ECC REPORT 124

Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COEXISTENCE BETWEEN FIXED SERVICE OPERATING IN 71-76 / 81-86 GHz AND THE PASSIVE SERVICES

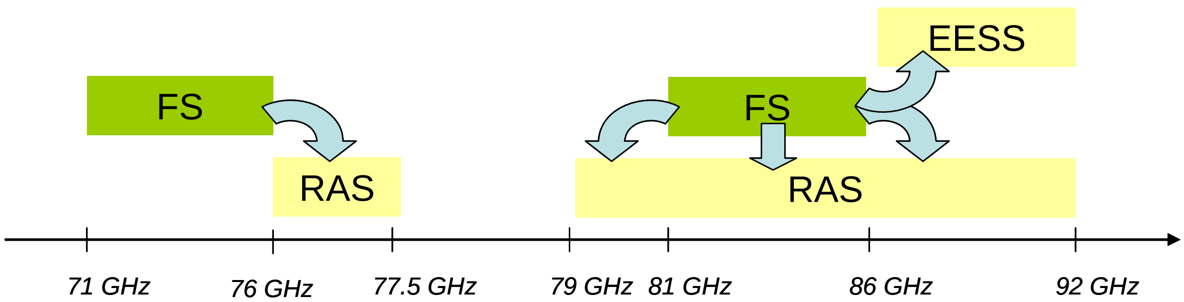
Vilnius, September 2008

0 EXECUTIVE SUMMARY

This report was developed in order to assist ETSI in the definition of appropriate unwanted emission limits in shared and adjacent bands for FS operating in the bands 71 – 76/81 – 86 GHz.

The definition of unwanted emissions limits is based on the following compatibility studies:

1. Protection of Earth Exploration Satellite Service (EESS) stations operating in the bands 86-92 GHz from unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;
2. Protection of Radio Astronomy Service (RAS) stations operating in the bands 76-77.5 GHz from unwanted emissions of Fixed Service stations operating in the band 71-76 GHz;
3. Protection of RAS stations operating in the bands 79-92 GHz from both in-band and unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;



The following results were achieved:

Active service	Passive Service	Conclusion
FS in the band 81-86 GHz	EESS in the band 86-92 GHz	For the FS operating in the band 81-86 GHz, the following unwanted emission mask in the band 86 – 89 GHz is proposed starting with -41 dBW/100 MHz at 86 GHz and decaying to -55 dBW/100MHz at 87 GHz (see section 3.4).
FS in the band 81-86 GHz	RAS in the band 81-86 GHz	Any FS station should not be in LoS from the RA station.
FS in the band 71-76 GHz	RAS in the band 76-77.5 GHz	A separation distance between the RAS station and the FS station should be considered depending on the FS station orientation. This separation distance should be determined on a case-by-case basis by national Administrations.
FS in the band 81-86 GHz	RAS in the bands 79-81 and 86-92 GHz	

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
CEPT	European Conference of Postal and Telecommunications Administrations
CRAF	Committee on Radio Astronomy Frequencies
ECA	European Common Allocation Table
EESS	Earth Exploration Satellite Service
ETSI	European Telecommunications Standards Institute
FS	Fixed Service
LoS	Line Of Sight
Pfd	Power Flux Density
RAS	Radio Astronomy Service
VLBI	Very Long Base Interferometry
WRC	World Radiocommunication Conference

Coexistence between Fixed Service operating in 71-76 / 81-86 GHz and the passive services

1 INTRODUCTION

This report was developed in order to assist ETSI in the definition of appropriate unwanted emission limits in adjacent bands for FS operating in the bands 71 – 76/81 – 86 GHz.

The definition of unwanted emissions limits is based on the following compatibility studies:

1. Protection of Earth Exploration Satellite Service (EESS) stations operating in the bands 86-92 GHz from unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;
2. Protection of Radio Astronomy Service (RAS) stations operating in the bands 76-77.5 GHz from unwanted emissions of Fixed Service stations operating in the band 71-76 GHz;
3. Protection of RAS stations operating in the bands 79-86 GHz and 86-92 GHz from unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;

Figure 1 summarizes the different compatibility schemes studied.

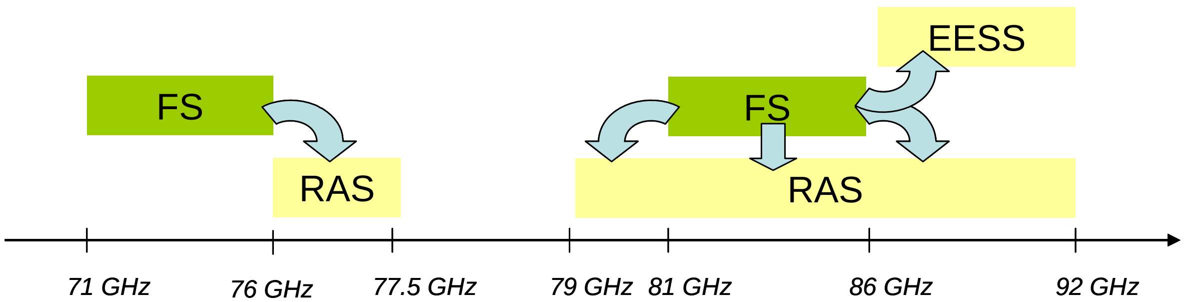

Figure 1: Compatibility schemes assessed in various studies

2 FIXED SERVICE CHARACTERISTICS

2.1 FS transmitter characteristics

Recommendation ECC/REC 05-07 contains information about channel arrangement for FS system operating in the bands 71-76 / 81-86 GHz.
The ETSI standard EN 302 217-3 [4] describes the characteristics and requirements for point-to-point equipments and antennas. The masks contained in this standard give the maximum antenna sidelobe levels not to be exceeded. However, in this report which considers the aggregate effect of several thousand FS links on passive sensors, recommendation ITU-R F.1245 was used.

The transmitter power spectral density mask for FS in 81-86 GHz is presented in Figure 12 of Annex C.

Typical FS applications are expected to operate in this frequency band with bandwidths below 1250 MHz and such systems are expected to be deployed in urban and sub-urban areas.

