Public Sector Spectrum Release (PSSR)

Technical coexistence issues for the 2.3 and 3.4 GHz award

Consultation

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Section 1

Executive Summary

1.1 This consultation sets out our proposals for addressing technical issues related to the forthcoming award of 190 MHz of spectrum in the 2.3 and 3.4 GHz bands. It focuses in particular on the future coexistence between potential new users of the spectrum and existing users of adjacent frequencies.

Overview of the award

1.2 The frequency bands identified for award are currently designated as Crown spectrum and assigned to the Ministry of Defence (MoD). The MoD has decided to release two blocks of spectrum to Ofcom for civilian use:

- 40 MHz of spectrum within the 2.3 GHz band (2350-2390 MHz)
- 150 MHz of spectrum within the 3.4 GHz band (3410-3480 MHz and 3500-3580 MHz)[1].

1.3 We propose to conduct a market led award of the spectrum through an auction process. We anticipate the bands will attract interest from mobile network operators looking to use the spectrum for high power 4G mobile, using technologies such as Long-Term Evolution (LTE). In certain circumstances, LTE has the potential to cause interference to applications/devices using spectrum in adjacent frequency bands. We have therefore considered the nature and significance of this potential interference - and the possible mitigations.

1.4 Two respondents to our recent consultation and Call for Inputs on this award[2] suggested consideration should be given instead to low power use of the spectrum. The spectrum will be awarded on a technology neutral basis and could be used for high or low power applications, provided use conforms to licence conditions.

Statement on a band plan for the 3.4 GHz band

1.5 We have already consulted on a proposal to award the available 3.4 GHz spectrum in a way that is consistent with an unpaired (TDD-compatible) band plan only[3]. Most respondents to the consultation supported our proposal[4]. Having considered and assessed all the responses, we now intend to proceed with the award of the 3.4 GHz band in line with our proposal.

Coexistence for licence exempt use of adjacent frequencies

1.6 We have undertaken detailed technical analysis of the potential impact of the 2.3 and 3.4 GHz award on users of adjacent frequencies, based on an assumption that the bands will be used for high power LTE.

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[1] We have consulted separately on a proposal to consolidate 2 blocks of 20 MHz of spectrum within the 3.4 GHz award band currently held by UK Broadband into a single block of 40 MHz at 3560-3600 MHz.

[2] http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/

[3] http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf

[4] See Section 5 of this consultation

1.7 We have assessed the impact for both licensed and licence exempt uses of adjacent spectrum. Our primary concern has been the impact to licence exempt applications operating in the 2400 to 2483.5 MHz frequencies adjacent to the 2.3 GHz award band. This includes Wi-Fi, Bluetooth, and ZigBee devices (see below).

1.8 Our judgement is that the impact is limited. Our technical tests suggest the scale and extent of interference is low in most cases – and in almost all cases, appropriate mitigations can be applied through expected market developments.

1.9 In setting out this position for consultation, we accept that our analysis has focussed necessarily on a small number of devices and there is inevitably some room for uncertainty (although we believe our sample to be representative of equipment on the market). In light of this uncertainty, we welcome any additional evidence that stakeholders may be able to submit before we finalise our position.

1.10 We also note that LTE has already been deployed in the 2.3 GHz band in a number of other countries with no significant issues reported. We acknowledge that the nature of these overseas deployments may not be directly comparable. Nonetheless, we believe relevant concerns may have surfaced if there was a significant risk of interference.

Wi-Fi applications

1.11 Wi-Fi is the most widespread use of spectrum within the licence exempt band adjacent to the 2.3 GHz award band. It is deployed in 17.5 million UK households to access the internet via a broadband connection. It also provides coverage to commercial and independent 'hotspots' at a wide range of public locations, both indoors and outdoors.

1.12 Our technical analysis confirms a risk of interference, in specific circumstances, to both Wi-Fi routers/access points and to client devices. We identify the main source of interference as LTE base stations. Interference is most likely in urban environments where there may by a dense deployment of both LTE base stations and Wi-Fi networks. In the very worst cases, customers would not be able to use services - but it is much more likely they will experience a drop in performance, unless mitigations are applied.

1.13 Overall, the extent and severity of interference on a nationwide basis is not high: our analysis suggests only around 0.1% of households with Wi-Fi are at risk of interference (based on central assumptions). If realised, this could potentially affect around 17,400 households – assuming there was a full GB wide roll-out of LTE in the 2.3 GHz band. For public Wi-Fi, our testing suggests that interference may affect around 6.8% of the 4,000 postcode locations where outdoor networks are established[5]. Certain parts of the 78,000 indoor public Wi-Fi locations (around 1.4%) and the 680,000 self-contained enterprise networks in large and medium sized organisations (around 1.2%) may be affected.

1.14 In almost all cases, we believe appropriate mitigations are available. In some cases, simply moving equipment might provide sufficient protection (such as moving routers away from a window or changing the position in which a mobile device is held). In other cases Wi-Fi equipment/devices may be able to access the alternative 5 GHz Wi-Fi band.

[5]There may be a number of access points within a single location in some densely populated areas.

1.15 If additional action is needed to upgrade routers or public access points, we believe ISPs will be able to include addressing the impact of 2.3 GHz LTE interference within their existing operational processes. For example, routers are often replaced by ISPs after around two years or so in line with network upgrades or in response to consumer concerns about performance. Similarly, public access points are regularly upgraded. We expect there will be further market-driven improvements to Wi-Fi reliability before new LTE services are deployed, which will be from 2016 at the earliest.

1.16 In respect to mobile devices, our testing found one smartphone was entirely resilient to 2.3 GHz LTE interference. This suggests the appropriate technology is already available within the market. This is significant because many mobile devices (such as smartphones and tablets) are generally replaced by consumers after around 18 or 24 months e.g. for mobile phones, in line with network contracts. We also note that many devices (including tablets and smartphones) have both Wi-Fi and mobile internet capability. It does not seem unreasonable therefore to assume that chipset manufacturers will ensure future equipment will work properly alongside new 2.3 GHz LTE.

1.17 However, we acknowledge there may be an issue for legacy equipment purchased directly by the end user. We note that users may need to understand how to implement certain mitigations (such as by using Ethernet wiring). We are conducting some further market research to assess the volume of legacy equipment which might be at risk of interference. We are also considering whether it might be practical and effective to support an information campaign for the consumers potentially affected.

Bluetooth

1.18 Bluetooth applications include mobile phone headsets, in car audio, file transfer, wireless keyboard/mice and games console controllers. These are generally very short range applications i.e. the transmission and receive points are close together.

1.19 Our testing suggests there is little risk of interference from LTE. Tests on audio applications show interference is not likely to be noticeable to the user, and we have no outstanding concerns.

ZigBee

1.20 Typical ZigBee applications include home and industrial automation (e.g. lighting control or smart meters). These types of devices may be at slight risk of some potential degradation in very particular situations – notably if operated over very long links or if used in close proximity to an LTE interferer (such as a base station).

1.21 However, this situation only applies under pessimistic scenarios. In most cases, interference can be overcome by mesh networking and other mechanisms specified within the ZigBee standard. The residual risk is very low.

1.22 The Department for Energy and Climate Change (DECC) estimate that 70% of UK households could be connected by the 2.4 GHz Licence Exempt band to smart metering by 2020. Our analysis suggests that this figure could decrease by 0.25 percentage points to 69.75% as a result of LTE deployment in the 2.3 GHz band.[6]

[6] The remaining 30% of households are not expected to achieve the required signal strength at 2.4 GHz and may need to be served by lower frequencies

Other licence exempt equipment

1.23 We have taken particular account of the potential impact for citizens and consumers in assessing the risk of harmful interference to devices associated with health/medical uses. Relevant devices include routine monitoring equipment in hospitals; low data-rate communication by ambulance crews; assisted listening devices in schools and other institutions; and video monitoring devices (such as baby monitors).

1.24 Our analysis suggests the risk of interference is low in all cases. However, we recommend that hospitals work with relevant licensees to satisfy themselves that any proposed 2.3 GHz base station deployments on hospital premises do not cause unacceptable interference to critical hospital systems.

1.25 We are offering use of our technical facilities to manufacturers of assisted listening devices so they can conduct their own testing to ensure devices are robust against interference.

Coexistence for licensed use of adjacent frequencies

PMSE

1.26 PMSE users (wireless cameras for sport events and news coverage) face a loss of useable spectrum as a result of the 2.3 and 3.4 GHz award. At present, PMSE has access to a total of 33 x 10 MHz channels on a shared basis with the primary users. Clearance of the 2.3 and 3.4 GHz award bands will reduce the number of usable channels to 19, of which 8 are allocated to news broadcasters (9 in London).

1.27 This still leaves sufficient spectrum to support the demands of 98% of events – and mitigations are available for the remaining occasions requiring more than 10 channels (such as the F1 Grand Prix and the Grand National). The mitigations include:

- Migration of PMSE to the alternative 7 GHz spectrum band. The 7 GHz band will become the main ‘home’ for an increasing volume of PMSE equipment in future, so this is the most important mitigation;
- More efficient sharing of PMSE channels assigned for news coverage;
- Temporary borrowing of additional spectrum through agreement with MoD and Ofcom to support transition to the above longer term mitigations.

1.28 In the short-term, we propose to allow PMSE continued access to the 3.4 GHz band in particular locations until the point at which new services are actually deployed there. PMSE access would cease at that time.

Amateur radio

1.29 We have already consulted on a proposal to end amateur radio access to the award bands. That consultation also detailed the uncertainty around continued amateur access to the adjacent bands. We will publish a statement on amateur use of spectrum later this year (2014).

Satellites

1.30 Our technical analysis suggests there will be no significant interference to satellite operations close to the award bands. However, we expect all licensees to cooperate in reaching a resolution in the unlikely event that interference was to occur. We believe this will address any issues and we are proposing no additional regulatory intervention.

Maritime radar

1.31 We have found low ranges of potential interference to S-band maritime radars (mandatory on ships with a gross tonnage greater than 3,000 tonnes). In view of the results of these tests, it has been agreed with the Maritime and Coastguard Agency that it is not necessary to propose any additional mitigation to address interference from 3.4 GHz LTE.

Aeronautical radar

1.32 We propose to follow the approach put in place for the earlier 2.6 GHz release. This requires a coordination procedure to be implemented alongside existing radar remediation filtering, as agreed with the Civil Aviation Authority. This is expected to provide a good level of robustness for aeronautical radars.

Next steps

1.33 This consultation and the associated annexes set out our analysis of the technical issues surrounding the 2.3 and 3.4 GHz award in detail. In light of this analysis, the consultation sets out our proposed policy approach towards coexistence issues. We now seek responses from stakeholders and others to a series of questions included in this document. We also invite stakeholders to raise any other issues related to technical matters arising from the 2.3 and 3.4 GHz award but not covered in the questions. The closing date for responses is Thursday 15 May 2014.

Section 2

Introduction

2.1 This consultation considers the award of 190 MHz of radio spectrum in the 2.3 and 3.4 GHz bands.

2.2 The award bands are currently designated as Crown spectrum and are assigned to the Ministry of Defence (MoD). However, the MoD has decided to release to Ofcom 40 MHz of spectrum within the 2.3 GHz band (2350-2390 MHz) along with a further 150 GHz of spectrum within the 3.4 GHz band (3410-3480 MHz and 3500-3580 MHz) for civilian use.

2.3 Before releasing the bands, the MoD intends to clear them of existing military/Government uses, except in a very few localised areas. Ofcom will award this spectrum in line with its duties.

2.4 The award bands are likely to be attractive to mobile network operators looking to use the spectrum for high power applications such as Long Term Evolution (LTE) mobile broadband.

2.5 We have already published a 'Call for Inputs'[7] in which we sought the views of stakeholders on the most appropriate timing for the award. We are still considering the responses[8] and will consult on proposals later in the year (2014). We also indicated that the financial year 2015/16 was the quickest possible timescale on which we would expect to make an award of the spectrum.

2.6 Whatever the exact timings of the award, we need to consider the potential impact of likely new uses of the bands on current users of spectrum in adjacent frequencies. This document therefore sets out our assessment of the technical coexistence issues involved, and presents proposals on how we should proceed. We believe it is important to consult on these proposals now in order to allow the greatest possible time for us to consider industry views and to adapt to any potential issues, if this proves necessary.

Structure of this document

2.7 The remainder of this consultation document is set out as follows:

Section 3 sets out the legal framework under which we must make our decisions. This includes outlining our statutory duties in managing the spectrum and identifying our obligations to consider the impact of our decisions on other spectrum users.

Section 4 is an overview of the award and the key issues we need to address. It begins by describing the nature of the spectrum that is being released and its likely future use. It goes on to identify the potential interference issues we need to consider in respect to adjacent frequencies, and sets out the broad policy frameworks we have used in developing our proposals.

[7] http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf
[8] 2.3 & 3.4 GHz bands Consultation and Call for Inputs Responses

Section 5 is a statement of our position on a band plan for the 3.4 GHz award band, following our earlier consultation.

Section 6 assesses the potential impact of the award on domestic and commercial Wi-Fi applications in frequencies adjacent to the 2.3 GHz award band. It summarises the technical work we have undertaken to understand the nature of potential interference issues, and sets out the main results of our analysis. The section then goes on to describe the policy approach we have adopted in respect to Wi-Fi, and the conclusions we have reached.

Section 7 assesses the potential impact of the award for other licence exempt users of frequencies adjacent to the 2.3 GHz band, including Bluetooth and ZigBee applications. As with Wi-Fi, it summarises the technical work we have undertaken to understand the nature of potential interference issues and considers the results of our analysis.

Section 8 studies the implications of the award for licensed Programme Making and Special Events (PMSE) applications (wireless cameras and video links).

Section 9 provides an outline of the approach we are adopting towards use of spectrum adjacent to the award bands by licensed amateur radio enthusiasts.

Section 10 considers the impact of the award for use of adjacent spectrum by civilian maritime navigational radar.

Section 11 considers the impact of the award for use of adjacent spectrum by aeronautical radar used in air traffic control.

Section 12 sets out our analysis of the potential impact of the award on satellite and space services operating near to the 2.3 and 3.4 GHz award bands.

Section 13 sets out the technical licence conditions we propose to apply to the spectrum award including coordination requirements to protect MOD uses

Section 14 considers how we should take account of incumbent use of the 3.4 GHz award band where there are adjacencies to the 150 MHz spectrum that is to become newly available.

Section 15 details the next stages in the consultation process and our anticipated timelines.

2.8 The annexes to this consultation set out in more detail the technical analysis we have conducted in the process of developing our proposals. They also include details of how stakeholders may respond to this consultation. These technical annexes (numbered annex 7 to 13) are published separately alongside this document.

Section 3

Legal framework

3.1 In this section we describe the general legal and policy framework in the UK within which we are considering the issues surrounding the award of the 2.3 and 3.4 GHz spectrum bands. The legal framework derives from our duties under both European and domestic legislation, specifically from:

- the European Common Regulatory Framework[9] for electronic communications networks and services, in particular, the Framework Directive and the Authorisation Directive; and
- the Communications Act 2003 (the "Communications Act") and the Wireless Telegraphy Act 2006 (the "WTA") which transpose the provisions of those directives into national law.

3.2 We also discuss Commission Decision 2008/411/EC on the harmonisation of the 3400-3800 MHz frequency band and the regulations implementing that decision.

European Regulatory Framework

3.3 Article 8 of the Framework Directive sets out the objectives that national regulatory authorities (NRAs) must take all reasonable steps to achieve. These include:

- the promotion of competition in the provision of electronic communications networks and services by, among other things, ensuring that there is no distortion or restriction in competition in the electronic communications sector, and encouraging efficient use of radio frequencies; and
- contributing to the development of the internal market by, among other things, removing obstacles to the provision of electronic communications networks and services at a European level, and encouraging the interoperability of pan-European services.

3.4 In pursuit of these policy objectives, Article 8 requires NRAs to apply objective, transparent, non-discriminatory and proportionate regulatory principles by (amongst other things) ensuring that, in similar circumstances, there is no discrimination in the treatment of undertakings providing electronic communications networks and services; safeguarding competition to the benefit of consumers; and promoting efficient investment and innovation in new and enhanced infrastructures.

3.5 Article 8 also requires EU member states to ensure that in carrying out their regulatory tasks, NRAs take the utmost account of the desirability of making regulations technologically neutral.

[9]The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC).

3.6 Article 9 of the Framework Directive requires member states to ensure the effective management of radio frequencies in accordance with (amongst other things) Article 8.

3.7 Article 5 of the Authorisation Directive provides that where it is necessary to grant individual rights of use of radio frequencies, member states must grant such rights through open, transparent and non-discriminatory procedures and in accordance with the provisions of Article 9 of the Framework Directive. When granting those rights, member states are required to specify whether they can be transferred by the holder, and if so, under which conditions.

3.8 Article 7 of the Authorisation Directive provides that where member states decide to limit the number of rights of use to be granted for radio frequencies, they must (amongst other things) give due weight to the need to maximise benefits for users and to facilitate the development of competition.

3.9 The legal duties imposed on the UK by the Framework and Authorisation Directives are transposed into UK law and given effect by the Communications Act and the WTA.

Duties under the Communications Act 2003

3.10 Section 3 of the Communications Act 2003 provides that our principal duty is:

- to further the interests of citizens in relation to communications matters; and
- to further the interests of consumers in relevant markets, where appropriate, by promoting competition.

3.11 In carrying out our functions, section 3(2) provides that we are required, amongst other things, to secure the optimal use for wireless telegraphy of the electromagnetic spectrum; and the availability throughout the UK of a wide range of electronic communication services.

3.12 Section 3(3) provides that, in performing our duties, we must in all cases have regard to the principles of transparency, accountability, proportionality and consistency, as well as ensure that our actions are targeted only at cases in which action is needed.

3.13 Section 3(4) requires us, in carrying out our functions, to have regard to certain factors as appear relevant in the circumstances, including the desirability of encouraging investment and innovation in relevant markets; and the different needs and interests of everyone who may wish to use the spectrum for wireless telegraphy.

3.14 In performing our duty under Section 3 of furthering the interests of consumers, we must have regard, in particular, to the interests of those consumers in respect of choice, price, quality of service and value for money.

3.15 Section 4 requires Ofcom to act in accordance with the six Community requirements, which give effect to the requirements of Article 8 of the Framework Directive.

Duties under the Wireless Telegraphy Act 2006

3.16 Section 3 of the WTA imposes a number of further duties relating to spectrum management. Amongst other things, in carrying out our spectrum functions, we are

required to have regard to the extent to which the spectrum is available for use and to the demand, both current and future, for the use of the spectrum.

3.17 In carrying out those duties, Section 3(2) requires us to have regard to (amongst other things) the desirability of promoting the efficient management and use of the spectrum; the economic and other benefits that may arise from the use of wireless telegraphy; and the development of innovative services and competition in the provision of electronic communications services.

Wireless telegraphy licences

3.18 The WTA sets out our legal power to grant wireless telegraphy licences. Section 8(1) makes it an offence for any person to establish or use any station for wireless telegraphy or to install or use any apparatus for wireless telegraphy except under and in accordance with a licence granted by us under that Section (a wireless telegraphy licence). However, the WTA does not bind the Crown, so Crown bodies, such as government departments and executive agencies, do not need authorisation from Ofcom in order to install or use radio equipment, and there is no basis for Ofcom to license them.

3.19 Section 9(1) of the WTA gives us the power to grant wireless telegraphy licences subject to such terms as we think fit. This broad discretion is, however, subject to the rule that we must impose only those terms that we are satisfied are objectively justifiable in relation to the networks and services to which they relate, not unduly discriminatory, and proportionate and transparent as to what they are intended to achieve (see Section 9(7)).

3.20 In addition, our discretion under Section 9 must be interpreted in a way that is consistent with the licence conditions permitted under the Authorisation Directive.

Granting licences

3.21 In accordance with Section 10 and Schedule 1 of the WTA, Ofcom may grant licences in accordance with procedures prescribed in regulations made by Ofcom.

3.22 Ofcom has made general regulations in relation to licensing procedures (the Wireless Telegraphy (Licensing Procedures) Regulations 2010[10]). Where Ofcom decides to award licences by auction or 'beauty contest', it makes specific regulations for those purposes, in accordance with section 14 of the WTA in relation to auctions, and Schedule 1 of the WTA in relation to 'beauty contests'.

3.23 The Wireless Telegraphy (Licensing Procedures) Regulations make provision for Ofcom to grant licences in relation to particular wireless telegraphy stations or apparatus, where an applicant has provided Ofcom with the requisite information set out in Regulation 5.

Charging fees for wireless telegraphy licences

3.24 Section 12 of the WTA permits Ofcom to charge fees for wireless telegraphy licences, subject to certain specified exemptions relating to licences granted in accordance with auction regulations made under Section 14 of the WTA.

[10]Made under section 10 and Schedule 1 of the Wireless Telegraphy Act 2010.

3.25 Under Article 13 of the Authorisation Directive, any fees imposed for rights of use of radio frequencies must reflect the need to ensure the optimal use of the resources. Such fees must be objectively justifiable, transparent, non-discriminatory and proportionate in relation to their intended purpose and take into account the objectives set out in Article 8 of the Framework Directive.

Our approach to applying our duties

3.26 The duties set out above require us to balance a range of considerations. In doing so, we have a variety of regulatory tools and market mechanisms at our disposal in order to carry out our functions. In general, as set out in our Spectrum Framework Review[11], we prefer to use market mechanisms to manage the spectrum.

3.27 We consider that market-based mechanisms, such as trading, liberalisation, administered incentive pricing and auctions are more likely to achieve our statutory objective of securing optimal use of the spectrum than 'command and control' methods based on regulatory and administrative decisions.

3.28 We have recently consulted on a new Spectrum Management Strategy[12]. This proposes a slightly revised position whereby we would rely on market mechanisms where possible and effective, but also take regulatory action where necessary. The consultation proposed that once the conditions required for the use of market mechanisms are in place, they should generally be considered the most effective method of allocating scarce resources to ensure they are used efficiently. The consultation responses are still under consideration.

Commission Decision 2008/411/EC on the harmonisation of the 3400-3800 MHz frequency band

3.29 On 21 May 2008, the European Commission adopted a decision which seeks to harmonise the conditions for the availability and efficient use of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the EU[13]. In relation to the 3400-3600 MHz band, the decision provides that member states should designate, by 21 November 2008, the band, on a non-exclusive basis, for terrestrial electronic communications networks in compliance with the parameters set out in the Annex to the decision.

3.30 The Commission Decision was implemented in the UK by way of the 3400-3800 MHz Frequency Band (Management) Regulations 2008[14], which required Ofcom to exercise its functions under the WTA so as to give effect to the obligations of the United Kingdom under the Commission Decision.

3.31 Any award of the 3.4 GHz band has to be compliant with the Commission Decision. We note however that, as further described in Section 4, the Commission Decision is currently under review. In particular, the technical parameters set out in the Annex to the Decision are likely to be changed substantially. A decision is anticipated in March 2014.

[11] http://www.ofcom.org.uk/consult/condocs/sfr/
[12] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/
[13] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:144:0077:0081:EN:PDF
[14] S.I. 2008/2794; http://www.legislation.gov.uk/uksi/2008/2794/pdfs/uksi_20082794_en.pdf

Impact Assessment

3.32 This consultation as a whole, including its annexes, comprises an impact assessment as defined in Section 7 of the Communications Act.

3.33 Impact assessment provides a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practise policy-making. This is reflected in Section 7 of the Act, which means that generally we have to carry out impact assessments where our proposals would be likely to have a significant impact on businesses or the general public, or when there is a major change in Ofcom's activities.

3.34 The following sections and annexes contain analysis of all the policy options relating to an award of spectrum in the 2.3 and 3.4 GHz bands that we have considered, and the potential impact of our proposals. In particular, we have considered the citizen and consumer interests in relation to our policy objectives. We have also considered the impact of our proposals on the manufacturers and users of devices and applications using spectrum in adjacent channels, including additional costs involved in mitigations for potential interference.

3.35 Ofcom is an evidence based organisation and welcomes responses to this consultation. Any comments about our assessment of the impact of our proposals should be sent to us by the closing date for this consultation. We will consider all comments before deciding whether to implement our proposals. For further information about our approach to impact assessments, see the guidelines*, Better policy-making: Ofcom's approach to impact assessment*, which are on our website: http://www.ofcom.org.uk/consult/policy_making/guidelines.pdf

Equality Impact Assessment

3.36 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on race, disability and gender equality. Equality Impact Assessments (EIAs) also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity.

3.37 We do not consider that our proposals to award the 2.3 and 3.4 GHz spectrum are likely to have a particular impact on one group of stakeholders as opposed to another.

3.38 Nevertheless, we considered whether some existing users of adjacent spectrum may be disproportionately affected. In that context, we considered especially the impact of potential interference on users of licence exempt devices which may be perceived as having health or safety implications. This includes users of medical monitoring equipment and assisted listening devices. These issues are discussed in detail in section 8 of the consultation and in associated annexes.

3.39 We have also considered the impact on amateur radio enthusiasts both in the context of this consultation and in respect to our earlier consultation on the impact of the award on amateurs. By its nature, amateur radio is a hobby accessible to people with disabilities - including those with mobility, sight and hearing impairments. Organisations representing the amateurs stress their inclusivity and their encouragement of all participants on an equal basis.

3.40 However, it is not apparent to us that any conclusions or proposals in respect to amateurs are likely to have any particular impact on race, disability or gender equality. Specifically, we do not envisage the impact of any outcome to be to the particular detriment of any one group of amateur users of the spectrum compared to another.

3.41 The award of the 2.3 spectrum relates to licences which will apply to Great Britain (i.e. to England, Scotland and Wales but not to Northern Ireland). For that reason there is no need for us to carry out separate EIAs in relation to race or gender equality or equality schemes under the Northern Ireland and Disability Equality Schemes.

3.42 The award of the 3.4 GHz spectrum band relates to all of the United Kingdom (i.e. to England, Scotland, Wales and Northern Ireland). We do not believe any aspect of the award raises issues requiring separate EIAs in relation to race or gender equality or equality schemes under the Northern Ireland and Disability Equality Schemes.

Section 4

Overview of the 2.3 and 3.4 GHz award

4.1 In this section, we set out an overview of the proposed award of the 2.3 and 3.4 GHz spectrum bands.

4.2 We begin by describing the nature and characteristics of the spectrum to be awarded, and then identify its likely future use. We go on to summarise the current use of frequencies adjacent to the award bands - and note the potential for interference from new uses/users of the 2.3 and 3.4 GHz bands. Finally, we set out the policy frameworks we have used in developing the proposals contained in this consultation.

The spectrum to be awarded

4.3 The MoD's decision to release 190 MHz of spectrum to Ofcom is part of a Government commitment to release 500 MHz of public sector spectrum by 2020 for new civilian uses. This commitment aims to address the increasing UK demand for spectrum, fuelled by the adoption of devices such as smartphones and tablets.

4.4 The award will comprise two separate spectrum bands currently assigned to the MoD under the 2013 UK Frequency Allocation Table (FAT):

- The 2.3 GHz band: 40 MHz of spectrum between 2350 and 2390 MHz;
- The 3.4 GHz band: 150 MHz of spectrum (3410-3480 MHz and 3500-3580)[15].

4.5 The 2.3 GHz spectrum will be made available for new uses throughout Great Britain (i.e. in England, Scotland and Wales, but not in Northern Ireland). The 3.4 GHz spectrum will be made available throughout the whole of the UK.

4.6 As described in the previous section, Ofcom has a duty to secure the optimum use of radio spectrum. This will usually be the most valuable use. We therefore have a preference for allowing market based mechanisms to determine the outcome of an award[16], such as an auction process[17].

4.7 In this case, we expect the award bands to be cleared of all existing uses[18] (except in a few localised areas where MoD use will continue) - although we propose to allow PMSE (wireless cameras) continued access to the 3.4 GHz band in particular

[15]This excludes the 2 blocks of 20 MHz currently licensed to UK Broadband in the 3.4GHz band up until July 2018. For the purposes of our coexistence analysis we have considered that this spectrum will be used for similar services after this date.
[16] Ofcom Spectrum Framework Review: http://stakeholders.ofcom.org.uk/binaries/consultations/sfr/statement/sfr_statement
[17] We have recently consulted on a revised Spectrum Management Strategy (see section 3) which slightly revises our approach. It proposes that*: "In order to deliver optimal spectrum use, we rely on market mechanisms where possible and effective, but also take regulatory action where necessary ..."*
[18] We have already consulted on a proposal to clear amateur radio form the award bands and while we have not yet made our decision, for the purpose of this consultation we are proceeding with the preference expressed in that consultation

locations until the point at which new services are rolled out there (see section 8). PMSE access will cease at that time.

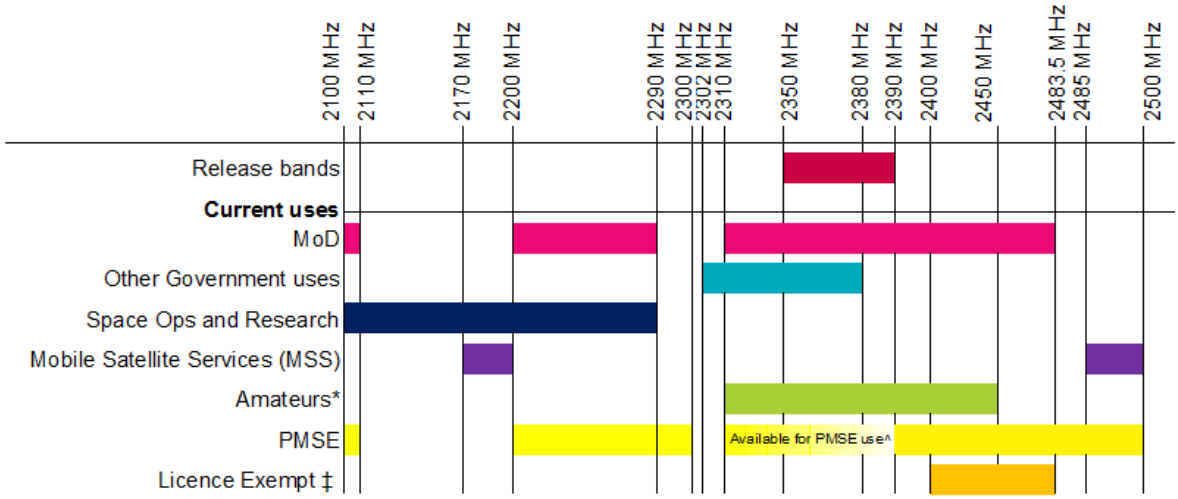
The 2.3 GHz band

4.8 The 2.3 GHz award band (2350-2390 MHz) is illustrated in Figure 4.1 below. In addition to MoD and other Government uses, the spectrum is currently used for amateur radio and (occasionally) for PMSE (in order to enable television coverage of major sporting events). We consulted on a proposal to end amateur radio access to the 2.3 GHz award band in 2013[19] and will publish a statement on this shortly.

4.9 The illustration also shows current use of the frequencies adjacent to the award band. As with the award band itself, these uses include amateur radio (2390-2450 MHz) and PMSE (2200-2290 MHz and 2390-2500 MHz)

4.10 Other deployments include significant use of frequencies between 2400 and 2483.5 MHz for licence exempt applications. These include domestic and commercial Wi-Fi; Bluetooth; and ZigBee devices, such as smart meters and monitoring equipment. The 2400-2483.5 MHz range (sometimes referred to as the 2.4 GHz licence exempt band) is also used by licence exempt ISM apparatus (Industrial, Scientific and Medical applications). In some circumstances, these can produce a noisy interference environment for communications systems.

Figure 4.1: The 2.3 GHz spectrum band showing current uses and uses of adjacent frequencies



4.11 In addition to the uses detailed in Figure 4.1, there are a small number of fixed links in rural areas in the 2200 to 2290 MHz band. We do not perceive there to be any interference issues from the award band.

The 3.4 GHz band

4.12 The 3.4 GHz award band is illustrated below in Figure 4.2. The band occupies the frequencies between 3410 MHz and 3600 MHz, but the award will not include the whole of this range. As noted in the table below, UK Broadband currently holds 40

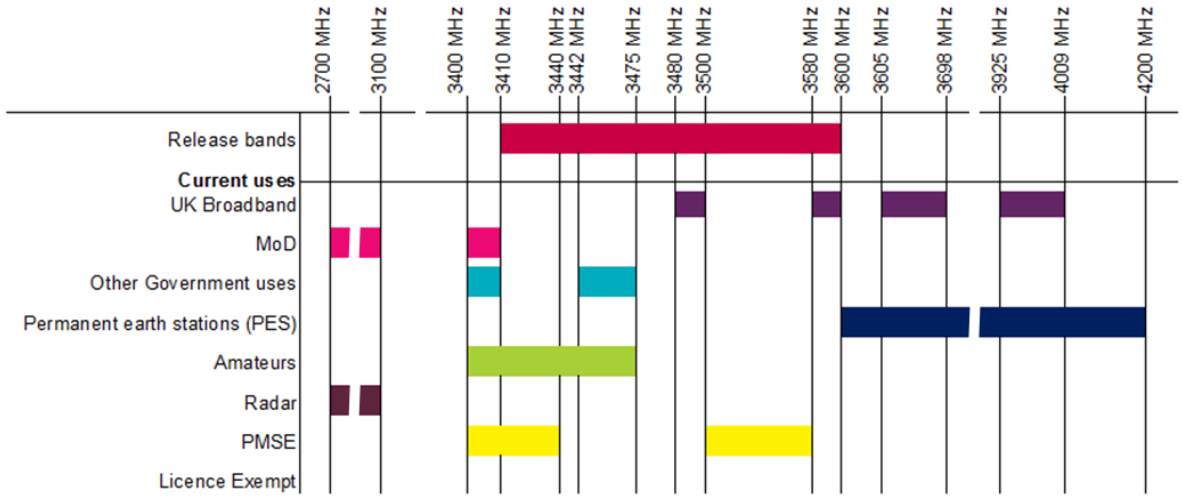
[19] http://stakeholders.ofcom.org.uk/binaries/consultations/public-sector-spectrum-release/summary/condoc.pdf

MHz of spectrum within this range in two separate 20 MHz blocks (3480-3500 MHz and 3580-3600 MHz). On 16 October 2013 we published a consultation which included a proposal to consolidate the UK Broadband holdings into a single block of 40 MHz at 3560 to 3600 MHz[20]. We are still considering the responses to that consultation.

4.13 As with the 2.3 GHz band, part of the 3.4 GHz release spectrum is currently used by amateur radio (3410-3475 MHz) and by PMSE (3410-3440 MHz and 3500-3580 MHz). Amateur radio and PMSE also have access to 10 MHz of spectrum adjacent to the award band below 3410 MHz.

4.14 The illustration also shows other current uses of the adjacent bands. These include radar (2700-3100 MHz) and permanent satellite Earth stations (3600-4200 MHz).

Figure 4.2: The 3.4 GHz spectrum band showing current uses and uses of adjacent frequencies



Potential future use of the award bands

4.15 The particular characteristics of the spectrum to be released, in terms of propagation and the penetration of signals, make it especially suitable for use by mobile broadband applications such as LTE. For example, the 2.3 GHz spectrum has propagation characteristics very similar to the 2.6 GHz band already used for 4G mobile. Such uses are also likely to be the most valuable in commercial terms. Equipment designed to operate in the bands is already being developed. According to the Global Suppliers Association (GSA), 207 LTE commercial devices supporting use in the 2.3 GHz band are now available on the market.

4.16 The 3.4 GHz band may be valuable in providing additional options for network operators facing capacity pressures in other frequencies, either as capacity itself or as backhaul for small cells with other bands. We note that LTE equipment and devices are also available for this band, although in lower quantity than for 2.3 GHz band.

[20] http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf

4.17 Over the past few years, the volumes of data carried over mobile networks have materially increased. The 2013 update of our Infrastructure Report[21] showed that data traffic carried by UK mobile networks went up by approximately 50% between June 2012 and June 2013 and more than doubled between March 2011 and June 2012.

4.18 Our 2013 Communications Market Report[22] identified household take up of tablet computers (such as the iPad or Google Nexus) rising from 11% at the beginning of 2012, to 24% by the beginning of 2013. In the same year, 49% of UK adults accessed the internet on their mobile phones – up from 20% in 2009. 51% of UK adults now own a smartphone. However, among mobile internet users take up is even higher, with 96% of users owning a smartphone.

4.19 Looking forward, data consumption by mobile devices over mobile and Wi-Fi networks might, according to one study, be as much as 80 times higher in 2030 than it was in 2012[23].

4.20 As explained in section 3, in 2008 the European Commission adopted a decision (2008/411/EC) which seeks to harmonise the 3.4 GHz band for Mobile/Fixed Communication Networks (MFCN), with technical parameters to support high power operation. As further explained below, that decision is currently under review. The 2.3 GHz band has also been identified as a possible candidate for the use of wireless broadband services and the European Commission is currently working on a mandate to the European Conference of Postal and Telecommunications Administrations (CEPT) to develop technical conditions for the introduction of wireless broadband in this band. Beyond Europe, there are other international moves towards making the 2.3 and 3.4 GHz spectrum available for mobile broadband[24].

4.21 All of these developments suggest the 2.3 and 3.4 GHz award is likely to attract interest from mobile network operators for either high power or low power LTE uses. We have used assumptions of high power LTE networks in our co-existence work described in this document. However, we propose that alternative uses should not be precluded if winning bidders for the spectrum have other plans (subject to compliance with technical parameters and consequent licence conditions).

4.22 The regulatory environment for future use of each band is discussed separately below.

Position for future use of the 2.3 GHz band

4.23 The European Electronic Communications Committee (ECC)[25] set up a project team (CEPT WG FM52) with a view to develop a draft ECC Decision aimed at harmonising implementation measures for MFCN in the 2.3 GHz frequency band[26].

