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(11/2011)

Coexistence between fixed service operating in 71-76 GHz, 81-86 GHz and 92-94 GHz bands and passive services

F Series
Fixed service

International Telecommunication Union

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R F.2239

Coexistence between fixed service operating in 71-76 GHz, 81-86 GHz and 92-94 GHz bands and passive services

(2011)

Scope

This Report provides results of sharing and compatibility studies between fixed service (FS) operating in the bands 71 76 GHz, 81-86 GHz and 92-94 GHz and passive services (RAS and EESS) operating in these or adjacent bands.

1 Introduction

The following sharing/compatibility cases are addressed:

1) fixed service stations operating in the band 81-86 GHz and 92-94 GHz with respect to the protection of Earth exploration-satellite service (EESS) stations operating in the adjacent band 86-92 GHz;

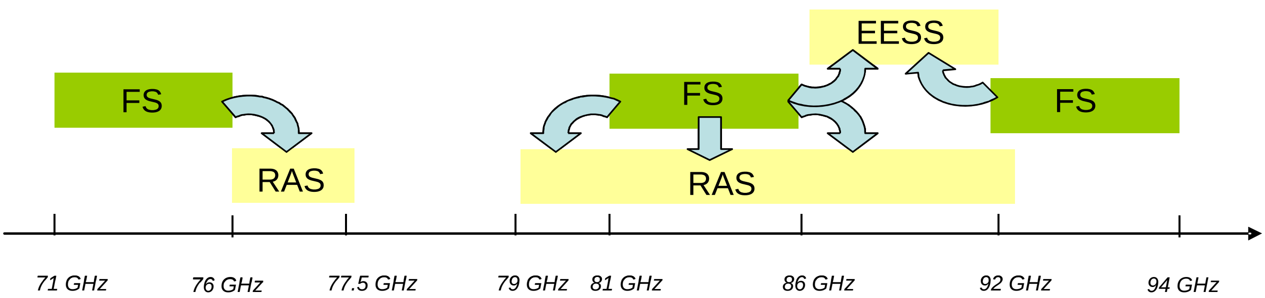
2) fixed service stations operating in the band 71-76 GHz with respect to the protection of radio astronomy service (RAS) stations operating in the adjacent band 76-77.5 GHz;

3) fixed service stations operating in the band 81-86 GHz with respect to the protection of RAS stations operating in the bands 79-92 GHz.

Figure 1 summarizes the different compatibility schemes studied.

FIGURE 1

Compatibility schemes assessed in various studies



2 EESS (passive) characteristics and protection criteria

Recommendation ITU-R RS.1861 provides characteristics of EESS passive sensors operating below 275 GHz. Relevant EESS (passive) systems and corresponding characteristics are given in Annex E.

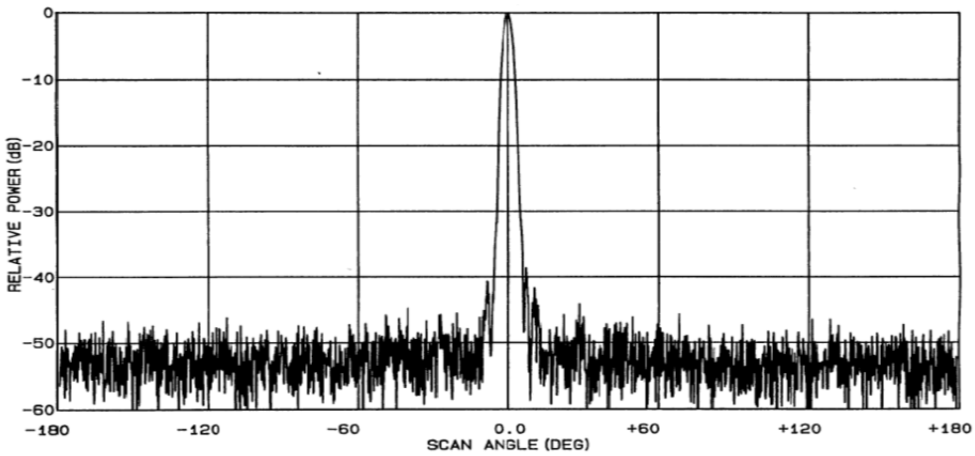
In addition Recommendation ITU-R RS.1029 provides the protection criterion for EESS operating in the frequency range 86-92 GHz which is a maximum received allowable power of −169 dBW in 100 MHz. This level may be exceeded for less than 0.01% of the time (for a 0.01% level, the measurement area is a square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

EESS receive filters frequency response is assumed to provide sufficient attenuation outside of the 86-92 GHz to allow limiting the compatibility analysis within the 86-92 GHz band.