2.2 Typical FS deployment and assumptions taken in studies

FS stations operating in the bands 71-76 GHz and 81-86 GHz are expected to operate at typical elevation angles lower than 20°. However it was also considered possible to have a relatively low number of FS links deployed with elevation angles up to 90°.

Some administrations provided information on deployment of FS links in bands above 37 GHz, showing that around 99% of them operate at angles below 20°.
The maximum density of FS links that may be deployed within an area has been assessed using the methodology contained in ECC report 20 [5]. The detailed calculation is given in Annex A. A density of 0.5 links per km² per frequency channel was assumed in this report but is limited to areas with high population densities (hot spots). 20 hot spots around major

European cities were assumed with a total of around 24,000 links, of which 1% (i.e. 240) was assumed to have elevation angles above 20° with uniform distribution. Outside the hot spots (further on considered as background deployment), an additional 100,000 links has been assumed within a reference area of 2,000,000 km^2. Assuming 15% of water within this reference area and restricting this number to landmass results in a maximum density of 0.06 links per km^2. The same number of links as for hot spots (i.e. 240) was assumed to have elevation angles above 20° with uniform distribution resulting in 0.24% outside the hot spots. The total percentage of high elevation links is hence 0.39% within the reference area of 2,000,000 km^2.

3 PROTECTION OF EARTH EXPLORATION SATELLITE SERVICE (EESS) STATIONS OPERATING IN THE BANDS 86-92 GHZ FROM UNWANTED EMISSIONS OF FIXED SERVICE STATIONS OPERATING IN THE BAND 81-86 GHZ

3.1 EESS Characteristics and protection criteria

ITU-R is currently developing a recommendation giving the characteristics of EESS passive sensors operating below 275 GHz (see Annex B).

In addition Recommendation ITU-R RS.1029 [3] provides the protection criterion for EESS operating in the frequency range 86-92 GHz which is a maximum received allowable power of -169 dBW in 100 MHz (see red spot in figures 4 to 6). This level may be exceeded for less than 0.01% of the time (for a 0.01% level, the measurement area is a square on the Earth of 2,000,000 km^2, unless otherwise justified).

Passive sensors are designed to have a high main beam efficiency resulting in slightly wider main beam and lower sidelobe levels. A typical antenna pattern for AMSU-A is shown in Figure 2.

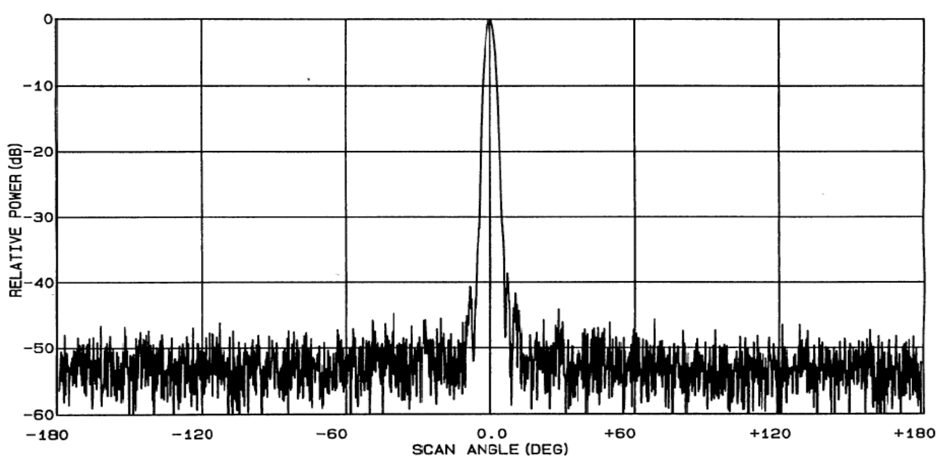

Figure 2: Typical AMSU-A antenna pattern around 89GHz

This makes sensors slightly more vulnerable to interference received in the main lobe but much more robust against interference received via side lobes. ITU-R is currently in the process of finalizing a new recommendation on suitable sensor antenna patterns to be used for interference assessment

3.2 Dynamic analysis with AMSU-A, MHS and CMIS sensors

A dynamic analysis has been conducted where the impact of an assumed distribution of FS stations over Europe within a reference area of 2,000,000 km^2 has been considered. This is a very time consuming process as the sensor scans the entire area and integrates the interference of many thousands of FS transmitters at each pixel. A number of simulation runs has been conducted and a summary of the most representative cases has been selected. Simulation duration was around 4 minutes for every pass over Europe with time steps of 320 or 32 ms, respectively. Figure 3 shows an overview of the assumed hot spot distribution and background density.