4.24 The work of the project team addresses frequencies between 2300 and 2400 MHz and therefore includes the award band 2350-2390 MHz. The scope of this work includes the development of:

[21] Infrastructure Report: 2013 update, October 2013, http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2013/
[22] http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf
[23] http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf
[24] http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr12/icmr/ICMR-2012.pdf
[25] One of three business committees of the European Conference of Postal and Telecommunications Administrations (CEPT)
[26] http://www.cept.org/ecc/groups/ecc/wg-fm/fm-52/client/introduction/terms-of-reference

- least restrictive technical conditions (LRTC), taking into account the existing standardisation framework, activities at the worldwide level, and an appropriate frequency arrangement;

- regulatory provisions based on Licence Shared Access (LSA)[27], to ensure the continuing long-term incumbent use of the band in the territory of administrations wishing to maintain such use (to note, our proposed eventual clearance of the band means LSA is not likely to be relevant in the UK for the award band).

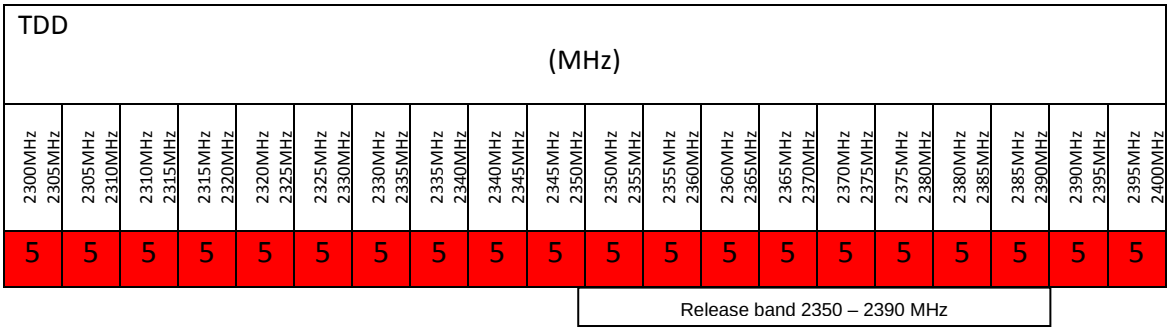
4.25 An ECC decision setting out harmonised technical and regulatory conditions for the band is currently available in draft[28] form, with the aim of adopting a decision in the first half of 2014. This ECC Decision is not mandatory. However, the Commission is proposing a mandate for CEPT to carry out work to result in an EC Decision for the 2.3 GHz band. This EC Decision will be mandatory.

4.26 Much of the work to formulate the draft ECC decision has been completed, and we are not expecting substantial changes between the draft ECC Decision and the final EC Decision. The draft ECC decision currently being developed contains a band plan (illustrated below in Figure 4.3) based on Time Division Duplex (TDD)[29] rather than the alternative Frequency Division Duplex (FDD)[30]. The spectrum is divided into 5 MHz blocks.

4.27 We intend to release the 2.3 GHz spectrum with technical licence conditions that will be consistent with those finally agreed in CEPT. Our proposals for relevant licence conditions in respect to the 2.3 GHz band are set out in section 13 of this consultation.

4.28 Around 60 countries worldwide have either assigned the 2.3 GHz band to mobile operators to deliver wireless broadband services or have announced their intention to do so within the next two years. LTE-TDD has already rolled out in India; Saudi Arabia; Australia; Russia; Oman; China; Korea, and Sri Lanka. A number of other countries have indicated future use for mobile broadband services including Singapore, Moldova and Greece. An assessment of international use of the 2.3 GHz band is included in annex 7.

Figure 4.3: Frequency arrangement for the 2300 - 2400 MHz band



[27] https://circabc.europa.eu/d/d/workspace/SpacesStore/3958ecef-c25e-4e4f-8e3b-469d1db6bc07/RSPG13-538_RSPG-Opinion-on-LSA%20.pdf

[28] http://www.cept.org/Documents/fm-52/14582/FM52(13)56-Annex3_Draft-ECC-Decision-on-MFCN-in-the-2300-2400-MHz-band

[29] Time division duplex is used to separate the outward and return signals in the same frequency channel by time

[30] Frequency division duplex is used to transmit the outward and return signals in different frequency channels, so both signals can be transmitted and received at the same time

Position for future use of the 3.4 GHz band

4.29 The 3.4 GHz band is already used for wireless broadband in a number of countries. In Europe there have been authorisations in Estonia, Germany, Ireland, Italy, Latvia, Macedonia, Norway, Spain, Sweden, Switzerland, Portugal and the UK (by UK Broadband). More widely, countries using or testing the band for wireless broadband include Nigeria, Hong Kong, New Zealand, Australia and Japan.

4.30 The USA is considering allowing shared access to the 3550-3650 MHz frequencies via a managed database system. This would be based on small cell use of the spectrum, to protect incumbent users. The proposal is for three tiers of users, each with different levels of rights and protections. The first tier would include federal government use; the second would include hospitals, utilities and public safety bodies; the third would include all other users, subject to protections determined via the database.

4.31 We published an initial statement (on 17 December 2010)[31] setting out the technical conditions we intended to apply to the 3.4 GHz band. At that time, it was expected that the spectrum would be traded by the MoD itself, rather than being released to Ofcom for award. The conditions were consistent with the European technical framework established in Commission Decision 2008/411/EC.

4.32 Since then, a CEPT ECC[32] meeting of 5-8 November 2013 has identified: *"a single TDD option as the preferred channelling arrangement at 3.4-3.6 GHz, with FDD as an alternative for those administrations which would prefer to use it"*.[33] It has also updated the technical conditions. These recommendations will be reviewed by the European Commission's Radio Spectrum Committee, but we expect confirmation in a final decision amending Commission Decision 2008/411/EC around March 2014. The decision will be binding on Member States.

Figure 4.4: Frequency arrangement for the 3400-3600 MHz band based on TDD

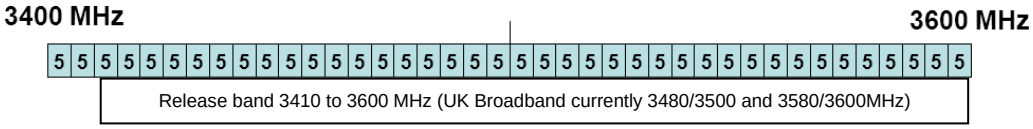
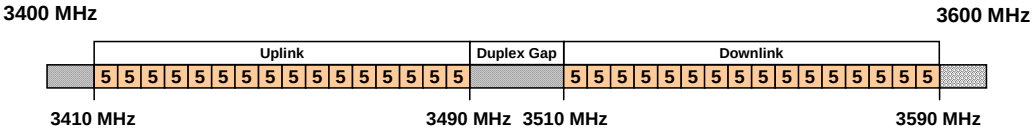


Figure 4.5: Frequency arrangement for the 3400-3600 MHz band based on FDD



4.33 Our consultation of 16 October 2013 included a proposal that licence conditions consistent with an unpaired TDD compatible band plan were appropriate for the award of the 3.4 GHz spectrum band. The next section of this document (section 5)

[31] http://stakeholders.ofcom.org.uk/binaries/consultations/crown-rsa/summary/crown-rsa.pdf
[32] The European Conference of Postal and Telecommunications Administrations (CEPT) Electronic Communications Committee (ECC)
[33] http://www.cept.org/Documents/ecc/14301/ECC(13)090-Annex09_Draft-amended-ECCDEC(11)06-for-PC-(with-rev-marks)

sets out our conclusions on the band plan for the 3.4 GHz band in light of consultation responses.

Other potential uses of the award bands

4.34 Our consultation of 16 October 2013 included a Call for Inputs from stakeholders to inform us of potential uses of the 2.3 and 3.4 GHz spectrum bands. The document noted Ofcom's general presumption for a market led process when awarding spectrum. It also set out our intention to make the bands available in a way that was suitable for licensed high power use (although we indicated low power use was not precluded if that was the outcome of a market led award).

4.35 Most respondents who expressed a view on this issue agreed the spectrum was best suited to licensed high power use. However, three respondents suggested alternative approaches.

4.36 Sky suggested "strong consideration" should be given to assigning the 3.4 GHz band to licence exempt uses. The response cited a shortage of spectrum for Wi-Fi, and said licence exempt status could promote innovation by lowering barriers to entry. It said there was little evidence of demand for high power use of the band.

4.37 We have considered Sky's response and note the following factors in determining our proposals for formal consultation.

4.38 Firstly, Sky was the only respondent to our Call for Inputs to suggest assignment for licence exempt use. Almost all the other respondents suggested there was demand for licensed high power use, with some citing an approaching 'spectrum crunch' for frequencies suitable for mobile broadband. We also note that the band will be harmonised throughout Europe for high power use. This means equipment for this use of the band is likely to become widely available.

4.39 At the same time, we note that the successful adoption of Wi-Fi technology to date has been driven to a very large extent by the fact that it is a global standard applied across globally harmonised spectrum. Having more spectrum available for Wi-Fi in a non-standard band will not bring the same value as harmonised spectrum.

4.40 There are currently no technical standards in place for licence exempt shared use of the 3.4 GHz band for low power LTE (typically, polite protocols such as listen before talk or low duty cycles are necessary). Under current Third Generation Partnership Project (3GPP)[34] timescales, the earliest 'freeze date' under which appropriate standards for licence exempt use could be finalised is 2016, but it could be later. We would then expect it to take at least three years – and possibly more – before any equipment would be developed for the market.

4.41 In view of these considerations, we propose to proceed on the basis of a market led award of the spectrum with licence conditions suitable for high power use, subject to further consultation responses. High power use requires licensing in order to avoid interference between users.

4.42 In its consultation response, BT supported the idea of a licensed use of the spectrum, but suggested it might be for licensed *low* power assignment. Its response suggested that a number of operators could share use of the band – possibly with a "neutral"

[34]3rd Generation Partnership Project (3GPP) aims to allow member telecommunications standard development organizations to define specifications

host managing the frequencies. BT referred to the proposals put forward by the US authority, outlined above. Espirito Ltd also suggested more spectrum efficiency could be gained through service sharing.

4.43 We note the interest in low power uses, but also note that most other potential users supported the idea of high power use. We further note that the possibility of low-powered shared access was offered in the 2.6 GHz award. However, there was only limited demand from bidders, and this was insufficient to outweigh the demand for high power use.

4.44 Our proposed technical licence conditions would support both high and low power use. However, unlike the 2.6 GHz award, we do not propose to design the auction in a manner that would enable the aggregation of low power bids, given the complexities this would add for bidders and auctioneer.

Coexistence of new and existing users

4.45 Before developing proposals for an award of the 2.3 and 3.4 GHz spectrum, we needed to understand the nature of potential interference issues for users of adjacent spectrum. First, we needed to identify the nature and volume of applications currently deployed in adjacent frequencies. Armed with this knowledge we would then be able to carry out detailed technical analysis of the likely impact of the award. We therefore took the following steps:

- Audit: An audit of the current uses of frequencies adjacent to the 2.3 and 3.4 GHz spectrum bands was commissioned from CGI[35].
- Call for Inputs: We were aware that the licence exempt nature of the frequency band between 2400 and 2483.5 MHz meant that even a thorough audit of current applications risked missing some uses. We therefore published a document inviting manufacturers and other stakeholders to inform us of any applications not covered in the audit.[36]
- Technical analysis: We then conducted technical analysis of a range of devices and applications to understand how they might be impacted by LTE in adjacent frequencies. The results of this testing are presented in sections 6 to 12 of this document and in associated annexes (see Figure 4.6 at the end of this section).

4.46 Our technical analysis assumed the award bands would be used for high power LTE, an assumption now reinforced through responses to our Call for Inputs on the award[37].

4.47 The proposals we set out in later sections of this consultation stem from our identification of three different categories of current spectrum users in and around the award bands. They are addressed as follows:

- Current co-channel users - the award bands will be cleared of existing uses[38], although we propose to allow PMSE (wireless cameras) continued access to the 3.4 GHz band in particular locations up until the point at which new services are rolled out there. PMSE access will cease at that time.

[35] See annex 5
[36] http://stakeholders.ofcom.org.uk/consultations/2400-mhz/
[37] http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/?showResponses=true
[38] We have consulted on clearing amateur uses, as noted earlier

- Licence exempt users of adjacent channels – the level of potentially harmful interference to users of adjacent licence exempt spectrum has been assessed. We have considered whether, in all the circumstances, intervention is necessary in order to protect licence exempt users. Among the licence exempt applications are Wi-Fi, Bluetooth, ZigBee, and ISM devices.

- Licensed adjacent channel users – the level of potentially harmful interference to existing licensed users has been assessed to determine whether intervention (such as requiring coordination procedures) may be justified. Among the licensed applications potentially affected are radar (maritime and aeronautical), satellites, PMSE and amateur radio.

Framework for assessing the significance of interference to licence exempt applications

4.48 As indicated above, our consultation assesses coexistence issues for both licensed and licence exempt use of the frequencies adjacent to the award bands. However, our chief concerns about the potential impact of interference have been for licence exempt applications operating in the 2400 to 2483.5 MHz frequencies adjacent to the 2.3 GHz award band.

4.49 In determining our approach to potential interference issues for licence exempt users we need to strike an appropriate balance between:

- recognising the principle of non-interference/non-protection that applies to all licence exempt use of spectrum[39]; and

- recognising our duty to consider any potentially negative impact on citizens and consumers arising from future use of the award bands for new uses such as LTE.

4.50 As identified in the previous section, we are required to secure the optimal use of spectrum whilst also taking account of the different needs and interests of all current or potential future users of the frequencies. This means considering the nature of any interference issues; the scale of any negative impacts - both in terms of the actual effect on existing devices and the number of people potentially affected; and the ease and cost of deploying mitigations.

4.51 As a result, we developed a framework to determine our policy approach. The proposals contained in this consultation reflect the analysis we have conducted within this framework. We identified three different potential levels of impact depending on how significant the potential for interference would be:

- Very significant impact: mitigation is expensive relative to the value of the award and we need to consider whether the award should go ahead in the manner proposed;

- Significant impact: mitigation is affordable but regulatory intervention is needed to ensure measures are applied (such as establishing a help scheme etc.);

[39]As a matter of principle, users of licence exempt spectrum may not cause interference to other spectrum users and may expect no protection themselves from other users. It is a matter for equipment manufacturers and users to find solutions to any issues.

- Limited impact: mitigation will be needed in some circumstances, but we can rely on developments in the market without the need for regulatory intervention.

4.52 We have considered our analysis of each category of licence exempt use separately using this framework. A relevant factor in determining the significance of potential interference is the likely timeframe for deployment of new services. We believe roll-out will begin in 2016 at the earliest, providing a window in which mitigations may be developed, if necessary.

4.53 Figure 4.6 summarises the uses of spectrum adjacent to the 2.3 and 3.4 GHz award bands and identifies where within this document the specific coexistence issues are discussed.

Figure 4.6: Summary of spectrum uses adjacent to the 2.3 and 3.4 GHz award bands

Uses		Frequencies	Description/devices	Section
Licence exempt				
Wi-Fi		2400–2483.5 MHz	Domestic devices (e.g. wireless internet accessing laptops, tablets and smartphones); outdoor networks; indoor public networks (hotels, pubs, cafes etc); commercial closed networks (e.g. internal company systems).	Section 6/ Annex 7
Other licence exempt uses	Bluetooth	As above	Includes wireless headsets; phone to phone transfer; in-car devices for mobile phones; keyboards, mice and games controllers; and hearing aid applications.	Section 7/ Annex 8/9
	ZigBee	As above	A range of home and industrial automation applications, including smart meters; street lighting control; medical monitoring and agricultural usage.	
	ISM	As above	Industrial, scientific and medical applications using less common or bespoke proprietary protocols (often similar to Wi-Fi and Bluetooth). Includes medical monitoring equipment, assisted listening devices, analogue CCTV, video baby monitors and other consumer devices (e.g. model aircraft).	
Licensed				
PMSE		2200-2290 MHz 2290-2300 MHz 2310-2350 MHz* 2390-2400 MHz 2400-2500 MHz 3400-3410 MHz	Equipment used in the television industries including wireless cameras, and communications systems. N.B. 2400-2500 MHz assigned to PMSE but unused due to interference from Wi-Fi. * 2310–2350 MHz used occasionally by PMSE for peak demand events subject to agreement from Home Office and MoD.	Section 8/ Annex 10
Amateur radio		2310-2350 MHz 2390-2400 MHz 2400-2450 MHz	Uses range from simple voice communication to more sophisticated functions such as use of TV repeaters and beacons, sometimes for amateur research and experimentation. Includes 'moon bounce' (the practice of broadcasting signals to the moon and testing its return echo).	Section 9
Radar	Maritime	2900-3100 MHz	Radars used by ships and for harbours/coastguards. Necessary for compliance with International Maritime Organisation requirements.	Section 10 / Annex 13
	Aeronautical	2700-3100 MHz	Air Traffic Control services in UK airspace for commercial and military aircraft plus recreational flying.	Section 11/ Annex 13
Satellite	Fixed Earth stations	2200-2290 MHz	Range of uses in particular parts of the band, including space research, amateur satellites and commercial application.	Section 12/ Annex 11
	Mobile satellite downlink	2170-2200 MHz	Band assigned but unused in the UK at present.	
	Mobile satellite downlink	2483.5-2500 MHz	Globalstar mobile satellite service downlink	
	Future Galileo allocation	2483.5-2500 MHz	Band allocated for future use by Galileo navigation system	
	Satellite fixed links	3600-4200 MHz	Used by foreign embassies, private companies and Met Office (though actual use is low)	

Other licensed uses of the 3.4 GHz band	UK Broadband	3605-3698 MHz 3925-4009 MHz (plus 40 MHz of spectrum within 3.4 GHz award band)	UKB provides wireless data capacity, equipment and services to the telecoms industry, service providers, and the public sector.	Section 14

Consultation questions

Question 4.1: Do you agree with our proposal to conduct a market led award through an auction process for licensed use of the 2.3 and 3.4 GHz bands? If not, please provide evidence to counter this proposal.

Question 4.2: Do you agree that we should not offer arrangements for aggregate bidding for low power use for these release bands? If you believe we should make such arrangements, please provide supporting evidence.

Section 5

Statement on a band plan for the 3.4 GHz award

5.1 This section of the document sets out our position on a band plan for the 3.4 GHz award band. It also considers progress on the development of our approach towards UK Broadband's existing spectrum holding within the 3.4 GHz band.

5.2 We published a consultation on these matters on 16 October 2013 and included two specific proposals[40]:

- A proposal to award the available 3.4 GHz spectrum in a way that is consistent with an unpaired (TDD-compatible) band plan only;
- A proposal to consolidate the 2 x 20 MHz of spectrum within the 3.4 GHz award band currently held by UK Broadband into a single block of 40 MHz.

5.3 We did not consult on a band plan for the 2.3 GHz spectrum because only an unpaired (TDD-compatible) plan is being considered under current moves towards European harmonisation. We have completed our consideration of the proposal for a band plan for the 3.4 GHz band in light of consultation responses, and our conclusions are set out below.

5.4 We have not yet reached a final decision on the consolidation of UK Broadband's existing spectrum holding. Our progress on this issue is also set out below.

Statement on a band plan for the 3.4 GHz spectrum award

5.5 This statement sets out our decision in respect of a band plan for the 3.4 GHz band (3410-3600 MHz).

5.6 In our document *"2.3 and 3.4 GHz Spectrum award: Consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a Call for Inputs on other aspects of the award"* we set out our proposal to award the 3.4 GHz band in a way that is consistent with an unpaired (TDD-compatible) band plan only.

5.7 Since then, as outlined in the previous section, the CEPT ECC has identified a preferred band plan for Europe with *"a single TDD option as the preferred channelling arrangement at 3.4-3.6 GHz, with FDD as an alternative for those administrations which would prefer to use it"*.[41]

5.8 In assessing the options for the 3.4 GHz band as a whole, we also considered the potential impact on UK Broadband's licensed holdings between 3480 and 3500 MHz and between 3580 and 3600 MHz.UK Broadband's holdings are entirely compatible with the proposed unpaired, TDD-compatible, band plan.

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[40] "*2.3 and 3.4 GHz spectrum award: consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a Call for Inputs on other aspects of the award"* http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/. (Published 16 October 2013 and closed 27 November).

[41] http://www.cept.org/Documents/ecc/14301/ECC(13)090-Annex09_Draft-amended-ECCDEC(11)06-for-PC-(with-rev-marks)

Responses

5.9 We asked for responses to our 16 October document by 27 November 2013. Amongst other questions, we asked: *"Do you agree with our proposal to award the 3.4 GHz band in a way that is consistent with an unpaired (TDD-compatible) band plan only, and to make this decision sooner rather than later? If not, please set out your reasons and any evidence for your view."*

5.10 Nineteen responses were received to this question, of which 7 were confidential. They almost all supported the proposal to award the 3.4 GHz band in a way that is consistent with an unpaired (TDD-compatible) band plan only. Some concerns were expressed about spectrum at 3400-3410 MHz, but that is outside the scope of our band plan proposal.

5.11 One respondent, Espirito Limited, a company looking at opportunities afforded by band-sharing of spectrum, opposed the proposal. It suggested there should be more flexibility in a band plan. However, such flexibility would be inconsistent with European harmonisation moves. Flexibility between paired and unpaired usage would also cause technical compatibility challenges.

5.12 High Speed Two (HS2) Ltd. agreed with the proposal, provided that the 2.3 GHz, band - also included in the award - could be used for paired (FDD-compatible) use. We understand HS2 is still exploring options for the most appropriate access to spectrum to meet its needs, including the use of unpaired TDD bands. The Department for Transport is leading the cross-Government and agency group looking at the best solution for HS2's requirements and Ofcom is actively supporting this work. It is not yet clear whether access to FDD spectrum at 2.3 GHz is the most suitable way of meeting HS2's needs. Ofcom will therefore proceed on the basis of its duties described in the introduction to this report. In doing so, we are minded to proceed in line with the European harmonisation measures, which, as described below, do not include any consideration of paired (FDD-compatible) use for the 2.3 GHz band.

5.13 Qualcomm Technologies Inc. agreed that harmonisation was critical for the development of an ecosystem for the band, but stated that support for either TDD and/or FDD in its chipsets would depend on future market demand and ecosystem readiness.

5.14 The Scottish Government was supportive of the bands being used for mobile broadband technologies, particularly to enable 4G technologies and to provide a platform for 5G in the future.

5.15 British Sky Broadcasting plc commented that the upper part of the 3.4 GHz band had the potential to be utilised for Wi-Fi and suggested Ofcom should take account of the fact that 3550-3650 MHz was being considered in the United States for small cell networks and spectrum sharing use. We have outlined our position in relation to licence exempt spectrum in the 3.4 GHz band in section 4.

Our conclusions

5.16 In view of the CEPT decision and the responses to our consultation, we now intend to proceed to award the 3.4 GHz band in a way that is consistent with an unpaired (TDD-compatible) band plan only. This is subject to the European Commission's Radio Spectrum Committee Decision, likely to be adopted in March 2014 (and which will be binding on member states) following the CEPT draft decision.

5.17 Harmonisation of spectrum can be an important factor in giving industry confidence around the expected availability of spectrum, allowing for greater economies of scale in respect of equipment - and leading to consumer devices that are able to work across national borders.

5.18 As already indicated, current and on-going European spectrum harmonisation suggests the 3.4 GHz band will be attractive to telecommunications companies wishing to deliver 4G fixed and mobile services.

Other issues

5.19 We have not consulted on a 2.3 GHz band plan. CEPT is looking into harmonisation of the 2.3 GHz band for mobile/fixed communications networks (e.g. mobile and fixed broadband) whilst ensuring current users are appropriately protected. Only an unpaired band plan has been proposed as part of the on-going CEPT work on the 2.3 GHz band i.e. CEPT has decided not to consider a paired (FDD-compatible) band plan. Given that the 3GPP[42] standard also contains only an unpaired band plan, and subject to this position being confirmed in future decisions, we are intending, as stated in our 16 October consultation document, to be consistent with these positions for the 2.3 GHz band.

5.20 Some responses to our question about the 3.4 GHz band plan raised additional issues relating to the development of technical and other proposals for the award. Please note our position as set out in section 4 about low power spectrum being made available in the 3.4 GHz band. We will consider the comments of respondents further as we proceed with the award process.

Proposal to consolidate UK Broadband's holdings in the 3.4 GHz spectrum band

5.21 The consultation of 16 October 2013 also included a proposal to consolidate UK Broadband's 2 x 20 MHz holdings in the 3.4 GHz band (3480-3500 MHz and 3580-3600 MHz) into a single block between 3560 and 3600 MHz. We proposed to do this by means of a variation to UK Broadband's WTA licence, which runs to 2018.

5.22 We have been reviewing the responses to our proposal since the closure of the consultation period on 27 November 2013. A number of important points have been raised by stakeholders, and we wish to consider these further before reaching our conclusions. We intend to publish a statement on this issue later in 2014.

[42] 3rd Generation Partnership Project (3GPP) aims to allow member telecommunications standard development organizations to define specifications

Section 6

Coexistence with Wi-Fi

6.1 In this section of the consultation we assess the potential risk of interference from LTE deployments in the 2.3 GHz band into Wi-Fi using the neighbouring 2.4 GHz licence exempt band.

6.2 Wi-Fi is deployed in the majority of UK households, chiefly to access the internet via a broadband connection. Altogether, we estimate there are around 17.5 million domestic networks[43]. In addition, Wi-Fi provides coverage to commercial and independent 'hotspots' at a wide range of public locations, both indoors and outdoors. It is therefore important for us to determine the potential risk of interference to Wi-Fi from future users of the 2.3 GHz award band.

6.3 Wi-Fi operates on a licence exempt basis in a shared environment which means it is already subject to impact from other users/uses of the spectrum. As such, its performance can already be less than optimal. There will be a 10 MHz 'guard band' between the lower edge of the licence exempt band and the upper edge of any 2.3 GHz LTE deployments. However, much Wi-Fi equipment is not particularly selective in its receiver capability and may be susceptible to receiving high power signals transmitted in other nearby bands.

6.4 We have tested a range of Wi-Fi equipment and user devices. We have considered the nature and effect of any potential interference; the number of people potentially affected; and the ease and cost of deploying mitigations. In doing so, we have used the framework described in section 4 to assess the significance of the potential impact. This determines whether we should:

- Propose a reconsideration of the whole award;
- Propose intervention in the market to ensure mitigations are put in place (such as by establishing a help scheme);
- Propose that mitigations are more appropriately left to natural market developments (such as market led improvements to equipment), without the need for additional intervention.

Extent of Wi-Fi usage in the UK

6.5 We have divided typical Wi-Fi usage into four main categories and have attempted to quantify the total number of networks in each category as follows (see Figure 6.1):

- Domestic networks – this refers to networks in home environments where users connect to a router in order to access a broadband connection using a PC, laptop, tablet or smartphone. This represents the most common use of Wi-Fi. In the majority of cases routers are supplied by an Internet Service Provider (ISP), but users generally buy their own client devices and, in some cases, routers.
- Outdoor public networks – this refers to commercially operated outdoor Wi-Fi hotspots typically located on lampposts or phone boxes. There are around 4,000

[43]We define any Wi-Fi network as comprising of a router or access point and one or more client devices.

postcode locations with outdoor public networks. It should be noted that a high proportion of access points may be in a relatively small number of densely populated locations. For example, there may be a large number of access points within the single postcode covering Oxford Street in central London.

- Indoor public networks – this refers to public hotspots in cafés, pubs, hotels, shopping centres, airports, etc. and includes both commercially operated networks and independent networks operated by the business owner. We estimate a total of 78,000 networks in this category.

- Enterprise networks – this includes networks in medium and large offices. We estimate a total of 680,000 networks in this category.

6.6 The derivation of these figures is explained more fully in annex 7, but it should be noted that these are estimates and contain some uncertainty. We recognise that Wi-Fi usage is increasing (particularly public Wi-Fi), but believe the estimated totals set out below are reasonable for the purposes of assessing the significance of any impact from interference.

Figure 6.1: Total number of Wi-Fi networks in each category

Category	Description	Numbers
1	Domestic networks	17,500,000
2	Outdoor public networks	4,000
3	Indoor public networks	78,000
4	Enterprise networks	680,000

6.7 It should be noted that categories 2 and 3 do not include the five million BT Fon networks, where public networks are provided on home routers alongside the private home network. These are considered as a sub-set of category 1.

6.8 The majority of Wi-Fi usage is currently in the 2.4 GHz band, however, use of another band - 5 GHz - is increasing in popularity. We explore use of the 5 GHz band as an alternative for 2.4 GHz Wi-Fi later in this section.

International use of the 2.3 GHz band for LTE

6.9 In addition to conducting technical analysis, we have approached regulators and operators in other countries where LTE has already been deployed in the 2.3 GHz band[44]. Wi-Fi is used in the 2.4 GHz band globally. Therefore experience from these countries may be relevant. There are also some deployments of WiMAX in 2.3 GHz in certain countries, which is likely to create a similar risk of interference.

6.10 Specific deployment scenarios vary between countries – in some cases frequencies up to 2400 MHz are allocated (i.e. no guard band between LTE and Wi-Fi) and in other cases only the lower part of the band is used. Additionally the scale of deployments varies widely.

[44]According to the Global mobile Suppliers Association (GSA), 8 countries have commercially launched LTE TDD networks in 2.3 GHz, and networks are in the process of being deployed or planned in a further 8 countries:http://www.gsacom.com/downloads/pdf/gsa_status_of_the_global_lte_tdd_market_120913.php4

6.11 Although we are clear there are no examples of overseas deployments which are directly comparable to the likely UK scenario, we believe that relevant concerns may have surfaced if there were significant general issues for LTE/Wi-Fi coexistence. To date, we have not been notified of any such evidence. A summary of our engagement with overseas bodies is set out in annex 7.

Test findings and proposals for consultation

6.12 Our technical analysis confirms a risk of interference to both Wi-Fi routers/access points and to client devices, but only in some particular circumstances. We identify the main source of interference as LTE base stations. In the very worst cases customers will not be able to use Wi-Fi services - but it is more likely they will experience a drop in performance, unless mitigations are applied.

6.13 The interference from LTE base stations is most likely in urban environments where there may by a dense deployment of LTE base stations, Wi-Fi hotspots and domestic Wi-Fi networks. However, the national scale of interference is not high. Our analysis suggests around 0.1% of the 17.5 million households with Wi-Fi are at risk (based on central assumptions). This would affect around 17,400 households if there were a GB wide roll-out of LTE in the 2.3 GHz band (which we believe is unlikely for quite some time).

6.14 For public Wi-Fi, our testing suggests that interference may affect around 6.8% of the 4,000 postcode locations where outdoor networks are established. A smaller percentage of the 78,000 indoor public Wi-Fi locations (around 1.4%) may be affected. It is also likely that only small parts of the larger indoor networks may be affected, for example the few access points close to a window.

6.15 Finally, our testing suggests around 1.2% of the 680,000 medium and large scale enterprise networks may be at risk from LTE interference. This amounts to around 8,000 networks. Again, the impact may only be to small parts of the network.

6.16 In almost all cases, we believe appropriate mitigations are available. In some cases, simply moving equipment might provide sufficient protection (such as moving routers away from a window or changing the position in which a mobile device is held). In other cases Wi-Fi equipment/devices may be able to access the alternative 5 GHz Wi-Fi band.

6.17 If additional action is needed to upgrade routers or public access points, we believe ISPs will be able to include addressing the impact of 2.3 GHz LTE interference within existing operational processes. We note that ISPs are constantly seeking to improve services in the already crowded licence exempt spectrum environment.

6.18 We understand Wi-Fi routers are often replaced by ISPs after around two years or so in line with network upgrades or in response to consumer concerns about performance. Similarly, public access points are regularly upgraded. In that context, we note that significant roll-out of 2.3 GHz LTE is unlikely before 2016. This provides a window in which mitigations may be developed, if necessary.

6.19 In respect to mobile devices, our testing found one smartphone was entirely resilient to 2.3 GHz LTE interference. This suggests the appropriate technology is already available within the market. This may be significant because many mobile devices (such as smartphones and tablets) are generally replaced by consumers after around 18 or 24 months e.g. for mobile phones, in line with network contracts. If more

resilient devices became the norm, then there would be even less cause for concern. We welcome the views of stakeholders.

6.20 We also note that many devices (including tablets and smartphones) have both Wi-Fi and mobile internet capability. It does not seem unreasonable therefore to assume that chipset manufacturers will ensure future equipment is developed to take account of both Wi-Fi and 2.3 GHz LTE.

6.21 However, we acknowledge there may be an issue for legacy equipment purchased directly by the end user. We note that users may need to understand how to implement certain mitigations (such as by using Ethernet wiring). We are conducting some further market research to assess the volume of legacy equipment which might be at risk of interference, but we expect this to be small. We are also considering whether it might be practical and effective to support an information campaign for the very small number of consumers potentially affected.

6.22 In light of these considerations, we propose that no intervention in the market is necessary to protect Wi-Fi from potential interference. Instead, we believe that mitigations will be developed as part of the natural evolution of the market over the next few years, broadly in line with existing replacement and renewal cycles.

6.23 In setting out this position for consultation, we accept that our analysis has focussed necessarily on a limited number of the thousands of devices available, and that there is inevitably some room for uncertainty in our assumptions (although we believe that we have adopted a set of assumptions which are appropriate in order to produce a realistic figure of impact at a national level). Where there is uncertainty in our assumptions, we have a slight bias towards more conservative individual assumptions, which may tend towards an *over*estimate of the actual impact nationally. In light of this uncertainty, we welcome any additional evidence that stakeholders may be able to submit as part of this consultation.

Assessment of potential risk of interference

6.24 The remainder of this section of the consultation sets out a summary of our analysis of potential interference for the different categories of Wi-Fi.

Outline of potential interference problem

6.25 Licence exempt devices using the 2.4 GHz band (2400 to 2483.5 MHz) are at risk of interference due to their proximity to the 2.3 GHz award band (2350 to 2390 MHz). While the 10 MHz separation between the band edges is expected to provide some protection, it is likely that licence exempt devices may not have been designed to account for high power uses in the adjacent bands.

6.26 Similarly, while all licence exempt devices must be designed to ensure coexistence *within* the 2.4 GHz band - with appropriate designs or transmission protocols - these do not account for the possibility of high power users in adjacent bands. Many of the protocols employed by devices in the 2.4 GHz band require the device to sense the channel for other users before transmitting. This is not the case for the adjacent band, where LTE transmitters can transmit regardless of any transmissions in other bands.

6.27 There are two main interference mechanisms which could affect Wi-Fi in the 2.4 GHz band – out of band emissions and blocking:

- Out of band emissions: The level of filtering on the LTE signal determines how much of the signal falls within the Wi-Fi victim's[45]channel.

- Blocking: The level of filtering on the Wi-Fi receiver determines how much of a high power signal outside of its own operating bandwidth is received. If the filtering is insufficient then signals can overload the Wi-Fi receiver and degrade its performance.

6.28 Interference due to out of band emissions is a function of frequency separation between the interferer and victim, and is therefore likely to have a more adverse impact on Wi-Fi applications operating in frequencies which are closer to the band edge. However, interference due to blocking has the potential to affect all Wi-Fi channels within the 2.4 GHz band equally. As set out more fully in annex 7, we conclude that blocking is likely to be the dominant effect in this case, as there is a 10 MHz frequency separation between the band edges.

6.29 The source of any potential interference could be either LTE base stations or mobile devices. This is because the award band is likely to be used by TDD technology, so both base stations and mobiles transmit in the same spectrum at different times[46]. However, base stations transmit at higher power and are therefore expected to give rise to a greater risk of causing interference. Outdoor Wi-Fi networks are more likely to suffer interference from base stations than indoor networks, which can expect some level of protection from the walls of buildings.

6.30 Although our analysis focuses mainly on the impact from high power base stations, we have also considered whether interference from mobile devices or femto cells may be an issue. Whilst these devices are considerably lower power they can also be located next to or within a few metres of a Wi-Fi device.

6.31 Interference could affect either Wi-Fi access points/routers or client devices (laptops, smartphones, tablets etc.). It should be noted that any impact to a router will also affect any client device connected to it – but interference could also affect the client device directly. The impact of interference to each may differ, as is explored in our analysis below.

Impact of interference on user experience

6.32 If interference occurs, it is likely to result in reduced speed (throughput) on the Wi-Fi connection, either for the whole network or an individual link. In some extreme cases, the link may not operate at all; however, we believe there are mitigations available in most circumstances.

6.33 At the onset of interference, a drop in network speed may not be noticeable to the user, depending on the application involved. For example, a home broadband user browsing the internet using a Wi-Fi link may not experience any noticeable effect because throughput is likely to be restricted by the capability of the services being accessed or by broadband line speed. Many applications do not operate at 'superfast' broadband speeds. If the throughput were to drop below the line speed, the impact may be more noticeable. For higher bandwidth applications such as

[45] The device causing interference is referred to in this document as the interferer and the device being interfered into is called the victim.
[46] This is different to most existing mobile spectrum bands which use FDD (Frequency Division Duplex) technology where the uplink (mobile devices) and downlink (base stations) transmit on different frequencies.

super-fast broadband and in-home media streaming, or on congested public networks, any drop in throughput may have a more noticeable impact.

6.34 If there were high levels of interference, the reduction in speed could potentially continue to the point at which the connection is no longer usable. We have measured three metrics to quantify these effects:

i) The onset of degradation – i.e. the interference level at which the throughput starts to drop below the maximum level achieved in testing;

ii) The point at which throughput drops below 50% of the maximum level. This is considered particularly useful when understanding the impact to client devices, which may not require the maximum level in the first place;

iii) The point at which the throughput drops below 1 Mbps – this is considered as the point below which the connection can no longer be considered usable for many typical applications.

