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Re: IEEE 802.15-09-0230-00-0thz

Abstract: This document is a follow-up and update of doc. IEEE 802.15-09-0230-00-0thz. It provides an overview on the status of preparation activities for agenda item 1,6 at WRC 2012 and its implications for future THz communication systems operating beyond 275 GHz.

Purpose: Information of THz IG on ongoing discussion towards WRC 2012

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Outline

- Agenda 1.6 at WRC 2012
- Background information on passive services
- Spectrum options for active services
- Current options under discussion for changing footnote 5.565 of the Radio Regulations
- Status of the international discussion
- Next steps

Agenda item 1.6 of WRC 2012

- 1.6: *to review No. 5.565 of the Radio Regulations in order to update the spectrum use by the passive services between 275 GHz and 3 000 GHz, in accordance with Resolution 950 (Rev.WRC-07), and to consider possible procedures for free-space optical-links, taking into account the results of ITU-R studies, in accordance with Resolution 955 (WRC-07);*

Current Situation in Radio Regulations

Footnote 5.565 *The frequency band 275-1 000 GHz may be used by administrations for experimentation with, and development of, various active and passive services. In this band a need has been identified for the following spectral line measurements for passive services:*

- *radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;*
- *Earth exploration-satellite service (passive) and space research service (passive): 275-277 GHz, 294-306 GHz, 316-334 GHz, 342-349 GHz, 363-365 GHz, 371-389 GHz, 416-434 GHz, 442-444 GHz, 496-506 GHz, 546-568 GHz, 624-629 GHz, 634-654 GHz, 659-661 GHz, 684-692 GHz, 730-732 GHz, 851-853 GHz and 951-956 GHz.*

Future research in this largely unexplored spectral region may yield additional spectral lines and continuum bands of interest to the passive services. Administrations are urged to take all practicable steps to protect these passive services from harmful interference until the date when the allocation Table is established in the above-mentioned frequency band. (WRC-2000)

Implication of AI 1.6 on Active Services

- In the current version footnote 5.565 of the Radio Regulations active services are explicitly mentioned.
- Since under agenda item 1.6 passive services only are under discussion there is a possibility that the term *active services* may disappear in the footnote.
- Moreover, identification of certain bands for passive services should not preclude future consideration of these bands for active services.

Some Background Information on Passive Services

- There are two different passive services to be considered:
 - Radio Astronomy Service and Space Research Service for Radio Astronomy Observations (RAS-SRS)
 - Earth Exploration-Satellite Service and Space Research Service for Passive Remote Sensing (EESS-SRS)
- The background information presented in the next couple of slides is mainly taken from [2,3]

Radio Astronomy (RAS-SRS)

- Purpose:
 - Understanding molecules state
 - Currently 2241 molecular transitions for more than 220 molecules in the atmospheric window between 275 and 3000 GHz are known
 - Doppler shift plays an important role for investigating distant galaxies
- Spectrum requirements:
 - Difficult to identify individual molecular transitions within the known atmospheric bands
 - Access to the whole frequency range 275-1000 GHz is important for RAS-SRS

Operational Conditions for Radioastronomy

- Earth atmosphere prevents doing radio astronomy observations in the Thz frequency range except at a small number of high mountain plateaus:
 - Plateau de Bure (France)
 - Pico Veleta (Spain)
 - James Clark Maxwell Telescope (Hawaii)
 - Atacama (Chile)
- Implications to active services:
 - avoiding operation of active services in close proximity to these high mountain plateaus

Earth Exploration Satellite Services (EES)

- Purpose:
 - Meteorology/Climatology
 - Cloud ice and water vapour measurements in the upper troposphere
 - Atmospheric Chemistry
- Spectrum requirements:
 - Earth atmosphere beyond 1000 GHz is virtually opaque => terrestrial active services do not practically interfere for frequencies beyond 1000 GHz
 - Currently no statement on the implications of active services on EESS below 1000 GHz is made
 - Detailed spectrum requirements provided by the Space-Frequency Coordination Group (see following slides taken from [2])