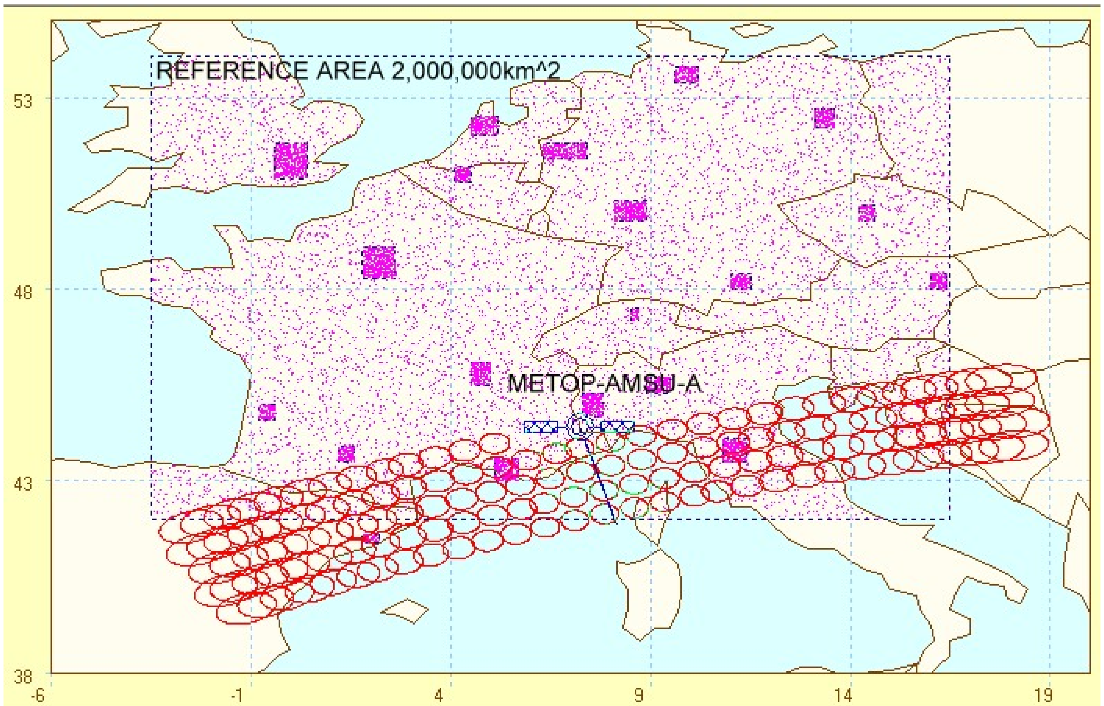

Figure 3: Dynamic Analysis Configuration for AMSU-A

An unwanted emission power level of -28 dBW in 100 MHz based on the currently envisaged ETSI mask specifying -48 dBW/MHz and the protection requirement of passive sensors given in a 100 MHz bandwidth was assumed in the simulations.

Figure 4 shows the results for the AMSU-A and Figure 5 for the MHS sensor, respectively. The generally higher excess for MHS can be explained by the higher antenna gain to pixel ratio. The following conclusions can be drawn. For links with elevation angles below 20 degrees, an interference excess of 8 dB can be expected. F For the scenario where 1% of FS links are deployed in hot spots with a uniform elevation angle distribution between 20° and 90°, as well as 0.24% outside the hot spots, the interference excess would be 18 dB.

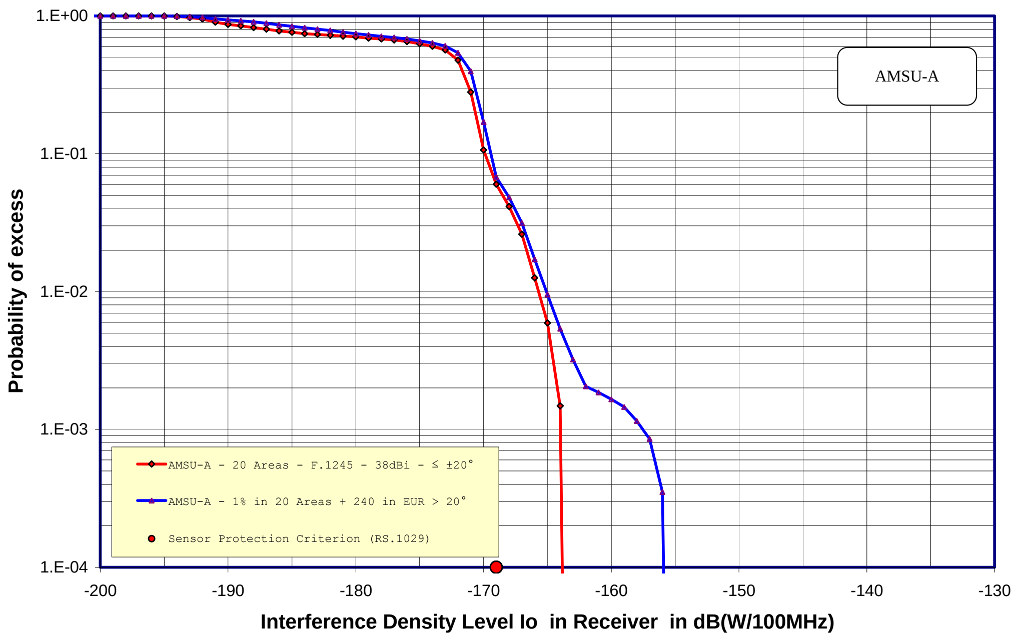

Figure 4: Interference Statistics for AMSU-A

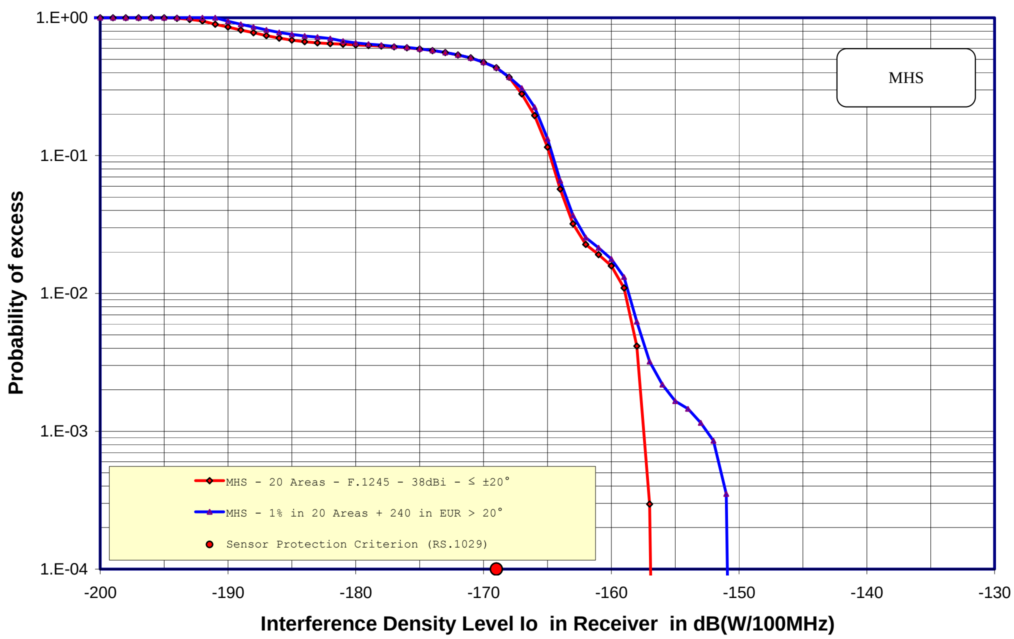

Figure 5: Interference Statistics for MHS

Figure 6: Interference Statistics for CMIS

Figure 6 shows a summary of the results for the CMIS sensor for the 1% scenario for elevation angles above 20º in hot spots and 0.24% in other areas. An average of 1.3 dB for attenuation due to propagation losses and signal blocking was taken into account. The red curve shows the aggregate interference of 24,000 stations with elevation angles below 20° and an unwanted power spectral density of -28 dBW/100 MHz deployed in 20 highly populated areas. The black curve shows the same but with an additional 100,000 stations (i.e. in total 124000 stations) distributed over the reference area of 2,000,000km^2. It can be seen that the density in hot spots determines the maximum interference excess because of the higher number of links per sensor pixel and the contribution from rural areas just adds to the non-critical background noise.

