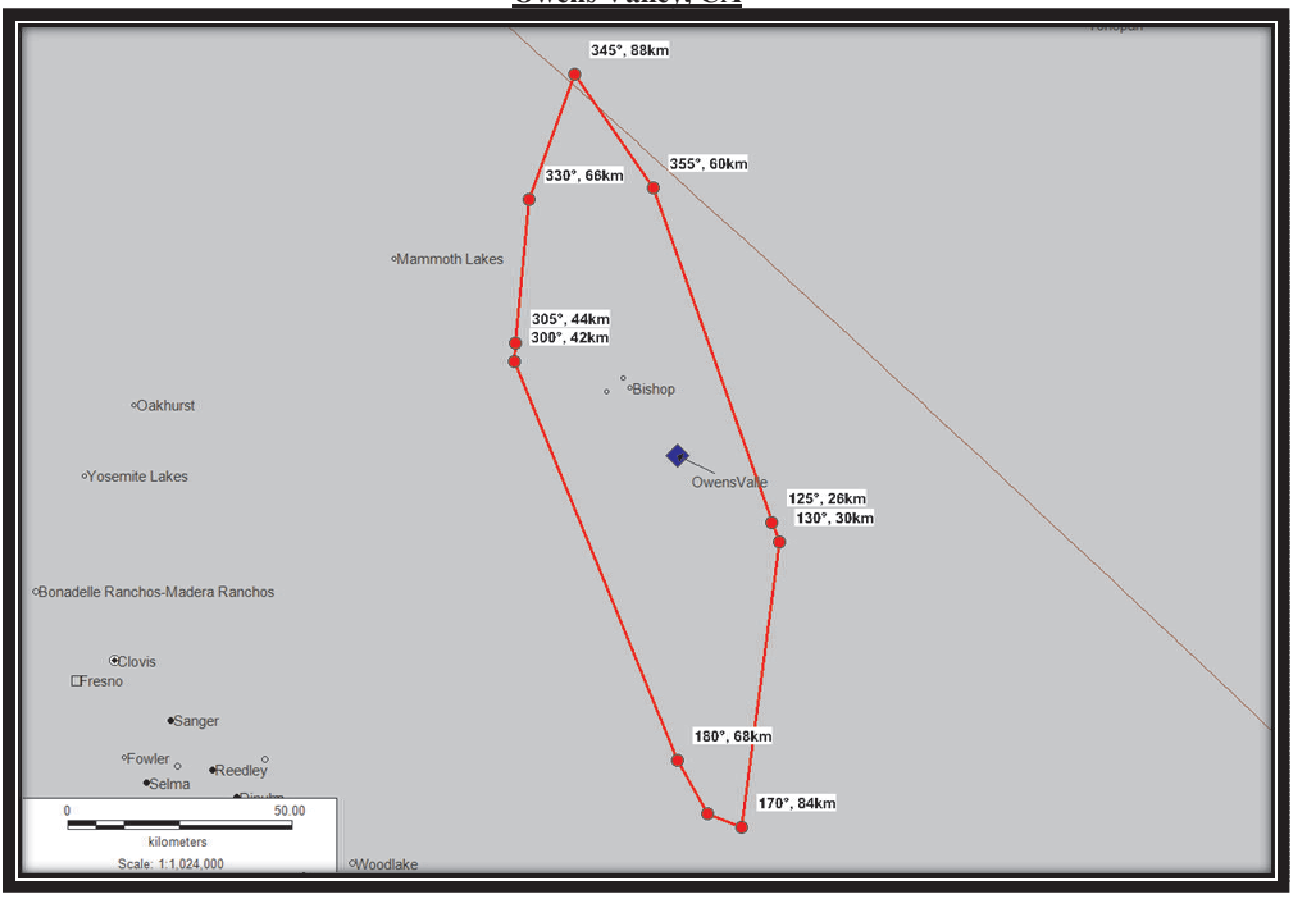
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
60	64	42	03	27.00	90	54	16.56
70	70	41	59	03.12	90	46	49.44
110	64	41	34	19.20	90	51	11.16
135	70	41	19	27.12	90	58	58.80
155	90	41	02	09.96	91	07	18.84
210	82	41	07	51.24	92	03	44.64
275	86	41	50	03.12	92	36	20.16
350	80	42	28	50.16	91	44	35.16