6.35 After discussion with some ISPs we are using the onset of degradation for the impact to routers in our central case used for the policy assessment. This is most appropriate in heavily used networks such as hotspots and those connected with superfast broadband connections.

6.36 For the impact to client devices we are using the 50% throughput drop point. This is in order to reflect the typical variability in throughput encountered by client devices, as supported by some of our field tests outlined below.

6.37 However we note that the full set of results may be useful in order to provide the full context for analysing the scale of impact. Results based on each metric are therefore presented in annex 7.

Measurements and analysis

6.38 Our measurement and analysis work has consisted of three broad activities:

- Measurements of devices to quantify their vulnerability to LTE signals;
- Field trials to validate the effects predicted in real world environments; and,
- Analysis, using these measurements, to extrapolate the potential scale of interference between LTE networks and Wi-Fi deployments.

6.39 In order to quantify the effects of interference, we have tested a sample of different Wi-Fi devices in a laboratory. A total of 21 devices were tested, including routers, laptops, smartphones and tablets. The measurements showed that interference is a possibility in certain scenarios if the power of the interfering LTE signal is high enough. The potential susceptibility to LTE signals was found to vary widely between different devices.

6.40 We also conducted field testing to determine the effects of interference from an LTE base station to Wi-Fi devices in real-world scenarios. The field testing focussed primarily on impacts to routers. However, an additional test was included to determine the variation in impact to a client device under different user movement situations and device orientations.

6.41 These tests supported the conclusions of the laboratory measurements and confirmed the possibility of interference in certain circumstances - although this is heavily dependent on the specific locations of both the interfering base station and the Wi-Fi device. The field trial also confirmed our hypothesis that outdoor Wi-Fi networks are more likely to suffer interference than indoor networks – indoor networks were only affected in cases where the Wi-Fi device was close to a window.

6.42 The field test on the client device confirmed that user movement and device orientation can have a significant effect on the results. A variation of similar magnitude to the effects of the degradations observed due to the LTE signal was seen without interference present – demonstrating that Wi-Fi connection speed is highly variable even in the absence of interference. This supports the view that the 50% throughput metric is more relevant in practice when considering the impact to client devices.

6.43 We have used the results from the measurements to perform a theoretical analysis of interference to all four categories of Wi-Fi networks across the UK. Our central case, as set out in this section, is based on the device which exhibits median performance in each category. We believe this is the most appropriate assumption to give a realistic impact figure on a national level. However, we recognise that impacts to individual devices may vary. Additional results based on the performance of the best case and worst case device are presented in annex 7.

6.44 In practice, we believe the best case results may be more appropriate for assessing outdoor public routers. This is because operators told us they prefer to deploy the highest grade infrastructure. Furthermore, we believe equipment will evolve to take account of LTE being rolled out in the 2.3 GHz band globally.

Results of analysis of interference from LTE base stations

6.45 Our results for the central case, set out below in Figure 6.2, are presented in terms of a percentage of affected network locations.

6.46 For the case where routers are the victim, we additionally present results in terms of absolute number of impacts[47]. For client devices it is difficult to quantify the total number of impacts, due to the mobile nature of most devices and the fact that multiple devices may be connected to a single network. Therefore, for client devices, results are presented purely in terms of the percentage of Wi-Fi coverage areas where any client devices connected to the hotspot may be at risk of interference.

6.47 These results show that some level of interference is possible in all categories – but the predicted number of cases of interference is relatively low in all scenarios. Domestic networks show the lowest percentage of locations impacted (0.1%) but this translates into the highest total number of cases (17,400) because of the large number of networks in this category (17.5 million). Outdoor routers show the highest proportion of affected network locations (6.8%) which translates into 270 postcode locations (noting that some postcodes may include more than one access point).

[47]Impact figures greater than 1,000 are rounded to the nearest 100; impact figures less than 1,000 are rounded to the nearest 10. Therefore percentages and impacts may not exactly match.

Figure 6.1: Interference from LTE base stations and impact to Wi-Fi in the central case

		Routers[48]		Client devices[49]
Category	**Number**	**% Locations affected**	**Total no. of impacts**	**% Locations affected**
1) Domestic networks	17,500,000	0.1%	17,400	0.1%
2a) Outdoor public networks – median device	4,000	6.8%	270	4.4%
2b) Outdoor public networks – best device		4.2%	170	N/A
3) Indoor public networks	78,000	1.4%	1,100	0.6%
4) Medium and large enterprise networks	680,000	1.2%	8,000	0.5%

6.48 Impacts based on the best router device are shown in addition for outdoor networks to take account of operators saying they always employ high grade equipment. In this case the impact is reduced to 170 locations. Furthermore, we believe the development of more effective Wi-Fi filtering will enable better selectivity of signals.

6.49 At affected locations any Wi-Fi user could experience a reduction in throughput, or in the very worst cases even lose their connection. For example, in an urban environment where outdoor Wi-Fi access points are likely to be located in close proximity to LTE base stations, the impact could be significant. Thus, while the impacts may seem small on a national level, we note that for users who are affected this could be a serious problem.

Interpretation of interference results

6.50 The results presented above are based on a nationwide network of LTE base stations using a 20 MHz channel. Smaller scale regional LTE-TDD networks, or use of lower channel powers, will result in lower impacts.

6.51 The analysis does not fully take into account the existing level of background interference within the 2.4 GHz band due to other Wi-Fi devices or other uses of the frequencies. As this is a widely acknowledged existing problem, the impacts presented above should be viewed in this context - the additional impact of interference from LTE-TDD may not be noticeable in many cases.

6.52 For client devices we found that small movements in position and orientation can lead to a significant variation in throughput. Thus users may not be aware of a reduction in performance or may move accordingly to reduce any impacts without realising it – therefore the figures presented above may not be as noticeably high in practice. The impact may also be dependent on what the Wi-Fi device is being used for (high data rate activities such as video streaming may be more likely to result in interference than simple web browsing, for example).

6.53 Finally it should be noted that all the figures above are estimates based on a number of assumptions. The sensitivity to key assumptions is explored further in annex 7, where alternative results based on variations to key assumptions are presented.

[48] Router results are based on the onset of degradation
[49] Client device results are based on the point where throughput drops to 50%

However, we believe that the assumptions we have selected are as realistic as possible.

Impact from mobile devices

6.54 The results outlined above are based on interference from an LTE base station. As stated above, mobile LTE devices are believed to cause a lower risk of interference due to their lower transmit powers. However, interference is a possibility when the LTE device is close to a Wi-Fi device.

6.55 We have calculated that separation distances of up to three metres between mobile devices and any 'victim' Wi-Fi may be required to avoid interference for the worst performing devices - but the majority of tested devices required separation distances of less than one metre under typical mobile transmit powers. It should be noted that interference from mobile devices will only occur when the mobile device is actually transmitting and will depend on location within the cell. In practice this varies depending on user behaviour, but can be expected to be intermittent.

6.56 We therefore believe that the impact from mobile devices will not be significant. In cases where it occurs - due to devices being in close proximity - we expect that the user can mitigate this by separating the interfering mobile device and the affected Wi-Fi device.

6.57 We expect devices which have both 2.3 GHz LTE and Wi-Fi capability (e.g. smartphones) to be designed to prevent interference within the device. We do not therefore consider this to be a concern. This is also the case for tethering and 'personal hotspot' devices - which may use a Wi-Fi connection to re-transmit data received from a 2.3 GHz LTE connection. In these cases we anticipate that interference will be avoided through appropriate scheduling or filtering, although care might be needed for Wi-Fi devices connected to the personal hotspots. We note such devices are already on the market and we have not been made aware of any problems.

Impact from LTE femtocells in the home

6.58 The risk of interference from 2.3 GHz LTE femtocells to Wi-Fi is likely to be similar to that from mobile devices. We note that while the maximum transmit power for a femtocell can be higher than for a mobile device, in practice femtocells are usually required to operate at low powers (at similar levels to mobile devices) in order to operate smoothly with the wider mobile network.

6.59 In an extreme case, a 2.3 GHz LTE femtocell may restrict the use of Wi-Fi within the same room. We believe manufacturers of 2.3 GHz femtocells will be aware of this risk and will design appropriately to account for interference. We note that in many cases femtocells operate in conjunction with a wired connection to a home router, which will also use Wi-Fi.

6.60 There is some evidence to suggest existing 3G femtocells operating at 2.1 GHz sometimes cause interference to Wi-Fi. This can usually be mitigated by increasing the separation between the devices, using a longer cable if required. This is also the case for interference from 2.3 GHz, although the required separation may be slightly greater.

6.61 Most mobile network operators have a number of different bands available and we think that coexistence of their services with their customers' Wi-Fi systems would be

a consideration when selecting which mobile communications bands to enable within femtocells in the home.

Mitigations for different categories of Wi-Fi use

Domestic Networks (category 1)

6.62 As set out in Figure 6.2, our technical analysis suggests around 0.1% of the 17.5 million households with Wi-Fi are at risk of interference from 2.3 GHz LTE base stations (based on our central case assumptions). The interference, if it occurs, may be to home routers or directly to devices. We believe there are appropriate mitigations available for both categories (noting that in nearly all cases interference will not occur), although mitigations may be more difficult for some older legacy equipment.

6.63 The mitigations for routers (usually supplied by the ISP) are:

- In some circumstances, simply moving a router deeper indoors might provide sufficient additional protection. This may not be practical in all cases, but moving a router off a windowsill onto a desk or shelf could be sufficient to solve the issue. ISPs could provide this advice in response to a support call.

- Improved filtering in routers. We did not test any routers that were sufficiently robust to rule out any chance of interference – but we believe filters do exist and manufacturer development will make this achievable.

- Use of the 5 GHz Wi-Fi band as an alternative to 2.4 GHz. The 5 GHz band is growing in popularity due to the higher data-rates available and the existing problems of congestion in the 2.4 GHz band - as well as recent improvements in cost and battery efficiency of 5 GHz devices. The majority of new router devices on the market now support the use of 5 GHz[50]- but we acknowledge there may be some older legacy devices that do not.

6.64 For client devices (usually purchased by consumers or supplied by mobile network operators):

- Development of more robust equipment (see paragraph 1.14 above). As noted, one device tested was entirely resilient to interference and we note that many devices (such as tablets and smartphones) will need to operate with both 2.3 GHz LTE and Wi-Fi within the same device. Importantly, we note that general replacement cycles for equipment of this kind is 18-24 months (although this may not always be the case, and some devices may be passed on to others at that point);

- A review of currently available client devices shows a similar trend in use of the 5 GHz band as for routers – with the majority of smartphones and tablets now supporting both bands[51]. Given the normal replacement cycles, support for 5 GHz is expected to increase over the next few years. Laptops have typically included 5 GHz capability as standard for 2-3 years. We have not done a full market

[50]The future role of spectrum sharing for mobile and wireless data services - Licensed sharing, Wi-Fi, and dynamic spectrum access, Ofcom, August 2013, paragraph 3.15: http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

[51]As for routers above, and supported by web research of popular smartphone and tablet devices.

analysis, but we understand from ISPs that some common devices allow automatic switching between Wi-Fi bands.

- Moving portable devices. Interference can be mitigated to some degree simply by moving to a slightly different location or changing body position to face away from a base station (even a slight change may be effective). We note that moving location may not be possible with more static client devices such as smart TVs and games consoles.

6.65 There remains, however, the possibility that there is legacy equipment that does not access the 5 GHz band and cannot be easily moved. In this instance, we would suggest power-line technology. We acknowledge consumers would need a degree of knowledge to implement a number of these mitigations. We are considering whether this information can be effectively disseminated to consumers.

Public Wi-Fi Networks (both outdoor and indoor) (categories 2 and 3)

6.66 Our analysis suggests that interference from 2.3 GHz LTE base stations may affect both outdoor access points and/or user devices. In the very worst cases customers would not be able to use the service - but our analysis suggests they are more likely to experience a drop in performance, unless mitigations are applied.

6.67 It is important to note that public Wi-Fi already operates in a congested environment (due to interference from other Wi-Fi and licence exempt devices) and does not always provide a high quality user experience. In order to manage interference issues, ISPs already have a set of tools and processes at their disposal. We believe ISPs will be able to address the impact of 2.3 GHz LTE interference within their existing optimisation processes in managing access - although this may mean that the useable Wi-Fi coverage area of an access point is reduced.

6.68 Where indoor networks are affected, we think that this will only apply to access points and users who are located close to a window. If multiple access points are deployed in a large building (e.g. a shopping centre or train station), not all the access points or users can be expected to be affected.

6.69 Overall, we believe appropriate mitigations can be applied for access points as follows:

- Equipment upgrades or deployment of filters[52] to improve the access point performance and make it more robust to interference;

- According to stakeholders, the use of access points with adaptive antenna technology may enable interference to be mitigated as part of the processing;

- ISPs can already make use of band selection in newer user devices to push traffic to the alternative 5 GHz Wi-Fi layer to alleviate some congestion on the 2.4 GHz layer. In the short to medium term (a few years), many more client devices will be able to do this. We note, however, that some ISPs see this as a loss in overall capacity in the Wi-Fi hotspot rather than a mitigation.

[52]We believe that similar filters are already available and the required filter performance will be similar to that which is required for protecting DTT from LTE800 so we anticipate could be designed and manufactured relatively cheaply.

6.70 Mitigations for consumers' client devices are similar to those for domestic Wi-Fi applications. Namely, upgrading of equipment (often in line with normal replacement cycles, such as mobile phone contracts); switching to use of 5 GHz frequencies for those devices with this capability (almost all equipment now on the market); or simply by moving location slightly or altering the orientation of the device (in line with existing common consumer experience).

Enterprise networks (category 4)

6.71 Some existing devices such as enterprise class routers support the ability to switch to other channels and also between bands to avoid congestion and interference. In this case the device may automatically switch from 2.4 GHz to 5 GHz if interference occurs.

6.72 Other mitigations are the same as for public networks. However, as noted above, enterprise networks are likely to be operated by IT professionals. We believe such personnel should have a level of understanding about potential issues and how they can best be mitigated – or at least have access to informed advice. IT departments are also likely to have control over client devices used in the network, which are also likely to be upgraded regularly.

6.73 As with public indoor networks, where multiple access points are deployed in one building (as is typical in a medium sized or large office) interference is only likely to affect access points and users located near a window.

Practical application of mitigations

6.74 We note there is some potential cost involved in applying mitigations to either domestic or public Wi-Fi in the small number of cases where this might prove necessary. This relates to the cost or upgrade of Wi-Fi routers/access points and/or user equipment. There may also be cost involved for consumers who need to use alternative wire technology for larger legacy devices, such as smart TVs.

6.75 We note that dominant interference to Wi-Fi relates to blocking. With a 10 MHz guard band between the LTE release band and the licence exempt band, we not believe that the dominant interference factor will be LTE emissions into the licence exempt band. Our assessment suggests that some Wi-Fi equipment, while meeting the recognised standards, is designed in such a way that it would pick up signals from the LTE award band (we note in this section that over time the Wi-Fi equipment could be designed in such a way that it limits this happening).

6.76 As we have seen, the overall impact of potential interference is small and likely to affect only a very limited number of Wi-Fi users. In most cases, mitigation is relatively cheap and straightforward. In contrast, the cost of setting up and administering a scheme for cost recovery is likely to be disproportionately high. At the least, it is likely to involve the establishment of some kind of 'help scheme' where claims could be made and assessed for validity before any payment is made.

6.77 In the absence of any such help scheme, we believe the replacement/upgrade of a great deal of domestic consumer equipment (including routers and user devices) would occur quite naturally. As noted, mobile phones are generally replaced or upgraded every 18 to 24 months in line with existing contracts. Domestic Wi-Fi routers are also regularly upgraded by ISPs. If a domestic Wi-Fi user was to experience a problem outside the normal replacement cycle, their initial call would be to their ISP who could send an updated Wi-Fi router (as they regularly do now).

6.78 Similarly, most ISPs have told us their equipment is constantly upgraded on rolling cycles. We believe they could deal with the risk of additional interference from LTE-TDD services operating in the 2.3 GHz band within this existing process. On the other hand, the existence of a help scheme is likely to act as a powerful disincentive to both Wi-Fi users and operators upgrading their equipment/devices. They would instead be tempted to wait until their costs were potentially recoverable. Additionally, on a practical level, we also believe it will be difficult to determine whether 2.3 GHz LTE transmissions are the source of additional interference.

6.79 On balance, therefore, we believe mitigation should be left to the market to determine. Those potentially affected are in the best position to assess the actual impact of interference, if it occurs. They will therefore be in the best position to apply mitigations and will be incentivised to keep costs to a minimum.

6.80 We therefore propose that no additional steps, such as the establishment of a help scheme, are taken to protect Wi-Fi from potential interference from LTE in the 2.3 GHz band.

Consultation questions

Question 6.1: Do you have evidence to challenge our methodology and assumptions, which show the number of Wi-Fi routers likely to be affected by LTE interference is low?

Question 6.2: Do you have evidence to challenge our methodology and assumptions, which show the number of Wi-Fi client devices affected by LTE interference is low?

Question 6.3: Do you agree with our assessment of the available options for mitigation of interference to home networks?

Question 6.4: Do you agree with our assessment of the available options for mitigation of interference to public networks (both indoor and outdoor)?

Question 6.5: Do you agree with our assessment of the available options for mitigation of interference to Enterprise Networks?

Question 6.6: Do you agree with our conclusion that the impact to Wi-Fi is not of a significant nature and therefore no regulatory intervention is necessary? If not, can you provide evidence?

Section 7

Other Licence Exempt uses of 2.4 GHz spectrum

7.1 Having considered issues for Wi-Fi in the previous section of this consultation, we now assess the potential impact of interference to other licence exempt applications in the 2.4 GHz band. We note that while use of this band is licence exempt - and therefore operates on a non-interference non-protection basis - we also have wider duties to consider the impact of our decisions on citizens and consumers. The technical analysis which has informed our proposals is set out in more detail in annexes 8 and 9.

Introduction - assessing potential interference issues

7.2 As with Wi-Fi, we have considered the nature and effect of potential interference to various applications; the number of people potentially affected; and the ease and cost of deploying mitigations where this is necessary. In doing so, we have used the framework described in section 4 to assess the significance of the potential impact. This determines whether we should:

- Propose a reconsideration of the whole award;
- Propose intervention in the market to ensure mitigations are put in place (such as by establishing a help scheme);
- Propose that mitigations are more appropriately left to natural market developments (such as market led improvements to equipment), without the need for additional intervention.

7.3 All applications operating in this band are required to coexist with other users through the use of polite protocols (typically listen before talk, low duty cycles or pseudo random hopping sequences). Systems are therefore designed to tolerate interference from other low power users, e.g. through multiple transmissions and retries.

7.4 However, our analysis shows there is a potential risk of interference from high power uses of the adjacent 2.3 GHz award band which do not have the same requirements for polite operations, and whose presence may not have been considered in the design of some existing licence exempt devices.

7.5 We recognise that some uses of this band are widespread and/or high profile, and that some have particular 'use cases' and link geometries that might make them particularly susceptible to interference. In some cases, uses may be operationally critical[53] (or may be perceived to be so). We have given particular consideration to issues for these applications in light of this.

7.6 Since there is no requirement for records to be kept of individual licence exempt uses of spectrum, it is difficult to be certain of exact deployments. In order to gather

[53]Typically this band is not used for safety critical applications where there is no additional safeguard in place. See Ofcom's Short Range Devices Information Sheet: http://stakeholders.ofcom.org.uk/spectrum/information/licence-exempt-radio-use/licence-exempt-devices/short-range-devices-information

information, we have drawn on the results of two market studies[54] on the use of the 2.4 GHz band. The first market study outlined the high level categories of each type of application in the band. The second was a more detailed market study with particular focus on applications which may be susceptible to interference. Many of the applications identified use one of the three IEEE technologies (Wi-Fi, Bluetooth and ZigBee).

7.7 The 2.4 GHz band has standards for a number of other applications which use only eight to 10 MHz of spectrum in the middle of the frequency range. We believe that these do not to have a high risk of interference because there is adequate frequency separation from the 2.3 GHz award band. We also believe that there are very limited deployments of these applications, and those in use are mainly very short range and therefore less susceptible to interference. We have not therefore considered the following applications:

- Railway applications (vehicle identification) (2446-2454 MHz)
- RFID (2446-2454 MHz)
- Radio determination (2445-2455 MHz)
- Short range indoor links (2445-2455 MHz)
- Industrial /commercial telemetry & tele-command (2445-2455 MHz)

7.8 In order to ensure there were no additional applications of interest not addressed in the market studies, we published a Call for Inputs on 9 May 2013[55]. We received nine responses[56] (non-confidential responses were submitted by ARM Holdings, Arqiva, BT, Intel, Intellect, Phonak UK, Radio Society of Great Britain and Sky). None of these raised major concerns about standards and/or devices in widespread consumer use of which we were previously unaware. Further details of the Call for Input responses are set out in annex 8.

7.9 For licence exempt applications (other than those set out in paragraph 7.7 above), we have assessed the impact of interference from LTE base stations and mobile devices by examining a representative cross section of uses based on those which are well established in the market; have the potential for future growth; or may be regarded by some as operationally critical. Whilst we have not examined all possible uses in this band, we think that our analysis provides a basis for assessing the likely impact on most, if not all, other uses.

7.10 Using the data from the market research and the call for input responses, the technologies we have examined are:

- **Bluetooth:** (including both regular Bluetooth and Bluetooth low energy or Bluetooth 'Smart' devices): these are typically used for short-range communications, with the most popular and widely recognised use being hands-free cordless headsets for mobile phones. Bluetooth low energy is a new variant targeting the emerging machine-to-machine (m2m) market.

[54] See annex 5
[55] http://stakeholders.ofcom.org.uk/consultations/2400-mhz/
[56] http://stakeholders.ofcom.org.uk/consultations/2400-mhz/?showResponses=true

- **ZigBee:** another m2m technology, where low power devices are intended to operate for several years off a single battery to provide low data rate communications. Applications include the provision of an in-home communications link for smart meters, as well as other monitoring and control tasks such as agriculture, traffic and street light control. We assume our analysis is applicable to all these applications

- **Video Devices:** including in-home video senders, door entry monitors and baby monitors. Although many new devices are digital, we recognise there are some analogue products still on the market, as well as some legacy analogue devices.

- **Audio Devices:** we have used radio microphones as representative of a broad range of audio devices in order to assess susceptibility to interference. We recognise there is also a growing market for assisted listening devices (ALDs) operating in this band.

- **Short Range Devices (SRDs):** a generic classification representing a large diversity of devices. We were unable to identify any particularly common equipment types. We have assessed the risk of interference from a theoretical standpoint based on ETSI standards.

- **Medical monitoring:** medical devices that use main standards (Wi-Fi, Bluetooth and ZigBee) or proprietary protocols. We believe from our conversations with manufacturers that the proprietary protocols are similar to those covered by the major standards and therefore our analysis for these technologies is applicable.

7.11 For each technology we have considered the likelihood and impact of interference from new services using LTE technology in the adjacent 2.3 GHz award band in typical scenarios. This includes assessing the separation distances that may be required from an LTE base station or mobile device; and discussion, where appropriate, of possible mitigations if interference was to occur.

7.12 The section below outlines the work we undertook on each specific application, the results, and our conclusions. In summary, our assessment shows that interference is possible in certain circumstances. However, we believe the applications and protocols will be robust to interference in almost all circumstances and that there are in any case potential mitigations. We propose that mitigations are more appropriately left to natural market developments.

Ofcom's analysis of each technology

Bluetooth

Overview

7.13 Bluetooth is a popular standard for short distance (<10 m) wireless communications for Personal Area Networks (PANs). The standard is managed by the Bluetooth Special Interest Group and is standardised as IEEE 802.15.1.

7.14 Typical Bluetooth applications include mobile phone headsets, in car audio, file transfer, wireless keyboard and mice, and games console controllers. The vast majority of mobile devices and tablets currently in the market support Bluetooth. As outlined above, our audits on the use of the licence exempt band found a number of

other applications which also use Bluetooth (or proprietary technologies that are very similar).

7.15 Bluetooth operates in the 2.4 GHz band on a licence exempt basis across 79 channels of 1 MHz bandwidth from 2402 to 2480 MHz, with a maximum data-rate of 1 Mbps. Adaptive Frequency Hopping is employed in order to avoid interference from other licence exempt devices. This means the link switches channel 1600 times per second while avoiding channels which have been identified as being occupied by other uses. It is therefore resistant to narrowband interference.

7.16 We conducted interference studies on Bluetooth devices which use basic rate and those using enhanced data rate modes - as well as Bluetooth low energy devices (which are marketed as Bluetooth Smart). The basic rate and enhanced data rate devices are fairly mature, representing the majority of Bluetooth devices, whilst Bluetooth Low Energy is less established but targeting the growing m2m market. This market requires a wireless protocol that accommodates intermittent, low data rate transmissions and a long battery life.

7.17 While Bluetooth is specifically designed to exist alongside other low-power uses within the 2.4 GHz band, there is a potential risk of interference from high power uses in the adjacent award band. Our analysis is summarised below, and set out in more detail in annex 8.

Measurement and analysis

7.18 We commissioned a measurement campaign by Multiple Access Communications (MAC) Ltd on a range of Bluetooth devices, in order to quantify the likely impact of interference from LTE in the award band, and to determine if adaptive frequency hopping is effective in avoiding interference. The report derived from this study is published alongside this consultation[57].

7.19 The results show that interference is a possibility in certain scenarios as a result of close proximity to high power signals in the adjacent band. This is typical of devices that have limited or no front end filters, as a result of cost and design constraints. The quantitative results are compared with qualitative tests which looked at typical Bluetooth audio applications. No noticeable degradation to the audio was encountered in these qualitative tests under any of the test scenarios.

7.20 The following table (Figure 7.1) shows the minimum separation distances for a range of typical Bluetooth applications:

Figure 7.1: Minimum separation distances for typical Bluetooth applications

Scenario	Bluetooth mode	Environment	Base station separation distance (m)	Mobile device separation distance (m)
Car	Standard	Outdoor	<1	<1
Car Kit	Standard	Outdoor	<1	<1
Gaming Device	Standard	Indoor	<1	<1
Headset	Standard	Outdoor	<1	<1
Home Entertainment	Standard	Indoor	<1	<1
Keyboard	Standard	Outdoor	<1	<1
Mobile Phone	Standard	Outdoor	<1	<1

[57] A list including this and other external reports linked to this consultation is set out in annex 5

Personal Computer	Standard	Indoor	<1	<1
Stereo Headphone	Standard	Outdoor	<1	<1
Stereo Speaker	Standard	Indoor	<1	<1
Garage Door	Low Energy	Outdoor	30	<1
Sensor	Low Energy	Outdoor	45	<1

7.21 Most typical applications using Standard Bluetooth have a very low risk of interference, at separation distances less than one metre.

7.22 We found that Bluetooth low energy devices were slightly more susceptible to interference than Bluetooth devices using basic rate or enhanced data rate modes (by a factor of 3 to 10 dB). This was because they are intended to operate at a lower signal level in order to use a lower transmit power and save energy for battery operation over periods of a few years between recharging.

7.23 The outdoor nature of the 'Garage Door' and 'Sensor' links means there is likely to be minimal additional loss to the interfering signal (compared to systems operating inside, where additional building or vehicle penetration losses provide greater protection from an external base station).

7.24 Our analysis suggests the risk of interference is minimal with separation distances of less than 50metres. However, if interference was to occur in practice – i.e. devices were in close proximity to a 2.3 GHz LTE base station - then the risk of interference could be mitigated in some cases by careful positioning of the sensors to use building shielding for additional protection. Interference could also be mitigated by moving the remote control closer to the door sensor and thus increasing the wanted signal, although this may not be possible in all circumstances. In some wideband blocking scenarios, interference may be slightly less at the upper channels in the band and frequency hopping may automatically select these channels making the link a little more resilient.

Assessment

7.25 The analysis of Bluetooth devices summarised here shows that new LTE services are unlikely to cause interference to devices using basic rate or enhanced data rate modes. This includes most applications in use today such as mobile phone headsets and hands-free kits.

7.26 There remains a very small risk that Bluetooth low energy devices operating in certain scenarios may suffer some interference if in very close proximity to an LTE base station. If interference does occur to fixed devices (such as remote control and garage door sensors), there are a couple of effective mitigation options, including shortening the Bluetooth link (where possible) and careful placement of outdoor sensors.

7.27 In cases where LTE and Bluetooth are integrated into the same device it is expected that manufacturers will take the necessary engineering precautions to prevent interference.

7.28 We therefore consider that the risk of potentially harmful interference to Bluetooth is not significant and that regulatory-led intervention in the market is unnecessary.

ZigBee

Overview

7.29 ZigBee is a popular standard for short distance wireless communications for sensor, control and automation purposes. The standard is managed by the ZigBee Alliance and is standardised under IEEE 802.15.4.ZigBee operates in the 2.4 GHz band on a licence exempt basis with16 channels of 5 MHz bandwidth from 2402.5 to 2482.5 MHz, with a target data-rate of 250 kbps. ZigBee uses direct sequence spread spectrum (DSSS) – where the transmitted data stream is coded and spread across a wide bandwidth - as an interference avoidance technique.

7.30 Our audits on the use of the 2.4 GHz band, as outlined above, found the following key applications which use ZigBee: home and industrial automation (e.g. lighting control), smart meters, agricultural usage, street light control, traffic light control and medical monitoring applications.

7.31 While ZigBee is designed to co-exist with other low-power uses within the 2.4 GHz band through the use of spread spectrum, there is a potential risk of interference from wideband high power uses in the adjacent 2.3 GHz award band.

Measurement and analysis

7.32 We commissioned MAC Ltd to conduct a measurement campaign on a range of ZigBee devices, in order to quantify the impact of interference from LTE in the 2.3 GHz award band, and to determine if the use of spread spectrum is effective in avoiding interference. The report from this study is published alongside this consultation (see annex 5).

7.33 The main tests showed interference is a possibility in certain scenarios as a result of close proximity to high power signals from base stations in the adjacent band. The interference risk from mobile devices is significantly lower – interference is only likely within one metre of the interfering device. This is typical of devices that have limited or no front end filters.

7.34 These quantitative results were compared with qualitative tests which considered the example of a home lighting automation application. The qualitative tests showed that normal operation of the ZigBee network was unaffected by an LTE mobile device transmitting at the maximum power in close proximity. If there are higher peaks in LTE mobile device transmit power, a combination of channel sensing and retransmissions appeared to mitigate interference. This is acceptable for ZigBee networks which are non-time-critical and have a low data rate with long periods between transmissions.

7.35 Where there are outdoor or longer links, such as for industrial automation, traffic light control or smart meters, our analysis suggests that (in most cases) some small separation from an LTE base station might be necessary. For agricultural links with very long links the separation distances required are greater. These are detailed in Figure 7.2 below.

Figure 7.2: ZigBee Scenarios and Minimum Separation Distances from a 20 MHz LTE base stations required to prevent the onset of degradation

ZigBee Scenario	Typical Link Dist. (m)	Minimum separation distance (m)
Industrial Automation	100	20
Smart Meters[58]	10	45
Agriculture	300	650
Traffic Light Control	40	20

7.36 As with Bluetooth, in most cases the risk of interference is low, with separation distances in the order of 10s of metres from a full power base station. ZigBee data is mostly not time or latency (delay) critical. Retransmissions may therefore be useful in helping to mitigate interference, though this may increase power consumption.

7.37 If interference were to occur in practice, then careful positioning or shielding of the ZigBee receiver may provide the additional protection required. As noted, the necessary separation distance is higher for agricultural systems. However, we note that these systems are deployed in very few locations in the UK currently and that they are not very likely to coincide with high density deployment of LTE base stations, as they are typically in more rural areas of the country. We therefore think that the overall risk remains low.

7.38 Should interference occur - or if deployments are planned close to LTE base stations - then reasonable mitigation can be achieved in most cases by ensuring shorter link lengths or adding additional mesh nodes (supported by the ZigBee architecture). We note that some additional costs may be incurred if improved equipment is required or power consumption is increased.

7.39 There is a current Government initiative to deploy smart meters on a nationwide basis by 2020[59]. The Department for Energy and Climate Change (DECC) estimates that some 70% of premises will have a home area network (HAN) using ZigBee technology in the 2.4 GHz band[60]. We have therefore worked with representatives from DECC to identify and understand the risk arising from the on-going programme.

7.40 We adapted the data used by DECC in arriving at the 70% figure to take account of interference from 2.3 GHz base stations. Our analysis suggested the proportion of Home Area Networks that could be served by 2.4 GHz technology could decrease by 0.25 percentage points, reducing the DECC estimate from 70% to 69.75%.

[58] Smart Meters can be installed in both indoor and outdoor locations. Attenuation of the wanted signal by obstructions such as walls and floors within buildings will impact the wanted received signal strength leading to greater minimum separation distances from LTE transmitters. See “Focus on Smart Meters” later in this document.

[59] “Smart Meters: a guide”, Department of Energy & Climate Change, 22 January 2013, https://www.gov.uk/smart-meters-how-they-work

[60] Availability of technologies for provisioning Home Area Network (HAN) connectivity to electricity and gas metering equipment, communications hub and in-home devices in cases where a 2.4GHz ZigBee wireless HAN will not work effectively”, Information request to the Smart Metering Implementation Programme, Department of Energy and Climate Change, 1st March 2013, https://www.gov.uk/government/publications/availability-of-technologies-for-provisioning-home-area-network-han-connectivity-to-electricity-and-gas-metering-equipment-communications-hub-and-in-home-devices-in-cases-where-a-2-4ghz-ZigBee-wireless-han-will-not-work-effectively

7.41 The ZigBee standard allows for use in the UK[61] of the 868 MHz short range devices band and the 915 MHz licence exempt band. The energy companies are already working toward use of these bands in order to cover much of the remaining 30% of premises which are not expected to be served by 2.4 GHz ZigBee. These bands therefore provide a credible alternative across the UK if there was a level of interference from LTE in the 2.3 GHz release band for a 2.4 GHz ZigBee solution to be inappropriate.

7.42 Whilst these bands may also provide an alternative for some other uses of ZigBee in the 2.4 GHz band, they have less overall spectrum available. Therefore this is unlikely to be a wholesale alternative to use of the 2.4 GHz band.

Assessment

7.43 Our results show that the operation of LTE base stations or mobile devices in the 2.3 GHz band is unlikely to cause significant disruption to ZigBee devices operating in the 2.4 GHz band, based on our modelled scenarios. In certain circumstances, the performance of some ZigBee devices with very little link margin may suffer some degradation if used very close to a base station. A number of already available interference mitigation techniques could be used in these more difficult scenarios.

7.44 Overall, we consider that the risk of potentially harmful interference to ZigBee is not significant and consequently that regulatory-led intervention in the market is not necessary.

Video devices

Overview

7.45 Our investigations into the uses of the 2.4 GHz licence exempt band found a number of analogue and digital video senders operating in the spectrum. This includes baby monitors with a video link[62].

7.46 These devices tend to use proprietary protocols and technology in order to co-exist with other licence exempt users of the band. Newer devices coming on to the market use digital modulation and frequency hopping technology to mitigate against interference and provide more robust security against video pictures being interrupted.

7.47 However, there remains a potential risk of interference from wideband high power uses in the award band.

Measurement and analysis

7.48 We selected two representative video senders (one analogue and one digital) and five digital baby monitors for use in the technical measurements. The particular devices were chosen as examples of commercially available off-the-shelf equipment. We could not find any examples of analogue baby monitors still available on the

[61] "Statement on 870-876 MHz and 915-921 MHz", Ofcom, 27 June 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/870-915/statement/statement.pdf

[62] Whilst we could not find any, there may also be audio-only baby monitors available in this band. These can be expected to be more resilient to interference than the video and audio devices examined here

market[63]. Since baby monitors are likely to be used for only a relatively short period (i.e. the first few years after a baby is born) we do not expect many analogue devices to be in use. We would welcome any evidence to the contrary, if it is available.

7.49 Our test results show that interference is possible, and the interference risk is significantly higher for the analogue device than for the digital versions. This is as expected because of the frequency hopping capability of digital devices. We have interpreted the results of our testing to derive the required separation distances for each device from both LTE base stations and from LTE mobile devices.

7.50 Close to base stations, the digital video devices are robust, but the analogue device has a relatively higher risk of suffering interference. The onset of degradation will occur when the analogue video sender is within ~200 metres of a high power LTE base station. A degraded service will still be available at smaller separation distances.

Figure 7.3: Scenarios and Minimum Separation Distances from LTE transmitters

Device	Video sender link distance (m)	Usage scenario	LTE minimum separation distance (m)	
			20 MHz base station	20 MHz mobile device
Baby Monitors				
DUT-A	10	Indoor	30	<1
DUT-B	10	Indoor	4	<1
DUT-C	10	Indoor	<1	<1
DUT-D	10	Indoor	25	<1
DUT-E	10	Indoor	25	<1
Video Senders				
DUT-X (Analogue)	10	Indoor	210	3
DUT-Y	10	Indoor	<1	<1

7.51 In proximity to an LTE mobile device transmitting at a typical power of 3 dBm, our analysis suggests a digital baby monitor is unlikely to suffer interference unless it is extremely close. Mobile devices may, however, transmit up to a maximum of 23 dBm EIRP. In these higher power scenarios, there may be some risk of a mobile device causing some interference to baby monitors (and receivers of video senders) in the same room. Typically, a one metre separation from the mobile device would be sufficient to protect against interference.

7.52 If interference was to occur it would only be while the user equipment was actually transmitting and is therefore likely to be intermittent and not a particularly common occurrence - depending on the data use of the LTE mobile device. In the rare event of interference occurring, a parent or guardian would be aware of any issues because the sound would fail and the picture would break up. We understand that some devices trigger an alarm in the event of failure.