In contrast to low elevation angle links, high elevation angle links outside hot spots contribute to basically the same extent to the interference as the links from hot spots because usually only one or few FS stations cause the high interference and it does not depend on where these stations are deployed. The average curves for 10 simulations with 240 links inside hots spots or outside are also shown in figure 6 for comparison.
It can be concluded that the interference excess for low elevation angle scenarios is around 14 dB with respect to the assumed -28 dBW/100 MHz. A maximum power density level of around -42 dBW/100 MHz is therefore required if only low elevation links would be deployed.

Key contributions to the aggregate interference are the FS station density in hot spots and the elevation angle deployment scenario. In case FS links are deployed at higher elevation angles, a maximum power density level of -50 dBW/100 MHz is required for the 1% uniform scenario for hot spots and 0.24% for rural areas.

3.3 Discussion of Results

The key contribution to the aggregate interference is the FS station density in urban/sub-urban areas. Elevation angles in excess of around 20º degrees can significantly increase the interference levels as main beam coupling may occur. The required level to protect passive sensors from FS links deployed below elevation angles of 20º is an unwanted emission power level of -42 dBW/100 MHz at the antenna port of the FS station.
The required level to protect passive sensors from 1% high elevation FS links in hot spots and 0.24% in rural areas is -50 dBW/100 MHz at the antenna port of the FS station.
Having 2 different levels for unwanted emission limits is not considered practical in view of 2 equipment standards and more complicated licensing. Consideration of a single unwanted emission level of -50 dBW/100 MHz without any further restrictions would be a simpler approach.
Having to meet a constant level of -50 dBW/100 MHz throughout the band 86-92 GHz would imply that this level has to be met already at the band edge of 86 GHz. Taking into account the typical operations of current sensor receivers with 2

channels in the entire 6 GHz bandwidth, it would be possible to deviate from the protection criterion contained in Recommendation ITU-R RS.1029 based on 100 MHz and allow for a higher interference power level at the band edge, provided that the total interference does not exceed the aggregate value obtained with a level of -50 dBW/100 MHz over a 3 GHz channel in the band 86-89 GHz.
To further reduce any potential burden on the FS, an alternative single mask is recommended following consultation with ETSI starting with -41 dBW/100 MHz at 86 GHz and decaying to -55 dBW/100MHz at 87 GHz.
FS systems working in accordance with Recommendation ECC(05)07 and Recommendation ITU-R SM.1541 can meet the levels required to protect EESS (passive) without any additional filtering.

3.4 Conclusions

Consideration of a single unwanted emission level of -50 dBW/100 MHz without any further restrictions on the FS has the advantage to provide adequate protection to EESS(passive) while allowing maximum flexibility for deployment of FS stations.
Based on proposals received during the consultation process and a liaison statement from ETSI, a preferred unwanted emission mask as shown in figure 7 has been identified based on an equal amount of interference in the band 86-89 GHz starting with -41 dBW/100 MHz at 86 GHz and decaying to -55 dBW/100MHz at 87 GHz.

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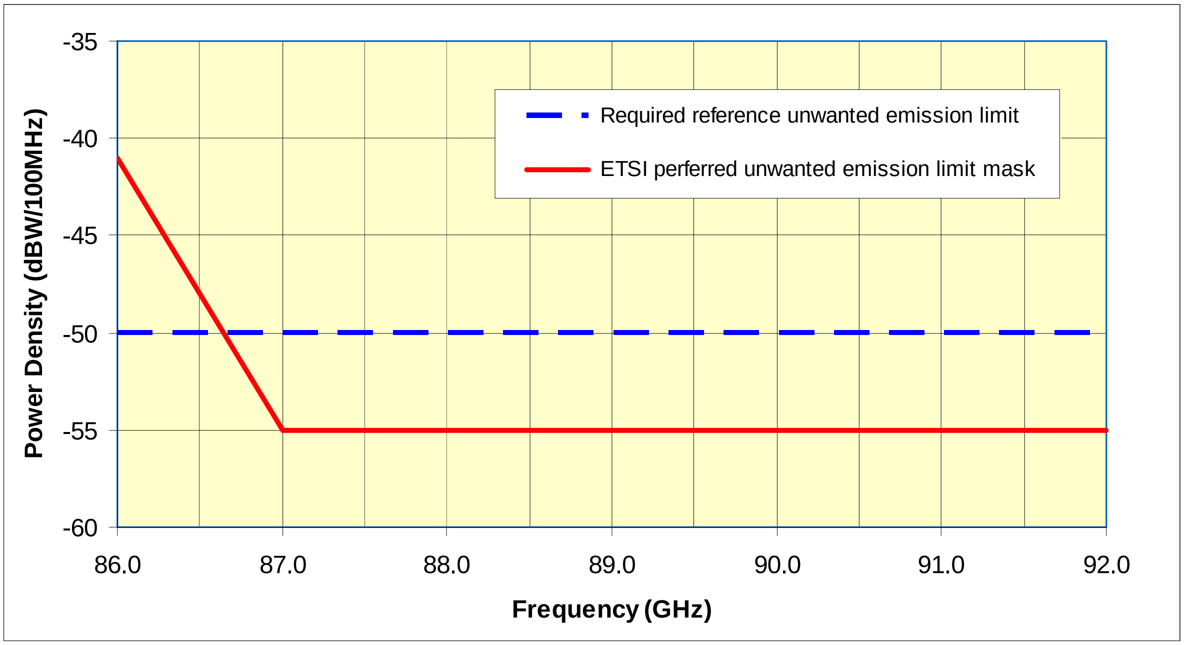


Figure 7: Unwanted Emission Specifications for FS Systems

4 PROTECTION OF RAS STATIONS OPERATING IN THE BANDS 76-77.5 GHZ FROM UNWANTED EMISSIONS OF FIXED SERVICE OPERATING IN THE BAND 71-76 GHZ

4.1 RAS Observations in the Frequency Range 76-77.5 GHz

According to the CRAF web site, this band is used in Germany, France, Italy, Spain and Sweden (http://www.craf.eu/76g.htm#4).