Brewster, WA



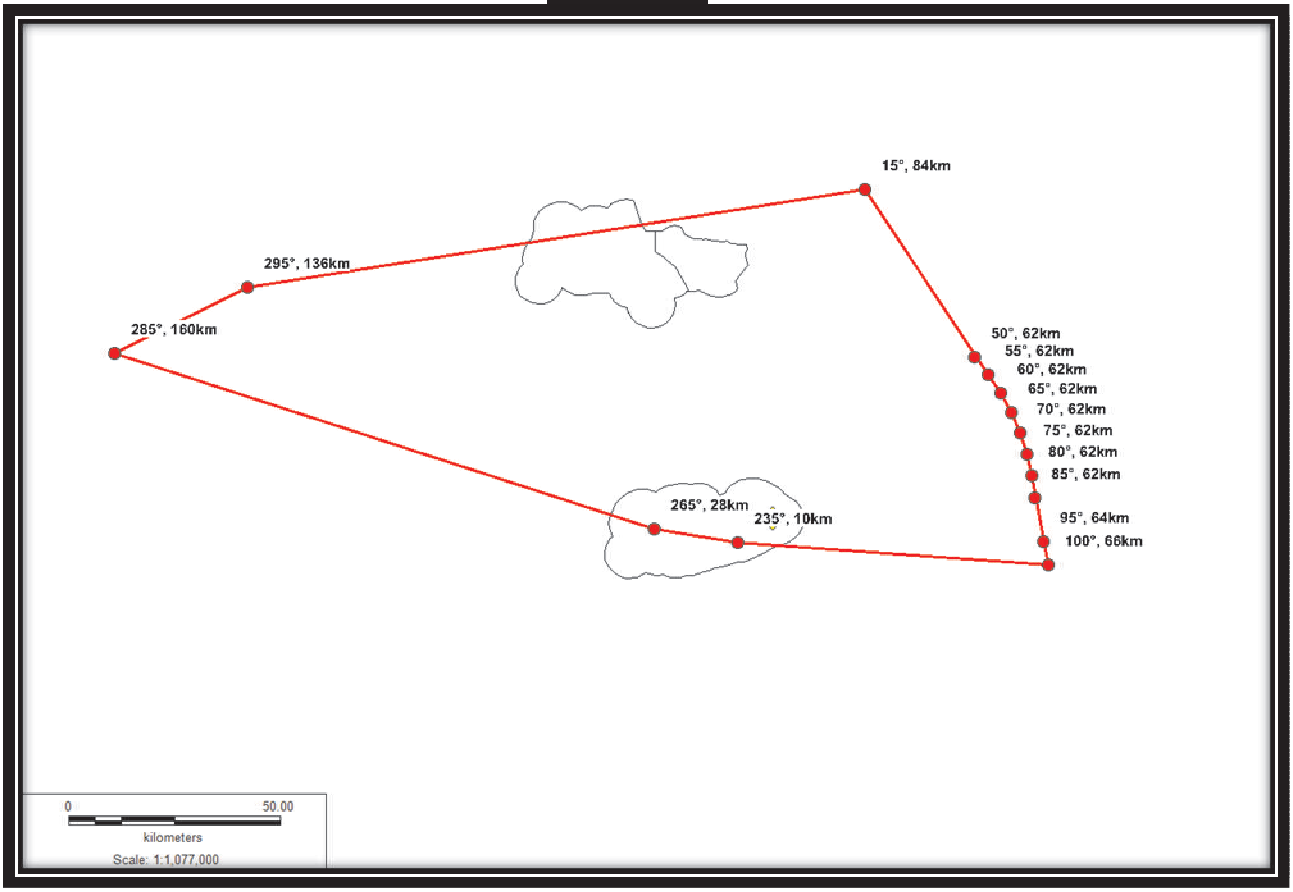
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
20	20	48	18	00.36	119	35	27.60
25	18	48	16	40.08	119	34	51.60
30	16	48	15	20.52	119	34	33.60
45	12	48	12	26.64	119	34	08.40
90	8	48	07	51.96	119	34	33.60
105	8	48	06	44.64	119	34	48.00
160	18	47	58	44.40	119	36	03.60
170	24	47	55	06.60	119	37	40.80
175	28	47	52	48.72	119	39	03.60
240	26	48	00	49.68	119	59	06.00
350	36	48	26	59.64	119	46	04.80
355	34	48	26	08.52	119	43	22.80