Assessment for video devices

7.53 These results show that the operation of LTE base stations and mobile devices in the 2.3 GHz band is unlikely to cause significant disruption to digital video senders or baby monitors in most circumstances.

[63] One analogue device was found on the market, but we do not believe it to be CE compliant so is not legal to be sold in the UK

7.54 In certain circumstances, the performance of some analogue video devices may suffer some degradation if used very close to a base station or mobile device. However, the more recent digital devices are unlikely to suffer any significant degradation in performance.

7.55 We consider that the risk of potentially harmful interference to video devices is not significant and that regulatory-led intervention in the market is not necessary.

Radio Microphones

Measurement and analysis

7.56 We have also performed tests on three non-professional[64] digital radio microphone receivers. The selected devices were chosen as examples of commercially available off-the-shelf equipment.

7.57 The results show similar performance across all three devices. Interference is unlikely, with the required minimum separation distances from an LTE base station being in the order of a few 10s of metres. The separation distances in Figure 7.4 have been derived from the measured values presented in annex 9, based on the maximum operating range specified on their data sheets.

Figure 7.4: Radio Microphone Scenarios and Minimum Separation Distances from LTE base stations

Radio Microphone	Radio microphone link distance (m)	Usage scenario	LTE minimum separation distance (m)	
			20 MHz BS	20 MHz UE
DUT-A	30	Outdoor	15	<1
DUT-B	100	Outdoor	45	<1
DUT-C	30	Outdoor	40	<1

7.58 These results show that all devices work up to their maximum specified range in the presence of interference from a mobile device.

7.59 Minimum separation distances between the radio microphone receivers and base stations were broadly similar, with degradation in performance a possibility when within 45 metres of a base station. These distances are unlikely to occur in practice and will be reduced further for indoor scenarios or where the radio microphone link is operating with a greater margin (i.e. when not at the maximum range). Minimum separation distances between the radio microphone receivers and user equipment need to be less than one metre.

Assessment for radio microphones

7.60 We consider that the risk of harmful interference to radio microphones is not significant. The range over which interference may be a problem is likely to be minimal and can be mitigated by operating at shorter link distances, and thus a greater link margin. Professional users have access to alternative licensed spectrum when a higher level of guaranteed service is required.

[64]The 2.4 GHz band is not typically used by professional users, who prefer other bands where greater levels of protection can be guaranteed.

Short range device standards

7.61 Short Range Device (SRD) is a generic term used to describe a number of devices which are usually licence exempt and have low range and transmission power. Applications include alarms, telemetry, radio microphones, radio local area networks and anti-theft devices. The maximum power levels are around 500 mW at VHF and UHF frequencies. They are usually for terrestrial use only and operate on a non-interference non-protection basis in specific bands.

7.62 There are a range of non-specific short range devices operating in the 2.4 GHz band. These devices are required to conform to the ETSI standard EN 300 440[65], as set out in IR 2030[66]. The blocking levels defined in this standard vary - based on the receiver category definition - and are not always specified[67]. We have derived theoretical minimum separation distances based on these specifications in Figure 7.5.

7.63 This analysis suggests that an LTE base station may cause some interference to SRDs at large separation distances. However, the assessment is likely to be pessimistic because the technical specifications of different devices vary widely. The ETSI standard is a minimum base level. As with Bluetooth and ZigBee devices, many SRDs perform better than this minimum. Many have significantly better selectivity.

Figure 7.52: Theoretical minimum separation distances for SRDs from LTE interferers to prevent the onset of degradation from interference in the reference indoor and outdoor suburban base station geometries

SRD Category	Usage scenario	LTE minimum separation distance (m)	
		Base station (BS)	Mobile device (UE)
#1	Outdoor	50	<1
#2	Outdoor	280	2
#1	Indoor	15	<1
#2	Indoor	170	2

Summary for short range devices

7.64 We consider the risk of interference to SRDs to be acceptable because real devices are likely to perform better than the minimum selectivity required by the standard, especially with 10MHz of separation between the bands. However, where devices have widespread use and/or are used for operationally critical or medical reasons, we have conducted more detailed investigations as set out in the following paragraphs.

[65] "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods", *ETSI EN 300 440-1*, V1.6.1, 2010-08, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=33512

[66] "IR 2030 - UK Interface Requirements, 2030, Licence Exempt Short Range Devices", Ofcom, December 2011, http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-policy-area/spectrum-management/research-guidelines-tech-info/interface-requirements/IR_2030.pdf

[67] Category 1, highly reliable SRD communications media; Category 2, medium reliable SRD communications media, category 3, Standard reliable SRD communications media

Medical monitoring

7.65 Medical monitoring devices operate in a number of frequency bands, some of which are dedicated to such use. However a number of other devices (in particular medical telemetry and monitoring) make use the 2.4 GHz licence exempt band. This can be beneficial because such devices can inter-connect with existing Wi-Fi networks.

7.66 Uses of 2.4 GHz medical monitoring equipment include recording heart rate, electrocardiograms, blood pressure, temperature, carbon dioxide concentration and/or oxygen saturation in the blood. These devices are often deployed for ease of patient movement, improving efficiency of medical staff and for infection control (fewer wire surfaces to be cleaned). They are undoubtedly a useful tool for clinicians, and in many cases the information is not latency critical and can, we understand, be retransmitted if interference occurs - although unmitigated constant interference would be problematic.

7.67 In addition to hospital usage, there is a growing market for home monitoring where 2.4 GHz links may be used to transmit non-critical patient information to a central hub for communication back to a hospital via the internet. However, our analysis has focussed mainly on hospitals and emergency scenarios as this is – in our judgement – the most important use to evaluate.

Hospital use

7.68 In order to investigate hospital use we have been in touch with the Department of Health, Public Health England[68], Medicines and Healthcare products Regulatory Agency (MHRA)[69], a large London acute care hospital trust and several device manufactures. A review of the large acute care hospital's equipment revealed very few 2.4 GHz licence exempt healthcare devices were actually in use (the trust acknowledged that this was an area where current use was "minimal") but they expected use to grow in the future.

7.69 From research and conversations with manufacturers we understand the majority of applications make use of Wi-Fi, Bluetooth and ZigBee technologies - but there are also proprietary technologies in use in this band. However, we believe that even proprietary technologies are likely to be based on the same radio chipsets as the main standards and typically incorporate spread spectrum or frequency hopping technologies for interference avoidance (similar to Bluetooth and ZigBee standards).

7.70 Like Wi-Fi, Bluetooth and ZigBee, medical monitoring devices using these technologies may be vulnerable to interference in certain circumstances from base stations and to a lesser degree from mobile devices e.g. mobile handsets and tablets.

7.71 To note, St Jude Medical manufacture a product line for use by interventional cardiologists in cardiac wards to monitor pressure and temperature inside a patient's heart to assist with diagnosis. St Jude Medical say this measurement data is not safety-of-life critical and they are not significantly concerned about the possibility of

[68] "Public Health England's mission is to protect and improve the nation's health and to address inequalities through working with national and local government, the NHS, industry and the voluntary and community sector. PHE is an operationally autonomous executive agency of the Department of Health."

[69] Government agency with responsibility for regulating all medicines and medical devices by ensuring they work and are acceptably safe.

4G/LTE interference to their product, as LTE mobile equipment is unlikely to cause significantly more interference than Wi-Fi, with which these products currently coexist. This is the only application of this type that was identified in our audit of the use of this band.

Analysis

7.72 We deduce from the technical analysis undertaken for Wi-Fi, Bluetooth and ZigBee, that interference to licence exempt healthcare devices is not likely to be significant. We also note it is already standard practice for many hospitals to require mobile devices to be switched off in areas where licence exempt medical equipment is being used.

7.73 However, there remains a small risk of interference from LTE base stations. There are around 850 hospitals in the UK and our analysis suggests around 2.5% could be close to 2.3 GHz base stations (based on existing 3G deployments). We note that some transmitters are located within hospital sites. Our analysis suggests that only small areas of any hospital site may be impacted by LTE (i.e. part of a ward in around 20 hospitals) This is similar to the impact to enterprise Wi-Fi networks set out in section 6, where we note that impacts are likely to be much reduced deeper within buildings.

7.74 We understand that many hospital devices are fitted with alarms that sound if monitoring stops for any reason (interference, for example). This means clinicians would be alerted to any interference issues and could re-set the device. However, on-going interference could repeatedly trigger the alarm and would be more difficult to resolve.

Assessment

7.75 Our analysis suggests a very low likelihood of interference problems occurring in practice. We therefore consider that regulatory-led intervention in the market would be disproportionate.

7.76 Nevertheless, as a precaution against interference, we would recommend that hospitals work with the relevant licensee to satisfy themselves that any proposed 2.3 GHz base station deployments on hospital premises do not cause unacceptable interference to critical hospital systems operating in the 2.4 GHz licence exempt band. This could take the form of an RF test under controlled conditions prior to deployment for example. We also note that future licensees should be conscious of the potential risks associated with placing base stations too close to hospital perimeters.

Emergency services

7.77 We have spoken to the emergency services about their use of licence exempt devices in the 2.4 GHz band. We understand there are no critical fire service systems using this band. We have spoken with police representatives and they are content with the plans we have set out.

7.78 There is some use of 2.4 GHz licence exempt equipment by some ambulance services, although we understand from an audit of all ambulance trusts in England (conducted by the Ambulance Service) that use is not widespread. We also understand from the information obtained in these audits that most monitoring equipment has some ability to deal with sub-second delays in transmission.

7.79 Ambulance service use varies between trusts, but some use 2.4 GHz licence exempt equipment with a monitoring function. This use is within (or near to) the ambulance. In a typical usage scenario[70] a patient would be connected to a monitoring device which would transmit data to a receiver in the ambulance vehicle. Data would then be transmitted back to the hospital from the ambulance via another service which would be a much lower data rate service (e.g. GPRS).

Analysis

7.80 When considering this potential impact to ambulance monitoring it is important to note that, in most usage scenarios, the data rate being transmitted back to the hospital is limited by the speed of the backhaul link which may often be a 2G data service (GPRS).

7.81 The speed of the backhaul link means the data rate being transmitted from the monitoring device to the ambulance will also be low, and therefore should be able to get through even if there is a small amount of degradation to the service caused by interference. This is demonstrated in our analysis on the risk of interference to Wi-Fi in section 6 - where the impact to low throughput applications is found to be less severe than that for higher throughput applications. We believe this analysis is relevant to ambulance services as many use Wi-Fi or similar technologies. The main issue of concern would therefore be the likelihood of complete loss of these services.

7.82 Calculations based on the median performing Wi-Fi router in our tests indicate that there is a risk of loss of service for licence exempt devices at 0.05% of all call-out locations -noting that not all ambulance services use this equipment and not all call outs require use of such equipment.[71]

7.83 The risk will be greatest in locations in close proximity to a 2.3 GHz base station. At each location where there is a risk of total loss of service, the likelihood of this occurring in practice will be heavily dependent on the specific location of the ambulance with respect of the interfering base station.

7.84 For interference from mobile devices to occur, interfering devices would have to be close to the licence exempt device (i.e. the device would need to be <1 metre of the licence exempt device). In this scenario, paramedics and patients could be asked to avoid using mobile devices (as happens now in many hospitals and medical practices). We note there are already signs in many ambulances advising patients to avoid using mobile phones, though this is not a requirement.

Assessment

7.85 We believe the risk of interference set out above is limited and is in line with expected reliability of licence exempt equipment. We also note that licence exempt equipment is already operating in a congested band sharing with other services, for example, other Wi-Fi users and Bluetooth.

[70] One such example scenario is a patient's heart rate being transmitted back to hospital so paramedics can receive advice on which drugs to administer

[71] This calculation uses the same methodology used in our Wi-Fi analysis. We have assumed residential population as a proxy for ambulance call-out locations. The calculation is based on an outdoor scenario for the median Wi-Fi router. A 1Mbps blocking level is used as this is believed to be applicable to the data-rates used in the ambulance applications. Other assumptions are the same as the central case in the Wi-Fi analysis.

7.86 We understand from conversations with the Ambulance Service that there was awareness that interference could be an issue when systems using licence exempt technologies were being developed. The service is aware of the need to look at alternatives (e.g. wired versions of devices or for Wi-Fi devices, options to use 5 GHz) for devices.

Hearing Aids and Assistive Listening Devices (ALDs)

7.87 We have spoken to manufactures of hearing aids and ALDs (including those recommended to us by Public Health England and Action on Hearing Loss[72]) because we understand several ALDs on the market use the 2.4 GHz band. Uses for such devices include:

- Streaming audio to hearing aids from a main speaker (e.g. a teacher in a class room has a device which transmits and is picked up by the devices worn by a pupils);
- In home media streaming to a body worn device or directly to the hearing aid;
- Streaming between in-ear devices in the left and right ears.

7.88 In the particular circumstance where hearing aids and ALDs are being used (i.e. in classroom and in home scenarios) we believe it is reasonable for users be made aware of the slight risk of interference from LTE mobile devices (e.g. phones and laptops). Most issues can be resolved by careful positioning of these LTE devices or by switching off mobile phones in the classroom.

7.89 One of the manufacturers we spoke to said they would be happy to advise schools using their products about issues arising from proximity to base stations.

7.90 We note that it is important there is no transmission delay, in order to maintain user experience, and that there are uncertainties about the form interference might take and the impact on a hearing impaired user (i.e. loss of service or noise). Since this may impact a potentially vulnerable group of users, during the consultation period we are planning a test day where manufactures can self-assess their devices in the presence of a simulated base station signal.

7.91 Further details about this opportunity for manufacturers to test their devices will be communicated to manufacturers as well as through device suppliers including Action on Hearing Loss. However, interested parties are encouraged to email pssr@ofcom.org.uk as soon as possible to express their interest directly to us.

Consultation questions

Question 7.1: Do you agree that we do not need to perform technical analysis on the applications in the middle of the band as set out in paragraph 7.7?

Question 7.2: Do you agree with our technical analysis in relation to Bluetooth devices operating in the 2.4 GHz band, and that no additional restrictions are required in order to protect these applications?

[72]Action on Hearing Loss was formerly known as Royal National Institute for Deaf People (RNID)

Question 7.3: Do you agree with our technical analysis in relation to ZigBee devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.4: Do you agree with our technical analysis in relation to video sender devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.5: Do you agree with our technical analysis in relation to radio microphones devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.6: Do you agree with our technical analysis in relation to short range devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.7: Do you agree with our technical analysis in relation to medical devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.8: Do you agree with our technical analysis in relation to emergency services use in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.9: Do you agree with our technical analysis in relation to hearing aids and assisted listening devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Section 8

Programme making and special events (PMSE)

Introduction

8.1 This section of the consultation considers the impact of the 2.3 and 3.4 GHz award on PMSE (wireless cameras and video links).

8.2 In December 2008, the MOD informed PMSE users they should prepare to vacate the 3.4 GHz band in anticipation of an award of the band. This followed an MOD statement on its programme of spectrum reform[73]. The MOD allowed continued PMSE access to the band under a three month rolling notice period up until it was released for award.

8.3 In our statement on future spectrum access for PMSE[74], published in August 2010 we provided access to 26 x 10 MHz channels at 7 GHz (7110-7250 MHz and 7300-7425 MHz) to provide the security of tenure which is vital to promote the necessary investment in new equipment. We stated that the spectrum would be available to PMSE with a rolling 5 year notice period not to be triggered before 2016.

8.4 In light of these developments, this section identifies the extent to which PMSE access to usable spectrum will be reduced due to the release of the 3.4 GHz band and the consequential impact of MoD's remediation from the release bands. It identifies and assesses the effectiveness of available mitigations. It then goes on to consider whether it is appropriate to allow PMSE to have some continued access to spectrum within the award bands until the time new services are deployed in a particular area. Finally, it sets out our proposals in respect of PMSE, and invites stakeholders to respond to a number of specific questions.

8.5 The principal use of PMSE spectrum in the band 2010 to 3580 MHz is for portable and mobile wireless cameras and video links (including airborne links) at sporting and other events and in news reporting for the benefit of citizens and consumers. The current transmission technology deployed for these applications is typically digital, using coding and modulation based on the DVB-T standard with a nominal occupied bandwidth of 8 MHz. There are also proprietary coding and modulation systems that have been developed with an occupied bandwidth which can extend to 9.6 MHz.

8.6 To accommodate the typical channel bandwidth requirements, PMSE channels are generally planned on the basis of 10MHz spacing between channels (although non-standard spacing may occasionally be assigned according to users' requirements at major events). Our analysis set out below considers spectrum availability in terms of the numbers of 10 MHz channels.

[73] www.mod.uk/NR/rdonlyres/40622FC9-DC7B-40FC-B48A-90408F6F7676/0/spectrumstatement_051208.pdf

[74] http://stakeholders.ofcom.org.uk/consultations/bandmanager09/statement310810/

Summary and proposals

8.7 The release of the 2.3 and 3.4 GHz bands will reduce the number of usable channels available to PMSE in the 2-4 GHz range from 33 to 19 × 10 MHz channels. This would consist of 10 channels available to any PMSE user on a bookable basis for individual events and nine channels which are currently exclusively allocated to news broadcasters (eight UK wide and one extra channel in London). Our analysis has shown that these 10 channels are sufficient to meet the requirements of 98% of events. In addition to the spectrum available in the 2-4 GHz range there are up to 26 × 10 MHz available in the 7 GHz bands.

8.8 For those events requiring more than 10 bookable channels, actions are needed to ensure sufficient spectrum is available. We have identified mitigating actions to enable these events to meet their production requirements - but we note that the precise implementation of these actions will vary depending on the individual spectrum requirements. The mitigations are:

- Increased use of spectrum in other bands allocated to PMSE i.e. the 7 GHz band where we have made more channels available;
- The re-use of news channels as appropriate. This is particularly significant in supplementing the ten bookable channels for scenarios where the use of 7 GHz spectrum may be problematic.

8.9 Our analysis of the 10 annual events with the greatest demand for spectrum (which account for less than 1% of all events) shows that the majority can be accommodated using the actions outlined above i.e. the demand can be satisfied from the remaining spectrum (after release) allocated to PMSE within the 2 GHz and 7 GHz bands.

8.10 There are two sporting events requiring an additional mitigation. In order to satisfy the demand for the F1 Grand Prix and the London Marathon, our analysis shows that access to loaned spectrum will be required. For the Grand Prix this is due to the very high spectrum demand of the event. For the marathon it is due to the high requirement for mobile and airborne cameras, and video links, which we have assumed cannot easily migrate to 7 GHz based on current technology.

8.11 In our discussion with the stakeholders for these two events, they have indicated that actions could be taken to maintain the production levels in a more spectrum constrained environment. This would be done either by reducing the overall demand at the event by making operational changes (for F1) or by making more use of the 7 GHz band than currently (for London Marathon).

8.12 We have not seen any evidence to suggest that there will be a significant increase in demand for spectrum across major events beyond current levels. However, in order to provide greater assurance for our strategy in this respect we are conducting further work into technology developments and sector requirements. We intend to conclude on this work before taking final decisions on the award.

8.13 Stakeholders have indicated that it will take time to migrate to the 7 GHz bands and therefore other actions are required to meet the spectrum requirements of peak demand events in the interim period. PMSE has regularly borrowed spectrum from neighbouring bands, such as MoD and Mobile Satellite Service bands, in order to meet peak spectrum demand. We do not see these loan opportunities significantly

changing in the short to medium term, but we cannot give certainty over access to loan spectrum in the long term.

8.14 Changes in allocation to or use of these bands by services that are incompatible with PMSE may remove these loan opportunities. We therefore strongly encourage the PMSE community to start to migrating to 7 GHz equipment as soon as is practically possible.

8.15 In order to support the PMSE sector during the transition to 7 GHz, we are discussing with other public sector users the possibility of pre-agreed loans for specific events. This will remove some of the uncertainty around ad-hoc requests for additional non-PMSE spectrum.

8.16 We recognise the importance of a degree of stability and certainty over access to the remaining spectrum available for wireless cameras for industry planning and investment. Any significant changes to PMSE access to the 7 GHz bands (7110-7250 MHz and 7300-7425 MHz) and the 2290-2300MHz band is already subject to a rolling five year notice period not to be triggered before 2016. Additionally, we are proposing to grant security of tenure with a rolling 5 year notice period to the 2025–2110 MHz band.

8.17 We are consulting on the basis that the proposed MoD remediation work around the 2.3 GHz band does not significantly affect PMSE access in the 2200-2290 MHz band. However, at this stage, the MoD is still working through its remediation and is not in a position to confirm security of tenure. Nevertheless, both Ofcom and the MoD are clear that by the time we make our final decision on the clearance of PMSE from the 3.4 GHz band, we will need to have come to a formal position on tenure in the 2200–2290 MHz band in order to support the strategy set out in this section.

8.18 Our overall view is that the release of the 2.3 and 3.4 GHz bands will have no impact on the majority of PMSE use cases (i.e. for the 98% of events for which 10 channels in the 2 GHz bands are sufficient). Further, following our discussions with stakeholders, we believe that the spectrum requirements for the small subset of remaining peak demand events can be accommodated through the implementation of one or more of the mitigations outlined above.

8.19 This view supports our overall strategic view for PMSE of greater use being made of spectrum in the 7 GHz bands to support a remaining core of spectrum at 2 GHz. Underpinning this strategy are the following assertions:

- that access to these bands will not be subject to further change within a reasonable timeframe; and
- that demand will not increase beyond current expectations and the available spectrum supply.

8.20 In order to further support PMSE users' transition to the new arrangement, and to promote efficient use of spectrum, we propose to allow PMSE to have continued access to the 3.4 GHz spectrum in areas where new services have not been rolled out.

8.21 Additionally, we are considering extending this ongoing access arrangement to the 2.3 GHz release band. However, our initial view is that there is little incremental benefit and less opportunity to access the 2.3 GHz spectrum, as services are likely to roll out more quickly in this band.

Outline of analysis

8.22 In the remainder of this section, we set out a fuller analysis of the impact of the 2.3 and 3.4 GHz band award on PMSE outlined above.

8.23 We have focussed on the 10 annual events with the greatest demand for spectrum. Additionally, we have assessed the impact on an example of a national occasion (such occasions include royal weddings, state funerals etc). This analysis has enabled us to identify potential pinch points.

8.24 We then considered what actions are required to mitigate the reduced volume of spectrum currently used by PMSE. In summary, we have:

- Defined future spectrum supply in the light of both clearance of the 2.3 and 3.4 GHz award itself and of the consequent re-planning of MoD spectrum use of adjacent channels;
- Determined demand from the PMSE sector using licensing records for 2012[75] and directly with stakeholders responsible for the planning of the identified events;
- Validated the licensed demand against actual deployment;
- Compared future spectrum supply against the 2012 level of demand[76];
- Proposed mitigations that have the potential to be effective within the timescale of the spectrum release programme and are consistent with a longer term roadmap for PMSE access to spectrum suitable for wireless cameras;
- Validated our mitigation proposals through stakeholder engagement;
- Evaluated the effectiveness of individual mitigations, and of combined mitigations, taking account of stakeholder input;
- Identified residual risks that are specific to each event.

8.25 In order to validate our analysis we sought input from:

- Formula 1 Management: the UK based host broadcaster for F1 GP;
- Dorna Sports: the Spanish based host broadcaster for MotoGP;
- Broadcast RF: the UK hire company and facilities provider supporting many of the annual events and key player for the national occasion;
- SIS Live: the leading UK outside broadcast facilities provider contributing to The Open Championship; F1GP; London Marathon; Great North Run; Grand National; Boat Race; FA Cup Final; BTCC;

[75] We excluded the requirements of the London Olympic and Paralympic Games in this analysis

[76] We have no evidence at present that spectrum requirements will change significantly over the coming years. We have commissioned a study looking at technological development in the PMSE sector to determine how it may lead to increasing spectrum demand, such as higher definition video cameras, and how it might mitigate this increasing requirement, for example more efficient coding and modulation schemes. This study is expected to conclude in the Spring of 2014.

- Presteigne Charter: the UK hire company supporting many of the outside broadcast facilities companies at the selected annual events;
- Arqiva PMSE (formally JFMG); the PMSE spectrum manager;
- News broadcasters including BBC News, BBC Nations and Regions, ITV Regions, BSkyB, and news producer ITN.

8.26 Our analysis is set out below. A more detailed account, including assessment of the impact for individual major events, is set out in annex 10.

8.27 In our analysis, we considered that the channels adjacent to the 2.3 GHz band (and other mobile bands) were unlikely to be suitable for continued PMSE use. However, our licensing database shows that these channels have been used in the past. Furthermore, our coexistence study provided in annex 10 confirms that there are some circumstances where these channels could be fully used given sufficient spatial and/or frequency separation. Increased use of these 'shoulder' channels, where possible, would also help meet spectrum demand, especially if used for non-broadcast applications such as return video.

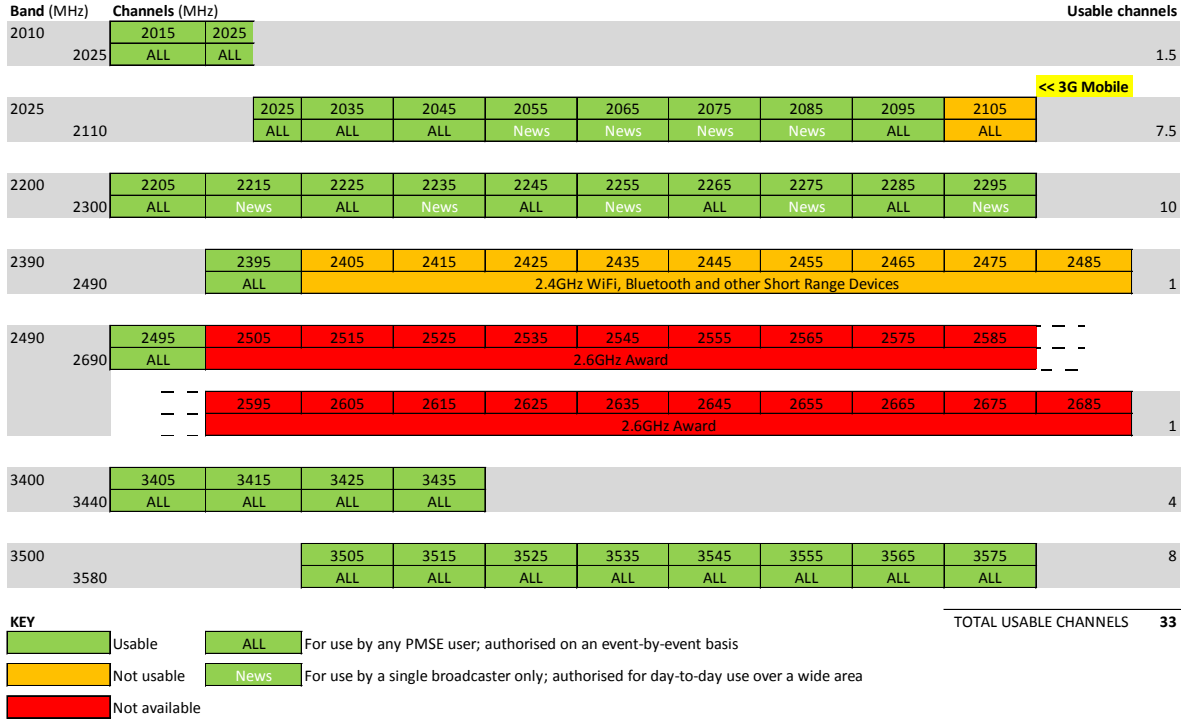
Current spectrum availability

8.28 Based on the standard 10 MHz spacing, PMSE currently has access to 43 × 10 MHz channels within the 2-4 GHz range across five sub-bands. However, 10 channels are considered unusable due to the risk of interference from and to Wi-Fi and Bluetooth between 2400 and 2490 MHz, or due to adjacent channel interference e.g. from 3G cellular mobile base stations into the channel at 2105 MHz.

8.29 As a result of our combined 800 MHz and 2.6 GHz spectrum award, access to the band 2500-2690 MHz for PMSE ceased in February 2013.

8.30 These limitations on spectrum availability mean that the current pool of usable channels is 33. The current inventory of channels available to PMSE within the band 2 to 4 GHz is shown in Figure 8.1.

Figure 8.1: Current PMSE spectrum availability



Future spectrum availability

8.31 Our analysis shows that 19 × 10 MHz channels would be available for PMSE after clearance. This is as a result of the loss of 11 channels in the 3.4 GHz award band[77], and the assumption that channels at 2395 MHz and 3405 MHz would have limited utility in future due to interference from new mobile services in the adjacent release bands at 2.3 and 3.4 GHz respectively. Additionally, it is also assumed that the channel at 2495 MHz will become less usable as 4G mobile services are deployed more widely in the 2.6 GHz band.

8.32 We have carried out measurements to evaluate the effect of adjacent channel interference from LTE into wireless cameras. This assessment, attached at annex 10, shows that these channels may be usable for some PMSE applications operating with a reduced bandwidth and offset from the LTE channel edge (such as return video). However, in our supply/demand analysis we have disregarded these channels.

8.33 As a result of the MoD relocating some services from the award bands into 2200-2290 MHz a small geographical restriction has been implemented across the band in the islands making up the Outer Hebrides[78], Isle of Skye and the Small Isles[79]. We do not think these additional restrictions will have a material impact on spectrum availability for PMSE.

8.34 We had previously identified the 2010-2025 MHz band as a candidate band for award and made the band available to PMSE on a rolling three months notice

[77] We examine the possibility of allowing some continued access to 3.4 GHz frequencies later in this section.
[78] This includes: Lewis and Harris; North and South Uist, Benbecula, Barra and 10 other inhabited islands plus about 50 uninhabited islands
[79] Part of the Inner Hebrides

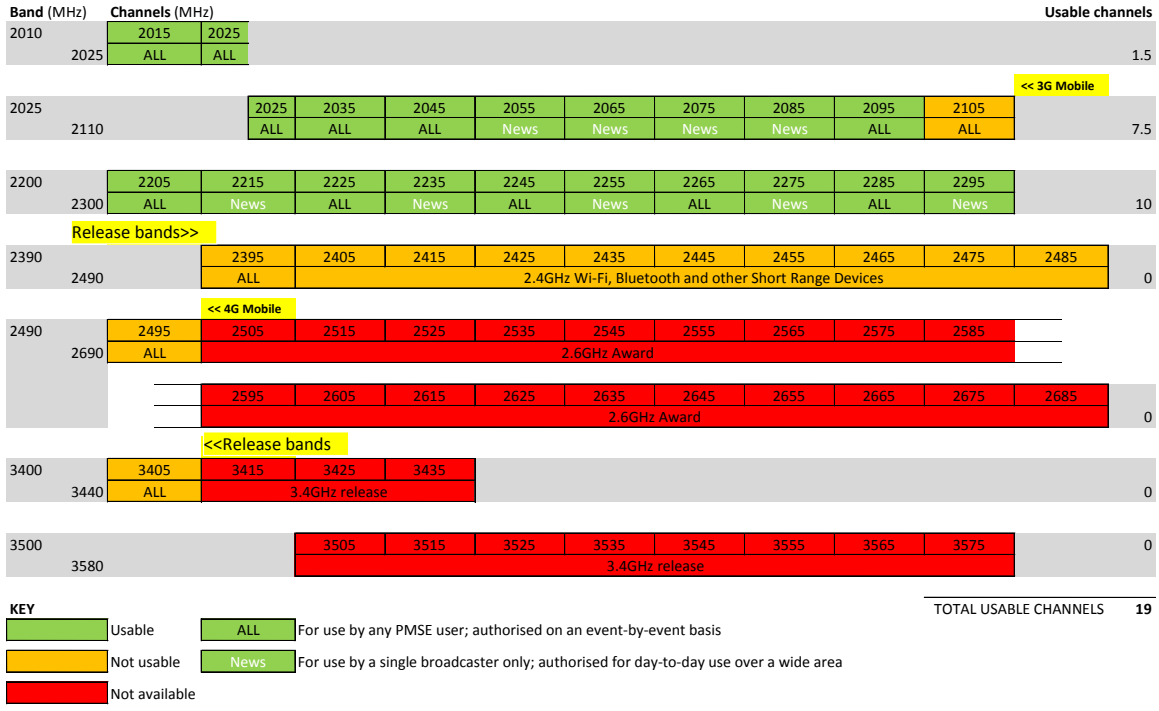
pending the award process[80]. However, since we were no longer planning to award the band, we have removed this notice period. In our consultation. Our recent consultation on Mobile Data Strategy[81] shows that the band is considered low priority for mobile services.

8.35 The European Commission has asked CEPT to assess the utility of the band 2010-2025 MHz (along with 1900-1920 MHz this makes up the unpaired 2 GHz bands) for a variety of applications including PMSE. The Commission highlights that shared use between the different applications should be studied in order to ensure efficient spectrum use. By engaging in this work it is our intention to maintain access for PMSE either through exclusive or shared access arrangements.

8.36 The future configuration of channels available to PMSE is shown in Figure 8.2. This reflects our view that any requirement for the MoD to relocate services from the award bands into the 2200-2290 MHz band will have a minimal impact on the availability of spectrum within the band for PMSE i.e. any changes to spectrum access would be limited in location and may still be accessible via coordination with the MoD.

8.37 The 2025-2070 MHz band had been identified for possible (time limited) release by the MoD, but we can confirm that this is no longer being considered and MoD is content to allow a 5 year rolling notice period for PMSE.

Fig 8.2: Future PMSE spectrum availability



[80] Release of the 2010-2025 MHz band –Statement
http://stakeholders.ofcom.org.uk/consultations/release_2010_2025/statement/
[81] http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/

Spectrum demand

Annual events

8.38 Assuming all 19 remaining PMSE channels are fully available our analysis suggests that all but one of the top 10 events experiences a shortfall in spectrum supply. This shortfall would need to be mitigated by spectrum outside this core of 19 channels (see Figure 7.3 below).

Figure 8.3: Demand v Supply for annual events

Event	Location	Demand (x 10MHz)	Shortfall (x 10MHz)
F1 GP	Silverstone	48	29
Moto GP	Silverstone	27	8
London Marathon	London	27	8
Open Championship	Various	26	7
Boat Race	London	26	7
Grand National	Aintree	25	6
Great North Run	South Shields	22	3
FA Cup Final	Wembley	22	3
Cheltenham Festival	Cheltenham	20	1
British Touring Cars	Brands Hatch+	16	-3

8.39 The greatest shortfall would be at the F1 Grand Prix – although our analysis indicates that the spectrum demand for the event (derived from licensing records) appears to exceed the actual operational requirement - with validated demand being 42 channels rather than 48[82]. For the other events assessed, the validated demand accurately reflected the licensing data.

8.40 It is therefore clear that effective mitigation will be required to support the current level of demand at all these 'top 10' events, with the exception of the British Touring Cars Championship.

National occasion

8.41 Our analysis of a national state occasion – in this case the funeral procession of Baroness Thatcher - indicates there would be a shortfall of at least five channels post award (see Figure 8.4 below). Effective mitigation of a reduced spectrum supply will also be required to support future events of this nature.

[82]Based on F1 Management's own records of accredited wireless cameras and other accredited video links and Ofcom's spectrum monitoring of the event.

Figure 8.4: Demand v Supply for a national occasion

Event	Location	Demand (x 10MHz)	Shortfall (x 10MHz)
Funeral of Baroness Margaret Thatcher	London	24	5

Potential mitigations

8.42 We have identified two possible mitigations (re-use of news channels and greater use of 7 GHz spectrum) which could be deployed separately or combined to address any shortfall of spectrum for PMSE at major events. These are summarised below.

8.43 We also list below the option of borrowing spectrum - but this may only be available in the medium term as an interim solution to enable PMSE stakeholders to transition to 7 GHz. In addition, Ofcom notes that the PMSE industry is investing in technology research and development which aims to make more efficient use of the spectrum available for wireless cameras and thereby give further assurance that demand can continue to be met in the longer term.

8.44 For some of the top events, we have found that a single mitigation approach is not sufficient to meet the spectrum requirement. In these cases a combination of our mitigation approaches is required.

8.45 For all events except the British Grand Prix and the London Marathon, re-use of news channels and migration to 7 GHz frequencies satisfies the spectrum requirements. For these two events, additional loan spectrum will be required. Figure 7.6 summarises the effectiveness of the combined mitigations against a spectrum availability of 19 channels. In all events we believe that a combination of mitigations is sufficient in the medium term. However, in recognising that access to loan spectrum cannot be guaranteed in the long term, we note that for F1 and the London marathon, loss of access to all of the seven loan channels would result in a shortfall of 4 channels and 3 channels respectively.

Figure 8.6: Combined mitigation for annual events

Event	Location	Demand (x 10MHz)	Mitigated[1] demand (x10MHz)	Surplus (x 10MHz)
F1 Grand Prix	Silverstone	48	16	3
MotoGP	Silverstone	27	10	9
London Marathon	London	27	15	4
Open Championship	Various	26	12	7

Note 1: Mitigated demand – This is the residual demand, once all mitigations have been applied, that has to be met from the 19 × 10 MHz channels allocated to PMSE

8.46 Formula 1 Management has told us they are confident of being able to maintain the production levels of the Grand Prix in a more spectrum constrained environment, and indicated it would be possible to implement operational changes in order to address potential reductions in spectrum availability. They suggested, for example, that some pit lane cameras are not used during the race and not all on-board cameras need to

be used before or after the race. It may therefore be possible to share channels between pit lane and on-board cameras in order to reduce overall demand. Additionally it may be possible to move large screen video feeds to alternative bands or provide the feed over cable.

8.47 In our discussion with SiS Live regarding the London Marathon, it was suggested there could be potential for more use of the 7 GHz band than is currently factored in to our analysis, but technical limitations may prove challenging.