N° 5.149 applies to the band 76-77.5 GHz. It has to be noted that recommendation ITU-R RA.769-2 [2] does not provide any protection criterion for the RAS in this particular frequency band. The protection criteria applicable for the band 79-92 GHz is also considered for this band.

4.2 Considerations on the protection of the RAS station

The protection criterion used is derived from ITU-R Recommendation RA.769-2. Since no value is provided for this particular band, it is proposed to consider the threshold values given for 86 GHz. The calculated difference between the given (86 GHz) and the needed (76 GHz) criterion is about 1 dB.

The FS emission power corresponding to a given separation distance from the RAS may be calculated assuming either free space loss or diffraction loss in close proximity to the ground. The calculation of the loss L0 for spectral line observations is made in the following manner:

$$L_0 = 92.5 + 20\log(f_{GHz}) + 20\log(d_{km}) + \gamma d_{km} + \gamma_{diff}$$
$$P_{769} = P_{TX} + G_{TX} - L_0 \Rightarrow P_{TX} = P_{769} - G_{TX} + L_0$$

where:

- P_{TX}: Emission power of FS emission
- G_{TX}: Antenna gain (including potential sidelobe rejection factor)
- P_{769}: Protection requirement given by RA.769 (-209dBW/MHz)
- γ_{diff} : Diffraction in ground proximity (7dB)
- γ : Atmospheric absorption (0.3dB/km)

For a FS antenna gain of 38 dBi, the resulting separation distance is given in the figure 8 depending on the FS transmitter power density at the antenna port of the FS station.

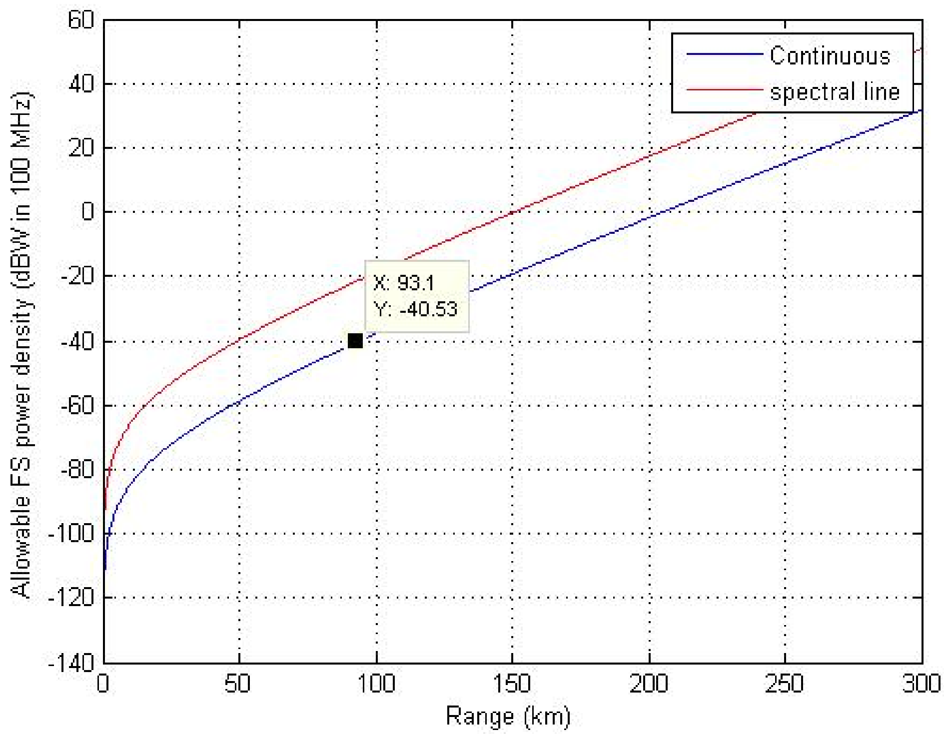


Figure 8: Separation distance vs FS power density

It may be noted that the separation distance corresponding to an unwanted emission power of -40 dBW in 100 MHz derived for the protection of EESS (passive) in the band 86-92 GHz, associated with a maximum FS antenna gain of 38 dBi is about 100 km, beyond the horizon.

This separation distance may be reduced when considering an FS station pointing direction different from the RAS station direction. An antenna sidelobe rejection factor of 38 dB for a separation azimuth angle >16° will result in a relaxation of the separation distance down to about 20 kilometers. There may also be additional attenuation by shielding, topography or clutter surrounding either the FS station or the RAS station.

The calculation of these distances should be done on a case by case basis by the national Administration.

5 PROTECTION OF RAS STATIONS OPERATING IN THE BANDS 79-92 GHZ FROM EMISSIONS OF FIXED SERVICE OPERATING IN THE BAND 81-86 GHZ

5.1 RAS Observations in the Frequency Range 79 to 92 GHz

N° 5.149 applies in the band 79-86 GHz. N° 5.340 applies in the band 86-92 GHz.

According to Recommendation ITU-R RA.769-2 [2], in this frequency range, three type of measurement may be performed:

- Continuum observations centred at 89 GHz with a 8 GHz bandwidth (the overall Primary allocation to the RAS is extending from 79 GHz to 94 GHz) with a received power threshold level of -189 dBW in 8 GHz;
- Spectral line observations centred at 88.6 GHz with a bandwidth of 1 MHz with a received power threshold level of -209 dBW in 1 MHz;
- VLBI observations centred at 86 GHz with a pfd threshold level of -172 dB(W/(m2 . Hz)).

It has to be noted that according to the CRAF web site, these bands are used in Germany, France, Italy, Spain and Sweden (http://www.craf.eu/81.htm and http://www.craf.eu/84g.htm). Other stations not included on this website may also operate in this band.

5.2 Considerations on the protection of the RAS station within the band 81-86 GHz

The band 81-86 GHz is allocated on an equal primary basis to the Fixed Service and Radio Astronomy Service.