Owens Valley, CA



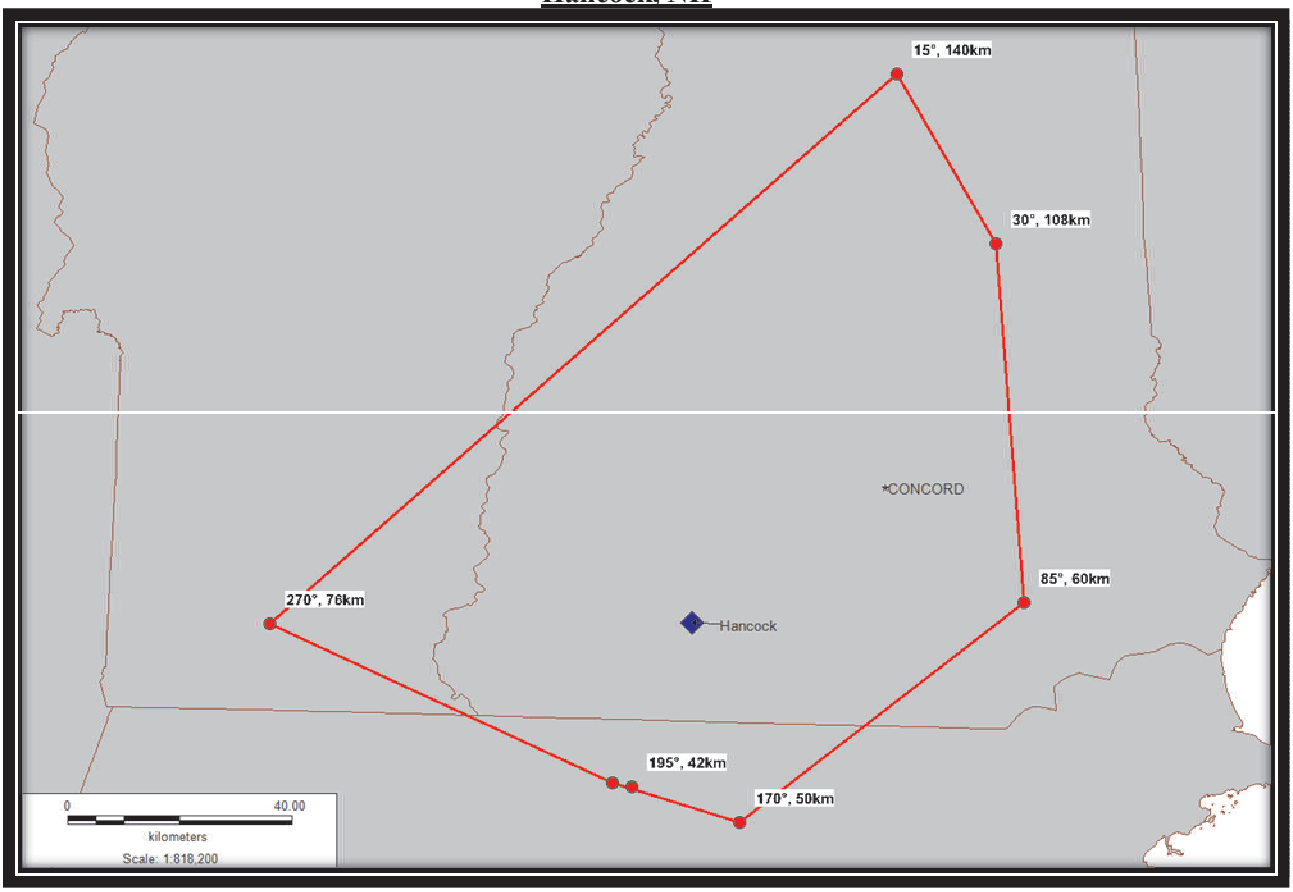
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
125	26	37	05	49.56	118	02	13.20
130	30	37	03	27.36	118	01	08.40
170	84	36	29	09.96	118	06	50.40
175	80	36	30	48.60	118	11	56.40
180	68	36	37	08.04	118	16	37.20
300	42	37	25	12.72	118	41	16.80
305	44	37	27	30.24	118	41	02.40
330	66	37	44	45.96	118	39	03.60
345	88	37	59	49.92	118	32	09.60
355	60	37	46	12.72	118	20	09.60