8.48 The different mitigations are considered separately below.

1. More efficient use of news channels – long term solution

8.49 With a reduced overall pool of spectrum for PMSE, the current allocations to news broadcasters will represent an even more significant share. Some of the eight channels allocated to broadcasters for day-to-day news reporting (nine channels in London) could be used to supplement the pool of spectrum available for event coverage – since news broadcasters may not necessarily be operating at, or near, the event. We note, however, that some events can attract strong regional news interest and/or that news broadcasters may be active in the local area unconnected with the event itself. This is particularly likely at events in London.

8.50 There is already some evidence of cooperative sharing of news channels at events. However, in their contributions to our analysis, news broadcasters made it clear that attendance at past events was not a reliable indicator of future interest. Further, news broadcasters understandably do not wish to compromise their ability to respond to breaking news by releasing spectrum for use at events.

8.51 Our analysis suggests full utilisation of news channels would satisfy the spectrum demand of all those events requiring more than 10 channels except for the nine largest events i.e. in most cases, demand could be wholly met from the 19 channels available to PMSE in the 2-4 GHz range. However, the current ad-hoc arrangements for accessing news channels may not provide an effective, reliable mitigation for the spectrum shortfall at some of the biggest high profile events.

8.52 We believe that it is essential to make the best possible use of the available PMSE spectrum to satisfy requirements for both news applications and those of major events. We are considering a range of options for facilitating wider access to news allocations and will be engaging with stakeholders on this in the near future.

2. Use of other PMSE bands – long term solution

8.53 Alternative bands currently available to PMSE are suitable to support some types of wireless camera operations. We have discounted the PMSE allocations at 5 GHz as, like 2.4 GHz, these bands are used by licence exempt applications and are not considered suitable for the quality of service required for live broadcast cameras.

7 GHz band

8.54 The best available alternative candidate bands are at 7 GHz (7110-7250 MHz and 7300-7425 MHz)[83].After a significant reduction in the need for annual PMSE link

[83] We note that 7300 – 7450 MHz is also allocated to MOD for Fixed-Satellite Services (space to earth) and coordination/restrictions around MOD sites (similar to those in the 3.4 GHz band) may be required as a result of increased PMSE usage in this band

licences in these bands, there are up to 26 channels available for wireless camera use across much of the UK. As outlined above, access to these bands is on a five year notice basis not to be triggered before 2016 and so provides the security of tenure which is vital to promote the necessary investment in new equipment. It is equivalent to that of other spectrum licensees.

8.55 In discussion with stakeholders, we have determined that some portable camera operations and links from static camera positions could migrate to the 7 GHz band. However, given current technology, our assessment considers that mobile applications such as onboard cameras and airborne use are not suitable for 7 GHz.

8.56 Our analysis shows that use of the 7 GHz bands is a successful single mitigation option for all events except the British Grand Prix and London Marathon.

8.57 Stakeholders have indicated that UK programme makers and hirers currently hold very little 7 GHz wireless camera equipment, although cameras capable of operating at these frequencies are available from manufacturers. They said it would take time to transition to 7 GHz and it would be necessary to align such a move with normal equipment replacement cycles.

8.58 Our strategic view for PMSE is that greater use will need to be made of the 7 GHz bands, but it is clear that PMSE cannot move displaced demand to 7 GHz immediately. Other means of mitigation, such as use of loan spectrum, will be needed in the interim. However, we are clear that the PMSE community should start to migrate to the 7GHz band, as access to loan spectrum cannot be guaranteed on a long-term basis.

3. Borrow additional spectrum for PMSE – interim solution

8.59 We have considered the potential for temporary loans of non-PMSE spectrum to make up shortfalls in supply for wireless cameras. We recognise that loaned spectrum must be in bands compatible with currently available PMSE equipment. Further, we recognise that any change in allocation or use of these bands, for example to new mobile services, may remove the opportunity for being loaned to PMSE. However, we believe that the bands identified below will provide a valuable short to medium term loan opportunity, before any such future use is realised in practice .This will allow time for users to migrate to the 7 GHz bands

8.60 Within the band 1950-2700 MHz, we identified a total of 10 ×10 MHz channels that could be available for loan to PMSE. There are six potential loan channels in the MSS bands at 1980-2010 MHz and 2170-2200 MHz. However the channel at 2175 MHz is not considered usable in this analysis as it is adjacent to the 3G downlink band - although we note that it has been used successfully in the past. A further four channels are available in the band 2300-2340 MHz which is currently used by the MoD and other Government agencies. We have not considered the channel immediately adjacent to the 2.3 GHz release band as interference from new mobile services may make the channel unusable by PMSE. However, as our coexistence study between PMSE and adjacent TDD-LTE in annex 10 shows, there is some scope to use shoulder channels given sufficient frequency and spatial separation.

8.61 The five ‘usable’ MSS channels have been successfully borrowed for use by PMSE to supplement spectrum availability for a number of peak demand events.

8.62 The four channels at 2300-2340 MHz have been loaned to PMSE in the past. However, at some events frequencies may be used for non-PMSE purposes so

would not be available to borrow. In addition, military equipment has been migrated from 2350-2390 MHz to this band, so access may be more limited than previously. For our analysis we have assumed that only two of the four channels might typically be available for PMSE.

8.63 Our analysis, therefore, assumes seven of the 10 identified channels could potentially be available for temporary loan to PMSE. With 19 channels already available to PMSE and the previously discussed mitigations, the additional seven channels would enable the current demand to be met at all of the events[84].

8.64 While access to loan spectrum is an efficient and effective way to meet the spectrum requirements of peak demand events, any change in use of these bands may preclude use by PMSE. We therefore consider use of loan spectrum as a temporary arrangement while users carry out the necessary changes in order to more fully exploit the 7 GHz bands.

8.65 Access to these loan channels is currently via a coordination process between Ofcom and the primary user, including the MoD, on a case-by-case basis. However, in order to achieve greater certainty over access (while the loan opportunity continues to exist), we are exploring alternative ways of securing loan spectrum at specific events under a pre-agreed arrangement with the other users. In the meantime the current coordination process will remain in place.

PMSE access to spectrum in the award bands

8.66 We have considered whether it may be possible for PMSE to have on-going access to spectrum within the 2.3 and 3.4 GHz award bands on a geographically interleaved basis with the new services. This would supplement the actions identified previously to meet the spectrum requirements of peak demand events including helping to ease the transition to more use of 7GHz spectrum as well as promoting efficient shared use of spectrum. We discuss below whether this should be for both award bands, or just the 3.4 GHz award band.

8.67 Any on-going access for PMSE in a particular location would be subject to change as new services rolled out i.e. access to spectrum for PMSE would cease once new services had rolled out in a particular area. On this basis there would be no security of tenure for PMSE after the award and access to the band could be removed at short notice.

8.68 If the 2.3 and 3.4 GHz bands are acquired by mobile network operators for high power applications such as LTE, the roll-out of services may vary considerably between 2015 and 2020 based on responses to our Call for Inputs. Even when deployments commence, it is likely that initial roll-out will be to areas of highest demand for the offered mobile services. This could leave spectrum unused for some time in many geographical areas, including locations where some annual peak spectrum demand events are staged.

8.69 PMSE is a valuable use of spectrum and could deploy in frequencies that might not otherwise be used to their full potential, at least in the short to medium term. Such an outcome could represent a more efficient use of the spectrum, in line with Ofcom's statutory duties.

[84] If loan spectrum was a mitigation on its own then with the 19 channels already available to PMSE it would satisfy the demand of all but 3 of the top 10 events (2 of those having a shortfall of only 1 channel)

8.70 We have engaged with representatives of the PMSE community to discuss the value of allowing continued access to the 3.4 GHz spectrum. They confirmed that there would be some merit in having continued access to the band in areas where new services had not rolled out. They said there was a good deal of legacy equipment which operates in the 3.4 GHz band and continued access would allow this to be used until it reaches its natural replacement date as part of a transition to other bands.

Practical considerations

8.71 If we were to confirm on-going PMSE access to one or both of the award bands we would need to ensure that new licensees are adequately protected from the risk of harmful interference from PMSE. Additionally PMSE stakeholders would need certainty that the spectrum is not in use at a particular location in order to guarantee the high quality of service that PMSE typically requires.

8.72 Protecting new users and providing certainty about where PMSE can operate would only be possible if there is good information about where new licensees intend to deploy and when. With this information we would be able to ensure that PMSE is only authorised to operate in areas where interference will not be caused to new licensees and that PMSE users will have confidence about the spectrum environment.

8.73 A workable solution would require some level of cooperation from new licensees to provide information on network roll out. We believe it is important that any process should not place an onerous burden on the new licensee nor be cumbersome to implement. We are sensitive to the fact that new acquirers of the spectrum may not wish to divulge full details of their current and future roll-out plans for commercial reasons.

8.74 Our technical analysis, based on the assumption that the bands are awarded to new LTE mobile services, shows that a co-channel exclusion zone of 20 km would be sufficient to protect new licensees from interference from PMSE. We note that there may be a small risk of interference to LTE if PMSE was operating up to 1km in rural areas (typically only a few hundred metres in more built up areas) from an LTE base station. However, we note that PMSE users do not usually use ‘shoulder’ channels to mobile services and therefore we are not proposing to formalise any protection for LTE in the adjacent channel.

8.75 Once information about network roll-out is received, the exclusion zones would be applied within our licensing database (coordination and exclusion zones are already implemented within the PMSE licensing database in a number of bands to protect other services from the risk of interference from PMSE). Our analysis of the derived exclusion zones is presented in Annex 10.

8.76 Noting that we do not wish to place an onerous burden on new licensees, and that we acknowledge the fact new licensees may be sensitive to providing detailed network information, we have considered the following options for providing location information:

- Postcode locations – this would likely be at district or sector level e.g. DA11 (district) or DA11 1 (sector);
- NGR coordinate and radius;

- Coverage maps, similar to those provided as part of the infrastructure report analysis showing only where services are deployed or not;

- Polygon in a GIS (geographical information system) readable format.

8.77 Exclusion zones can be implemented quickly. However, to provide some degree of notice it is suggested that information should be provided three months before network deployment.

8.78 Femto cells could be deployed by new licensees. So consideration needs to be given as to how femto cells could be protected from interference from PMSE if we allowed PMSE ongoing access to the award bands. Our understanding of current femto cell technology is that network operators require the location of the femto cell in order to manage the network. The location can be provided to the network either by the user inputting the location or automatically from information received from the macro cell. On this understanding we believe that new licensees would be able to provide information on the location of femto cells which could then be used to provide the necessary protection.

8.79 We consider above that three months notice would be a reasonable time period in order to implement any exclusion zone for a network deployment, but we recognise that this is not appropriate for femto cell use. Our PMSE licensing database allows for the implementation of exclusion zones within a very short timescale. In the event of an installation of a femto cell an exclusion zone would be applied within 24 hours of notification of its location.

8.80 We seek the views of stakeholders on the most appropriate way in which useful information may be provided.

8.81 In view of the fact that on-going PMSE access to spectrum in the award bands is of particular importance for only a small number of key events, it may be possible for any requirement for the provision of information to apply only to certain particular locations such as Silverstone, St Andrews (and other Open Championship golf courses) etc.

8.82 Under this scenario Ofcom would provide a list of areas where ongoing access to the award bands would be helpful. New licensees would then inform us when they planned to roll out in those defined areas. Once such a notification was received PMSE access to that channel in that location would be removed.

8.83 Some stakeholders may consider this to be a preferred solution, but we note that this arrangement would not provide the most efficient uses of spectrum. The views of stakeholders on this option are also requested.

8.84 Finally, we believe it may be appropriate to limit the timescale of any continuing PMSE access to newly awarded spectrum. We believe it is important that PMSE stakeholders seek more sustainable longer-term solutions and that access should simply provide a ‘breathing space’ for adaptation. We believe a maximum five year period from the award of new licences provides sufficient time for adaptation and is broadly in line with equipment replacement cycles. However, if universal roll-out of new services is slower than expected we may extend the period of continuing access if it allows for efficient spectrum use.

8.85 Depending on views expressed on these questions by stakeholders, Ofcom will consider including expectations and obligations in the detailed conditions for the award of new licences for continuing access.

PMSE access to 2.3 GHz spectrum

8.86 Our initial assessment of continuing use of spectrum in the award bands focussed on the prospects for using the 3.4 GHz band as this band is currently allocated to PMSE. We have also considered whether similar arrangements might apply to the 2.3 GHz band.

8.87 There are some important differences between the bands. Firstly, the 2.3 GHz band is not part of the current permanent PMSE spectrum inventory although it has been used as loan spectrum in the past. There is also less spectrum available at 2.3 GHz (40 MHz compared to 150 MHz at 3.4 GHz). Consequently any roll-out of 2.3 GHz services in an area is likely to curtail access to the majority of the 40 MHz, whereas in 3.4 GHz there may still be the opportunity to access other spectrum within the band. Additionally, there are more immediately available mobile devices that operate in 2.3 GHz than 3.4 GHz, so network roll-out could reasonably be expected to take place quicker and more extensively than in the 3.4 GHz band.

8.88 However, the 2.3 GHz release band falls within the normal tuning range of wireless camera equipment so users would be able to access the band with their current equipment. PMSE already has access to the upper adjacent channel to the release band (2390-2400) and could have loan access to the lower adjacent channel (we have disregarded these channels in our supply/demand analysis above due to the risk of adjacent channel interference from new services within the 2.3 GHz release band). Knowing where new services were operating would increase the utility of these adjacent channels.

8.89 Access to the 2.3 GHz spectrum after the award would be under the same conditions as for the 3.4 GHz band i.e. new licensees would have to provide information on network roll-out in order to apply exclusion zones.

8.90 On balance, we believe there is little incremental benefit in allowing continuing access to the 2.3 GHz band but the views of stakeholders on this matter are invited.

Consultation questions

Question 8.1: Do you agree that the available mitigations address the potential shortfall of spectrum for PMSE at major events and that no additional regulatory intervention is necessary to protect PMSE in frequencies adjacent to the award bands?

Question 8.2: Do you agree that PMSE should have some continuing access to spectrum in the 3.4 GHz band until new services are rolled out in an area?

Question 8.3: Which option for the provision of information about the roll-out of new services is most the appropriate? Should the requirement to supply information apply only in designated locations?

Question 8.4: Do you agree that any continuing access should be limited to five years from the award of new 2.3 and 3.4 GHz licences?

Question 8.5: Do you agree with our assessment that there is little incremental benefit in on-going PMSE access to the 2.3 GHz award band?

Section 9

Amateur radio

9.1 This section of the consultation outlines the work we are undertaking to review current use of the 2.3 and 3.4 GHz bands by amateur radio enthusiasts and the impact of our proposed spectrum award. Amateur satellite use is considered within the next section.

Description of uses and issues

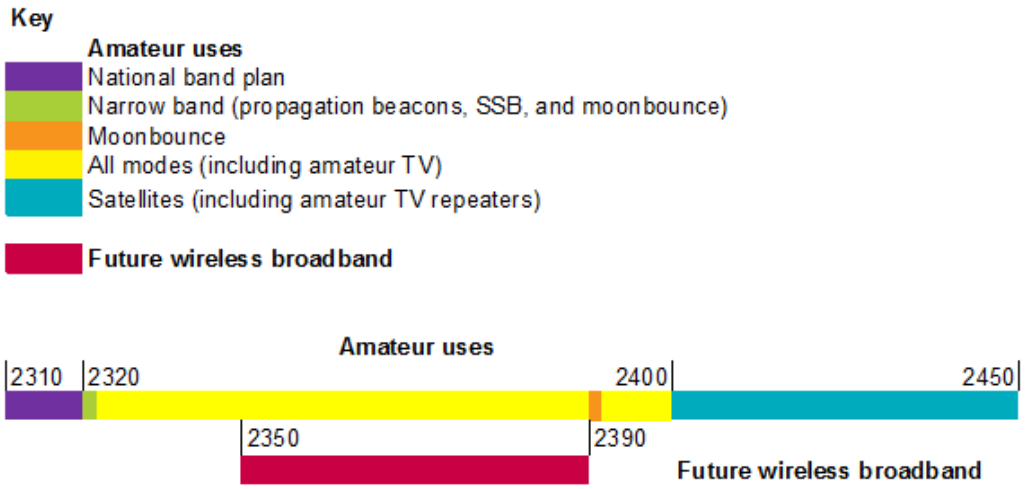
9.2 Amateur radio enthusiasts communicate with fellow amateurs at home and abroad using a broad range of technologies.[85] Amateurs may use the spectrum for any purpose provided they operate within the terms specified in their licence.

9.3 At present, amateurs have access to 53 different frequency bands from 135.7 kHz to 250 GHz. These bands have various uses depending on each band's propagation properties. Amateurs favour bands that suit their chosen use and not all bands would be suitable for any given use.

9.4 One indication of 'use type' is the Radio Society of Great Britain's (RSGB) band plan for amateur use.[86] The band plan helps amateurs avoid interference from incompatible uses and has allowed for developments of specific interests in common spectrum.

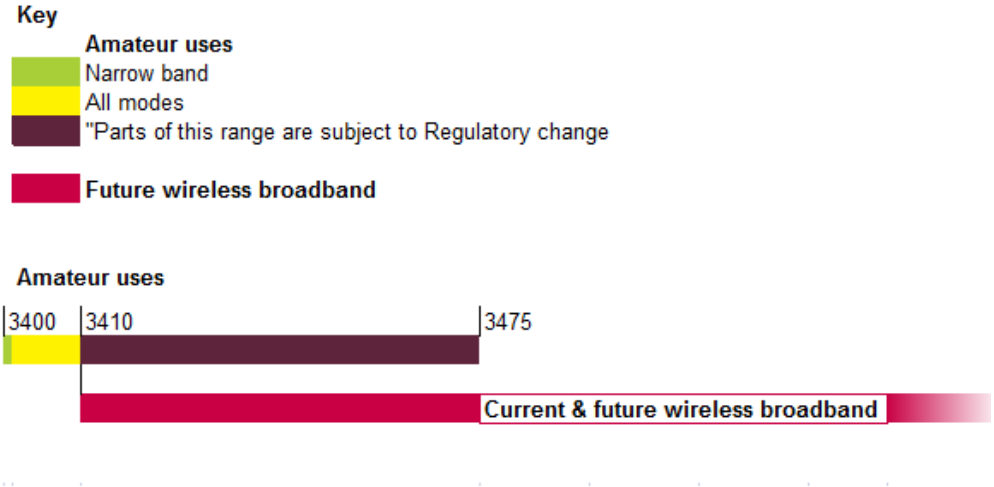
9.5 Uses specified in the band plan of the release bands are detailed in Figure 9.1and Figure 9.2. Further information about these uses is set out below. We understand that amateurs' current use of the award bands is relatively low density which, along with the ability of the amateur community to adapt and experiment with equipment, enables amateur uses to co-exist with others.

Figure 9.1: Use by amateurs of the 2.3 GHz band



[85] http://licensing.ofcom.org.uk/radiocommunication-licences/amateur-radio/guidance-for-licensees/monthly-stats/
[86] http://rsgbbeta.org/operating/band-plans/

Figure 9.2: Use by amateurs of the 3.4 GHz band



Source: RSGB band plan

9.6 The amateur licence grants access to some bands on a 'primary' basis and others on a 'secondary' basis. Amateur licences indicate access is secondary in both the 2.3 GHz amateur frequencies (2310 to 2400 MHz[87]) and the 3.4 GHz amateur frequencies (3400 to 3475 MHz). Both of these bands overlap with the award bands.

9.7 The meaning of secondary access is not defined in the current amateur licence. However the former Amateur Radio licence terms and conditions booklet indicates that amateurs using bands allocated on a secondary basis are *"required not to cause undue interference to stations of a primary or permitted service to which frequencies are already assigned or to which frequencies may be assigned at a later date."*[88]

9.8 The MoD is currently responsible for managing primary uses in both the 2.3 GHz band (i.e. fixed and mobile) and in the 3.4 GHz band (i.e. mobile and radiolocation). Amateur use of these bands has been agreed by the MoD but it is administered by Ofcom.

Consultation on amateur use

9.9 With MoD and other Government uses of the 2.3 and 3.4 GHz spectrum ending, we believe an award of the spectrum for high power use is likely to deliver greater benefit to UK consumers and citizens than continued amateur use. This means that we must withdraw authorisation for use of the award bands by amateurs if coexistence between amateur use and new uses is not possible.

9.10 In June 2013 we published a consultation on amateur use of frequencies at 2310 to 2450 and 3400 to 3475 MHz.[89] [90] The consultation set out analysis and technical assessments which suggested that the impact and likelihood of harmful interference being caused by amateurs to new uses in the release bands (i.e. 2350 to 2390 MHz

[87] The Full and Intermediate Amateur Radio Licences also grant access to 2400 to 2450 MHz.
[88] http://www.ofcom.org.uk/static/archive/ra/publication/ra_info/br68r11/br68.htm
[89] http://stakeholders.ofcom.org.uk/binaries/consultations/public-sector-spectrum-release/summary/condoc.pdf
[90] To note, since the consultation the MoD has announced that it will release the spectrum to Ofcom to award. Having considered this release against our duties we are clear that that this does not change the positions set out in our consultation.

and 3410 to 3475 MHz) were sufficiently severe to preclude continued use by amateurs following the MoD's release. The consultation therefore proposed to vary the amateur licence to remove the award bands.

9.11 The consultation also detailed the uncertainty about continued amateur access to the adjacent bands (i.e. 2310 to 2350 MHz, 2390 to 2400 MHz and 3400 to 3410 MHz). This was based both on the likelihood that other existing uses (i.e. MoD, other Government departments and PMSE) would be concentrated in the adjacent bands and on the conclusions drawn from our technical assessments.

9.12 Three options were proposed:

i) Removal of access to the adjacent bands;

ii) Retention of access to the adjacent bands on the current terms - but with clarification of the notice period required for amateur use to cease if amateurs cause interference to other users in the release band or the adjacent band;

iii) Restriction of amateur access to a smaller part of one or more adjacent bands.

9.13 Of these three options our preference in the consultation was for option two i.e. the retention of amateur access to the adjacent bands with clarification of the notice period required in the case of interference. The consultation closed on 22 July 2013.

9.14 Ofcom received 110 responses to the consultation as well as representations from the MoD and other Government departments.

9.15 In light of the need for amateur users to coexist with the MoD, other Government departments, and PMSE in the adjacent bands, we have been carefully considering the evidence submitted. We expect a statement to be published in due course. Although we have not yet made our decision, we are considering the preferences expressed in the consultation on amateur use for the purpose of this consultation.

9.16 The MoD and other Government users have raised some concerns about amateur usage in close proximity to a number of their sites as a result of the retuning and remediation works that they are undertaking in order to move systems out of the award bands. We are working closely with the MoD to establish what, if any, additional protections or coordination processes may be required around some MoD sites, including Aberporth, Boscombe Down and the Hebrides. In some cases these restrictions may only apply during the remediation works.

Section 10

Maritime radar

This section of the consultation considers the potential impact of the 3.4 GHz award on civilian maritime radar systems.

10.2 S-band maritime radars are mandatory on ships with a gross tonnage greater than 3,000 tonnes. These radars operate in the frequency range 2900-3100 MHz. The lowest communications frequency in the 3.4 GHz award band is located 310 MHz higher in frequency than the top frequency of the maritime radar band.

10.3 It should be noted that most common maritime radars are magnetron based and typically operate at 3050-3070 MHz. This range is indicated in red in the maritime radar block in the figure below. However, there are an increasing number of solid state radars being installed in maritime fleets covering the entire 2900-3100 MHz band.

10.4 Figure 10.1 illustrates both civil maritime and air traffic control radar deployment. The 3.4 GHz award band (3410-3600 MHz) and S-band radar allocations are shown in their approximate relative positions.

Figure 10.1: Frequency bands of S-band radars and their relationship to 3.4 GHz communications award band

10.5 Further analysis is provided in Annex 13

Potential interference issues

10.6 There are several possible ways in which radar performance could be degraded by the presence of communications transmissions nearby:

- Communications out of band/noise/spurious emissions entering into the radar band;
- Compression of the radar dynamic range caused by communications signals power entering the radar receiver - due to poor radar selectivity and resulting in inter-modulation effects in the radar;
- Mixer and other inter-modulation product effects causing communication signals to appear in the radar band.

Previous work and issues

10.7 As part of our preparations for the 2.6 GHz award we considered the possible coexistence implications of new communications services on maritime radar in

considerable detail. This work was summarised in our information update in December 2009[91].

10.8 Some technical work[92] commissioned by the Maritime and Coastguard Agency (MCA)had suggested that if out of band(OOB) emissions from 3.4 GHz equipment were at the ITU spurious recommendation level of -30 dBm/MHz conducted value then the interference ranges for maritime radar may extend to several tens of kilometres. However, subsequent measurements of emissions from example 3.4 GHz communications equipment falling in the radar band were 40 to 50 dB below the required spurious levels of -30 dBm/MHz. These emissions levels (assuming that they are typical) would result in short interference ranges.

10.9 Prior to our earlier 2.6 GHz award, we had wide stakeholder engagement with the MCA and their stakeholders. At this time, discussion with maritime stakeholders indicated that if there was no interference at ranges beyond 2.1 nautical miles, there was not expected to be any significant operational impact on the use of these longer range sensors.

10.10 As interference from the 2. 6 GHz award was not expected to exceed 2.1 nautical miles, there was no requirement for any additional protection from 4G services operating in the 2.6 GHz award.

10.11 In the radar band itself (2.9 to 3.1 GHz), the radar is highly sensitive to any received interference. As the interfering communications frequency diverges from the radar frequency, the compression sensitivity reduces. The level of communications device out of band noise and spurious emissions will determine which effect dominates - compression or noise.

10.12 Radar compression measurements undertaken by ERA (footnote 2) suggested a high sensitivity to the exact interference conditions and any measurement uncertainty, especially in the region 3410-3460 MHz. This was not relevant to the 2. 6 GHz award, but might be to the proposed 3.4 GHz award.

Our coexistence analysis for 3.4 GHz release

10.13 We have considered both OOB/noise/spurious and compression effects in determining whether there may be any impact on S-band maritime radar from 3.4 GHz base stations operating near shipping routes.

10.14 We engaged with key radar manufacturers to understand in detail the vulnerabilities to 3.4 GHz band signals. This engagement suggested that there was unlikely to be a significant concern.

10.15 However, it was also considered appropriate by the MCA, supported by Ofcom, that a measurement on full maritime radar systems, using a bespoke LTE test rig (as we did for 2.6 GHz) should be undertaken to provide additional evidence. Radars were subjected to clean communications transmissions, to allow an understanding of the selectivity susceptibility.

10.16 This measurement does not consider OOB effects which are specifically excluded by filtering. The trial in conjunction with two major UK maritime radar manufacturers was

[91] Coexistence of S-Band radar systems and adjacent future services. http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-awards/awards-in-preparation/infoupdate.pdf
[92] ERA report reference CTS report no. 2009-0258, June 2009

undertaken at the UK type testing range at Shoeburyness. It was witnessed by MCA, Ofcom and MoD representatives, and the data then analysed by the manufacturers themselves. Further details are provided in annex 13.

10.17 The testing at Shoeburyness included:

- Measurement of the baseline performance of two magnetron and one solid state radar systems;
- Test for LTE resilience via measurement of the radar performance in the presence of varying 3.4 GHz band LTE base station signals (i.e. to establish the change in performance of the maritime radars under simulated LTE signal illumination)

10.18 The measured mean power flux density for a 120 MHz bandwidth signal where there was no observable impact on the operation of the maritime radar was recorded.

10.19 Our subsequent analysis confirmed that the interference ranges for all three tested radars was less than 2.1 nautical miles. The calculated interference ranges were between 0.5 and 1.7 nautical miles for up to eight LTE base stations operating with a 65dBm/5 MHz in block power over the 3.4 GHz band.

Recommendations

10.20 The analysis of the 3.4 GHz trials results indicated the range of interference from the scenarios used of multiple (8) signals with 65dBm/5MHz EIRP transmission scenario would-be less than 2.1 nautical miles.

10.21 In view of this result we propose that there is no need to apply any coordination procedures or other additional restrictions with respect to maritime navigation radar.

Question 10.1: Do you agree with our conclusion that no coordination procedure is necessary in respect to maritime radar?

Section 11

Aeronautical radar

Introduction

11.1 This section of the consultation document considers the potential for interference to air traffic control (ATC) and air traffic management (ATM) radar as a result of the 2.3 and 3.4 GHz award.

11.2 In the frequency band 2700-3100 MHz there are a number of ATC and ATM radars, both civil and military, used for aviation radio navigation purposes. In total there are approximately 92 S-band ATC/ATM radars distributed around the UK. These radars are primary sensors, and their effective operation is integral to the air traffic management of UK airspace. The target detection range is from 40 to 80 nautical miles.

11.3 These radars are generally located at airports, military bases or other positions that allow the air traffic management function to be achieved. There are a number of radars located to allow the detrimental effects of wind farms to be mitigated.

11.4 The radar comprises of a transmitter, antenna and receiver system with associated processing and control systems. The radar receiver design in this ATC/ATM band traditionally had low radio frequency selectivity due to the historic absence of adjacent users.

Potential interference issues

11.5 The use of the 2.6 GHz band for 4G communications services raised particular concerns associated with radar performance vulnerability. There is potential for similar issues to arise as a result of the proposed award of the 3.4 GHz spectrum if the band is used for high power applications, such as LTE.

11.6 There are two possible sources of vulnerability:

i) Insufficient selectivity within the radar to enable signals from outside the radar band to be rejected. The vulnerability may be in the front end of the receiver chain or further down the receiver chain and results in receiver compression or the mixing of the communications signals into the radar bandwidth;

ii) The reception of radio frequency noise emissions from sources in other bands into the radar band

11.7 Either vulnerability can result in a loss of target detection. A lack of selectivity could result in inter-modulation effects on the radar. It may also cause performance loss due to dynamic range compression (target loss) and mixer products in the super-heterodyne architecture of the radar. Similar effects would also arise if there was excessive noise received at the radar from the out of band emissions of the communications system.

11.8 Earlier technical analysis carried out ahead of the 2.6 GHz release – including measurements by NATS, Selex, Raytheon, Thales and BAE Systems, among others - suggested that high power communications networks operating in the 3.4 GHz band may cause interference to a number of ATC radars operating in the 2700 to 3100 MHz band.

11.9 However, the radar manufacturers in a number of studies suggested the risk of harmful interference to ATC/ATM from communications transmissions operating at 3.4 GHz was less than the risk of interference from similar systems at 2.6 GHz. Nevertheless the risk was not negligible and remediation was required.

11.10 During the period between late 2010 and early 2013 there was a cross-Government (CAA, DfT and Ofcom) radar remediation programme that has ensured that ATC/ATM radars in the 2.7 GHz band (2700-3100MHz) were modified to become more resilient to interference to emissions from new communications users in the 2.6 and 3.4 GHz band.

11.11 In relation to the 2.6 GHz band, Ofcom further put in place a coordination procedure to limit:

a) the communications signal at the radar face; and

b) the noise that could be present at the radar face.

11.12 Radar selectivity and efficient radar performance in the presence of LTE signals was achieved by several approaches, but the key remediation was associated with RF filters in the radar front end. This served to improve selectivity before harmful interference reached any critical components.

Policy proposals for 3.4 GHz coexistence with radars

11.13 As the 3.4 GHz spectrum release was already anticipated at that time, Ofcom included a requirement for manufacturers to design protections against expected new uses of both the 2.6 GHz and 3.4 GHz bands when carrying out the 2.6 GHz remediation programme. This was incorporated into the remediation requirement and the manufacturers designed and tested accordingly. This approach was followed to avoid the need to repeat the 2.6 GHz remediation work for the 3.4 GHz award, which would have caused significant further expense.

11.14 However, even after this remediation programme was completed, the radars still have some residual sensitivity to communications emissions from the 2.6 GHz and 3.4 GHz band - both in band signal and out of the communications band emissions. As set out above, in relation to 2.6 GHz transmission, this is already dealt with via coordination procedures to ensure there is no detrimental interference energy in the radar band. We now propose that we should follow a similar approach as in the 2.6 GHz band for the 3.4 GHz band and also put in place coordination procedures to ensure that there is no risk from any residual vulnerability.

11.15 Each part of the 2.6 GHz coordination procedure was derived from measurements of individual radar vulnerabilities and the design of the filters to provide protection to the specific design - to a level of +8 dBm/m^2 in either of the 2.6 or 3.4 GHz bands.

11.16 As there was a need to manage the potential for simultaneous transmissions in the radar beam-width, the level set for the 2.6 GHz band was +5 dBm/m^2 to allow for a

similar +5 dBm/m^2 total signal level in the 3.4 GHz band. A term is also included to account for any noise emissions into the radar bandwidth.

11.17 For a coordination procedure applicable to the 3.4 GHz band there are three options, as set out in Figure 11.1 below.

Figure 11.1 options for coordination parameters

Options	Considerations
1. Apply the same total power across the 3.4 GHz (190 MHz) band as across the 2.6 GHz (120 MHz) band.	As the 3.4 GHz release band is 190 MHz and the 2.6 GHz band is 120 MHz, this option would result in a lower power flux density (pfd) per MHz in the 3.4 GHz release band, but the same aggregate value across each of the two bands.
2.(**Our preferred option**) Apply the same pfd per MHz across the band in the 3.4 GHz band as the 2.6 GHz band.	This could result in up to 2dB more aggregate signal from the 3.4 GHz band at the radar, due to the additional bandwidth in the 3.4 GHz band as opposed to 2.6 GHz band.
3. Adopt a case-by-case approach whereby the pfd level per MHz was shaped to the radar filter response.	This would be extremely difficult and overly complex to specify for one radar type. For a number of radars, of which the filters are different, the complexity would be extremely high. In addition there would be a frequency dependency for the communications channels, which would add complexity to our release and the subsequent implementation. The design criteria on the radar filters were a set level value across the communications band.

11.18 Our preferred option is option 2. Option 2 avoids the need for overly complex case-by-case coordination, while still restricting the pfd levels reaching the radars. Following the radar remediation programme, the ATC/ATM radar filter designs are required to +8 dBm/m^2 across either band. This results in a limit set for the coordination requirements to be a maximum of +5 dBm/m^2 across the band to manage the risk associated with multiple bands illuminating the radar, especially such as 2.6 GHz and 3.4 GHz being simultaneously within the radar beam-width.

11.19 Option 2 is the preferred option compared to option 3 as it also eliminates the need to calculate the pfd level at the radar for each separate channel in the release band. The option 3 calculation would be cumbersome and difficult to ensure consistently correct results, as the filter and receiver characteristic for each individual ATC radar would be required.

11.20 It should be noted that whilst option 2 results in an additional 2 dB over option 1 and the original 2.6 GHz requirement, the condition is related to the assumption that both the 2.6 GHz and 3.4 GHz bands have all channels transmitting at full power at a range of 1km and directly pointing at the radar with the full antenna gain. This is likely to be improbable in practical deployments.

Recommendations

11.21 We believe intervention in the 3.4 GHz band is justified to retain the integrity of the ATC/ATM radio navigation services in the 2.7-3.1 GHz band. The intervention we propose follows the approach put in place for the 2.6 GHz release. A coordination

procedure should be implemented in addition to the already improved radar selectivity performance associated with different manufacturers' filter designs.

11.22 For the 3.4 GHz award band, there should be a coordination procedure to specify power flux density (pfd) limits for both signal and noise that must not be exceeded at the defined radar locations. The use of the radar remediation filter and the limited coordination conditions as supported by the CAA is expected to provide a good level of resilience for the ATC/ATM radar to the potential 3.4 GHz deployments.

11.23 Compliance with the procedure implies only modest requirements for new licensees. However, it ensures the adjacent ATC radar band can continue to provide the radio navigation services used by airports and the military ATC/ATM services to ensure satisfactory on-going operation.

Radars to be protected

11.24 The coordination procedure proposed would apply to the radars listed in the link below. The area where the radar is protected is limited by the current position and within the airfield boundary and can be found in a CAA link[93]. The 3.4 GHz licensee would be required to ensure that its planned deployment is able to comply with the thresholds in relation to all of that area.

11.25 This list can be found at: http://stakeholders.ofcom.org.uk/binaries/spectrum/clearance-coexistence/Protected_radar.pdf.

Consultation question

Question 11.1: Do you agree with our proposal to require coordination procedures for the 3.4 GHz band - in order to protect of air traffic control radar - in line with those applied to the 2.6 GHz band?

[93] The CAAhas records of airfield boundaries as part of its aerodrome licensing, available athttp://www.caa.co.uk/default.aspx?catid=375&pagetype=90&pageid=5373.

Section 12

Satellite and space services

12.1 This section of the consultation concerns satellite and space services operating near to the 2.3 and 3.4 GHz award bands.

12.2 Satellite services include, but are not limited to, television programme transfer, data downloads for meteorological services, financial systems and embassy communications. Users take these services from the different international satellite operators, including those licensed by Ofcom and operators who hold grants of Recognised Spectrum Access (RSA)[94].

12.3 Specifically, this section of the consultation addresses:

- MSS 2 GHz - mobile satellite and integrated Complementary Ground Component (CGC) mobile receivers (2170-2200 MHz);
- MSS 2.4 GHz - mobile satellite services (MSS) (2483.5-2500 MHz);
- SR and SO - space research and space operations (2200-2290 MHz);
- AmSat - amateur satellite services (2400-2450 MHz); and
- C-band PES - permanent Earth stations (3600-4200 MHz).

Each use is discussed along with our approach to coexistence. The uses and bands are detailed below in Figures 12.1, 12.2 and 12.3.