The protection criterion used is derived from ITU-R Recommendation RA.769-2. The coordination distance is calculated in accordance with either the free space loss or diffraction loss due to curvature of the Earth, following the same methodology as in section 4.

The ETSI standard EN 302 217-3 [4] describes the characteristics and requirements for point-to-point equipments and antennas. The emission mask indicates a maximum emission power density of about -15 dBW/MHz, or 5 dBW in 100 MHz. Associated with a maximum FS antenna gain of 38 dBi, this leads to a coordination distance of around 220 km, beyond the horizon. If the FS station orientation is such that the main beam is not pointed towards the RAS station the coordination distance will decrease to about 130 km. Due to the lower permitted FS transmitted power compared to the typical emission powers of FS as given in [4], no FS station should be in LoS from the RA station. It should be noted that it does not prevent “beyond the horizon” interference situations. It has to be concluded that any FS station planned to operate in visibility of a given RAS station needs to be coordinated with this RAS station.

5.3 Considerations on the protection of the RAS station within the band 79-81 and 86-92 GHz

The separation distance corresponding to an unwanted emission power of -40 dBW in 100 MHz derived for the protection of EESS(passive) in the bands 86-92 GHz, associated with a maximum FS antenna gain of 38 dBi is about 100 km.

This separation distance may be reduced when considering an FS station pointing direction different from the RAS station direction. An antenna sidelobe rejection factor of 38 dB for a separation azimuth angle >16° will result in a relaxation of the separation distance down to about 20 kilometers. There may also be additional attenuation by shielding, topography or clutter surrounding either the FS station or the RAS station.

The calculation of these distances should be done on a case by case basis by the national Administration.

6 CONCLUSIONS

This report assesses the impact of unwanted emissions of FS operating in the bands 71-76 / 81-86 GHz on passive services in shared and adjacent bands. This includes:

1. Protection of Earth Exploration Satellite Service (EESS) stations operating in the bands 86-92 GHz from unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;
2. Protection of Radio Astronomy Service (RAS) stations operating in the bands 76-77.5 GHz from unwanted emissions of Fixed Service stations operating in the band 71-76 GHz;
3. Protection of RAS stations operating in the bands 79-86 GHz and 86-92 GHz from unwanted emissions of Fixed Service stations operating in the band 81-86 GHz;

The following results were achieved:

Active service	Passive Service	Conclusion
FS in the band 81-86 GHz	EESS in the band 86-92 GHz	For the FS operating in the band 81-86 GHz, the following unwanted emission mask in the band 86 – 89 GHz is proposed starting with -41 dBW/100 MHz at 86 GHz and decaying to -55 dBW/100MHz at 87 GHz (see section 3.4).
FS in the band 81-86 GHz	RAS in the band 81-86 GHz	Any FS station should not be in LoS from the RA station.
FS in the band 71-76 GHz	RAS in the band 76-77.5 GHz	A separation distance between the RAS station and the FS station should be considered depending on the FS station orientation. This separation distance should be determined on a case-by-case basis by national Administrations.
FS in the band 81-86 GHz	RAS in the bands 79-81 and 86-92 GHz	

7 REFERENCES

[1] Recommendation ECC/REC 05-07: Radio Frequency Channel Arrangement for FS systems operating in the bands 71-76 GHz and 81 - 86 GHz, www.ero.dk

[2] ITU-R RA.769-2: Protection criteria used for radio astronomical measurements, www.itu.int

[3] Recommendation ITU-R RS.1029: Interference criteria for satellite passive remote sensing, www.itu.int

[4] ETSI EN 302 217-3, Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 3: Harmonized EN covering essential requirements of Article 3.2 of R&TTE Directive for equipment operating in frequency bands where simplified or no frequency co-ordination procedures are applied, http://portal.etsi.org

[5] ECC Report 20: Methodology to Determine the Density of Fixed Service Links, www.ero.dk

[6] Recommendation ITU-R P.676: Attenuation by atmospheric gases , www.itu.int

[7] Recommendation ITU-R P.530 : Propagation data and prediction methods required for the design of terrestrial line-of-sight systems, www.itu.int

[8] Recommendation ITU-R P.837: Characteristics of precipitation for propagation modeling , www.itu.int

[9] Recommendation ITU-R P.838: Specific attenuation model for rain for use in prediction methods , www.itu.int

[10] Recommendation ITU-R F.1245: Mathematical model of average radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz , www.itu.int

[11] Report ITU-R SM.2092, ‘Studies related to the impact of active services allocated in adjacent or nearby bands on EESS passive service

[12] Recommendation ITU-R F.699 : Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ANNEX A: ESTIMATION OF THE MAXIMUM DENSITY OF FS LINKS

Methodology

Step 1: A first station (S1) is set up in an area of a radius: $d+d_{max}$ where d_{max} is the maximum length of the FS link. Then, another station (S2) is associated to this station. I is set up in a radius of d_{max} centred around the first station (see figure 9).

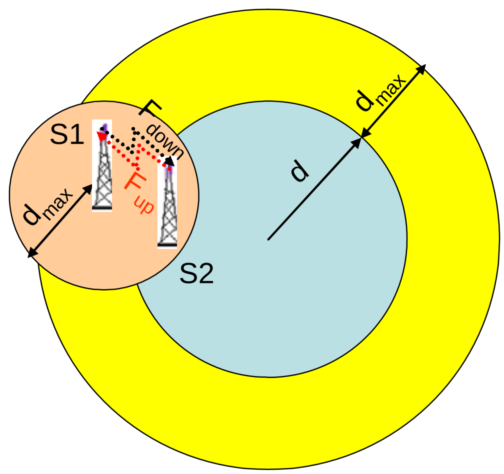


Figure 9: First link

The power at the receiver is assumed to be 3dB above the sensitivity, and the power at the Tx is calculated taking into account the oxygen absorption (see Rec. ITU-R P676 [6]) and the rain fading (see Rec. ITU-R P.530 [7]). It has to be mentioned that this methodology considers free-space propagation losses and does not take into account topography and shielding in urban and suburban areas (which may lead to higher densities in those areas). It has to be noted that the tool is based on former versions of Rec. ITU-R P.837 [8] and P.838 [9] (zone “K” is assumed in the simulations).