St. Croix, VI



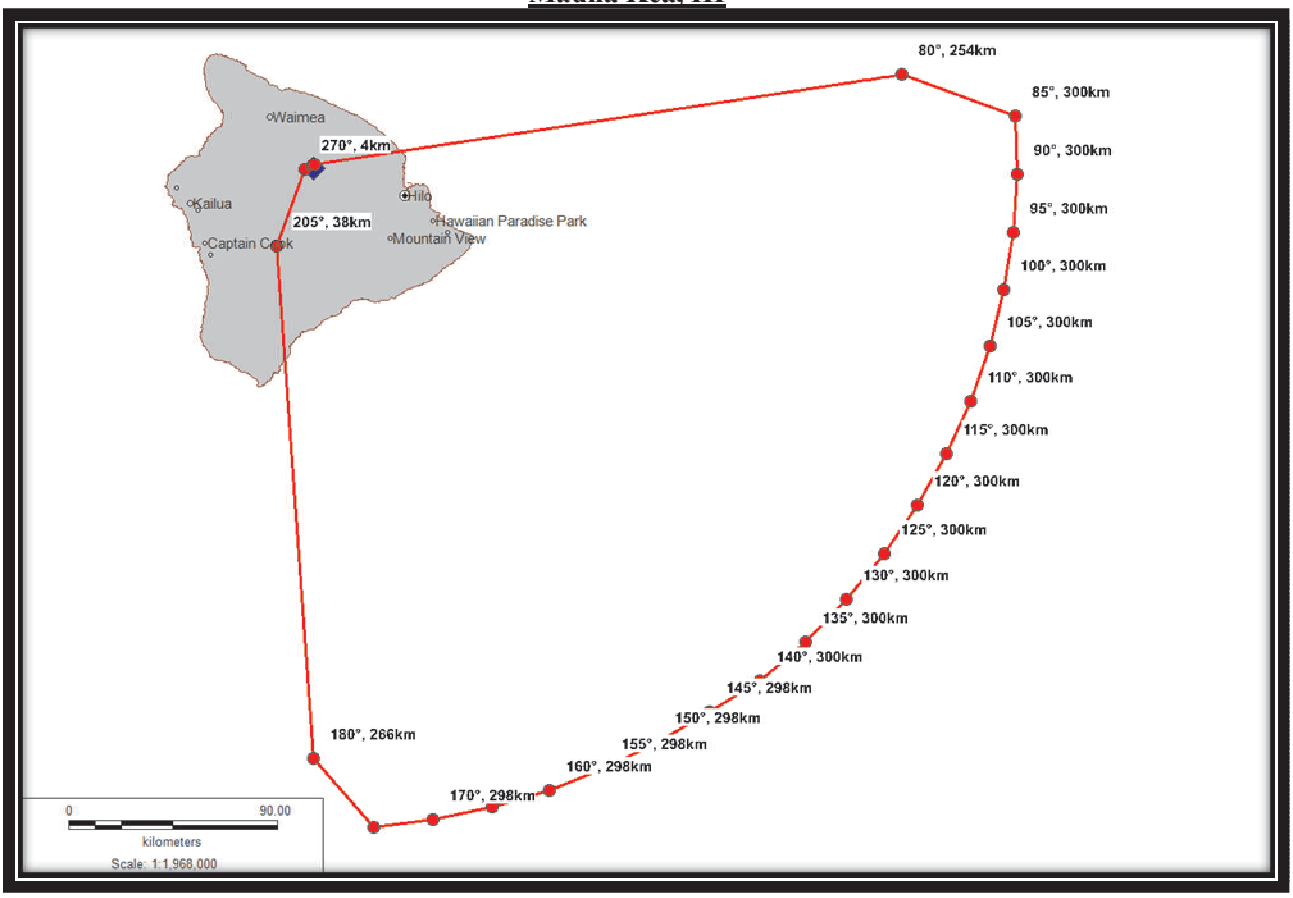
Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
15	84	18	29	15.36	64	22	38.28
50	62	18	06	51.12	64	08	03.84
55	62	18	04	31.44	64	06	12.24
60	62	18	02	02.76	64	04	33.96
65	62	17	59	26.52	64	03	09.36
70	62	17	56	43.80	64	01	59.52
75	62	17	53	56.04	64	01	04.80
80	62	17	51	03.96	64	00	25.56
85	62	17	48	09.72	64	00	02.16
95	64	17	42	19.08	63	58	57.36
100	66	17	39	07.92	63	58	15.96
235	10	17	42	10.44	64	39	37.44
265	28	17	43	57.00	64	50	46.32
285	160	18	07	24.24	66	02	36.96
295	136	18	16	13.80	65	44	56.04

Hancock, NH



Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
15	140	44	08	59.64	71	32	01.68
30	108	43	46	24.60	71	18	57.60
85	60	42	58	41.88	71	15	14.04
170	50	42	29	25.08	71	52	51.96
195	42	42	34	05.88	72	07	08.76
200	42	42	34	41.52	72	09	41.76
270	76	42	55	47.28	72	55	03.72

Mauna Kea, HI



Bearing (Deg)	Distance (km)	Latitude (North)			Longitude (West)		
80	254	20	11	01.32	153	03	43.20
85	300	20	00	52.92	152	35	56.40
90	300	19	46	42.60	152	35	34.80
95	300	19	32	33.36	152	36	28.80
100	300	19	18	31.68	152	38	38.40
105	300	19	04	44.04	152	42	07.20
110	300	18	51	16.56	152	46	51.60
115	300	18	38	15.72	152	52	44.40
120	300	18	25	46.56	152	59	49.20
125	300	18	13	55.20	153	07	55.20
130	300	18	02	46.68	153	17	06.00
135	300	17	52	26.40	153	27	14.40
140	300	17	42	57.96	153	38	16.80
145	298	17	35	20.04	153	50	45.60
150	298	17	27	52.20	154	03	10.80
155	298	17	21	27.00	154	16	15.6
160	298	17	16	08.40	154	29	49.20
165	298	17	11	57.84	154	43	51.60

170	298	17	08	57.48	154	58	08.40
175	298	17	07	09.12	155	12	43.20
180	266	17	23	53.52	155	27	21.60
205	38	19	29	13.92	155	36	21.60
270	4	19	47	53.88	155	29	27.60
335	2	19	48	52.92	155	27	39.60
355	2	19	48	58.68	155	27	14.40

STATEMENT OF
CHAIRMAN TOM WHEELER

Re: Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37 (ET Docket No. 14-165); Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap; Promoting Spectrum Access for Wireless Microphone Operations (GN Docket No. 14-166); and Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions (GN Docket No. 12-268).