12.4 This section also considers coexistence of UK Broadband blocks below 3600 MHz having technical licence conditions consistent with the rest of the band post 2018. However, UK Broadband may continue to have their current technical licence conditions up until that point. The increased use of radio spectrum between 3400 and 3600 MHz following the planned award may combine with any changes to the technical licence conditions for UK Broadband held spectrum and lead to a slight increase in the risk of interference in certain receivers that historically also cover this band. This is considered in relation to satellite services operating at the 3600 MHz boundary as these are the most likely to be impacted due to their sensitivity and proximity to users below 3600 MHz.

[94]Among others, RSA is available to receive only earth stations which, as they do not transmit, do not need a licence.

Figure 12.1: Civil satellite and space services and the 2.3 GHz release band

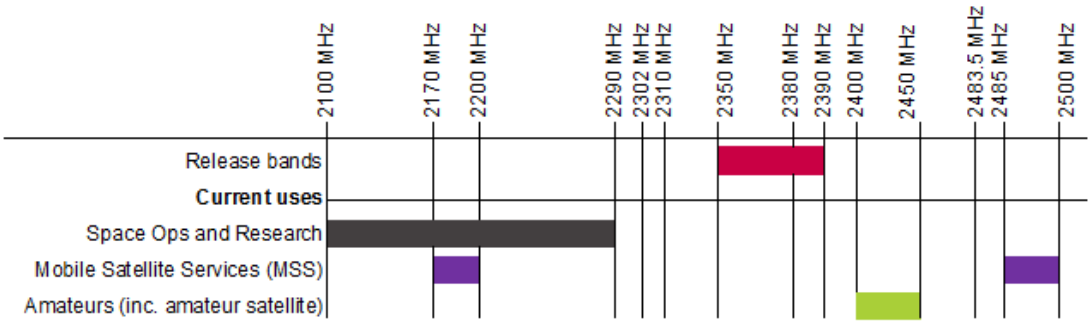


Figure 12.2: Civil satellite and space services and the 3.4 GHz release band

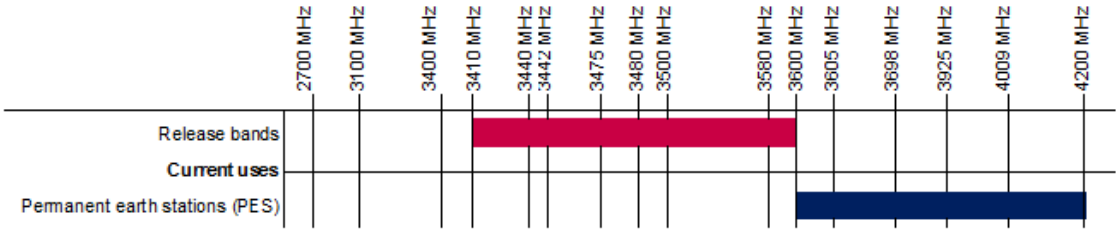


Figure 12.3: Frequencies discussed below and their allocation in the UK

Frequency range	Allocation to UK Services	Comments
2170 to 2200 MHz	Mobile-satellite (space to Earth)	Commission Decision (harmonised use of 1980-2010 MHz and 2170-2200 MHz for MSS) applies[95] The band is also used for complementary ground component of the MSS which may have similar characteristics to LTE.
2483.5 to 2500 MHz	Mobile-satellite (space to Earth) Radiodetermination-Satellite (space-to-Earth)	Globalstar has just deployed its second generation constellation and Galileo is set to use the band as well.
2290 to 2300 MHz	Earth exploration satellite (EESS) and Space Operations (space to Earth)(space to space) Space Research (space to Earth) (deep space)	This band is managed by the Spectrum Frequency Coordination Group (SFCG) made up of most of the national space bodies.
2400 to 2450 MHz	Amateur-satellite (space to Earth)	This band is used by small pico/nano satellites (i.e. < 100 kg), and specifically

[95]Commission Decision 2011/667/EU, October 2011:http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:265:0025:0027:EN:PDF

		cube-satellites (10cm cubed)
3600 to 4200 MHz	Fixed-satellite (space to Earth)	The 3600 to 4200 MHz band is allocated in the ITU-R Radio Regulations with a co-primary allocation for commercial satellites on a global basis (and also across Europe).[96]

Summary of technical work

12.5 We have undertaken technical analysis on some of the bands in the table above. In other cases, where we think the risks of harmful interference are much lower, we have described why no work was needed. The technical work detailed in annex 11 considers the implications of the 2.3 and 3.4 GHz award for UK satellite and space services using expected technical conditions and emissions from LTE.

12.6 Our analysis suggests that the award of the 2.3 GHz and 3.4 GHz release bands are unlikely to cause a significant increase in the risk of interference to satellite services operating in adjacent bands and we propose that no additional regulatory intervention is required. If in the unlikely event interference was to occur in practice, we believe that this could be reasonably addressed on a case by case basis.

12.7 The rest of this section provides an overview of each type of use and an assessment of the technical analysis.

Mobile satellite and integrated Complementary Ground Component (CGC) mobile receivers (2170 to 2200 MHz)

12.8 In 2009, the EC selected two satellite operators, Inmarsat (Inmarsat Ventures) and Solaris (Solaris Mobile) to provide MSS in the 2 GHz band across Europe. The selection awarded rights to provide mobile satellite services in the 1980-2010 MHz and the 2170-2200 MHz bands until 2027, subject to meeting various commitments. Both operators have committed to deploy a satellite component, and may also deploy a terrestrial component referred to as CGC.

Assessment of technical analysis

12.9 We considered LTE type emissions against the operating conditions of the integrated part of the mobile satellite system - the complementary ground component of the satellite system's terrestrial base station network.

12.10 This MSS downlink band (i.e. 2170-2200 MHz) has 150 MHz of frequency separation from the lowest edge of the release band (with potential LTE type transmitters) and is adjacent to 3G transmitters (with similar parameters) which operate in the band 2110-2170 MHz.

12.11 The CGC emission limits (+4 dBm/MHz) given in the licence conditions for CGC base stations which might operate in 2170 to 2200 MHz are much higher than those

[96] UK Frequency Allocation Table 2013:http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-information/UKFAT_2013.pdf

expected to result from LTE type equipment in the award band (-30 dBm/MHz within the MSS downlink band).

12.12 We therefore conclude that any risk of interference from systems in the 2.3 GHz release band is likely to be considerably lower than from existing 3G base stations in the adjacent 2110-2170 MHz band and self out of band interference from CGC base stations in the 2170-2200 MHz MSS band. Therefore no further analysis has been conducted.

Mobile Satellite Services (MSS 2.4 GHz) and Radio Determination Satellite Services (RDSS)

12.13 Mobile satellite services (MSS) are used for voice and data communications. A commercial MSS operator, Globalstar, uses 2483.5 and 2500 MHz as a downlink transmission for satellite phones. This is a non-geostationary satellite system providing global commercial satellite services with 48 satellites. Its second generation constellation has just been deployed.

12.14 Radio Determination Satellite Service (RDSS), is a band for the use of the next generation of satellite navigation systems such as Galileo. RDSS systems have characteristics as published in Recommendation ITU-R M.1787.

12.15 This band supports simultaneous RDSS and MSS system operation based on scenarios agreed at the ITU study groups. These transmissions overlay each other and therefore they have to coordinate their respective power flux densities at the Earth's surface to ensure that both systems can operate successfully. The MSS and RDSS services in the UK operate on a licence exempt basis.

Assessment of technical analysis

12.16 During Ofcom's work on the 2.6 GHz award process, Mason Communications produced a study in which they investigated the adjacent compatibility of Mobile Satellite Services (MSS) and LTE.[1] The report identified that localised interference could occur from out of band/unwanted emissions of base stations and mobiles above 2500 MHz to the receivers of MSS satellite terminals below 2500 MHz. However the report identified that the likelihood of harmful interference being caused by LTE in the 2.6 GHz band to satellite phones was very low. The frequency separation here is similar to that for the 2.3 GHz release band. This took into account the global subscriber base of around 200,000 (as of February 2006, the time of the study).

12.17 The award at 2350-2390 MHz has at least 93.5 MHz separation from MSS systems working above 2483.5MHz (which is slightly higher than assumed for TDD base stations in the 2.6 GHz band) and therefore we believe that the conclusions from the previous report will apply and we expect no adjacent compatibility problem. Therefore no further analysis is considered necessary.

12.18 We believe that there is a similar position for the potential RDSS applications in the band. In addition, we expect RDSS to have greater emission bandwidths than Globalstar's 1.23 MHz, and therefore a greater resilience to interference.

[1]2500-2690MHz, 2010-2025MHz and 2290-2302MHz Spectrum Awards – Engineering Study (Phase 2), Mason Communications Ltd, 2006: http://stakeholders.ofcom.org.uk/binaries/consultations/2ghzawards/annexes/masonresearch.pdf

Space research and space operations (SR and SO)

12.19 Space research, space operation and Earth exploration satellite services use the band 2200-2290 MHz to receive transmissions from all types of satellite orbit, including low orbiting and highly elliptic non geostationary satellites as well as geostationary satellites. These transmissions include telemetry, tele-command and control signals to manage the satellite operation. The data signals are received at a few Earth sites in the UK. A few of these are controlled by the MoD and three are civilian sites. They also receive and analyse data collected on space missions.

Assessment of technical analysis

12.20 The evidence suggests that the specifications of LTE type equipment operating in the 2.3 GHz award band may cause some risk of harmful interference to SR and SO. This band has a minimum 60 MHz frequency separation from the lower edge at 2350 MHz of the 2.3 GHz release band and in practice the out of band emissions and spurious emissions are considerably lower (by about 20-30 dB) and therefore in practice the risk is likely to be minimal.

12.21 Even if considering a worst case value for spurious radio signals from the mobile network base stations, provided they are not located geographically close to these licensed receive sites, there will be little likelihood of harmful interference.

12.22 There is also evidence from the 3G uses below 2170 MHz which indicates that we have experienced only one case of a coexistence problem - and this was when a 3G base station was sited close to the SO receiver (<500 m), and the SO was operating with an elevation angle of 15° with the 3G base station virtually on bore site azimuth. The problem was resolved by insertion of a band stop filter in the SO feed. This 3G band is closer to the SR and SO operations in the lower part of 2200 to 2290 MHz than the proposed release band above 2350 MHz.

12.23 Our conclusion, therefore, is that LTE type equipment operating in the 2350 to 2390 MHz band, at least with a separation of 60 MHz from the highest edge of the SO/SR band (2200 to 2290 MHz), will not cause an issue to SR and SO, provided the LTE base stations are appropriately sited.

12.24 However, if spurious signals from LTE type equipment did unexpectedly become an interference issue for SR and SO, Ofcom would in the first instance recommend that case by case resolution occurs between the space research operators and relevant mobile operator. In such cases, local LTE site engineering may be required or local LTE equipment may need additional filtering to mitigate any interference.

Amateur satellite services

12.25 Amateur satellite operations are permitted under the amateur radio licence between 2400 and 2450 MHz. Ofcom recently published a consultation about the implications for amateurs of the planned release.[97]

12.26 There are 16 amateur satellites registered in the ITU-R filing database for these bands. Some of these are recent launches and have regulatory deadlines[98] of

[97]Public Sector Spectrum Release: Amateur use of 2310 to 2450 and 3400 to 3475 MHz, Ofcom consultation, June 2013:
http://stakeholders.ofcom.org.uk/consultations/public-sector-spectrum-release/

2019.We have identified about 11 known or planned new amateur satellites systems, whose frequencies of use range from 2402 up to 2437MHz. Another two satellites are already in orbit and should be operational. Nine satellites that have completed their missions are still in orbit but are now off-line. It is expected that due to the low cost of developing and launching nano/pico satellites (such as Cubesats) the use of amateur satellite bands is likely to increase

12.27 As part of the amateur radio licence conditions, amateur uses in the 2400-2450 MHz band must already accept interference from Industrial Scientific and Medical (ISM) equipment operating co-channel. In general, because of the ISM in this band, the 2400 MHz amateur satellite service usage is nearly always configured for downlinks only.

12.28 In the UK some amateur radio users have previously installed satellite equipment for the Oscar satellite. However, current reception activity has tailed off. Most of the current and expected future usage is in low Earth orbit from either small satellites (an example is cubesats) or from the new amateur DATV system on the Space Station (developed by Amsat-Italy), which may increase usage.

12.29 In our consultation on amateur usage we acknowledged that the 2400-2450 MHz band could experience an increase in background noise as a result of the release and set out advice for amateurs planning continued use of these bands.

12.30 We consider that there is no need for further detailed analysis of the impact of the release on the amateur satellite service as there is a 10 MHz separation between this use and release band and there should be no issue greater than the in-band ISM interference.

Permanent Earth stations (PES) and Receive Only Earth Stations (ROES)

12.31 There are several types of satellite Earth station and the only stations that we provide a licence for in the UK are Permanent Earth Stations (PESs). Other satellite use, such as Transportable (satellite station on vehicles) and Uncoordinated Earth Stations (i.e. TESs and VSATs) can operate in C-band on a non-interference/non-protection basis.

12.32 Licensed Permanent Earth Stations (PES) in C-band operate from a permanent and specified location to a space station (satellite) and are typically used to provide telephony and data backhaul, broadcast feeder links, broadband data for private corporate networks and satellite telemetry, tele-command and control.

12.33 Satellite Earth stations at the Earth's surface normally receive communications from geostationary space stations. The C-band frequencies for PESs are allocated under the Fixed Satellite Service (FSS) and the operational downlink frequencies of PESs are within the 3600-4200 MHz band (commonly referred to as the C-band downlink) and on their licences the uplink frequencies are also noted. These are normally in the 5950-6450 MHz range (however there are also uplink frequencies ranging up to 7075 MHz).

[98]The regulatory deadline is the final date by which they must have provided formal notification of bringing the satellite into use. If this date is missed, then the date precedence in terms of coordination with other satellite systems has to be reset. This has implications in any negotiation.

12.34 There are about 1,500 separate C-band frequency assignments spread across the 3600-4200 MHz band to 107 different antennas. More specifically, in the 3600-3700 MHz band there are 125 separate frequency assignments spread over 24 locations, the rest are in the 3800-4200 MHz range.

12.35 In addition to dual-link (up-link and down-link) PESs, in the UK we also have receive only Earth stations (ROES) operating in the 3600-4200 MHz range. There are two categories of ROES:

- For those ROES operators who require protection in the bands 3600-4200 MHz, it is possible to apply for a Grant of Recognised Spectrum Access (RSA). We have issued five grants of RSA for ROES in this band. These RSA grants provide in-band protection for ROES (i.e. from current and new uses between 3600-4200 MHz), but do not provide protection from out of band emissions from uses below 3600 MHz. Those with grants of RSA for operation near the 3600 MHz boundary are considered in the analysis contained in the annex. Where we refer to PES, we also mean ROES that have an RSA granted; and

- Because ROES are exempt from licensing, and because grants of RSA are optional, a ROES operator may decide to operate without formal recognition. Since Ofcom does not have records of these stations, they are not taken into account in the analysis contained in the annex.

12.36 There are five PES sites with a grant of RSA or licence, operating in the lower 60 MHz of the band, adjacent to the 3600 MHz boundary of the 3.4 GHz release band.

Assessment of technical analysis

12.37 Our analysis considered the technical licence conditions of the existing licensee directly below 3600 MHz (UK Broadband) and the risk of interference to PES and ROES operating above 3600 MHz. The risk was considered both under the current technical licence conditions and new technical conditions proposed by CEPT. The CEPT proposed conditions are likely to be used in a future European Commission (EC) decision and we expect to make any new grants of access in the 3.4 GHz band under these new conditions. This may include the spectrum currently held by UK Broadband if these conditions are varied before or after the current UK Broadband licence expires in 2018. See annex 11 for further details.

12.38 For both sets of technical licence conditions there are two possible causes of interference to receiving satellite Earth stations:

- LTE equipment out of band emissions - from LTE equipment deployed in the release band whose out of band/unwanted emissions fall in the pass-band of the Earth station receiver above 3600 MHz. We concluded that infrequent spurious emissions will have minimal impact and these can be ignored. Our technical analysis therefore focuses on frequencies up to 10 MHz from the 3600 MHz band edge, i.e. 3600 to 3610 MHz.

- Blocking by LTE equipment – caused by high power LTE signals saturating the Earth station receiver. Many Earth station receivers have a wide band front-end filter which may be capable of operating in the band down to 3400 MHz and therefore these receivers may be susceptible to transmissions anywhere in the 3.4 GHz release band even where the actual in-band satellite receive frequencies are above 3600 MHz.

12.39 The technical analysis in annex 11 looks at both of these mechanisms separately.

Changes to the out of band emission limits at the 3600 MHz boundary

12.40 Our proposed licence conditions presented in section 13 are based on new technical licence conditions proposed by CEPT for the 3.4 and 3.8 GHz bands[99]. This work considers two possible block edge masks for 4G deployments within the 3.4 GHz award band. A more permissive mask which can be used when adjacent operators have a bilateral agreement, typically around synchronisation, and a more restrictive one when there is no such agreement in place.

12.41 UK Broadband has access until July 2018 to the 20 MHz from 3580-3600 MHz which is adjacent to the band used by PES. UK Broadband has a different set of licence conditions to those being proposed by CEPT, which are likely to be included in a new Commission decision. However, we have conducted our analysis on the basis that this block of spectrum may in the future have licence conditions that are consistent with the proposed Commission decision.

12.42 Our proposed permissive mask is more permissive than the current UK Broadband mask. We recognise that UK Broadband currently also operates above 3605 MHz and that it is possible that they may synchronise this network with the licensee operating below 3600 MHz (currently also UK Broadband). This means that this may create a greater risk of causing interference to satellite Earth stations (including those that have RSAs) if these more relaxed emissions masks operate at the 3600 MHZ band edge. The restrictive mask is more restrictive than the current UK Broadband mask and therefore the risk of interference will be less than the current position. We have therefore only analysed the current position of the UK Broadband mask and the potential future permissive mask.

12.43 The analysis in annex 11 suggests that if practical out of band emissions were produced consistent with these new technical licence conditions it may create a risk of harmful interference out to approximately 8.5 km in the two worst affected PES sites, depending on the roll out scenarios of the 3.4 GHz licensee. More realistic LTE deployments (lower height and increased downtilt) suggest an upper limit of 7.5km with full antenna boresight coupling for this interference zone. The analysis suggests that the distance of interference extends approximately three times further for these new technical conditions than for the current UK Broadband mask.

12.44 Our results also show that with an additional 10dB of margin (achievable through LTE site engineering to include: antenna orientation and downtilt, power reductions or additional filtering on the LTE base station) that the likely ranges where interference may occur are reduced to around 1 to 3 km. This is a similar range for interference caused by blocking (see below).

12.45 The impact is mainly to those PES assignments in the first 10 MHz of the adjacent band, i.e. 3600-3610 MHz.

Blocking

12.46 Whilst, our normal policy is not to consider adjacent channel blocking as part of the coordination and assignment process for satellite Earth stations, we have considered

[99] CEPT Report 49 - Technical conditions regarding spectrum harmonisation for terrestrial wireless systems in the 3400-3800 MHz frequency band, November 2013: http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP049.PDF

the blocking effects of LTE to the front end Low Noise blocks (LNB) of the C-band Receiver PES receivers and potential filtering and mitigation options for completeness. However, we are not actively considering adjacent channel coordination in line with our normal assignment process.

12.47 Our blocking analysis suggests that there is some potential risk of interference to PES and ROES operating above 3600 MHz with separation distances up to about 8 km from an LTE base station operating below 3600 MHz. We believe that the risk is likely to be less for PES and ROES operating higher up the 3600-4200 MHz band depending on the exact specifications of the equipment.

12.48 We have identified a number of commercially available high pass filters having a 3700 MHz pass band edge. There are also a small number of similar devices available with a 3600 MHz band edge. In addition, we have identified a band pass channel filter, with a 28 MHz pass band characteristic.

- Taking account of these possible filter characteristics, we assume that C-band PES use in the band 3600-3650 MHz might be most affected by the top 20 MHz of spectrum (to 3600 MHz) which is currently licensed to UK Broadband.

- If a high power LTE base station was installed near to a PES site (operating from about 3600-3650 MHz), then an affected C-band PES, may need to install a filter to ensure there are no blocking effects from signals below 3600 MHz. Local site engineering on the LTE site using the top 20 MHz to include antenna discrimination between the two sites could also assist.

12.49 There are no specific coordination requirements attached to UK Broadband's licence below 3600 MHz. In general we expect licensees not to cause harmful interference to adjacent users and there term in UK Broadband's licence reflecting this position.

- There are five C-band PES assignments with operating frequencies spanning part of the 3600-3610 MHz band. We are unaware of harmful interference being suffered by satellite users as a result of current UK Broadband deployments however the geographical coverage in the UK of UK Broadband currently limited.

- The geographical extent of services may be greater in the future, and in this situation we believe that filters may be a possible mitigation for many of those PES sites that operate above 3600 MHz.

- If interference was to occur, cooperation with case by case arrangements between PES operators and the licence holder at the top of the release band (i.e. up to 3600 MHz) should result in a reduction of incident power at the PES (e.g. antenna tilting and direction, power reductions or filters).

12.50 In the future we expect there to be only a few new PESs deployed in the UK and of these we would expect few, if any, to propose the use of frequencies very close to 3600 MHz. In either case there would be prior knowledge by that PES operator of the conditions and use of the release band, which should be considered in any PES site design. We consider that should a PES be deployed in an area prior to the deployment of LTE in that area that we also expect case by case mitigation discussions with the operator implementing the local LTE base stations should take place.

12.51 Given that there are only a small number of PES sites that operate close to the 3600 MHz boundary and our analysis suggests that the risk of blocking is low, we do not

consider that it is necessary to reconsider our existing policy and we therefore propose that it is unnecessary to apply any restrictions to the release band in order to protect PES from suffering potential blocking.

Possible Mitigations

12.52 We have considered in our policy options below a number of possible mitigations to avoid or deal with interference if it does arise in practice.

12.53 Local site engineering at the LTE base station will result in lower incident signal strengths at the PES location. This may include adjusting antenna orientation and downtilt along with carrier power reductions.

12.54 As noted above, additional filters on Earth station receivers would provide further mitigation from potential harmful interference due to out of band blocking by high power LTE deployments, if it were to occur in practice.

12.55 C-band PES are usually fixed to a specific set of satellite transponders and may have less flexibility in changing frequency and direction of operation than LTE deployments (depending on the frequencies licensed by a particular 3.4–3.6 GHz operator).

12.56 Formal coordination procedures would require new deployments of 4G services to be coordinated with existing PES stations in order to avoid interference. This would place an additional regulatory burden on the 4G operator. However, as there are only a limited number of PES sites in the lower part of the 3.6 GHz band which may be most susceptible to interference this may not be a large burden.

Policy options for a band edge mask at 3600 MHz

12.57 In the following paragraphs we consider options for the least restrictive conditions for the release band, while ensuring technical conditions for continued protection of adjacent recognised satellite users.

12.58 Our current policy approach to coexistence issues is that to provide coexistence and adjacent band protection to services, including satellite Earth stations at C-band, we use suitable technical conditions within licences and interface requirement documents.

12.59 Where required, we also protect satellite Earth station receivers on an in-band basis through coordination (e.g. The UK Broadband licence above 3605 MHz protects holders of RSA and licences between 3600 and 4200 MHz). Coordination procedures are not currently applied for adjacent band coexistence issues.

12.60 Given the small likelihood of interference we have set out policy options below.

Option one: The existing UK Broadband mask (at the 3600 MHz boundary) is maintained

12.61 This first option is to keep the status quo for the UK Broadband mask (at the 3600 MHz boundary). Satellite Earth station operators just above 3600 MHz would retain the same risk with regards to likelihood of interference as they currently do. UK Broadband (or a new operator if this spectrum was released or traded after July 2018) below 3600 MHz would maintain current licence conditions and would not have the option to be granted the new EC technical conditions with a synchronised mask at the 3600 MHz boundary.

12.62 This option would also mean that new C-band PES Earth stations operating on frequencies just above 3600 MHz would not be coordinated with mobile and fixed services in 3400-3600 MHz. The C-band PES will have to manage any adjacent band interference situation and if necessary discuss suitable local mitigations with users of the 3400-3600MHz band.

12.63 In this option we would need to justify and balance the effects of this level of restriction (i.e. a more restrictive mask than is being proposed as part of the mandatory EC decision) on the new uses versus the protection it affords to satellite uses. We would need to be sure that this option is consistent with the least restrictive conditions likely to be required by the EC Decision.

12.64 To place additional restrictions for the top LTE block nationwide in order to protect five satellite sites against a small risk of harmful interference may not be proportionate.

Option two: Adopt our proposed mask with informal cooperation on a case-by-case basis if required

12.65 This option considers the impact of the block of spectrum below 3600 MHz having technical licence conditions consistent with those proposed by the CEPT Report 49 recommendations to the European Commission. This is likely if either the spectrum is released with rights from 2018 or UK Broadband's licence is varied to include these revised harmonised conditions.

12.66 Section 13 sets out options for both restrictive and more permissive masks depending on whether there are bilateral agreements between adjacent licensees.

12.67 Whilst the more restrictive mask provides a lower risk for satellite operations, we believe it is likely that adjacent licensees would choose to coordinate their high power use in certain circumstances. We note that currently UK Broadband holds licences above and directly below 3600 MHz. With this more permissive mask, there is a higher risk of interference to satellite operators from new or existing 4G services in the band.

12.68 Our preferred option is to adopt the mandatory EC decision as updated. However, this means the likely outcome of this option will be a situation where the risk of harmful interference into C-band PES is slightly higher than it is at present resulting in interference zones having approximately increased to a three times bigger radius. In making this recommendation we have therefore considered options for dealing with the increased risk posed to C-band PES operators. These further options are set out below.

12.69 Should situations of interference arise, we would expect PES operators and 4G operators to voluntarily cooperate to resolve any problems. This may mean some additional site engineering on the relevant party may be required. If any user and any adjacent users had difficulty in reaching an agreement Ofcom could act in an advisory role to mediate the situation where appropriate.

12.70 With only a very limited number of PESs operating close to the 3600 MHz boundary we do not believe it is appropriate for us to mandate specific coordination procedures as part of the licence conditions.

12.71 This option has the benefit of providing some protection for C-band PES sites if necessary, without requiring burdensome constraints on licensees when it is likely

that harmful interference may not occur in practice subject to the location and nature of the LTE deployments.

12.72 This option will also allow any C-band PES operator to enter into a discussion with the relevant licensee prior to deploying any new sites that wanted to use the first 10 MHz above 3600 MHz.

Option three: Adopt our proposed mask with mandatory coordination procedures

12.73 Option 3 is to attach mandatory coordination procedures to any new or existing licences covering the 20 MHz spectrum block below 3600 MHz where the technical conditions attached to the licence are aligned with our proposed new BEM. This would list the five existing PES sites (detailed above) as sites that should be protected from emissions falling within the wanted satellite operating band.

12.74 Placing restrictions around these satellite receive sites would give a degree of comfort to these users that their interests would be protected following the release.

12.75 This option would be less restrictive than option one (which introduces more restrictive conditions over most of the UK) and it would allow coordination to take account of local topography. It would only protect the current five PES sites and not any future ones operating at the lower end of the 3600–4200 MHz band.

12.76 This option would however also place a burden of coordination on any new or existing licensee operating in the top block below 3600 MHz which for five PES sites may not be proportionate.

12.77 However, this option would diverge from our policy position not to carry out coordination procedures for adjacent band coexistence. Indeed, during previous spectrum releases we did not recommend protection through coordination process for satellite receivers in adjacent channels.

Conclusion and recommendations

12.78 Our preferred option is option two. This is because if interference were to occur then practical local site engineering for a network operator and/or satellite Earth station should resolve the issue. We believe that mandating coordination procedures thereby placing the burden of coordination on any licensees operating in the top block below 3600 MHz to protect five C-band PES sites may not be proportionate when local solutions would resolve the issue if it were to occur in practice.

Consultation questions

Question 12.1: Do you agree that for mobile satellite services operating in the band between 2170 and 2200 MHz, coexistence with LTE operating in the award bands above 2.35 GHz is unlikely to be an interference problem?

Question 12.2: Do you agree that satellite services operating in the band 2483.5 MHz to 2500 MHz can coexist with LTE operating in the award bands (i.e. 2350 to 2390 MHz and 3410 to 3590 MHz) and there is unlikely to be an interference problem?

Question 12.3: Do you agree with that for satellite services operating between 2200 and 2290 MHz, coexistence with LTE operating in the release bands is unlikely to be an interference problem?

Question 12.4: Do you agree that for amateur satellite services operating between 2400 and 2450 MHz, coexistence with unwanted/out of band emissions of LTE operating in the release bands (the nearest release band is 2350 to 2390 MHz) is unlikely to be a greater problem than the current in-band interference from licence exempt and ISM uses?

Question 12.5: Do you agree with our preferred option to adopt our proposed mask with informal co-operation on a case-by-case basis if required?

Section 13

Technical licence conditions

13.1 This section of the consultation contains the technical licence conditions we propose to include in the licences for the 2.3 GHz and 3.4 GHz award. The licences will contain the minimum necessary restrictions on the permitted use of the spectrum bands to limit harmful interference and to ensure compliance with our statutory duties, national and international obligations.

13.2 Given the similar nature of the service(s) likely to be rolled out in the two bands, many of the licence conditions will be the same or similar for each band. Where they are different we highlight this. The technical licence conditions are designed to define and limit the level of interference that the licensee may cause to other users of spectrum.

In December 2010, after a number of consultations, we published a statement in preparation for the release of 3.4 GHz spectrum for mobile broadband systems. The associated technical conditions were based on the existing EC Decision 2008/411/EC.

13.3 Our proposals in this consultation have taken into account the work in progress in the CEPT working group ECC FM52 (for the spectrum we are awarding within 2300-2400 MHz) and working group ECC PT1 (for the spectrum we are awarding within 3400-3800 MHz) which has been updating the technical conditions that are currently within EC Decision 2008/411/EC. We believe the technical work within CEPT is at a mature stage, and that the technical licence conditions are likely to be adopted in an ECC decision for the 2.3 GHz band in May 2014 and an amended EC decision for the 3.4 GHz band around March 2014.

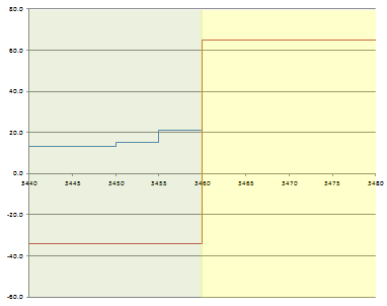
13.4 The Commission is proposing a mandate for CEPT to carry out work to result in an EC Decision for the 2.3 GHz band. Much of the work to formulate the draft ECC decision has been completed, and we are not expecting substantial changes. If there are changes to the technical conditions to come out of this new work, we will ensure that these changes are highlighted and consulted on prior to our further statement, if appropriate.

13.5 Commission decisions are binding on EU member states.

13.6 Our proposals for non-technical licence conditions were set out in paragraphs 5.21 to 5.27 of the earlier 'Call for Inputs'[100] document. We are currently assessing the responses. The proposals for technical licence conditions set out in this document detail our preferred Block Edge Masks for the 2.3 GHz and 3.4 GHz bands as demonstrated in Figure 13.1 below.

[100] http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/

Figure 13.1: 2.3 GHz and 3.4 GHz band preferred block edge masks

Block edge masks 	All spectrum is assigned to licensees. All assigned spectrum may be used at maximum power. An option of two out of block masks in the adjacent licensee's block: • A permissive mask to protect where there is a bilateral agreement in place between two licensees (blue line). This may be where the networks are fully or partially synchronised. • A restrictive mask to protect networks where there is no bilateral agreement (red line). Licensees can negotiate further permissive out of block emissions by bilateral agreement.

13.7 The summary of our proposed technical licence conditions for the 2.3 GHz and 3.4 GHz bands are set out in Figure 13.2.

Figure 13.2: Summary 2.3 GHz and 3.4 GHz band technical licence conditions

Base stations

	2.3 GHz		**3.4 GHz**	
Band plan	TDD		TDD	
In block power limit EIRP	61 dBm / 5 MHz		65 dBm / 5 MHz	
Out of block baseline power limit (BS)	**Permissive mask (synchronised)**	**Restrictive mask (unsynchronised)**	**Permissive mask (synchronised)**	**Restrictive mask (unsynchronised)**
	Min(PMax [101]– 43, 13) dBm / 5 MHz EIRP per antenna	-36 dBm/5 MHz EIRP per cell	Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna	-34 dBm /5 MHz EIRP per cell
	Applies only within the spectrum to be made available in this award i.e. 2350 – 2390 MHz.		Applies within 3400 – 3800 MHz where there is a licensed wireless broadband operator i.e. a winner of the upcoming spectrum award or an existing licensee such as UK Broadband.	

[101] Where P_{Max} is the maximum carrier power for the base station in question, measured as EIRP and is used in the baseline and transitional region levels.

Transitional levels For TDD blocks the transitional region applies in case of synchronized adjacent blocks, and in-between adjacent TDD blocks that are separated by 5 or 10 MHz.	**-5 to 0 MHz offset from lower block edge** **0 to 5 MHz offset from upper block edge**	**-10 to 5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge**	**-5 to 0 MHz offset from lower block edge** **0 to 5 MHz offset from upper block edge**	**-10 to 5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge**
	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
	The transition region extends below 2350 MHz and above 2390 MHz.		The transition region extends below 3410 and above 3600 MHz.	
Other levels to protect MoD systems	Below 2340: -36 dBm / 5 MHz		Below 3400: -59dBm / MHz	
Coordination requirements	Yes		Yes	

User terminals

	2.3 GHz		**3.4 GHz**	
In block power limit	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment
	25 dBm TRP[102] (Licence exempt)	25 dBm EIRP (Licence exempt)	25 dBm TRP (Licence exempt)	35dBm/5 MHz EIRP (Not licence exempt)

Background

Block Edge Mask (BEM)

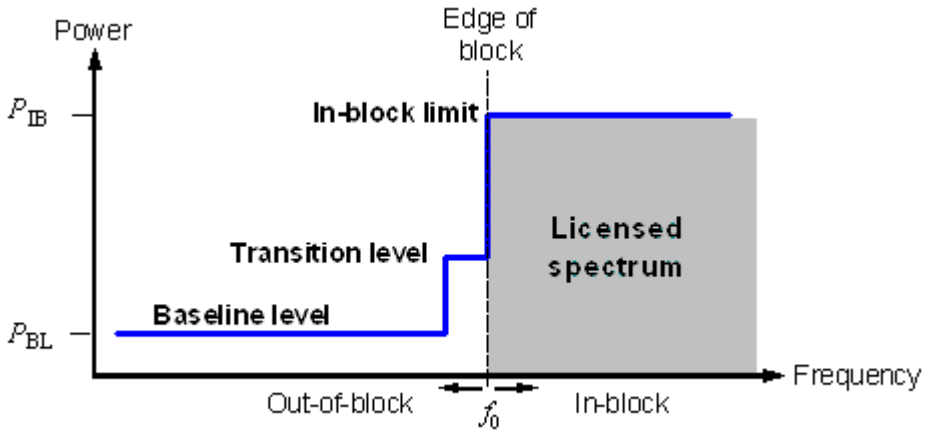
13.8 In order to reduce interference with adjacent users we must put in place appropriate technical parameters. Block Edge Masks (BEM) have been developed by CEPT and are intended to form part of the authorisation conditions for spectrum usage. The following paragraphs discuss the different options we have considered and are the same for systems operating in either the 2.3 GHz or 3.4 GHz bands.

13.9 A BEM is an emission mask that applies at the edge of a licensed block of spectrum. It is designed to offer appropriate protection from interference to the receiving system

[102] Total Radiated Power (TRP). TRP is a measure of how much power the antenna actually radiates. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere. EIRP should be used for fixed or installed terminal stations and the TRP should be used for the mobile or nomadic terminal stations.

in an adjacent frequency block. The emissions of any transmitters operating within a licensed block of spectrum must comply with the BEM. On one side of this frequency boundary is the in block power limit and on the other side is the out of block spectrum mask. The out of block component of the BEM itself consists of a baseline level and, where applicable, intermediate levels which describe the transition from the in block level to the baseline out of block level (transitional region) as a function of frequency. This is illustrated in Figure 13.3 below.

Figure 13.3: Illustration of a general block-edge mask



Synchronisation

13.10 In addition to the use of BEMs to help manage interference between adjacent licensees, it is also often necessary to coordinate nearby base stations to avoid the situation where one base station is transmitting in the same timeslot as another is receiving. Base stations are typically at a higher height (often above surrounding clutter) and transmit at a significantly higher power than mobile devices. Base stations will also have a more sensitive receiver to pick up the lower power mobile signals. Therefore there is a significant risk from two nearby located base stations when one is transmitting and the other is trying to receive.

13.11 Similarly, for two nearby mobile devices, there is a greater degree of out of block emissions than for base stations. Avoiding a situation where one is trying to receive while the other is transmitting is also helpful in minimising interference.

13.12 This coordination of timeslots is called synchronisation and applies to networks in adjacent spectrum as well as within a licensee's own network.

13.13 Figure 13.3 shows the BEM with a single baseline power level. However, the work within CEPT has proposed two baseline levels. If a licensee is synchronised with another licensee (i.e. all base stations in the two networks transmit on exactly the same downlink timeslots as each other and at the same time) within the band, the higher power level is applicable (the "permissive mask"). Where licensees are not synchronised in the band (i.e. one or more timeslots has downlink transmissions for one network and uplink transmissions for another) the lower power limit is applicable (the "restrictive mask").