Step 2: Step 1 is repeated to set up new links. (see figure 10)

Each time a link is set up, the tool calculate the interference from the new transmitter on the existing receiver at the considered frequency taking into account the oxygen absorption.

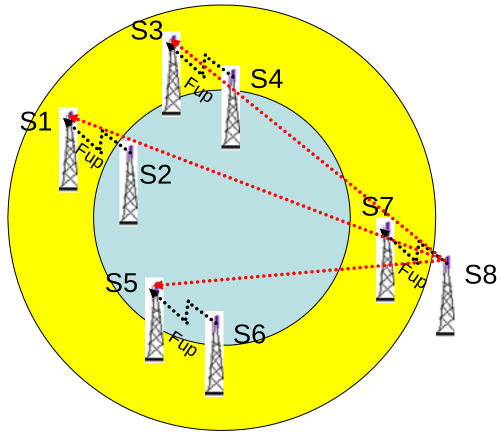


Figure 10: Interference from the new transmitter at each existing receivers

Then, the aggregate interference is calculated.

Step 3: Each time a link is set up, the tool calculate the interference from the existing transmitters on the new receiver at the considered frequency taking into account the oxygen absorption (See figure 11).

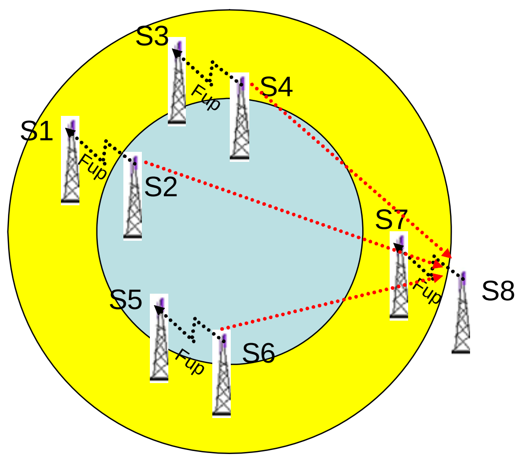


Figure 11: Interference from each existing transmitter to the new receivers

Then, the aggregate interference is calculated.

Step 4: the aggregate interference at the existing and at the new receiver is compared with a threshold. If the threshold is met, the link is accepted and the tool will try to set up an additional new link. If the threshold is not met, the last link is rejected and the tool will test another link. If the tool is not capable to set up a new link after X consecutive failures, it is considered that the maximum density is achieved.

Step 5: the tool provides the density of stations in the tested area (radius d) and in the overall simulation area ($d+d_{max}$).

Assumptions

The following assumptions are used in the simulations:

- Number of consecutive failures (X): 20
- Only one direction of the link is tested
- Frequency: 86 GHz
- Maximum antenna gain: 55dBi
- Antenna Pattern: Rec. ITU-R F.1245
- Noise level : -114dBW in 250 MHz
- Hop length: 50m- 2.5 km
- Minimum FS antenna height: 20 m (20 m + random value from 0 to 80 m)
- Radius of the tested area (d): 5 km
- Pe: 9 dBm in 250 MHz
- Sensitivity : -90 dBm in 250 MHz
- Availability of 99.99 %
- Interference criterion 3 dB i.e. I equals to N.

Results

The following table provides some results of simulations (10 runs).

Total number of Stations	Total number of Stations in d+dmax	Total number of Stations in d	Total number of Rx at 86 GHz Stations in d	Density of Stations in d+dmax	Density of Stations in d	Density of Rx at 86 GHz Stations in d
50	46	23	11	0.2603	0.2928	0.1401
104	97	45	23	0.5489	0.573	0.2928
162	152	64	33	0.8601	0.8149	0.4202
76	67	27	13	0.3791	0.3438	0.1655
84	77	36	19	0.4357	0.4584	0.2419
206	193	93	43	1.0922	1.1841	0.5475
156	149	79	39	0.8432	1.0059	0.4966
140	132	63	30	0.747	0.8021	0.382
108	100	38	20	0.5659	0.4838	0.2546
48	46	24	13	0.2603	0.3056	0.1655

Table 1: Results of simulations

It leads to the conclusion that an estimation of FS links density could be 0.5 Tx/km².

ANNEX B: TYPICAL TECHNICAL AND OPERATIONAL CHARACTERISTICS OF EARTH EXPLORATION-SATELLITE SERVICE (PASSIVE) SYSTEMS OPERATING BELOW 275 GHz

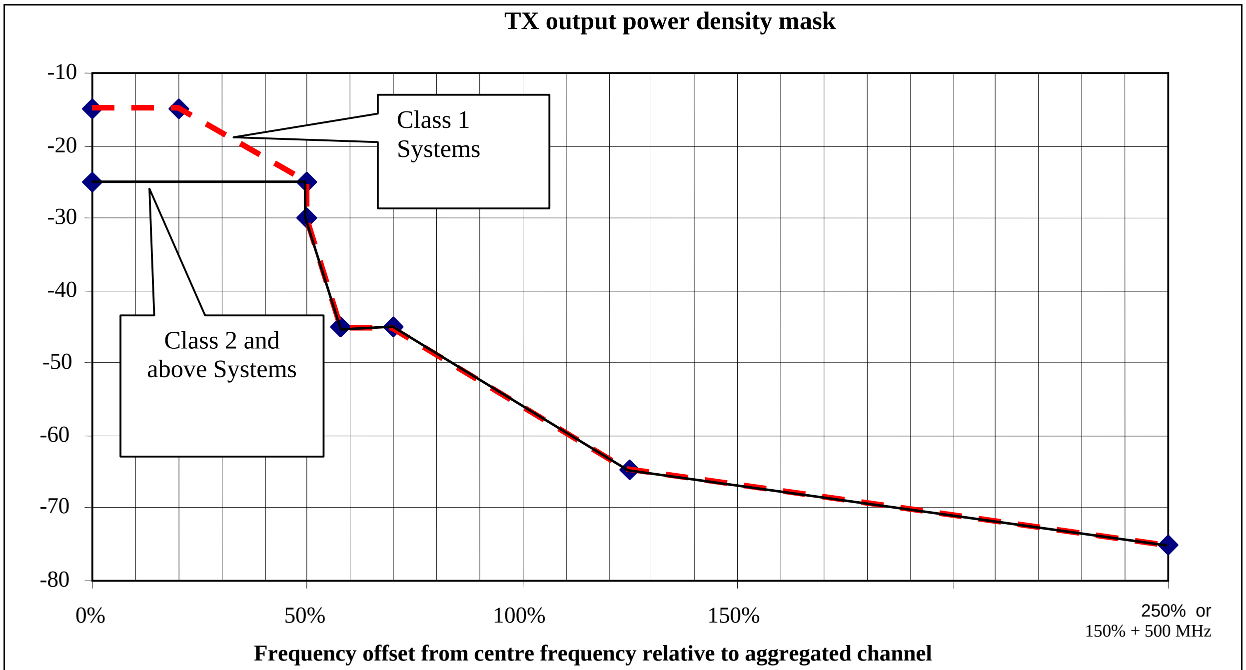
Table 2: EESS (passive) sensor characteristics operating between 86 and 92 GHz