As the Commission continues its preparations for next year's Incentive Auction, we are committed to laying the foundation for an efficient, effective and timely auction that serves the public interest. This week, we adopt two companion items important for achieving these objectives: the Part 15 Report and Order and the Wireless Microphones Report and Order.

These items contain important components that must be in place before the Incentive Auction. We establish clear rules for unlicensed devices and wireless microphones in the 600 MHz band, including the duplex gap and guard bands, that also protect and create certainty and protections for the licensed users – including broadcasters and future 600 MHz band licensees.

We provide for continued operation of the various stakeholders following the incentive auction in the 600 MHz band, Channel 37, and the television band. Wireless medical telemetry devices and radio astronomy services will continue to have interference protection on Channel 37, while unlicensed users gain access to the channel in areas where WMTS and RAS are not using it. Wireless microphones, both licensed and unlicensed, will be able to operate in the 600 MHz band duplex gap and guard bands, and continue to operate in the 600 MHz wireless band during the post-auction transition period.

We fulfill our commitment to ensure unlicensed use of the 600 MHz and TV bands nationwide. Unlicensed spectrum has been a powerful platform for driving innovation, investment, and economic growth. Breakthroughs like Wi-Fi, which relies on unlicensed spectrum, have generated hundreds of billions of dollars of value for our economy and consumers. This item will benefit consumers in the form of increased investment and innovation in unlicensed products and services.

We continue our work to accommodate the long term needs of licensed microphone users by increasing the utility of bands where they already have access and expanding access to other spectrum bands. Added to the steps we took last year to allow more microphone users to become licensed, today's item solidifies our commitment to address the important needs of microphone users.

No party gets everything it wants in these items. The results of auctioning 600 MHz spectrum means the 600 MHz band operating parameters will be new to everyone after the auction. For this reason, today's Part 15 item lays out a number of steps that must be taken before unlicensed operations may begin. It also provides common sense procedures that stop harmful interference if it were to occur.

Collectively, the actions we take in these two Orders promote efficient use of our nation's spectrum resources, address the important needs of the unlicensed and wireless microphone communities, and protect other licensed users in these bands – all of which are critical as we move toward the Incentive Auction next year.

STATEMENT OF
COMMISSIONER MIGNON L. CLYBURN

Re: *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37; Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap;* ET Docket No. 14-165*; and Expanding the Economic and Innovation Opportunities of Spectrum through Incentive Auctions,* GN Docket No. 12-268, Report and Order

The world's first ever reverse incentive auction is not just about broadcast TV stations turning in spectrum licenses to be resold for commercial wireless services. A successful incentive auction also impacts the amount of spectrum available for incumbent communications services, such as wireless microphones, wireless medical telemetry and TV White Space devices, which provide important services. Wireless medical telemetry services provide real-time lifesaving information to medical professionals. Wireless microphones allow for broadcasters to report the news in an untethered manner and for performers to entertain us on stage without the worry of tripping over cords. And TV White Space devices offer low-cost ways to bring mobile broadband to unserved and underserved areas, such as rural and lower income urban communities.

Our action today will better enable these services to operate in the future. We take steps to allow white space devices to operate in TV channels previously unavailable to them, while continuing to protect TV services from harmful interference. We adopt technical rules for white space operations in the 600 MHz band, and take steps that will continue to accommodate unlicensed microphone use in the TV bands and in the 600 MHz band. We improve the location and frequency information in the white space databases, and update the procedures for white space devices and database administrators to reflect the changes we make today. And we adopt transition periods for the certification, manufacturing, and marketing of white space devices and unlicensed wireless microphones.

All together, these rule changes will allow innovative and important services to coexist in an era where spectrum is increasingly constrained. They also help promote the public interest goal of maximizing the efficient use of spectrum.

Earlier in this proceeding, I said that the time had come to kick the lawyers out of the room and let the engineers lead the way. With this item, the engineers did just that and performed remarkably well. This item clearly reflects the hard work of OET's staff and others throughout the Commission. I thank Julie Knapp and the Office of Engineering and Technology for their presentation and hard work throughout this proceeding.

STATEMENT OF
COMMISSIONER JESSICA ROSENWORCEL

Re: *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap*, *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, ET Docket No. 14-165, GN Docket No. 12-268
(August 6, 2015)

The universe of people who know why the Commission's Part 15 rules matter is—let's admit it—small. But the universe of people who use Part 15 services is big—really, really big. In fact, the odds are you will use an unlicensed device authorized under our Part 15 rules today. It could be the shiny new tablet or laptop you used to go online with coffee and Wi-Fi this morning. Or maybe it was the old cordless phone you dusted off to make a quick call. It could have been the baby monitor you used overnight or the remote control you pressed in the morning to get out of the garage and make your way to work. Or perhaps it was the Bluetooth you used in the office or the health monitoring equipment you will use at home tonight.

Our Part 15 policies—which establish the parameters for unlicensed devices that operate in so many of our spectrum bands—are essential to the use of unlicensed spectrum. And the use of unlicensed spectrum is now an essential part of everyday, modern life.