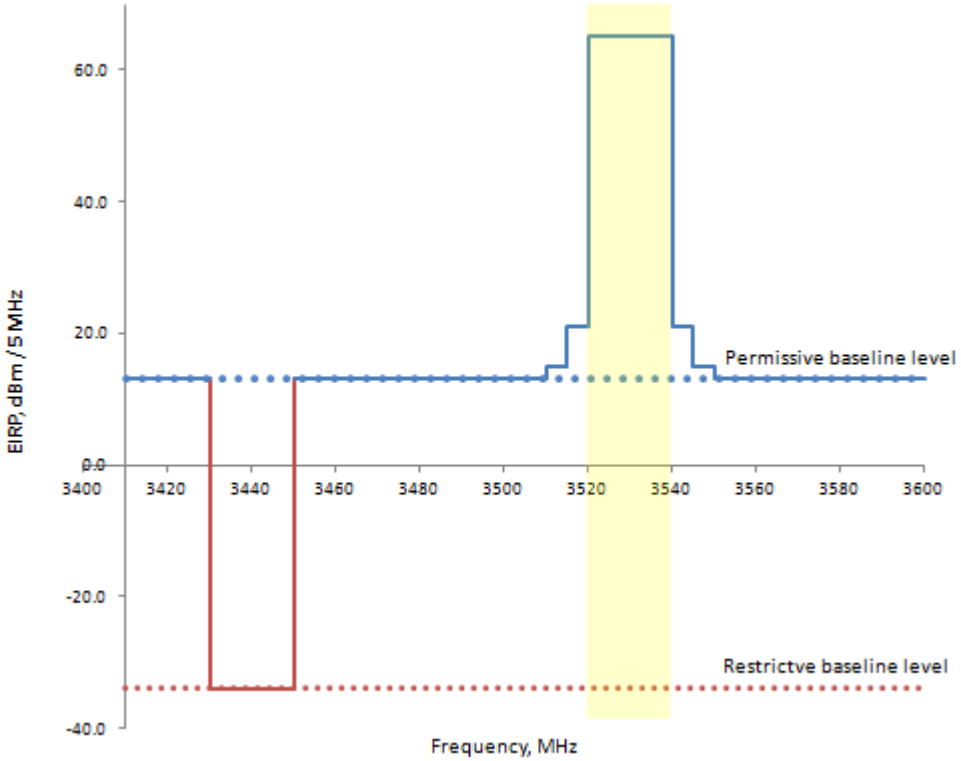
13.14 CEPT proposes for both the 2.3 GHz and the 3.4 GHz band that, where two networks are unsynchronised, each must ensure that its base station emissions are below the more restrictive baseline level by the boundary of the other licensee's spectrum in the band. Where the two networks are synchronised, then the baseline is the higher

more permissive level *and* the transition regions are permitted to encroach within the boundary of the adjacent licensee's spectrum.

13.15 Figure 13.4 below illustrates an example where the licensee with the spectrum block between 3520 and 3540 MHz is synchronised with all other users of the 3.4 GHz band apart from the licensee using 3430-3450 MHz. The out of block emissions have to meet the transition emissions to 10 MHz outside of the block, and then meet the permissive baseline level for the remainder spectrum blocks where there is an agreement between licensees. For the spectrum between 3430 and 3450 MHz, where there is no agreement between licensees, the more restrictive baseline level needs to be met.

13.16 Although this figure demonstrates the CEPT requirement in the 3.4 GHz band, there is also a need for this to be adhered to for the 2.3 GHz MHz spectrum, if there is more than one winner of the award.

Figure 13.4: Example out of block emission requirements for a licensee using block 3520–3540 MHz



Our Assessment

13.17 3GPP specified seven different configurations of frame structure for LTE-TDD, which provide a different ratio of uplink and downlink traffic depending on the requirements of the network[103]. We commissioned Real Wireless to study the potential for synchronisation (they included full and partial synchronisation[104]) and the potential spectral efficiency benefits of including transition regions in unallocated spectrum

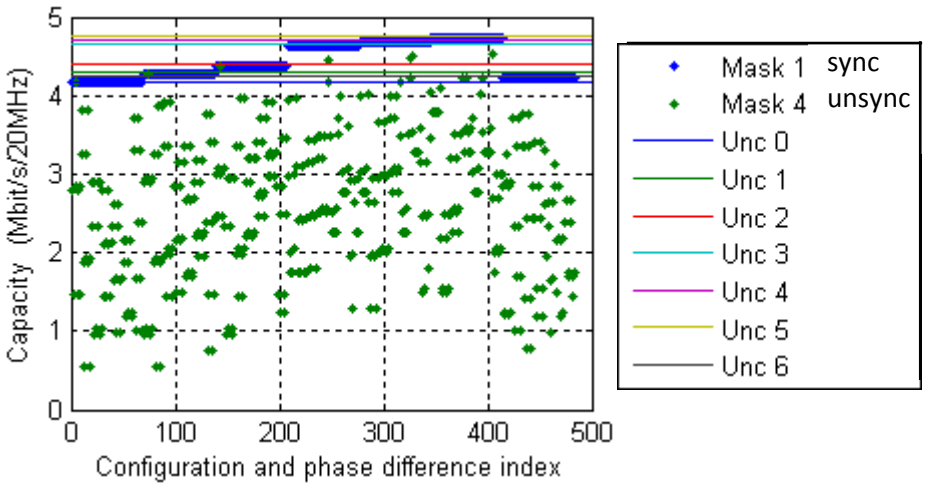
[103] See Annex 7 Table 9 for the seven different LTE-TDD frame configurations.
[104] We define partial synchronisation where two networks have TDD configurations that are not fully synchronised but where the frame structures have been aligned so as to reduce the number of occurrences where the downlink (uplink) from one network clashes with the uplink (downlink) of the other.

between licensees[105] We discuss some aspects of this report within our analysis of BEM options below.

13.18 Figure 13.5 shows the potential capacity throughput per 20 MHz channel, for all possible frame structure configuration combinations (timing of uplink and downlink traffic) between licensees using adjacent spectrum (there are 490 in total and each possible configuration has been given an index number on the x-axis).The synchronised timeframes use mask 1 with the permissive baseline limits and all combinations of different configuration pairs (unsynchronised) using the restrictive baseline limits (mask 4). The horizontal lines at the top represent the target capacity when there is no adjacent channel interference.

13.19 This graph shows that although there are differences in the capacity throughput depending on the chosen frame configuration, there are spectral efficiency benefits from synchronisation.

Figure 13.5: Capacity of synchronized and unsynchronized cases, cell edge, geometry 1, macrocell case, Real Wireless



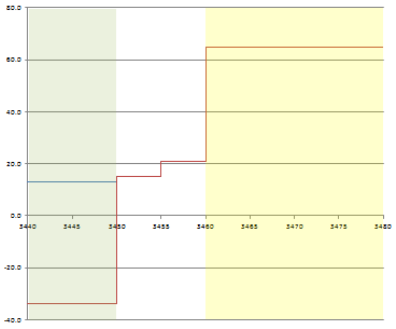
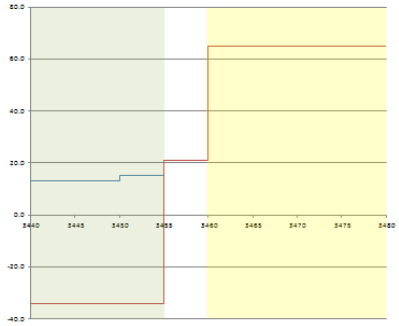
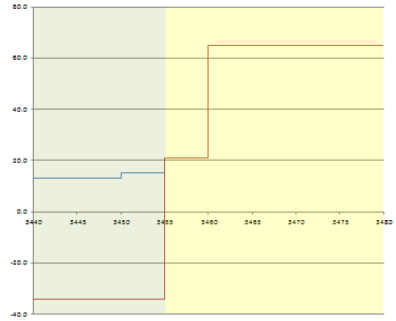
BEM options

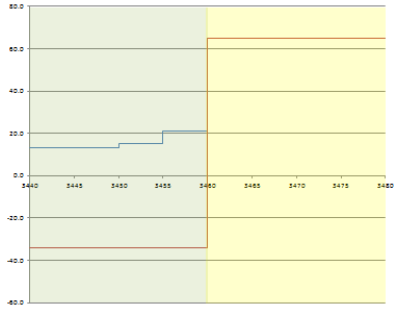
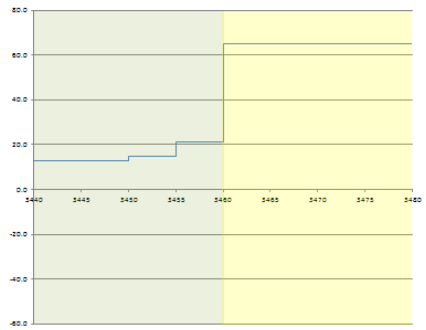
13.20 The work in CEPT gives some flexibility for administrations to apply the technical licence conditions. Based on the CEPT work, we have considered four options for BEMs. These are set out below and described in more detail in Figure 13.6:

- Option 1 - a required transitional region of 5 to 10 MHz between licensees' spectrum, and allowing both the restrictive and permissive baseline power levels depending on bilateral agreements;
- Option 2 - a restricted block of 5 MHz and allowing both the restrictive and permissive baseline power levels;
- Option 3 – a transitional region of 0 MHz between licensees and allowing both the restrictive and permissive baseline power levels (our preferred option); and
- Option 4 - a transitional region of 0 MHz between licensees allowing only the permissive baseline power level.

[105] A full list of documents published alongside this consultation can be found at Annex 5

Figure 13.6: Description of options for BEM

Option	Benefit	Cost
1) <u>Transition region = 10 MHz</u>  <u>Or 5 MHz</u>  A 10 MHz or 5 MHz transitional region between licensees' spectrum that is not assigned to either licensee. All assigned spectrum may be used at maximum power. Two out of block restriction in the adjacent licensee's block: • Restrictive mask (red line) • Permissive mask (blue line).	• This can give additional protection in some problematic interference environments. • It provides a greater ability to meet the restrictive mask baseline levels where appropriate without internal restrictions	• Spectrally inefficient for both synchronised and unsynchronised operation due to unassigned transition regions (see Real Wireless analysis). • The transitional region is not assigned to either licensee so to fully utilise it (with bilateral agreement between adjacent licensees) would require a licence variation through Ofcom. • There could be a lack of incentive for a licensee to participate in negotiation of the utilisation of the transition region if they plan to deploy on a different timescale to the adjacent licensee.
2) <u>Restricted block of 5 MHz</u>  All spectrum is assigned to licensees. A 5 MHz restricted block between licensees spectrum that is assigned to one licensee.	• The restricted block is similar to having a 5 MHz transitional region but also provides an opportunity for the 5 MHz to be used for useful traffic, e.g. unsynchronised femto cell use. • Can possibly be used for ICIC or eICIC techniques where part of the spectrum can be used for synchronised (within own network) low and high power use although this may depend on vendor implementations. • An unprotected restricted block could assist licensees to meet the restrictive baseline emission level in the case	• The restricted block reduces the utility of part of the spectrum by restricting the power level in part of a licensee's spectrum holding. • A wider block of spectrum may be needed in practice for femto cell use; if a wider channel for femto cell is needed then this could be taken from the high power allocation. • If the networks co-operate, the restricted block is not needed, but only one licensee gets the main benefit leading to asymmetric motivations (unless they agree to share the block).

All assigned spectrum may be used at maximum power apart from the restricted block. Two out of block restriction in the adjacent licensee's block: • Restrictive mask (red line) • Permissive mask (blue line). Licensees can negotiate more permissive out of block emissions or higher power used in the restricted block by bilateral agreement.	where licensees do not have a bilateral agreement.	
3) Transition region = 0 MHz **Our preference**  All spectrum is assigned to licensees and may be used at maximum power. Two out of block restriction in the adjacent licensee's block: • Restrictive mask (red line) • Permissive mask (blue line). Licensees can negotiate more permissive out of block emissions by bilateral agreement.	• Maximum amount of spectrum can be utilised. • Gives the flexibility for a licensee to use the entire spectrum block for up to high power or apply an internal guard band/restricted block if they choose. • It does not prescribe the amount of spectrum needed to achieve the baseline restrictive level (if no agreement in place). • It avoids the negotiation of sharing the use of the transitional region with the adjacent licensee, if fully want to utilise the spectrum when bilateral agreements are in place.	• A licensee may need an internal guard band, for example 5 MHz, to meet the restrictive mask baseline level if no bilateral agreement is in place • It may give less protection in some problematic interference environments, however analysis suggests a higher spectral efficiency is achieved if there is no spectrum gap (see Real Wireless analysis). • There could be a lack of incentive for a licensee to participate in negotiation of the utilisation of the permissive mask if they plan to deploy in a different timeframe or geographical area to the adjacent licensee.
4) Permissive mask only  All spectrum is assigned to licensees and may be used at maximum power. A single out of block restriction in the adjacent licensee's block based	• This encourages synchronisation which can lead to the spectrum being used more efficiently. • This overcomes the potential difficulty of a licensee that deploys earlier than others needing to make agreements to use this permissive mask where there is no other network deployment to protect. • For incumbent licensees with multiple bands, this band is likely to be used as a complement to other core bands, in cases where interference does arise; it is possible to envisage mitigating	• A permissive only mask would require co-operation between licensees, delays in co-operation could lead to delays in deployment and utilisation of the spectrum. • Licensees may acquire spectrum for different business models that require different traffic profiles. In this circumstance it could be difficult for licensees to agree a synchronised traffic profile that offered them the downlink and uplink ratio that each require.

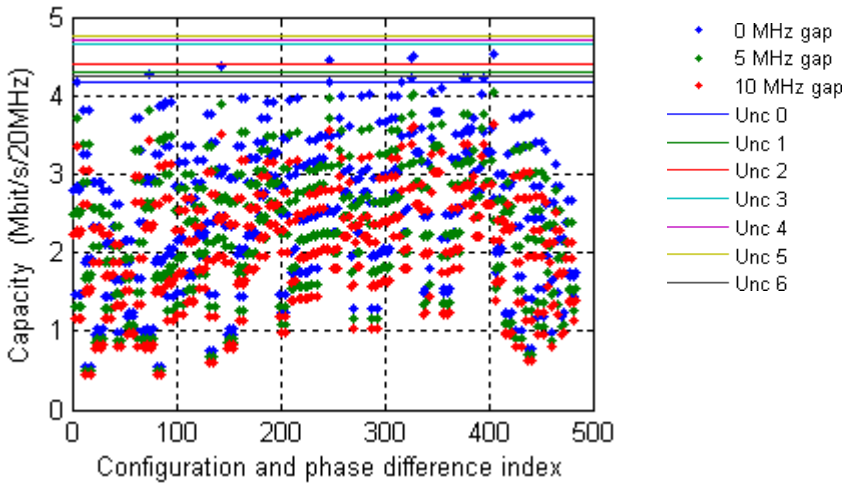
on the permissive mask only (blue line). Licensees collaborate with each other to ensure that the best spectral efficiency is achieved.	by simple techniques such as handover to other bands.	

Summary analysis of using of BEMs

13.21 Figure 13.5 above showed the capacity advantages to a licensee synchronising with the adjacent licensee. However, it may not always be beneficial for licensees to always synchronise. Licensees may acquire spectrum for different business models that require different traffic profiles. In this circumstance it could be difficult for licensees to agree a synchronised traffic profile that offered them the downlink and uplink ratio that each require.

13.22 The analysis produced by Real Wireless (see annex 5) models three different situations (geometries) where the levels of interference were expected to be significant. They model the relative scaled capacity for an ideal radio channel (i.e. follows block edge masks exactly) for all possible frame structure configuration combinations (timing of uplink and downlink traffic). Adjacent licensees are modelled with a frequency separation of 0 MHz, 5 MHz and 10 MHz. Figure 13.8 shows the scaled capacity for each for one example geometry, for all possible frame structure configuration combinations between licensees using adjacent spectrum (there are 490 in total and each possible configuration has been given an index number on the x-axis). The horizontal lines at the top represent the target capacity when there is no adjacent channel interference.

Figure 13.8: Capacity of unsynchronised cases with variable gap, cell edge, geometry 1, macrocell



13.23 Real Wireless analysis indicated that in some high interference environments a frequency gap was able to prevent receiver blocking. However in nearly all the simulations the increased spectrum occupancy of the frequency gap reduced overall spectrum efficiency.

13.24 The Real Wireless analysis modelled some specific interference geometries where the levels of interference were expected to be significant. There is a balance to be

made against minimising the opportunity for any interference by introducing restrictive power limits and/or frequency gaps. However, introducing these to protect against worst case interference scenarios resulted in inefficient spectrum use where the interference environment is less severe.

13.25 Where a licensee is particularly concerned about coexistence with the adjacent network, there are some mitigation options available.

13.26 Dominant modes of interference identified were between the base station and user terminal (often referred to as the near-far problem). Co-locating base stations with similar EIRP, would mean that any downlink adjacent channel interference would be suppressed by the user terminal selectivity, and that adjacent channel interference in the receiver would be significantly below its desired signal level. In addition, the interfering user terminal power control when it is close to the serving cell would also reduce interference into a co-located victim base station.

13.27 Within the 3.4 GHz band there are potentially up to nine different 20 MHz channels, and there is a possibility that an adjacent channel is not used in the same area. The band is likely to be used as a complement to other core, less bandwidth-rich channels, in cases where interference does arise. It is also possible to envisage mitigating by simple techniques such as intelligent scheduling and handover to other bands.

13.28 If the licensee wished to deploy a guard band, they may still do so if they believe that this is of benefit to them.

13.29 A number of TDD operators, including UK Broadband, commented in a CEPT document[106] that some form of agreed partial synchronisation also provided significant benefits without the need of a guard band.

> "Next generation TDD technologies, such as LTE-TDD, enable the use of techniques to enable coexistence between operators without the need for guard bands., ... As long as the operators synchronise the frame start point (commonly everyone uses GPS today, and Galileo could be used in the future), then the LTE-TDD system ensures there will always be certain regions of the frame that are 'interference free'. These 'interference free' zones can be used to schedule co-located users where user-user interference is experienced or where the signal level at the BS [base station] is low and desensitization by other BSs is occurring and cannot be tolerated. The other zones can then be used for other users."

Meeting the BEMs

13.30 The analysis summarised above by Real Wireless assumes an ideal emission that meets the block edge mask exactly.

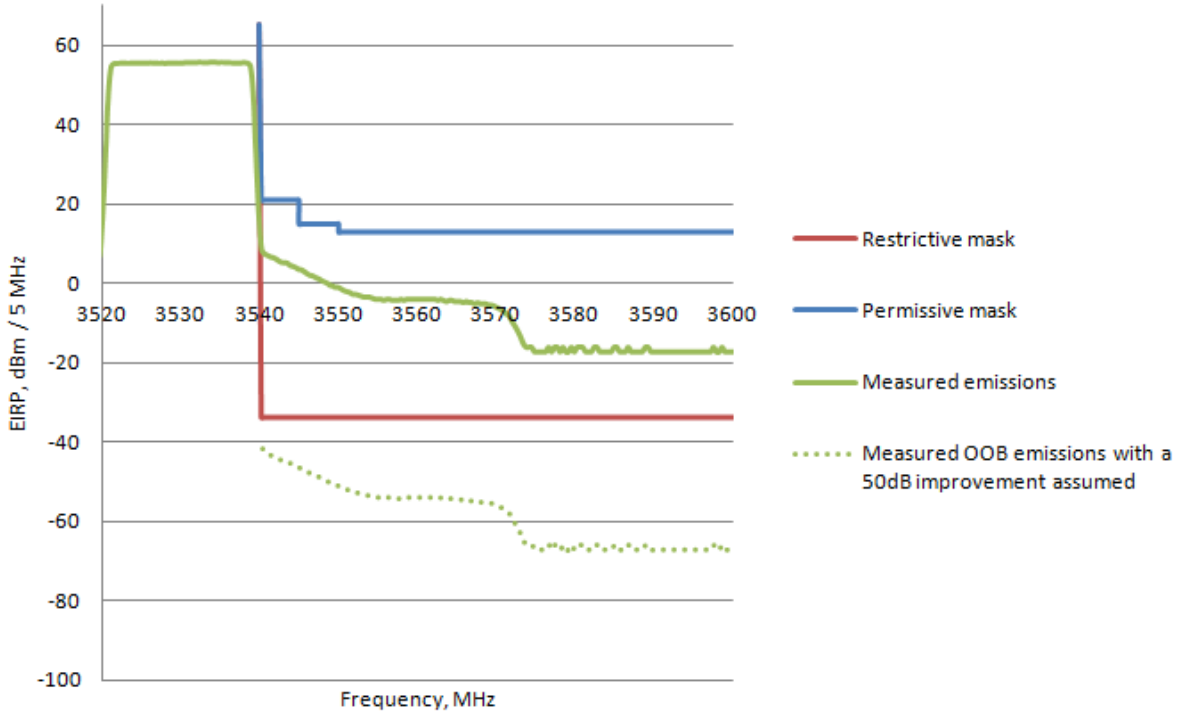
13.31 The Figure 13.7 below shows the Restrictive and Permissive mask against the emissions from a measured LTE base station using a mid-channel in the 2.6 GHz band (solid red line) and the out of block (OOB) emissions with a 50 dB improvement.

[106] IMT channel arrangements for the 3.4 ~ 3.8 GHz band", ECC PT1(10)115, 17th May 2010

13.32 It is likely that a separation of the order of 5 MHz may be needed to meet the restrictive baseline emission level. However, we believe that the mitigation to this issue is best left to the licensee to decide. For example[107] a ceramic filter for a channel bandwidth of 20 MHz can achieve the 50 dB suppression potentially needed for macro cells within 5 MHz - and an advanced ceramic filter may also achieve this for a channel bandwidth of 100 MHz.

13.33 Alternatively we expect that the restrictive mask could also be achieved with a lower in-band power and a filter with a lower suppression capability, although we recognise that in either case some frequency separation between the edge of the transmission block and the edge of the licence block (internal guard band) will be required. If licensees are synchronised or otherwise agree to use the more permissive mask, it is easier for a licensee to meet the required out of block emissions without the need of significant filtering.

Figure 13.7: Measured emissions from base stations against the Restrictive and Permissive mask



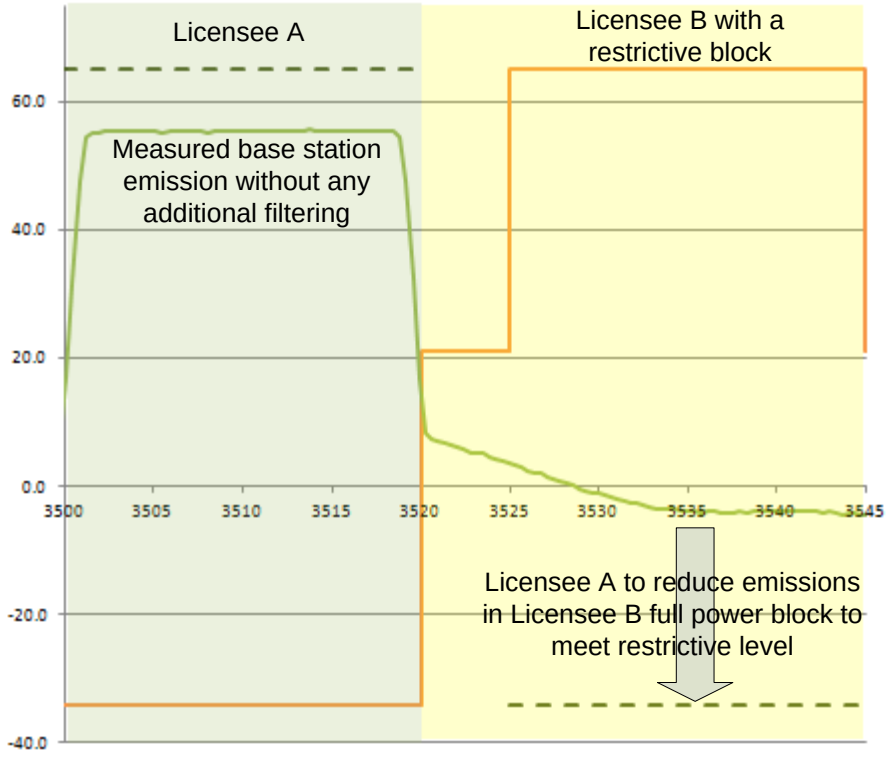
13.34 We note that the use of unsynchronised systems can have drawbacks. The requirement to meet more restrictive BEMs (although with bilateral agreement we are minded to allow licensees greater flexibility than requiring full synchronisation) may mean additional equipment is needed or a limited use of some spectrum. These requirements are removed with bilateral agreements (usually around synchronisation), where there is not such a need for restrictive out of block emissions.

13.35 If licensees do not come to any agreement such as using the permissive mask for synchronisation and they both require a 5 MHz internal guard band to meet the restrictive mask, this would result in 10 MHz between the two carriers.

[107] ECC Report 203

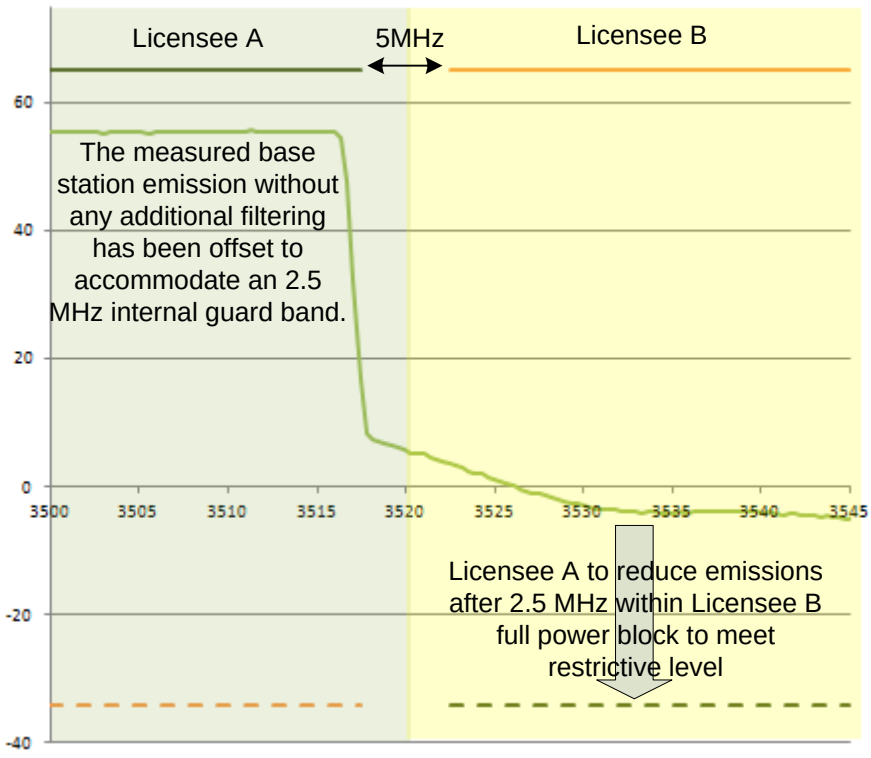
13.36 A 5 MHz restricted block that is not protected to the restrictive baseline level could assist in the spectrum to be used more efficiently if licensees do not come to any agreement such as synchronising. Figure 13.8 demonstrates this with two licensees, Licensee A and Licensee B. Without any agreement otherwise Licensee A needs to meet the restrictive mask 5 MHz outside of their spectrum holding where Licensee B's high power channel starts.

Figure 13.8: Out of block emissions from a base station and meeting the restrictive mask with a restrictive block



13.37 Although this option can help in the unsynchronised cased, there could also be options for licensees to come to a bilateral agreement to try to use the spectrum more efficiently without a restricted block for example to share an internal guard band of 5 MHz which they agree would not need to be protected to the restrictive mask level and to each offset their carrier by 2.5 MHz. This is demonstrated by Figure 13.9 below.

Figure 13.9: Out of block emissions from a base station and meeting the restrictive mask with a bilateral agreement to share a 5 MHz internal guard band



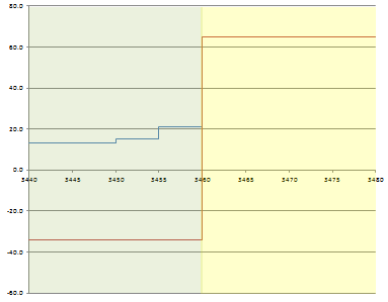
13.38 We believe that full or partial synchronisation between licensees may be likely. However there are some challenges to meet the restrictive mask, if licensees do not synchronise or come to some other agreement.

13.39 Our preference is to not prescribe how the restrictive mask is met or prescribe the amount of bandwidth that needs to be used to meet the restrictive baseline level. We allow for each licensee to determine the appropriate methodology.

Preferred BEM

13.40 Our preference is Option 3 (Transition region = 0 MHz). This is summarised again in Figure 13.10. We now outline our reasoning for this preference below this figure.

Figure 13.10: 2.3 GHz and 3.4 GHz band preferred block edge masks

Option 3: 	All spectrum is assigned to licensees. All assigned spectrum may be used at maximum power. An option of two out of block masks in the adjacent licensees block: • A permissive mask to protect where there is a bilateral agreement in place between two licensees (blue line). This may be where the networks are fully or partially synchronised. • A restrictive mask to protect use where no bilateral

	agreements are in place (red line). Licensees are free to negotiate more permissive out of block emissions by bilateral agreement.

13.41 In our earlier 'Call for Inputs' document[108], we asked stakeholders to tell us what use this spectrum could be put to. We have also considered the responses to an ECO questionnaire[109] for the 3.4 GHz band. Stakeholders have indicated that the spectrum may be deployed in a range of ways. We expect some or all of these potential uses of spectrum to be similar for the 2.3 GHz band. Therefore any proposed BEM needs to be able to take these different potential deployment scenarios into account.

13.42 The responses indicated a preference for:

- Small cell deployments to support capacity in hot spots in urban areas, by the use of micro, pico and femto cells;
- Fixed wireless access;
- Small cell backhaul; and
- Rural coverage for broadband services.

13.43 We believe that Option 3 provides licensees with the maximum flexibility over their spectrum allocations to enable them to adapt quickly to changes in demand and technology. As a principle, we aim to ensure that licences are technology neutral in order to enable a change of use, wherever possible, without resorting to Ofcom to vary the technical licence conditions. Although we think it is likely the deployment will be for LTE services, our proposed licence conditions would support both this use and other technologies

13.44 Spectral efficiency advantages increase with improvements to equipment performance of the base station and user terminal. We believe that if the spectrum is assigned to licensees, as per Option 3, then the right incentives are in place to facilitate improved equipment performance such as receiver selectivity and transmitter roll-off of out of block emissions. This may ultimately lead to an even greater spectral efficiency over time. One of Ofcom's duties is to ensure the optimal use of spectrum. Option 3 ensures that all spectrum that is potentially available is assigned to licensees.

13.45 If the licensee wished to deploy a guard band, as set out in Option 1, they may still do so under our preferred Option 3 if they believe that this is of benefit to them. We expect to package the spectrum in such a way as to facilitate this option should a bidder require it. We plan to further consult on packaging in a consultation in summer 2015.

13.46 Conventional cellular networks have been designed to maximise the coverage for symmetric voice services - with basic data services overlaid on the existing voice-centric networks - whereas next generation wireless broadband networks need to maximise data network capacity and may be optimised to support different traffic

[108] http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/
[109] Summary of replies to the ECC PT1 questionnaire on a preferred frequency arrangement for the 3400-3600 MHz, ECC PT1 #43, Berlin, 2-3 May 2013, source ECO.

profiles. For data services it can be more spectrally efficient to fully utilise the spectrum rather than to have spectrum unassigned in a transition region (Option 1) or with power restrictions, such as with a restrictive block (Option 2).

13.47 For example, for the 2.3 GHz band, there is 40 MHz of spectrum available in the award, so two licensees may acquire 20 MHz each. In this instance, all of the spectrum will be assigned to the licensees. This would enable all of the above potential uses, without unnecessarily restricting part of the spectrum in an award, i.e. through a transitional region *between* licensees or a restricted block. It gives the greatest flexibility to take advantage of higher spectral efficiencies with improved receiver performances or techniques, such as network synchronisation with adjacent licensees.

13.48 We believe that full or partial synchronisation between licensees may be likely and mutually beneficial to maximise the throughput achieved in many circumstances. We expect that all licensees will require an accurate timing reference within their network to avoid self-interference between contiguous or nearby cells. We therefore believe that once a compatible traffic profile is agreed between licensees, the additional overhead to synchronise with another licensee's network is small.

13.49 It may not always be beneficial for licensees to synchronise. Licensees may acquire spectrum for different business models that require different traffic profiles. In this circumstance it could be difficult for licensees to agree a synchronised traffic profile that offered them the downlink and uplink ratio that each require. Therefore we believe it is sensible that our technical licence conditions allow for the possibility of licensees synchronising with each other whilst allowing them to choose not to do so.

13.50 We therefore propose to include both the permissive and restrictive masks within the technical licence conditions in line with those developed through CEPT. By default, a licensee will need to deploy with the restrictive mask except where they have a bilateral agreement in place with their neighbouring licensee - in which case they can deploy equipment operating to the more permissive mask. We do not propose to stipulate whether this requires full, partial or even any synchronisation to be in place.

Power limits

2.3 GHz base station power levels

13.51 Whilst the work on-going in CEPT FM52 for the 2.3 GHz band states that an in block EIRP limit is not mandatory, we recognise that there are risks around coexistence with services in adjacent bands (including the 2.4 GHz licence exempt band and continued MoD uses below the release band) that mean it is necessary to provide an upper limit for in block power.

13.52 This is also consistent with the established practice for licences we have issued in the 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz frequency bands - which include a maximum base station EIRP power density that applies consistently to 5 MHz, 10 MHz and 20 MHz uses of the spectrum.

13.53 We therefore propose that the 2.3 GHz licences will have the same in block power limit as we awarded and licensed for the 2.6 GHz band, at a level of 61 dBm/5 MHz EIRP per antenna. Whilst CEPT work supports up to 68 dBm/5 MHz we do not believe that a higher level sufficiently mitigates the risk of interference to MoD, other Government uses and licence exempt systems (in particular outdoor Wi-Fi) in

adjacent spectrum. For more information on our analysis on potential impact to Wi-Fi systems, see section 6 and annex 7 of this document.

13.54 The draft ECC Decision advises that for femto base stations, power control should be applied to minimize interference to adjacent channels.

13.55 The power limits below represent the out of block and transitional base station limits, as well as the in block user terminal limits, as developed by CEPT FM52, and we propose to adopt those. As outlined previously, we are proposing to allow the use of both the permissive (synchronised) and restrictive (unsynchronised) masks as part of the technical licence conditions. Figure 13.11 sets out the baseline out of block EIRP limit.

Figure 13.11: 2.3 GHz baseline requirements – BS BEM out of block EIRP limits over other TDD blocks) within the band

BEM element	Restrictive Mask) TDD	Permissive Mask TDD
Baseline	-36 dBm/5 MHz EIRP per cell(1)	Min(P_{Max}[110] – 43, 13) dBm/5 MHz EIRP per antenna

13.56 These baseline levels apply within the 2.3 GHz band i.e. 2350–2390 MHz.

13.57 The permissive baseline level can change depending on the power of the sector of the individual base station in question. For example, if a sector of a base station has an EIRP of 43 dBm /5MHz, then Min(P_{Max} – 43, 13) dBm/5 MHz gives 0 dBm/5MHz. However, if a sector of a base station has an EIRP of 61 dBm/5MHz, then Min(P_{Max} – 43, 13) dBm/5 MHz gives 13 dBm/5MHz.

13.58 Figure 13.12 shows the transitional region power limits. We are proposing a transitional region = 0 MHz for the restrictive mask. Therefore these transitional levels are only applicable for base stations where licensees have a bilateral agreement in place and at the band edges at 2350 MHz and 2390 MHz based.

13.59 In a similar way to the baseline level described in Figure 13.11, the transitional levels can change depending on the power of the antenna of the individual base station in question[111].

Figure 13.12: Transitional region requirements (when applicable) – base station BEM out of block EIRP limits per antenna over frequencies

BEM element	Frequency range	Power limit[112]
Transitional	-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge	Min(P_{Max} – 40, 21) dBm/5 MHz EIRP per antenna
Transitional	-10 to 5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge	Min(P_{Max} – 43, 15) dBm/5 MHz EIRP per antenna

[110] Where P_{Max} is the maximum carrier power for the base station in question, measured as EIRP
[111] We note that power levels in transitional regions may be part of bi-lateral agreements between adjacent licenses.
[112] Where PMax is the maximum carrier power for the base station in question, measured as EIRP

Note: For TDD blocks the transitional region applies in case of synchronized adjacent blocks, and in-between adjacent TDD blocks that are separated by 5 or 10 MHz. The transition region extends below 2350 MHz and above 2390 MHz.

Figure 13.13: Additional base station baseline requirements

Case	BEM element	Frequency range	Power limit
To protect incumbent MoD systems	Additional Baseline	Below 2340 MHz	-36 dBm/5 MHz EIRP per cell

13.60 The base station out of block power limits as described may be relaxed whenever there are bilateral agreements between licensees.

2.3 GHz user terminal power levels

13.61 We propose that the maximum value of the in block emission level for TDD user terminals will be up to a power limit of 25 dBm. This power limit is in line with the recommended upper limit within the current draft ECC Decision being developed within CEPT FM 52. This level includes a +2 dB tolerance level to reflect operation within extreme environmental conditions and production spread.

13.62 Although the draft ECC decision enables administrations to relax this limit in certain situations, for example fixed user terminal in rural areas, we are not proposing any changes to this limit to reduce the potential risk of interference to uses in adjacent spectrum. We expect that the recommended upper limit of 25 dBm that has come out of CEPT FM 52 will be sufficient for the intended uses of the 2.3 GHz band.

13.63 We propose that all user terminal equipment would be licence exempt. For out of block emissions the limits of the terminals will be defined by the appropriate technical standards. Figure 13.14 sets out our proposed power limits for user terminals.