Consolidated Table of Passive Bands of Interest for EESS (1/4)

Frequency band(s) (GHz)	N° 5.565	Total Bandwidth required (MHz)	Spectral line(s) (GHz)	Measurement			Typical Scan Mode	Existing or planned Instrument (s)	Supporting information
				Meteorology – Climatology	Window	Chemistry			
275-285.4	275-277	10 400	276.33 (N ₂ O), 278.6 (ClO)		276.4-285.4	N ₂ O, ClO, NO	Limb		Chemistry (275-279.6), Window (276.4-285.4)
296-306	294-306	10 000	Window for 325.1, 298.5 (HNO ₃), 300.22 (HOCl), 301.44 (N ₂ O), 303.57 (O ₃), 305.2 (HNO ₃), 304.5 (O ¹⁷ O)	Wing channel for temperature sounding	296-306	OXYGEN, N ₂ O, O ₃ , O ¹⁷ O, HNO ₃ , HOCl	Nadir, Limb	MASTER	Window (296-306 GHz), Chemistry (298-306)
313.5-355.6	316-334, 342-349	42 100	{318.8, 345.8, 344.5} (HNO ₃), 313.8 (HDO), {321.15, 325.15} (H ₂ O), {321, 345.5, 352.3, 352.6, 352.8} (O ₃), {322.8, 343.4} (HOCl), 345.8 (CO), {345.0, 345.4} (CH ₃ Cl), 345.0 (O ¹⁸ O), 354.5 (HCN), 349.4 (CH ₃ CN), {315.8, 346.9, 344.5, 352.9} (ClO), 351.67 (N ₂ O), 346 (BrO)	WATER VAPOUR PROFILING, CLOUD, Wing channel for temperature sounding	339.5-348.5	H ₂ O, CH ₃ Cl, HDO, ClO, O ₃ , HNO ₃ , HOCl, CO, O ¹⁸ O, HCN, CH ₃ CN, N ₂ O, BrO	Nadir, Conical, Limb	PREMIER, CIWSIR, MASTER, MWI, GOMAS, GEM	Water vapour line at 325.15 (BW: 3 GHz, max. offset: 9.5 GHz), CIWSIR Water line (314.15-336.15), MASTER Chemistry (321-326), Cloud Measurements {331.65-337.65, 314.14-348, 339-348, 314.14-317.15, 320.45-324.45, 325.8-329.85, 336-344, 339-348}, Window (339.5-348.5), GEM/MASTER Chemistry (342-346), PREMIER Chemistry {343.6-355.6, 313.5-325.5}, MWI cloud ice and cirrus (313.95-317.35, 332.95-336.35)
361-365	363-365	4 000	364.32 (O ₃)	Wing channel for water vapour profiling		O ₃	Nadir, Limb	GOMAS	GOMAS Water vapour (361-363), Chemistry (363-365)

Consolidated Table of Passive Bands of Interest for EESS (2/4)