But it was not always this way. Thirty years ago the Commission struggled with what to do with a bunch of underused frequencies in the 900 MHz, 2.4 GHz, and 5.8 GHz bands—bands that were initially designed for industrial, scientific, and medical uses. The services in these bands never materialized. In fact, so little was happening in this spectrum, these airwaves were known as "garbage bands." The conventional wisdom was that they were junk. They were scraps of spectrum where demand for wireless licenses would just be limited.

But then our predecessors at the Commission turned conventional wisdom on its head. They did more than just dismiss these bands as junk. They abandoned the traditional practice of providing licenses to single operators to control these specific bands for specific purposes and instead opened them to the public. And while the impact of this decision wasn't clear at the time, or even when Part 15 rules were revised in 1989, the results are everywhere today. This forward-thinking led to the development of Wi-Fi, which is now responsible for billions of dollars of economic activity every year. It also led to the development of countless innovative devices we rely on every day. It will lead us forward, too, to the coming Internet of Things.

So, we need to keep the cool coming—and with the changes coming to the 600 MHz band, we need to find ways to create more possibilities for unlicensed use. By and large, we do that today by updating our Part 15 rules. We expand the spectrum available to unlicensed devices. We codify rules to allow unlicensed wireless microphones to continue operation in the 600 MHz band. We increase the power levels for unlicensed devices serving rural areas in order to broaden their service range. At the same time, we bolster the amount of information in white space databases to help alleviate interference concerns.

I believe this decision will have real impact. Because by building on our Part 15 policies from the past—we can expand the future of unlicensed services, technologies, and innovations. That's exciting—and I look forward to seeing what develops.

STATEMENT OF
COMMISSIONER AJIT PAI,
APPROVING IN PART AND CONCURRING IN PART

Re: *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, ET Docket No. 14-165; *Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap*; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268.

In the Spectrum Act, Congress authorized the FCC to put the 600 MHz guard bands to productive, unlicensed use.[1] At the same time, it prohibited the Commission from permitting any such use that would cause harmful interference to licensed services.[2]

Congress did not impose this limitation out of animosity towards unlicensed operations. Rather, as the record here confirms, impairing licensed spectrum drives down auction revenues, reduces the overall amount of spectrum available for consumer use, and threatens the success of the incentive auction, none of which is in anyone's interest. Indeed, the record shows that even a 5% loss of spectrum capacity due to interference from guard band operations will lower spectrum values by 9%.[3] A 20% impairment will lower them by 43%.[4]

And in some cases, impairing licensed spectrum can carry much higher costs. Take, for example, the Wireless Medical Telemetry Service (WMTS), which is a licensed service that operates, in part, on Channel 37 in the 600 MHz band. WMTS is used in hospitals and health care institutions across the country, including at Labette Health in Parsons, Kansas, where my parents work. Hospitals use WMTS for a variety of critical functions, from tracking the vital signs of patients undergoing cardiac rehab to monitoring emergency room trauma and fetal activity. In short, WMTS can involve matters of life and death. Harmful interference could have serious and immediate consequences.

During this proceeding, hundreds of health care institutions told us that the Commission's protection zones would not be adequate to prevent unlicensed white space devices from causing harmful interference to WMTS. Their concern is understandable. Among other things, the FCC's technical analysis is based on the assumption that hospitals with WMTS devices are no more than three stories tall. But the record shows that a majority of hospitals with WMTS devices are taller than that.[5]

The WMTS community is not alone in its worry. A bipartisan group of nearly 20 members of the U.S. Senate and House of Representatives recently weighed in on this issue. They noted that the record "includes the results of real-world testing at three different hospitals demonstrating that interference to

[1] Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, 126 Stat. 156, Title VI § 6407(d) (2012) ("The Commission may permit the use of such guard bands for unlicensed use.") (Spectrum Act).

[2] Spectrum Act § 6407(e) ("The Commission may not permit any use of a guard band that the Commission determines would cause harmful interference to licensed services.").

[3] *See, e.g.*, Coleman Bazelon, Charles Jackson, Dorothy Robyn, *Unlicensed Operations in the 600 MHz Band: Fatally Flawed Twice Over* at iii, 32 (Feb. 25, 2015), *available at* http://go.usa.gov/3AhxA.

[4] *Id.*

[5] *See Order* at para. 210.

WMTS systems will be caused by a TVWS [TV white space] device operating at the power-levels and distances proposed by the Commission."[6]

I share this concern. Accordingly, I proposed that whenever a WMTS facility determines that the FCC's protection zones are not adequate to prevent harmful interference, those zones will automatically be extended up to three times their current size upon the licensee's filing of a waiver request. Those extended zones will remain in place until the FCC can adjudicate the merits of the request. I am grateful to my colleagues for accommodating my suggestion. With this mechanism in place, the *Order* now creates the right incentives for both the WMTS and unlicensed communities to negotiate in good faith and reach a consensus-based approach to sharing the spectrum while at the same time protecting WMTS from harmful interference. In particular, this change should help safeguard patients in hospitals that are more than three stories tall. I am voting to approve this part of the *Order* and look forward to monitoring the parties' progress toward reaching a workable solution.