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

FIGURE 2

Typical AMSU-A antenna pattern around 89 GHz



This makes sensors slightly more vulnerable to interference received in the main lobe but much more robust against interference received via side lobes. Recommendation ITU-R RS.1813 provides relevant EESS sensors antenna patterns to be used for interference assessment.

As assumed in Report ITU-R SM.2092, the EESS (passive) sensor antenna pattern may also conform to the reference antenna pattern specified in Recommendation ITU-R F.1245 that was used in Study 3 as described below.

3 Summary of compatibility studies between EESS (passive) and FS

Three independent studies were conducted to assess interference from FS systems operating in the frequency band 81−86 GHz to EESS (passive) sensors operating in adjacent frequency band 86-92 GHz.

These studies were produced based on different assumptions:

− Study 1 (presented in Annex A) assesses the maximum level of unwanted emissions of FS in the bands 71-76 GHz and 81-86 GHz, using typical characteristics of FS stations.

− Study 2 (presented in Annex B) assesses the maximum level of interference produced by a typical FS deployment and using actual maximum equipment in band emission power level (up to −10 dBW) in the 81-86 GHz and a relative unwanted emission level in the 86-92 GHz band.

− Study 3 (presented in Annex C) assesses the maximum level of interference produced by FS, based on actual deployments in one country in the 81-86 GHz.

3.1 Study 1

The Study 1 presented in Annex A of the Report assesses the maximum level of unwanted emissions of FS operating in the bands 71-76 GHz and 81-86 GHz on EESS passive services in adjacent bands.

3.1.1 Typical FS deployment and assumptions used in Study 1

FS stations operating in the bands 71-76 GHz and 81-86 GHz are assumed to operate at typical elevation angles lower than 20°. However it is also considered possible to have a relatively low number of FS links deployed with elevation angles up to 90°, as already depicted in some other FS frequency bands and current FS deployment.

Based on the methodology presented in Annex A2, Study 1 assumes an average density of 0.5 links per km^2 limited to areas with high population densities (hot spots). Outside the hot spots (further on considered as "background deployment"), a maximum density of 0.06 links per km^2 is considered.

The same number of links as for hot spots (i.e. 240) is 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 EESS reference area of 2 000 000 km^2 using a squared roll-off distribution.

In addition, using the same FS transmitter characteristics, simulations have also been performed to assess the impact of FS typical deployment characteristics by varying the FS density and elevations statistics. It can be seen that even by restricting the overall number of FS links, the elevation angles of FS stations to 45° and the percentage of elevation angles above 30° to very low percentages, consistent with actual deployment characteristics in other frequency bands (37-40 GHz) in some countries, the initial conclusions on the coexistence between fixed service operating in 71-76/81-86 GHz bands with the EESS (passive) in the 86-92 GHz band remain unchanged.

FS transmitter characteristics are the same in the different studies.