	Sensor 1 [CMIS]	Sensor 2 [AMSU-A]	Sensor 3 [AMSR-E]	Sensor 4 [ATMS]	Sensor 5 [MADRAS]	Sensor 6 [MTVZA-OK]
Sensor type	Conical Scan	Mechanical nadir scan	Conical Scan	Mechanical nadir scan	Conical Scan	Conical Scan
Orbit parameters						
Altitude	828 km	833 km	705 km	824 km	865 km	835 km
Inclination	98.7°	98.6°	98.2°	98.7°	20°	98.85º
Eccentricity			0.0015			0
Repeat period	17 days	9 days	16 days	9 days	7 days	
Sensor antenna parameters						
Number of beams	1	30 earth fields per 8 sec. scan period	2	96 earth fields per scan period		2
Reflector diameter	2.2 m	0.15 m	1.6 m	0.203 m	0.65 m	0.6 m
Maximum beam gain	56dBi	34.4 dBi	60.5 dBi	37.9 dBi		
Polarization	H, V	V	H, V	QV		H, V
–3 dB beamwidth	0.39°	3.3°	0.18°	2.2°		
Instantaneous Field of View	16 km × 12 km	Nadir FOV: 48.5 km Outer FOV: 149.1 × 79.4 km	A:6.5 km × 4 3.7 km B:5.9 km x 3.5 km	Nadir FOV: 31.6 km Outer FOV: 136.7 × 60 km		12 km × 28 km
Main beam efficiency	95%	95%	94.5%	95%	96%	
Off-nadir pointing angle	46.8°	±48.33° crosstrack	A:47.5º, B:47.0°	±52.725° crosstrack	44.5°	
Beam dynamics	31.6 rpm	8 sec scan period	40 rpm	8/3 sec scan period	20 rpm	2.88 sec scan period
Incidence angle at Earth	55.7°		A:55.0° / B:54.5°		52.3°	35º
Swath width	1 700 km	2 343 km	1 450 km	2 500 km		2 000 km
Sensor antenna pattern						
Cold calibration ant. gain		34.4 dBi	40.4dBi	37.9 dBi		
Cold calibration angle (degrees re. satellite track)			115.5deg			
Cold calibration angle (degrees re. nadir direction)		83.33°	97.0deg	82.175°		
Sensor receiver parameters						
Sensor integration time	1.2 msec	165 msec	1.2 msec	18 msec		
Channel bandwidth	4 000 MHz centered at 89 GHz	1 500 MHz centered at 89 GHz	3 000 MHz centered at 89 GHz	2 000 MHz centered at 87-91.9 GHz		2 GHz
Horizontal resolution		40.5 km	5 km		10 km crosstrack	19 km

	AMSU-A	MHS
Orbit parameters		
Sensor Type	Nadir Scan	Nadir Scan
Semi-Major Axis	7189.9042 km	7189.9042 km
Inclination	98.70583°	98.70583°
Eccentricity	0.0023021	0.0023021
Repeat Period	29 days	29 days
Sensor Antenna Parameters		
Number of Beams	30 earth fields (pixels)	90 earth fields (pixels)
Scan period	8 sec.	8 or 3 sec.
Reflector Diameter	0.15 m	0.30 m
Max. Beam Gain	34.4 dBi	47 dBi
Instantaneous Field of View	Nadir FOV: 48 km Outer FOV: 149.1x79.4 km	Nadir FOV: 16 km Outer FOV: 53x27 km
Main Beam Efficiency	95%	95%
Off-Nadir pointing angle to centre of edge pixel	+48.33° crosstrack	+49.44° crosstrack
Incidence angle at earth (Local Zenith Angle)	0 – 57.7°	0 – 59.2°
Half power beamwidth	3.3°	1.1°
Swath width	+1037 km	+1089 km
Sensor Receiver Parameters		
Sensor Integration Time	180 msec.	18.5 msec.
Channel Bandwidth	±3 GHz centred at 89 GHz	±1.4 GHz centred at 89GHz
Maximum Interference Level (RS.1029)	-169 dBW/100MHz	-169 dBW/100MHz
Percentage of area or time permissible interference level may be exceeded	0.01 % for a reference area of 2 000 000 km^2	0.01 % for a reference area of 2 000 000 km^2

Table 3: Characteristics for METOP Sensors AMSU-A and MHS

ANNEX C: TRANSMITTER POWER SPECTRAL DENSITY MASK FOR FS OPERATING IN 81-86GHz



Class 2 and above		Class 1	
Power density (dBW/MHz)	Offset (% of aggregated channel) (Note 1)	Power density (dBW/MHz)	Offset (% of aggregated channel) (Note 1)
		-15	0
-25	0	-15	20
-25	50	-25	50
-30	50	-30	50
-45	57,5	-45	57,5
-45	70	-45	70
-65	125	-65	125
-75	250 or 150 + 500 MHz (Note 2)	-75	250 or 150 + 500 MHz (Note 2)

NOTE 1: See definition of aggregated channel in clause 3.1.

NOTE 2: The 250% value applies only for aggregate channel ≤ 500 MHz; the other value for aggregate channel > 500 MHz

Figure 12: Transmitter power spectral density mask for FS