Now, Channel 37 didn't present the only difficult engineering issue. More broadly, FCC staff—including our engineers in the Office of Engineering and Technology—were tasked with crafting rules for unlicensed operations that would prevent the guard bands from laying fallow while also protecting licensed services from harmful interference, as Congress required in the Spectrum Act. This was not easy, to say the least.

For my part, I would have struck a different balance than the *Order* does. As I have said throughout this proceeding, I am a big proponent of making more spectrum available for unlicensed use. But we must convince more than just ourselves that unlicensed operations will not cause harmful interference to licensed services. For the incentive auction to succeed, we must make sure that bidders enter the auction confident that they are not going to be stuck with spectrum that is impaired by guard band operations.[7]

I am not entirely convinced that we got that last part right. Many have argued that the Commission's technical analysis is too optimistic, to put it mildly. They say that our analysis is predicated on 600 MHz devices performing orders of magnitude better than industry standards, that it uses unrealistic assumptions about the separation distances between licensed and unlicensed devices, and that it adds path losses that are not relevant when talking about devices that will be located only one meter or less apart.[8] These are credible objections.

But in the end, I am voting to concur with this part of the *Order* because I believe there's been meaningful progress on this issue, and I appreciate the efforts that the Chairman's Office and OET made to try to accommodate my concerns.

In particular, the *Order* now provides that if a licensed wireless provider believes that an unlicensed device is causing harmful interference to its licensed service, the relevant parties must work collaboratively

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[6] *See* Letter from Hon. Greg Walden *et al*. to Hon. Tom Wheeler, Chairman, FCC (July 31, 2015); *see also* Letter from Hon. Tammy Baldwin *et al*. to Hon. Tom Wheeler, Chairman, FCC (Aug. 5, 2015) ("Hospitals and professionals rely on WMTS every second of every day to keep patients alive and safe. It is essential that WMTS devices can continue to operate without interferences from TVWS devices.").

[7] This is particularly important for smaller providers and new entrants since they may not have other spectrum to use if they are affected by harmful interference within the 600 MHz band. *But see Order* at note 380 (noting that "wireless handsets are typically multi-band devices that can operate in another band in the event interference occurs").

[8] *See, e.g.*, CTIA Comments at 11; TIA Comments at 4; Qualcomm Comments at 4; *see also* Consumer Electronics Association, Technical Paper, "Protection Bands and Potential Interference at 600 MHz," GN Docket No. 12-268 (Dec. 16, 2013), *available at* http://go.usa.gov/3s2DA.

and in good faith with the licensed provider to address the issue.[9] Our hope is that questions of interference can be resolved by the relevant parties on a voluntary and expedited basis, so that the licensed provider won't necessarily have to ask for, and then wait for, the FCC to act.

In addition, the *Order* now makes clear that for unlicensed devices, compliance with our Part 15 technical rules does not create blanket immunity from non-interference requirements. Consistent with the Spectrum Act's provisions, they cannot cause harmful interference to licensed services. Although these aren't perfect or complete solutions, they are important improvements.

I also appreciate my colleagues' willingness to support my request that we not prejudge the pending commence operations proceeding.[10] Instead of deciding here how we will define the geographic areas around which 600 MHz licensees will be deemed to have "commenced operations"—a triggering event that determines whether unlicensed operations are allowed in a licensed area and an issue which has generated much disagreement—the *Order* properly defers this question to our upcoming proceeding. That's the right call.

* * *

Finally, it's important to put our labors in this proceeding in perspective. We have put substantial effort into finding 12, or if we're lucky, 18 MHz of spectrum in the 600 MHz band for unlicensed use. At the same time, Congress in 2012 opened up much more technically promising vistas in the 5 GHz band. I've been calling on the FCC to make up to 195 MHz of 5 GHz spectrum available for unlicensed use since then,[11] and the FCC has been considering the matter for two and a half years.[12] That band is ready to unleash the next Wi-Fi revolution; the 802.11ac technical standard already exists, and its wide, contiguous blocks allow 1 gigabit per second connectivity or more.

I hope that we carry the resolve we've shown in today's *Order* over to the 5 GHz proceeding. Whatever the future potential of 600 MHz unlicensed operations, 5 GHz spectrum is here, now, and ready to empower the next generation of entrepreneurs and wireless consumers.

[9] *See Order* at para. 133.

[10] *See Comment Sought on Defining Commencement of Operations in the 600 MHz Band*, GN Docket No. 12-268, Public Notice, 30 FCC Rcd 3200 (2015).