361-365	363-365	4 000	364.32 (O_3)	Wing channel for water vapour profiling		O_3	Nadir, Limb	GOMAS	GOMAS Water vapour (361-363), Chemistry (363-365)
369.2-391.2	371-389	22 000	380.2 (H_2O)	WATER VAPOUR PROFILING			Nadir, Limb	GEM, GOMAS	Water vapour line (369.2-391.2, BW: 3 GHz, max. offset: 9.5 GHz), GEM/GOMAS Water vapour sounding (379-381), Water vapour profiling (371-389), Polar-orbiting and GSO satellites (FY4) for precipitation over snow-covered mountains and plains (380)
397-399		2000		WATER VAPOUR PROFILING				GOMAS	
409-411		2000		Temperature sounding			Limb		
416-433.46	416-434	17 460	424.7 (O_2)	OXYGEN, Temperature profiling			Nadir, Limb	GEM, GOMAS	Oxygen line (416.06-433.46, BW: 3 GHz, max. offset: 7.2 GHz), GEM/GOMAS Oxygen (416-433)
439.1-466.3	424-444	27 200	{443.1, 448} (H_2O), 443.2 (O_3), 442 (HNO_3)	WATER VAPOUR PROFILING, CLOUD	458.5-466.3	O_3 , HNO_3 , N_2O , CO	Nadir, Limb, Conical	MWI, CIWSIR,	Water line (439.3-456.7, BW: 3 GHz, max. offset: 7.2 GHz), Cloud measurements (452.2-458.2, 444-447.2, 448.8-452, 459-466), MWI cloud ice and cirrus (439.1-442.5, 453.5-456.9), Chemistry (442-444), Window (458.5-466.64)
477.75-496.75		19 000	487.25 (O_2)	OXYGEN, Temperature Profiling			Limb	ODIN	Oxygen line (477.75-496.75, BW: 3 GHz, max. offset: 8 GHz), ODIN Oxygen (486489)
497-502	496-506	5000	497.9 ($N_2^{18}O$), {497.6, 497.9} (BrO), 498.6 (O_3)	Wing channel for water vapour profiling	498-502	O_3 , CH_2Cl , $N_2^{18}O$, BrO , ClO	Limb, Nadir	SOPRANO, MASTER, ODIN	Chemistry SOPRANO/ODIN/MASTER (497-499), Water window (498-502)
523-527		4 000	Window for 556.9	Wing channel for water vapour profiling	523-527		Nadir		

Consolidated Table of Passive Bands of Interest for EESS (3/4)

538-581	546-568	43 000	{541.26, 542.35, 550.90, 556.98} (HNO₃), 556.93 (H₂O), {544.99, 566.29, 571.0} (O₃), 575.4 (ClO)	WATER Vapour Profiling	538-542	HNO ₃ , O ₃ , ClO	Nadir, Limb	ODIN	Water window (538-542), Chemistry (541-558), ODIN water vapour profiling (546-568), ODIN water vapour sounding (552-562), ODIN Chemistry (563-581)
611.7-629.7	624-629	18 000	620.7 (H₂O), 624.27 (ClO₂), {624.34, 624.89, 625.84, 626.17} (SO₂), {624.48, 624.78} (HNO₃), 624.77 (⁸¹BrO), 624.8 (CH₃CN), 625.04 (H₂O₂), 625.37 (O₃), 624.98 (H³⁷Cl), 625.92 (H³⁵Cl), 627.18 (CH₃Cl), 627.77 (O¹⁸O), {625.07, 628.46} (HOCl), 625.66 (HO₂)	WATER Vapour Profiling, OXYGEN		OXYGEN, ClO ₂ , SO ₂ , BrO, O ₃ , H ³⁵ Cl, CH ₃ Cl, O ¹⁸ O, HOCl, HO ₂ , HNO ₃ , CH ₃ CN, H ₂ O ₂	Limb	MLS, SMILES, SOPRANO	Water line (611.7-629.7, BW: 3 GHz, max. offset: 7.5 GHz), MLS/SMILES/SOPRANO Chemistry (624-629)
634-654	634-654	20 000	635.87 (HOCl), 647.1 (H₂¹⁸O), 649.45 (ClO), 649.24 (SO₂), 649.7 (HO₂), 650.18 (⁸¹BrO), 650.28 (HNO₃), 650.73 (O₃), 651.77 (NO), 652.83 (N₂O)	Wing channel for water vapour profiling	634.8-651	H ₂ ¹⁸ O, HOCl, ClO, HO ₂ , BrO, HNO ₃ , O ₃ , NO, N ₂ O, SO ₂	Limb, Nadir	MLS, SMILES	MLS/SMILES Chemistry (634-654), Window (634.8-651)
656.9-692	659-661, 684-692	35 100	658 (H₂O), 660.49 (HO₂), 688.5 (CH₃Cl), 691.47 (CO), 687.7 (ClO)	WATER Vapour Profiling, CLOUD	676.5-689.5	HO ₂ , ClO, CO, CH ₃ Cl	Limb, Nadir, Conical	CIWSIR, MWI, MLS	Water line (669.7-676.5), Window (658.3-669.7, 676.5-689.5), Cloud Measurements {665.2-671.2, 677-692}, MLS Chemistry (659-661), CIWSIR Chemistry (677-692)
713.4-717.4		4 000	715.4 (O₂)	OXYGEN			Limb		