3.1.2 Summary of the results of Study 1

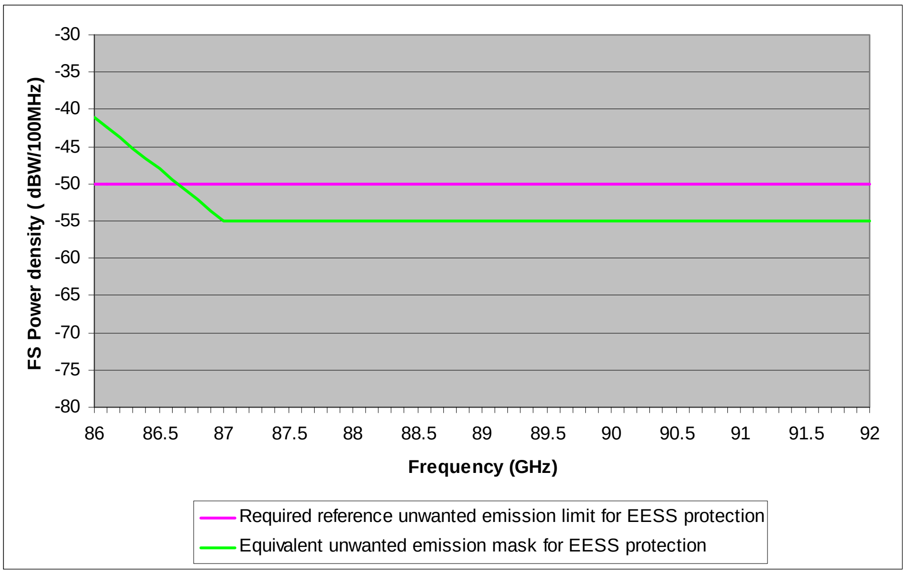
Based on results of Study 1 (see details in Annex A), protection of EESS (passive) in the band 86-92 GHz band would be met with a maximum FS unwanted emission level of −50 dBW/100 MHz.

Study 1 also derives an unwanted emission mask in the band 86-92 GHz, starting with −41 dBW/100 MHz at 86.05 GHz and decaying to −55 dBW/100 MHz at 87 GHz that provides an operational interference level that is equivalent to the interference caused by an emission mask of −50 dBW/100 MHz flat across the 86-92 GHz band. Utilizing such an emission mask better meets the needs of FS operation at the band edge compared to the flat limit given above.

These results are depicted in the following Fig. 3A.

FIGURE 3A

Summary results of Study 1



3.2 Study 2

The Study 2 presented in Annex B of the Report proposes to take into account typical fixed service deployment characteristics such as station density and elevation angles with a view to developing a near realistic worst-case interference scenario to address the potential for impact from the fixed services operating in the 81-86 GHz band into the EESS (passive) measurements in the adjacent 86-92 GHz band.

3.2.1 FS link density, elevation angle and antenna gain used in Study 2

The FS link density was calculated using a similar methodology to one presented in Annex A2, which calculates the maximum number of FS links that can be deployed in an area on an interference limited basis. This methodology was adjusted to calculate the density based on typical FS parameters across the entire 81-86 GHz band and the final figure for density was taken as an average over 1 000 runs of the method in order to give a repeatable result.

A truncated normal distribution of elevation angles for fixed links was considered of ±30 degrees which was considered to be a worst case to account for the possibility of short distance urban links at high elevation.

3.2.2 FS deployment scenarios used in Study 2

Two FS deployments scenarios were considered:

The FS deployment scenarios assumed a maximum urban link density of 0.19 links/km^2. The rural density was calculated relative to the urban density by a factor of 0.09 based on worst-case ratio of urban to rural densities in the 38 GHz band.

Scenario 1 (urban scenario) covered a worst-case high density deployment across an urban area and a surrounding lower density. In this scenario high density deployment was considered in an urban area (approx. 1 500 km^2), and a lower density in the surrounding rural area (approx. 28 500 km^2).

Scenario 2 covered a wide scale deployment with urban hotspots and a combined lower density over an area of 2 000 000 km^2 referenced in the Recommendation ITU-R RS.1029 specifying protection criteria for the EESS. A density of 0.01 links/km^2 is assumed across the reference area (i.e. the 'rural' density figure used in Scenario 1), resulting in 20 000 links in total. Additionally a layer of 15 urban deployments is included, each with 300 links. This result is 24 500 links in total.

3.2.3 FS characteristics used in Study 2

Interference analysis in Study 2 was performed using combinations of FS deployment parameters and EESS sensors given in Annex B.

The maximum in band FS transmit power level was set to −10 dBW (20 dBm) found in actual equipments and Recommendations ITU-R P.525 and ITU-R P.676, together with additional losses of 2 dB (to account for urban clutter and cross-polarization).

For 2 different FS bandwidths (i.e. 1 250 and 4 750 MHz) considered in the study, relative FS unwanted emission power levels falling within the adjacent 86-92 GHz band were derived based on actual FS planning assumptions (i.e. variable in band power level up to the maximum (−10 dBW) depending on individual link requirements).