[11] *See, e.g.*, Remarks of Commissioner Ajit Pai at CTIA's MobileCon, http://go.usa.gov/4tkA (Oct. 10, 2012); Statement of Commissioner Ajit Pai, Hearing before the Subcommittee on Communications and Technology of the U.S. House of Representatives Committee on Energy and Commerce, http://go.usa.gov/4t8Q (Dec. 12, 2012); *see also* Remarks of FCC Commissioner Ajit Pai, "Looking Back and Looking Ahead: The FCC and the Path to the Digital Economy," http://go.usa.gov/WRj4 (July 25, 2013); Commissioner Ajit Pai Applauds U.S. House of Representatives Committee on Energy and Commerce for Highlighting Promise of 5 GHz Band for Unlicensed Use and Calls for Prompt FCC Action to Facilitate Greater Use of 5 GHz Band, http://go.usa.gov/3WySC (Nov. 13, 2013); Remarks of FCC Commissioner Ajit Pai at WISPAPALOOZA, http://go.usa.gov/3WySF (Oct. 15, 2014).

[12] *See Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, ET Docket No. 13-49, Notice of Proposed Rulemaking, 28 FCC Rcd 1769 (2013).

STATEMENT OF
COMMISSIONER MICHAEL O'RIELLY
APPROVING IN PART, CONCURRING IN PART

Re: Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap, ET Docket No. 14-165, Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, Report and Order.

As we seek to maximize our valuable spectrum resources by opening bands to additional uses, the potential for harmful interference between existing and new operations can increase. Our job, as best as possible, is to rely on sound science to determine how devices will work in a real world environment. And this item demonstrates that there is very little consensus on many critical inputs.

After rounds of engineering and technical submissions by interested parties, the Office of Engineering and Technology has made their calculations and analysis about how the various stakeholders can amicably utilize the 600 MHz and TV bands. Although I support today's item, I do have some concerns that things may not work out as conveniently in real life as they do in this item. While I trust that OET's findings are correct, there is a lot riding on them.

For this reason, I requested that interference mitigation measures should be strengthened for wireless licensees, to ensure that we are fully compliant with the provisions in the law. The Spectrum Act states that "[t]he Commission may not permit any use of a guard band that the Commission determines would cause harmful interference to licensed services,"[1] signaling Congress' clear intent that licensed wireless services be protected from interference. The wireless industry, based on its engineering studies, however, has expressed serious concerns about the potential for harmful interference from unlicensed devices in the guard bands and duplex gap.

Although the item states that the FCC can take "immediate corrective action upon determining that there is harmful interference," there doesn't appear to be any process in place to ensure that the Commission's finding of interference will be timely. If the Commission is convinced that harmful interference is unlikely, then providing a means for the expeditious resolution of interference concerns should not be burdensome to the Commission. Not only does the Spectrum Act call for such measures, but the wireless industry understandably needs safeguards to provide the necessary comfort to bid the large amounts needed for this auction to be a success.

Similar interference concerns have been raised by the Wireless Medical Telemetry Service (WMTS) users, which going forward will share channel 37 with unlicensed devices. I appreciate the work of my colleague, Commissioner Pai, to ensure that hospitals that rely on this spectrum for such devices as heart and fetal monitors, something I have learned more about lately, can avoid harmful interference. While I would have preferred that the new language include an expiration date to ensure neither side has an incentive to slow the negotiations to reach a private sector sharing solution, preferably one based on coordination zones rather than exclusion zones, everyone should be on notice that all parties are expected to work together to find an acceptable sharing outcome. In the end, my colleagues and I expect channel 37 to be available for unlicensed use in a way that protects WMTS service.

Relatedly, the Commission needs to do further work on its technical rules regarding antenna

[1] Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6407(e), 47 U.S.C. § 1454(e) (2012).

height in rural America, as it relates to operating in both the TV band and other unlicensed bands. In those areas where spectrum constraints are less, such as rural areas, the Commission needs to seriously examine allowing wireless Internet service providers (WISPs) to place facilities on higher towers in order to avoid the surrounding topography. The current arbitrary height limitation does not make sense in every circumstance and may harm broadband deployment. Specifically, if done correctly, this could allow WISPs to expand their coverage areas, benefitting Americans in rural areas unserved by broadband providers. I hope that the Commission will review these rules in the near term.

Further, the Commission prohibits the use of personal and portable devices below Channel 14 without an experimental license. This is the same type of artificial limitation that was previously implemented and finally being eliminated to allow fixed devices on channels 3 and 4, personal/portable devices on channels 14 through 20, and white space devices on channel 37. The reasoning provided for this restriction is that, below Channel 14, the antenna size needed to receive a signal would be too large for a mobile device. Although this may be true now, we don't know what the future brings, and parties to this proceeding have expressed interest in these channels. We should provide industry and entrepreneurs the ability and incentive to innovate without additional regulatory barriers, as opposed to limiting opportunities that could benefit the development of new options for Americans.

For these reasons, I approve in part and concur in part. I thank the Office of Engineering and Technology for their efforts on this highly technical item.