Figure 13.14: Proposed User Terminal in block power requirements

Radio equipment	Maximum mean power
Mobile or nomadic Radio Equipment	25 dBm TRP
Fixed or installed Radio Equipment	25 dBm EIRP

3.4 GHz base station power levels

13.64 Whilst the work on-going in CEPT PT1 for the 3.4 GHz band, and the draft Commission Decision states that an in block EIRP limit is not mandatory, we recognise that there are risks around coexistence with services in adjacent bands (including civil and military radar and continued MoD and other Government department uses below the release band) that mean it is necessary to provide an upper limit for in block power.

13.65 This is also consistent with the established practice for licences that we have issued in the 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz frequency bands. These

include a maximum base station EIRP power density that applies consistently to 5 MHz, 10 MHz and 20 MHz uses of the spectrum.

13.66 Whilst CEPT work and the draft Commission Decision supports up to 68 dBm/5 MHz we do not believe that a higher level sufficiently mitigates the risk of interference to MoD and other Government uses in adjacent bands and radar systems in the 2.7 to 3.1 GHz band. For more information on our analysis on potential impact to radar systems, see sections 10 and 11 of this document.

13.67 We propose that the 3.4 GHz licences should have the same in block power limit as we have permitted for the 900 MHz and 2.1 GHz band at a level of 65 dBm/5 MHz EIRP per antenna. A higher EIRP in the 3.4 GHz band would likely require additional coordination requirements around a number of users which in some cases may be impractical to implement.

13.68 The draft EC Decision advises that femto base stations, power control should be applied to minimize interference to adjacent channels.

13.69 The power limits below represent the out of block and transitional base station limits, as well as the in block user terminal limits that have been developed by CEPT PT1 and are set out in the draft Commission Decision. We propose to adopt these. As outlined previously, we are proposing to allow the use of both the permissive (synchronised) and restrictive (unsynchronised) masks as part of the technical licence conditions.

Figure 13.15: 3.4 GHz baseline power limits for base stations

BEM element	Restrictive Mask TDD	Permissive Mask TDD[113]
Baseline	-34 dBm/5 MHz EIRP per cell	Min(P_{Max} – 43, 13) dBm/5 MHz EIRP per antenna

13.70 These baseline levels apply within 3400–3800 MHz where there is a licensed wireless broadband operator i.e. a winner of the upcoming spectrum award or an existing licensee, such as UK Broadband.

13.71 The permissive baseline level can change depending on the power of the sector of the individual base station in question. For example, if a sector of a base station has an EIRP of 43 dBm / 5MHz, then Min(P_{Max} – 43, 13) dBm/5 MHz gives 0 dBm/5MHz. However, if a sector of a base station has an EIRP of 65 dBm/5MHz, then Min(P_{Max} – 43, 13) dBm/5 MHz gives 13 dBm/5MHz.

13.72 Figure 13.16 shows the transitional region power limits. We are proposing a transitional region = 0 MHz for unsynchronised use. Therefore these transitional levels are only applicable for base stations where a bilateral agreement is in place between licensees and at the band edges at 3410 MHz and 3600 MHz.

13.73 In a similar way to the permissive baseline level described above the transitional levels can change depending on the power of the antenna of the individual base station in question[114].

[113] Where PMax is the maximum carrier power for the base station in question, measured as EIRP

Figure 13.16: Transitional region power limits

BEM element	Frequency range	Power limit
Transitional	-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge	Min(P_{Max} – 40, 21) dBm/5 MHz EIRP per antenna
Transitional	-10 to 5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge	Min(P_{Max} – 43, 15) dBm/5 MHz EIRP per antenna
Note: For TDD blocks the transitional region applies in case of synchronized adjacent blocks, and in-between adjacent TDD blocks that are separated by 5 or 10 MHz. The transition region does not extend below 3400 MHz or above 3800 MHz, however it does extend below 3410 and above 3600 MHz.		

13.74 The base station out of block power limits as described may be relaxed whenever there are bilateral agreements between licensees.

13.75 CEPT has also considered an additional base station baseline below 3400 MHz in order to protect military radio location services in these bands (see Figure 13.17) The MoD has indicated a likely preference for Option A at a power limit of -59 dBm/MHz below 3400 MHz for the protection of systems. We will confirm the required level in the Information Memorandum for the award.

Figure 13.17: Additional base station baseline requirements for country specific cases

Case		BEM element	Frequency range	Power limit
A	CEPT countries with military radiolocation systems below 3400 MHz	Additional Baseline	Below 3400 MHz	-59 dBm/MHz EIRP(2)
B	CEPT countries with military radiolocation systems below 3400 MHz	Additional Baseline	Below 3400 MHz	-50 dBm/MHz EIRP(2)
C	CEPT countries without adjacent band usage or with usage that does not need extra protection	Additional Baseline	Below 3400 MHz	Not necessary (spurious levels from standards apply)

3.4 GHz user terminal power levels

13.76 There is a recommended upper power limit for user terminals within the revised draft Commission Decision 2008/477/EC. The power level proposed is 25 dBm TRP for mobile user terminals and 25 dBm EIRP for fixed or installed user terminals. The draft Commission Decision 2008/477/EC suggests that administrations may relax the

[114] As before, we note that power levels in transitional regions may be part of bi-lateral agreements between adjacent licenses.

limit under certain circumstances, for example fixed terminals, provided that protection and continued operation of other existing use in the 3400–3800 MHz band is not compromised and cross-border obligations are fulfilled[115].

13.77 We note that the existing Commission Decision 2008/477/EC, which is in the process of being amended with the new technical conditions, currently allows fixed and nomadic terminal stations a maximum in band power of 50 dBm/MHz EIRP for outdoor use and 42 dBm/MHz EIRP for indoor use.

13.78 We have received feedback from stakeholders that they would be interested in the spectrum for FWA applications and backhaul use. A company has indicated to us that they would like to use a mobile device with an additional external antenna providing additional gain in the direction of the base station as an installed user terminal. This would then likely need a higher radiated power than 25 dBm. The company also indicated it was likely other users of the spectrum would wish to use a similar system.

13.79 The Real Wireless analysis has compared the spectral efficiencies for a fixed user terminal (also known as CPE or consumer premise equipment) and mobile terminal for three different potential interference geometries, as both a potential victim and interferer, and found the biggest difference calculated in the spectral efficiencies is less than 0.01 bps/Hz.

13.80 The 2.6 GHz band for TDD use has allowed higher power levels for both mobile and fixed or installed user terminals. The 2.6 GHz band allows for a mobile terminal to have a power of up to 31 dBm/5 MHz TRP and a fixed or installed terminal to have an EIRP of up to 35 dBm/5 MHz. These levels came from CEPT Report 19 *"Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS"* and were taken forward to the Commission Decision 2008/477/EC.

13.81 The ETSI/3GPP standard specifies the technical conditions for LTE mobile and has a maximum power of 23 dBm plus a 2 dB tolerance. We expect that the power level of 25 dBm TRP for mobile user terminals, which is currently within the draft ECC Decision, would be sufficient for mobile terminals. We propose that the power level used in the 2.6 GHz band for EIRP of up to 35 dBm/5 MHz would also be suitable for fixed or installed use within the 3.4 GHz band.

13.82 We propose that mobile user terminal equipment would be licence exempt but fixed or installed user terminal using a power higher than 25 dBm would not be licence exempt. For out of block emissions the limits of the user terminals will be defined by the appropriate technical standards.

13.83 Figure 13.18 sets out our proposed power limits for user terminals.

[115] We have considered coexistence with other uses when making our proposals outlined below and believe that cross border coordination can be managed

Figure 13.18: Proposed User Terminal in block power requirements

Radio equipment	Maximum mean power
Mobile or nomadic Radio Equipment	25 dBm TRP
Fixed or installed Radio Equipment	35 dBm / 5 MHz EIRP

Coordination requirements

13.84 As described earlier in this document, systems operating in the 2.3 and 3.4 GHz bands have potential to cause interference to other users of the radio spectrum. In order to mitigate the interference with existing military uses, licensees may need to coordinate their deployments with these users. We now set out the likely coordination provisions we are to place on licensees in the 2.3 GHz and 3.4 GHz bands.

International coordination requirements

13.85 The licensee will be required to operate radio equipment in compliance with the cross-border coordination that will be agreed with our international neighbours. These are likely to be based on internationally agreed criteria and we anticipate making further details available in the award Information Memorandum.

2.3 GHz band national exclusion and coordination requirements

13.86 The MoD has confirmed that it will have a requirement for continued on-going use within the 2.3 GHz band at two locations (St Kilda in the Outer Hebrides and Aberporth in West Wales) after the award of the spectrum.

13.87 Any risk of interference caused to a new user of spectrum within the 2.3 GHz band will be described in the Information Memorandum prior to the award. We do not expect it to be significant. However, there is a risk of harmful interference from new uses into the existing MoD use. Therefore, following discussions with the MoD, Ofcom has proposed an exclusion zone and coordination process that will protect the MoD uses from nearby 4G deployments in the 2.3 GHz band (details are given in Annex 12).

13.88 The MoD has also directed Ofcom that small coordination zones will be required around their sites at Oakhanger, Colerne and Menwith Hill in order to protect national security interests.

13.89 At present we are proposing an exclusion zone of about 170 km from St Kilda (Outer Hebrides). The area of the Outer Hebrides, the Isle of Skye and the Small Isles will not be included as part of the 2.3 GHz Award.

13.90 In addition to this, the following coordination requirements for licences awarded in the lower part of the 2.3 GHz release band are proposed:

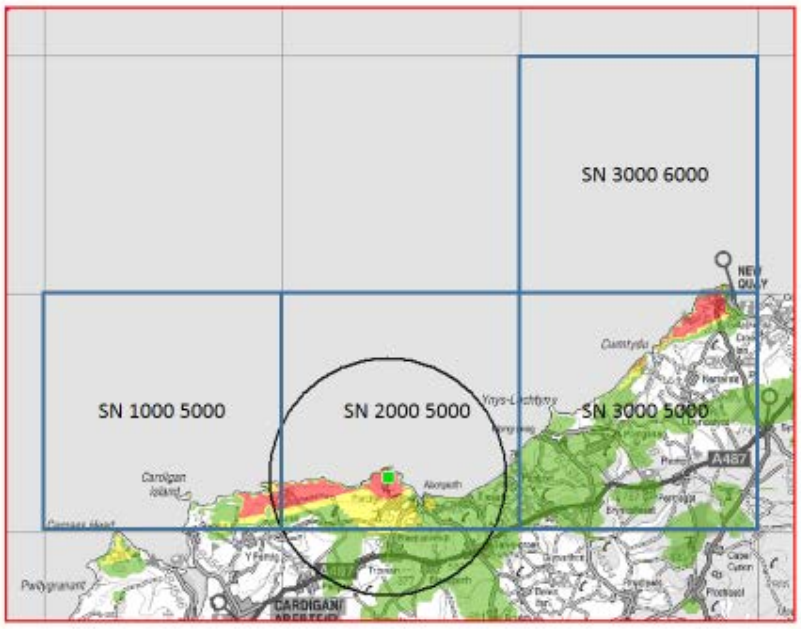
- Coordination between 170 and 225km from St Kilda for LTE sites.
- Coordination of a small coastal area around Aberporth, West Wales.

- Coordination within 5km of Oakhanger, Colerne and Menwith Hill

13.91 The MoD analysis suggests that the impact of the proposed coordination zone around St Kilda means that network deployments in parts of NW Scotland are likely to require careful deployment of locations and antennas in order to utilise the shielding effect of the local terrain. In some cases close to the west coast of Scotland antennas may need to be orientated away from St Kilda or transmit powers reduced. However, we do not think that this is likely to have a significant impact on the available services that can be offered in that area.

13.92 The MoD analysis suggests that the proposed coordination zone around Aberporth is unlikely to cause any significant restrictions on deployments in practice. In a few cases within about 20km linearly along the coast from Aberporth, this is likely to mean that local site engineering should be sufficient to ensure that deployments can take place. Careful selection of antenna directions and downtilt may be required within this area (as highlighted in the red and yellow areas of the figure below).

Figure 13.19: Coordination zones around Aberporth



13.93 The MoD analysis also suggests that the proposed coordination zones around Oakhanger, Colerne and Menwith Hill are unlikely to cause any significant restrictions on deployments in practice. In a few cases within 5km of each site, this is likely to mean that local site engineering should be sufficient to ensure that deployments can take place. Careful selection of antenna directions and downtilt may be required within this area.

3.4 GHz band national coordination requirements

13.94 The following coordination requirements will be applied to licenses awarded in the 3.4 GHz band:

- Related to continued MOD use around Bude,

- Related to aeronautical radars (similar to post remediation coordination in the 2.6 GHz band. Full details in section 11)

13.95 The MoD has confirmed that it will have a requirement for continued on-going use within the 3.4 to 3.6 GHz band at one location close to Bude in Cornwall after the award of the spectrum.

13.96 There will be no harmful interference caused to any existing or new user of spectrum within the 3.4GHz band. However, there is a risk of harmful interference from these new uses into the MoD use. Therefore, following discussions with the MoD, Ofcom has proposed a coordination process (details are given in annex 12) to protect the MoD uses from nearby LTE deployments in the 3.4 GHz band.

13.97 Our analysis suggests that this is likely to cause some significant restrictions to 3.4 GHz deployments within approximately 5 km of the MoD location. Out to 25km from the site, this is likely to mean that local site engineering should be sufficient to ensure that deployments can take place. Careful selection of antenna directions and downtilt may be required within this area.

13.98 As part of the 2.6 GHz award, a number of civil and military aeronautical navigation radars were remediated in order to make them less susceptible to interference from deployments. Part of this radiation also considered that a release of the 3.4 GHz band was likely, and protection for this band was also included.

13.99 Nevertheless, there remains a small risk of harmful interference to these radars as a result of deployments in the 3.4 GHz band. We are therefore proposing to require licensees to coordinate any base station whose in-band emissions would exceed a specific signal strength threshold at a radar location to coordinate with that particular location. We outlined the expected levels of necessary thresholds previously in this document and in annex 13. These are in line with the remaining post-remediation coordination with radars in the 2.6 GHz band.

13.100 We do not believe that these coordination requirements to protect aeronautical radars will provide significant restrictions on network deployments. It is likely to mean that local site engineering should be sufficient to ensure that deployments can take place. Careful selection of antenna pointing directions and downtilt may be required within a few kilometres of the radar location.

13.101 MoD analysis of military Navy radars and coexistence with new proposed services in the adjacent release bands is still on-going. It is therefore not yet clear whether any additional restrictions may be necessary to protect these military services. We will, however, provide confirmation in advance of the award.

Consultation questions

Question 13.1: Do you agree with our preference not to have a transitional region between blocks for licences in the 2.3 GHz band?

Question 13.2: Do you agree with our preference not to have a transitional region between blocks for licences in the 3.4 GHz band?

Question 13.3: Do you agree with our preference to not require synchronisation between different networks in the frequency band?

Question 13.4: Do you agree with our preference to include both the permissive (unsynchronised) and restrictive (synchronised) masks within the TLCs in the 2.3 GHz band?

Question 13.5: Do you agree with our preference to include both the permissive (unsynchronised) and restrictive (synchronised) masks within the TLCs in the 3.4 GHz band?

Question 13.6: Do you agree with our preference to not require synchronisation between different networks in the frequency band?

Question 13.7: Do you agree with our proposed maximum in band power limit for base stations in the 2.3 GHz band?

Question 13.8: Do you agree with our proposed maximum in band power limit for user terminals in the 2.3 GHz band?

Question 13.9: Do you agree with our proposed maximum in band power limit for base stations in the 3.4 GHz band?

Question 13.10: Do you agree with our proposed maximum in band power limit for user terminals in the 3.4 GHz band?

Section 14

Other licensed users of the 3.4 GHz award band

Introduction

14.1 This section of the consultation considers how we take account of UK Broadband as an incumbent mobile broadband user in the 3.4 GHz award band, with adjacencies to the 150 MHz spectrum that is to become newly available.

14.2 UK Broadband's allocation consists of two separate 20 MHz blocks, one at 3480-3500 MHz and one at 3580-3600 MHz. Its licence is currently valid until 2018. As discussed in section 5 we have previously consulted on relocating UK Broadband but are yet to reach a conclusion, therefore for the purposes of this consultation we consider the UK Broadband spectrum in its current position. However, if UK Broadband was relocated to a different position then our analysis is applicable in that context.

14.3 Emergency and Public Safety Services are also a current incumbent use (between 3440 and 3475 MHz) - but we expect that this use will be re-located to another band in cooperation with the MoD by the time of the award of the 3.4 GHz. It has therefore not been considered within this consultation document.

UK Broadband's Technical Licence Conditions

Prior to this consultation

14.4 In December 2010, after a number of consultations, we published a statement in preparation for the release of 3.4 GHz spectrum for mobile broadband systems in addition to that already licensed to UK Broadband. The associated technical conditions were based on the existing EC Decision 2008/411/EC, although we note that these conditions are due to be amended shortly (see below). Since that time there have been no additional licences issued in this band.

14.5 That statement recognised that the Commission decision seeks to balance different interests. On one hand, the decision requires member states to implement the conditions set out in its annex. These represent a compromise between spectrum efficiency and the protection of adjacent blocks under the assumptions of technical work at CEPT. On the other hand, the Commission decision is without prejudice to the protection of existing users.

14.6 We noted at that time that UK Broadband could have licence conditions consistent with EC Decision 2008/411/EC if they applied for them. We did not support the idea of a guard band between UK Broadband and potential new broadband wireless access (mobile broadband) users.

14.7 The technical conditions in the 2008/411/EC decision will be updated very shortly as a result of a commission mandate and we propose that the award of the 3.4GHz band should align with these revised conditions (see section 13).

UK Broadband analysis

14.8 As we have indicated in section 4, we anticipate that the spectrum currently licensed to UK Broadband is likely to be used for wireless broadband services after July 2018. We expect that this spectrum will have technical conditions consistent with those revised conditions expected for EC Decision 2008/411/EC. UK Broadband has the right to retain its current technical conditions for the remainder of its current licence period (until July 2018), although it also has the right to request amendment to these new harmonised conditions if it chooses. We have therefore considered two alternative cases:

- UK Broadband maintains its existing licence conditions;
- The spectrum currently held by UK Broadband will have the same technical conditions as we propose for any new licensees in the band. This is likely to be in July 2018 but could be earlier.

14.9 In the paragraphs below, we consider option 1) only, as option 2) is dealt with in our analysis of adjacent licensees in section 13. Figure 14.1, shows UK Broadband's existing block-edgemask; the new permissive mask and the restrictive mask we are proposing. The in block powers are compared in Figure 14.2.

Figure 14.1: Comparison of block edge masks

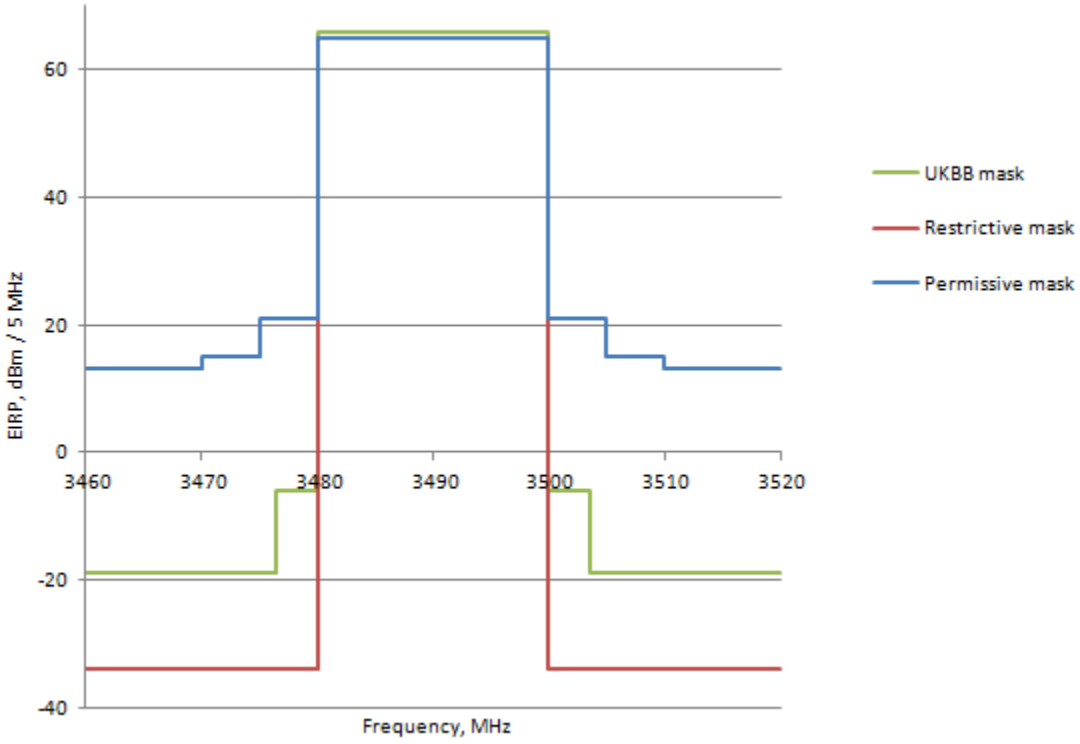


Figure 14.2: Comparison of in-band powers

License conditions	Mask	In-band power dBm / 5 MHz
UK Broadband	Radio equipment	66
	Mobile terminals	32
Proposed levels for award based on EC Decision 2008/411/EC	Base stations	65
	Fixed terminals	35
	Mobile terminals	25

14.10 As UK Broadband' current conditions don't specify the more permissive BEM, the benefits of a bilateral agreement are not equal between UK Broadband and its neighbour. Without any form of agreement, the neighbour will be required to use the more restrictive unsynchronised mask. We therefore consider that with the current UK Broadband conditions it has the potential to cause slightly more interference to the neighbour spectrum than a licensee with the new proposed conditions.

14.11 Firstly, UK Broadband is currently permitted slightly higher in-block power (EIRP) from its base stations and a different arrangement for power limits in its fixed and mobile terminals than our proposed new licence conditions (Figure 14.2). This applies whether there is a bilateral agreement between UK Broadband and the neighbouring licensee or not.

14.12 Secondly, where no bilateral agreements are in place, there is a higher level of permitted out of band emissions within 5MHz of the UK Broadband block edge. Although the baseline is 15dB higher, we consider that emissions will typically fall below this relatively quickly, and we do not consider the difference in baseline to be particularly material to the likely interference suffered by an adjacent licensee.

14.13 If UK Broadband were to agree to a bilateral agreement with a neighbour then UK Broadband's current out of band emissions are more restrictive.

14.14 As acknowledged in section 13 of this document, a licensee may in practice need an internal guard band of about 5 MHz to meet the restrictive mask baseline level (if they are unable to agree by bilateral agreement the use of the permissive mask). Therefore, unless UK Broadband has agreed the use of the permissive mask, the use of the adjacent spectrum will not cause any significant emissions into the UK Broadband spectrum.

14.15 Where UK Broadband has agreed the use of the permissive mask by the neighbour then we assume that UK Broadband will have considered any impact to their services

14.16 We are not, therefore, proposing any additional guard bands between UK Broadband and any adjacent licensee. An adjacent licensee will have to comply with the restrictive mask limit within the spectrum licensed to UK Broadband - unless they come to a bilateral agreement whereby the permissive mask can be used. This is consistent with our position from the December 2010 Statement.

Coordination Issues

14.17 In order to provide suitable protection for radar and MoD uses, we are proposing to put in place some coordination procedures around certain sites. Typically, the effects on these sites are cumulative and therefore the risk increases with the release of the additional 150 MHz of spectrum in the 3.4 GHz band.

14.18 We therefore propose that UK Broadband will need to comply with the following coordination procedures from the date that the first licence for part of the release spectrum comes into force. There is currently a condition in UK Broadband' licence (and all other WTA licences) requiring compliance with any coordination procedure applied by Ofcom.

Aeronautical Radars

14.19 Within this consultation document we are proposing a coordination procedure with radars for licensees in the 3.4 GHz band. This applies to both civilian and military radar sites. We are proposing the same approach we took for the earlier 2.6 GHz award. Section 11 and annex 13 set out how this will apply to aeronautical radars.

14.20 We do not believe that these coordination requirements will provide significant restrictions on network deployments, including those of UK Broadband. It is likely to mean that local site engineering should be sufficient to ensure that deployments can take place. Careful selection of antenna pointing directions and downtilt may be required within a few kilometres of the radar location.

MoD sites

14.21 As indicated earlier in this document there is potential for systems operating in the release bands to cause interference to MoD systems. For systems operating in the band 3410-3600 MHz a coordination procedure will be required around a MoD location at Bude. Annex 12 contains the specific coordination requirements around MoD sites.

Satellite

14.22 Subject to consultation, we do not plan to set coordination requirements with satellite Earth stations, but expect that local co-operation between interested parties would try to resolve any issue amicably if in the unlikely event that interference occurs. We understand that this is something that UK Broadband currently does, so this is not a change of position. This is likely to be confined to a fairly limited number of sites. Section 12contains further details about this issue.

Consultation questions

Question 14.1: Do you agree with our approach that it is not necessary to impose any guard bands or restricted blocks in order to manage the adjacencies between the incumbent UK Broadband and new users of spectrum to be awarded in the 3.4 GHz band?

Question 14.2: Do you agree with our approach to require UK Broadband to have the same coordination requirements as other users of the band?

Section 15

Next steps

15.1 This consultation will be open for responses from stakeholders and others until 15 May 2014 .We will consider all the responses we receive in full and intend to produce an information update later this year. This will signal our intentions – ahead of a full statement on the technical coexistence issues and our approach to the award.

15.2 The publication of this consultation should be viewed within a broader context of progress towards the award. It sits alongside a number of other events:

- Around March 2014 we expect the European Commission's Radio Spectrum Committee to confirm a CEPT decision to identify TDD as the preferred channelling arrangement at 3.4-3.6 GHz (i.e. including the 3.4 GHz award band) throughout Europe – but with FDD as an alternative for those administrations which would prefer to use it.

- Around April 2014 we intend to issue the statement on amateur use in the release bands (2.3 and 3.4 GHz) and adjacent spectrum bands.

- Around June 2014 we expect the European Electronic Communications Committee to confirm a draft decision setting out harmonised technical and regulatory conditions for the 2.3 GHz band based on TDD channelling arrangements only. This would not be binding on member states. However there may be a subsequent binding EC Decision based on this work around 2015

- In summer 2014 we intend to consult on proposals for auction design – including auction rules - and on non-technical licence conditions. The latter will be informed by responses to our earlier Call for Inputs on those aspects of the award.

- In spring 2015 we expect to be in a position to publish a full statement on auction design and technical coexistence issues, plus our Information Memorandum for the 2.3 and 3.4 GHz award.

- Between autumn and winter 2015 – on currently anticipated timelines – we could commence an auction process. This would be in line with the MoD's intention that an award process would be completed in the 2015/16 financial year, as set out in a press release of September 2013.

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on Thursday 15 May 2014.**

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/pssr-2014/howtorespond/form, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email PSSRcoexistence@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

A1.4 Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

John Glover
Floor 3
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact John Glover on 020 7981 3000.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether

all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website athttp://www.ofcom.org.uk/about/accoun/disclaimer/

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish an information update later in 2014. This will signal our intentions – ahead of a full statement on the technical coexistence issues and our approach to the award.

A1.12 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/static/subscribe/select_list.htm

Ofcom's consultation processes

A1.13 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.14 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your coversheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing ☐ Name/contact details/job title ☐

Whole response ☐ Organisation ☐

Part of the response ☐ if there is no separate annex, which parts?

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name Signed (if hard copy)

Annex 4

Consultation questions

A4.1 The questions below reflect those set out within the main body of the consultation. They are ordered and numbered as they appear in the respective sections of the document.

A4.2 Ofcom is an evidence based regulator. Where respondents disagree with our proposals – or with our assessments – we welcome evidence to support any alternative viewpoint.

Section 4

Question 4.1: Do you agree with our proposal to conduct a market led award through an auction process for licensed use of the 2.3 and 3.4 GHz bands? If not, please provide evidence to counter this proposal.

Question 4.2: Do you agree that we should not offer arrangements for aggregate bidding for low power use for these release bands? If you believe we should make such arrangements, please provide supporting evidence.

Section 6

Question 6.1: Do you have evidence to challenge our methodology and assumptions, which show the number of Wi-Fi routers likely to be affected by LTE interference is low?

Question 6.2: Do you have evidence to challenge our methodology and assumptions, which show the number of Wi-Fi client devices affected by LTE interference is low?

Question 6.3: Do you agree with our assessment of the available options for mitigation of interference to home networks?

Question 6.4: Do you agree with our assessment of the available options for mitigation of interference to public networks (both indoor and outdoor)?

Question 6.5: Do you agree with our assessment of the available options for mitigation of interference to Enterprise Networks?

Question 6.6: Do you agree with our conclusion that the impact to Wi-Fi is not of a significant nature and therefore no regulatory intervention is necessary? If not, can you provide evidence?

Section 7

Question 7.1: Do you agree that we do not need to perform technical analysis on the applications in the middle of the band as set out in paragraph 7.7?

Question 7.2: Do you agree with our technical analysis in relation to Bluetooth devices operating in the 2.4 GHz band, and that no additional restrictions are required in order to protect these applications?

Question 7.3: Do you agree with our technical analysis in relation to ZigBee devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.4: Do you agree with our technical analysis in relation to video sender devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.5: Do you agree with our technical analysis in relation to radio microphones devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.6: Do you agree with our technical analysis in relation to short range devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.7: Do you agree with our technical analysis in relation to medical devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.8: Do you agree with our technical analysis in relation to emergency services use in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Question 7.9: Do you agree with our technical analysis in relation to hearing aids and assisted listening devices operating in the 2.4 GHz band and that no additional restrictions are required in order to protect these applications?

Section 8

Question 8.1: Do you agree that the available mitigations address the potential shortfall of spectrum for PMSE at major events and that no additional regulatory intervention is necessary to protect PMSE in frequencies adjacent to the award bands?

Question 8.2: Do you agree that PMSE should have some continuing access to spectrum in the 3.4 GHz band until new services are rolled out in an area?

Question 8.3: Which option for the provision of information about the roll-out of new services is most the appropriate? Should the requirement to supply information apply only in designated locations?

Question 8.4: Do you agree that any continuing access should be limited to five years from the award of new 2.3 and 3.4 GHz licences?

Question 8.5: Do you agree with our assessment that there is little incremental benefit in on-going PMSE access to the 2.3 GHz award band?

Section 10

Question 10.1: Do you agree with our proposal that no coordination procedure is necessary in respect to maritime radar?

Section 11

Question 11.1: Do you agree with our proposal to require coordination procedures for the 3.4 GHz band - in order to protect of air traffic control radar - in line with those applied to the 2.6 GHz band?

Section 12

Question 12.1: Do you agree that for mobile satellite services operating in the band between 2170 and 2200 MHz, coexistence with LTE operating in the award bands above 2.35 GHz is unlikely to be an interference problem?

Question 12.2: Do you agree that satellite services operating in the band 2483.5 MHz to 2500 MHz can co-exist with LTE operating in the award bands (i.e. 2350 to 2390 MHz and 3410 to 3590 MHz) and there is unlikely to be an interference problem?

Question 12.3: Do you agree with that for satellite services operating between 2200 and 2290 MHz, coexistence with LTE operating in the release bands is unlikely to be an interference problem?

Question 12.4: Do you agree that for amateur satellite services operating between 2400 and 2450 MHz, coexistence with unwanted/out of band emissions of LTE operating in the release bands (the nearest release band is 2350 to 2390 MHz) is unlikely to be a greater problem than the current in-band interference from licence exempt and ISM uses?

Question 12.5: Do you agree with our preferred option to adopt our proposed mask with informal co-operation on a case-by-case basis if required?

Section 13

Question 13.1: Do you agree with our preference not to have a transitional region between blocks for licences in the 2.3 GHz band?

Question 13.2: Do you agree with our preference not to have a transitional region between blocks for licences in the 3.4 GHz band?

Question 13.3: Do you agree with our preference to not require synchronisation between different networks in the frequency band?

Question 13.4: Do you agree with our preference to include both the permissive (unsynchronised) and restrictive (synchronised) masks within the TLCs in the 2.3 GHz band?

Question 13.5: Do you agree with our preference to include both the permissive (unsynchronised) and restrictive (synchronised) masks within the TLCs in the 3.4 GHz band?

Question 13.6: Do you agree with our preference to not require synchronisation between different networks in the frequency band?

Question 13.7: Do you agree with our proposed maximum in band power limit for base stations in the 2.3 GHz band?

Question 13.8: Do you agree with our proposed maximum in band power limit for user terminals in the 2.3 GHz band?

Question 13.9: Do you agree with our proposed maximum in band power limit for base stations in the 3.4 GHz band?

Question 13.10: Do you agree with our proposed maximum in band power limit for user terminals in the 3.4 GHz band?

Section 14

Question 14.1: Do you agree with our approach that it is not necessary to impose any guard bands or restricted blocks in order to manage the adjacencies between the incumbent UK Broadband and new users of spectrum to be awarded in the 3.4 GHz band?

Question 14.2: Do you agree with our approach to require UK Broadband to have the same coordination requirements as other users of the band?

Annex 5

Table of references

A5.1 This annex lists the external reports commissioned by Ofcom or the Ministry of Defence in connection with the award of the 2.3 and 3.4 GHz bands and referenced elsewhere in this consultation.

Topic	Author	Full title	Link
Wi-Fi measurements	MASS	Study to Determine the Potential Interference from TDD LTE into Wi-Fi Annex: Test Results	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Potential_Interference_from_TDD_LTE.pdf To be published in due course
Wi-Fi analysis	Siradel	Prediction study of LTE Received signal strengths at short distances from base stations	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Prediction_Study.pdf
Wi-Fi analysis	CGI	LTE into Wi-Fi Additional Analysis	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/LTE_into_Wi-Fi_Additional_Analysis.pdf
Bluetooth measurements	MAC	The Effect of TDD LTE Signals in the 2.3 to 2.4 GHz band on Bluetooth Equipment Operating in the 2.4 GHz ISM band	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/The_Effect_of_TDD_LTE_Signals.pdf

Topic	Author	Full title	Link
ZigBee measurements	MAC	A Study to Determine the Potential for Harmful Interference from TDD LTE Systems Operating in the 2300 – 2400 MHz Band into ZigBee Devices	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexesHarmful_Interference.pdf
LE Band audit	CGI	ISM Band Audit (Audit of the LE 2400 MHz band)	http://stakeholders.ofcom.org.uk/binaries/consultations/2400-mhz/annexes/audit.pdf
LE Band market study	CGI	ISM LE Band Audit (Market Study of the LE 2400 MHz band)	http://stakeholders.ofcom.org.uk/binaries/consultations/2400-mhz/annexes/market-study.pdf
Capacity and synchronisation analysis	Real Wireless	Assessment of Capacity Impacts with Various TD-LTE Block Configurations	http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Capacity_Impacts.pdf

Annex 6

Glossary of terms

2G: 2nd generation mobile technology

3G: 3rd generation mobile technology

3GPP: 3rd Generation Partnership Project (standards body)

4G: 4th generation mobile technology

6lowpan: standard proposed for low power machine 2 machine applications

AFH: Adaptive Frequency Hopping

AGC: Automatic gain control

ALD: Assisted Listening Device

ATC: Air Traffic Control

ATM: Air Traffic Management

BEM: Block Edge Mask

Bluetooth: brand name for part of 802.15 PAN standards

BS: Base station

CDF: Cumulative distribution function

CEPT: European Conference of Postal and Telecommunications Administrations

CPE: Customer Premises Equipment

CW: Continuous Wave

DECC: Department for Energy and Climate Change

DSSS: Direct Sequence Spread Spectrum

ECC: Electronic communications Committee

EIRP: Equivalent Isotropic Radiated Power

ES: earth station (satellite)

ETSI: European Telecommunications Standards Institute (standards body)

FAT: Frequency Allocation Table

FDD: Frequency Division Duplex

Femtocell: small low power mobile communications base station

FHSS: Frequency Hopping Spread Spectrum

GPRS: General Packet Radio Service (2G data service)

GSA: Global Suppliers Association

HAN: Home Area Network

IEEE 802.11: family of Wi-Fi standards

IEEE 802.15: family of PAN standards (includes Bluetooth and ZigBee)

IEEE: Institute of Electrical and Electronics Engineers (standards body)

ISM: Industrial Scientific and Medical

ITU: International Telecommunications Union

LE: Licence Exempt

LNB: Low Noise Block (used on satellite receive dishes)

LRTC: Least Restrictive Licence Conditions

LSA: Licensed Shared Access

LTE: Long Term Evolution (4^{th} generation mobile technology)

M2m: machine to machine

Macrocell: high power mobile communications base station

MCA: Maritime and Coastguard Agency

MFCN: Mobile/Fixed Communications Networks

Microcell: medium power mobile communications base station

MoD: Ministry of Defence

NINP: non-interference non-protection

NRA: national regulatory authority

OFDM: Orthogonal Frequency Division Multiplexing

OOB: Out-of- band (emissions)

PAN: Personal Area Network

PES: permanent earth station (satellite)

Picocell: small low to medium power mobile communications base station

PMSE: Programme Making and Special Events

RF: Radio frequency

RFID: Radio Frequency Identification

RSA: Recognised Spectrum Access (licensing product)

SINR: Signal to Interference plus Noise Ratio

SRD: Short Range Device

TDD: Time Division Duplex

TD-LTE: LTE using TDD

TLC: Technical Licence Conditions

TRP: Total Radiated Power

UE: User equipment

UMTS: Universal Mobile Telecommunications Service (3G)

Wi-Fi: Wireless Fidelity

WLAN: Wireless Local Area Network

ZigBee: brand name for part of 802.15 PAN standards