Consolidated Table of Passive Bands of Interest for EESS (4/4)

729-733	730-732	4 000	731 (HNO_3), 731.18 (O^{18}O)	OXYGEN		O^{18}O , HNO_3	Limb		
750-754		4 000	752 (H_2O)	WATER			Limb		
771.8-775.8		4 000	773.8 (O_2)	OXYGEN			Limb		
823.15-845.15		22 000	834.15 (O_2)	OXYGEN					Oxygen line (823.15-845.15, BW: 3 GHz, max. offset: 9.5 GHz)
850-854	851-853	4 000	852 (NO)			NO	Limb		
857.9-861.9		4 000	859.9 (H_2O)	WATER			Limb		
866-882		16 000		CLOUD, WINDOW			Conical	CIWSIR	Cloud Measurements {866.5-869.5, 868-881, 878.5-881.5}, Window (866.9-881.9)
905.17-927.17		22 000	916.17 (H_2O)	WATER					
951-956	951-956	5 000	952 (NO), 955 (O^{18}O)	OXYGEN		O^{18}O , NO	Limb	SOPRANO	
968.31-972.31		4 000	970.3 (H_2O)	WATER			Limb		
985.9-989.9		4 000	987.9 (H_2O)	WATER			Limb		

Ground and Balloon based Remote Sensing

- In addition to EESS also ground and balloon based remote sensing (aeronomy) is under discussion
- Spectrum requirements below 1000 GHz are given in the table from [2]

Frequency band(s) (GHz)	Total Bandwidth required (MHz)	Spectral line(s) (GHz)	Platform
275 – 294	21 000	275.0: NO ₂ 275.2: SO ₂ 276.3: N ₂ O 278.6: ClO 281.8: HNO ₃ 293.5: O ₃	Ground
624-629	5 000	624.3: SO ₂ 624.8: BrO 625.9-625.94: HCl 626.7: O ₃ 627.1: H ₂ O ₂ 627.8: O ₂ 628.5: HOCl	Balloon
649-653	4 000	649.5: ClO 649.7: HO ₂ 650.3: HNO ₃ 650.7: O ₃ 651.8: NO 652.8: N ₂ O	Balloon

Spectrum Options for Active Services

- Assuming that it will be technically possible to avoid transmission close to the high mountain plateau radio astronomy stations EESS remains the most critical service to be considered.
- Active services may be operated in frequency bands not used by EESS without any further restrictions.
- Use of active services in same bands (sharing option) with EESS requires interference studies.

Potential Non-Sharing Spectrum for Active Services

Frequency Bands	Total available Bandwidth
286-294 GHz*	8 GHz
307-313 GHz	7 GHz
356-361 GHz	5 GHz
366-369 GHz	3 GHz
392-397 GHz	5 GHz
399-409 GHz	10 GHz
411-416 GHz	5 GHz
434-439 GHz	5 GHz
467-477 GHz	10 GHz
502-523 GHz	21 GHz
527-538 GHz	11 GHz
581-611 GHz	30 GHz
629-634 GHz	5 GHz

* currently under discussion for use by Areonomy

Frequency Bands	Total available Bandwidth
692-713 GHz	21 GHz / 19 GHz
718-729 GHz	11 GHz
733-750 GHz	17 GHz
755-771 GHz	16 GHz
776-823 GHz	47 GHz / 28 GHz
846-850 GHz	4 GHz
854-857 GHz	3 GHz
862-866 GHz	4 GHz
882-905 GHz	13 GHz
928-951 GHz	23 GHz
956-968 GHz	12 GHz
973-985 GHz	12 GHz
990-1000 GHz	10 GHz

bold: bandwidth within atmospheric windows

Current Options for the modification of the footnote

- Option 1:
 - update the frequency used by passive service.

- Option 2:
 - update the frequency used by passive service
 - reference to two resolutions (one for each passive services) describing the objectives of the use of these frequencies.

Why are the Resolutions relevant for Active Services?

- The resolutions contain detailed descriptions how the passive services will make use of the spectrum.
- In case of sharing bands between active and passive services such a description provides important input to the required interference studies.

What could be achieved for Active Services at WRC 2012?

- When rephrasing footnote 5.565 the term *active services* may not disappear. The wording footnote shall not prevent experiments with and development of active services.
- Adding references to resolutions describing operational conditions of passive services will be the preferred solution.
- The definition of an agenda item for WRC 2015 on spectrum allocation for active services may be of interest.

What is the Status in the international Discussion?

- The following slides summarize the current preliminary positions of different regional telecommunication organisations (source [2]):
 - CEPT (Europe)
 - APT (Asia)
 - CITEL (Americas)
 - Arab Group

CEPT (April 2010)

- CEPT supports the review of No. **5.565** considering in particular new technological advancements and planned applications for passive services (EESS, RAS and Space Research) to allow early assessment of scientific and meteorological next generation equipments.
- CEPT recognizes that the identification of possible use of certain bands in the range 275-3000 GHz by the passive services **shall not automatically preclude future consideration of these bands for active services.**
- However, CEPT is also of the view that the identification of bands for passive service should not be conditioned by identification for use by other services, as this item does not deal with allocations for either active or passive services. To this respect, CEPT supports on-going work within WP 7C and 7D on detailed definition of passive services requirements.
- CEPT believes that, considering specificities of different passive services/applications under consideration and the need to consider detailed requirements, this agenda item should lead to a **revision of N° 5.565 that would refer to 2 different Resolutions**, respectively addressing EESS/SRS at one hand and Radioastronomy/SRS and ground based passive sensing (Aeronomy) at the other hand.;
- CEPT supports a revision of RR N° **5.565** including a list of frequency bands and a reference to two Resolutions

CITEL (November 2009)

Preliminary View (Brazil, Canada and USA) on Resolution 950:

Support the modification of No. **5.565** to include all appropriate bands of interest to RAS, EESS (passive), and SRS (passive) in the range 275 – 3000 GHz based upon studies being conducted in Study Group 7. The identification of bands for use by the passive services above 275 GHz should not preclude the use of these bands by the active services in the future.

APT (March 2010)

- APT Members support to review No. 5.565 of the Radio Regulations and update the spectrum use by passive services in the range 275-3 000 GHz, taking into account the results of ITU-R studies related to Resolution 950 (Rev.WRC-07).
- One Member of APT is of the view that
 - The results of studies should not lead to monopolizing spectrum for passive services; **recognizing an identification of possible use of certain bands for passive services should not preclude future consideration of these bands for active services.** However, such identification should not be conditioned by identification for use by other services.
 - The on-going studies within the ITU-R should aim at, among other things, to the definition of passive services requirements. **Such studies should lead to a revision of N° 5.565 that would refer to corresponding Resolutions**
 - In connection with the regulatory methods to satisfy this agenda item (1.6/1) , both Methods are acceptable at this stage, since actually , Method B is similar to Method A which proposes, in addition to the Resolutions referenced in N° 5.565, also to include in RR 5.565 the list of frequency bands for passive services

Arab Group (March 2010)

- Support MOD of the footnote 5.565 to determine specific allocations of the passive services, in the band 275-3000 GHz by either:
 - Referring in this footnote to the Relevant Resolution(s),
or
 - Mentioning specifically these frequency bands in this
footnote

Next Steps

- Active contributions to the ongoing discussions in the different national or regional organisations.
- Discussion on agenda item for WRC 2015.
- Identification of overall spectrum demand for THz communications.
- Interference studies especially with EESS.

References

- [1] WRC agenda item 1.6 and its possible implications on THz communications, doc. IEEE 802.15-09-0230-00-0thz
- [2] Revised Draft CEPT Brief on Agenda Item 1.6, PT B(10)043 Annex 4, <http://www.ero.dk>
- [3] Revised PRELIMINARY DRAFT EUROPEAN COMMON PROPOSAL, PT B(10)043 Annex 3, <http://www.ero.dk>