3.2.4 Summary of the results of Study 2

Based on assumptions used in this Study, results of Study 2 (see details in Annex B) indicate that for currently available information on typical FS parameters and deployment scenarios of FS links, potential interference to EESS sensors is below the sensor protection criterion defined in Recommendation ITU-R RS.1029. This was shown for both scenarios considered.

3.3 Study 3

The Study 3 presented in Annex C of the Report assesses the maximum level of interference to EESS sensors in the 86-92 GHz using a realistic interference scenario for addressing the potential for impact from the FS operating in the 81-86 GHz band based on actual FS deployments in one country.

3.3.1 FS deployment scenarios and characteristics used in Study 3

In terms of FS parameters for the study, publicly available data on 2 850 actual frequency assignments of FS stations licensed in one administration was used.

From these assignments, real data was gathered for the simulation on locations (i.e. densities of the fixed stations), power levels (typically −10 dBW), centre frequencies (typically82-83.5 GHz), bandwidths (typically 1-2 GHz), antenna pointing azimuths, antenna pointing elevations (typically less than 5°) and maximum antenna gains (typically 42-44 dBi).

An FS reference antenna pattern based on Recommendation ITU-R F.1245-1 was used in the simulations.

3.3.2 Simulation assumptions used in Study 3

The unwanted emission power falling within the 86-92 GHz EESS (passive) band was calculated for each station by integrating the power spectral density (psd) of emissions over the first 100 MHz (86-86.1 GHz) of the EESS (passive) band based on the out-of-band emission mask provided in Annex C1, as well as the centre frequency, necessary bandwidth and maximum antenna gain of the licensed frequency assignment.

Of the 2 850 links used in Study 3, most links are operated within the 82-83.5 GHz band and make use of a −10 dBW power. Overall, associated with the mask assumed in Annex C1, the unwanted emissions power of these links over the first 100 MHz (86-86.1 GHz) of the EESS (passive) band varies as follows:

– −54 dBW/100 MHz for 1 250 MHz FS bandwidth operated at 82 GHz.

– −23 dBW/100 MHz for FS operated at 83.5 GHz

Simulations for this deployment model were conducted for the three adjacent, but non-overlapping, measurement areas between 32.524° and 45.476° North latitude and between 73.898° and 122.102° West longitude. Each of these areas has an area of 2 000 000 km^2. Interference from FS links into a passive EESS sensor was evaluated under free space propagation conditions, plus an additional loss for atmospheric (gaseous) absorption from Annex 2 of Recommendation ITU-R P.676-7. The temperature, pressure and surface water vapour content were generated using ITU-R P.835-4.

3.3.3 Summary of the results of Study 3

Based on assumptions used in the Study 3, including an unwanted emission mask in Annex C1, results of Study 3 (see details in Annex C) indicate that the EESS protection criteria specified in Recommendation ITU-R RS.1029-2 is not exceeded.

3.4 Possible application of 81-86 GHz studies to the 92-94 GHz band

3.4.1 Study 1

Appendix A of Annex A of this Report similarly considers the compatibility between FS operating in the 92-94 GHz band and EESS (passive) sensors in the 86-92 GHz band. It was concluded that based on the fact that the FS characteristics and deployment scenarios are likely to be the same as in the bands 81-86 GHz and that the propagation conditions and the EESS sensor characteristics are the same as already used, this Appendix A of Annex A allows to conclude that the above technical analysis conclusions are valid for FS in the 92-94 GHz band.

Therefore the same "mirror mask" starting with −55 dBW/100 MHz at 91 GHz and increasing to −41 dBW/100 MHz at 92 GHz for FS operating in the 92-94 GHz band would provide similar protection to EESS (passive).

3.4.2 Study 3

Although the propagation characteristics of the 81-86 GHz could be similar to those in the 92-94 GHz band, it may be possible that the deployment scenarios in these bands could be quite different.

Of the 70/80/90 GHz bands, the 70/80 GHz bands could likely hold the most interest. With the option of paired spectrum available, the 71-76/81-86 GHz allocations allow 5 GHz of full-duplex transmission bandwidth; enough to transmit a gigabit of data (1 Gbps) even with the simplest modulation schemes. With more spectrally efficient modulations, full-duplex data rates of 10 Gbps can be reached.

On the other hand, the 92-94.0 GHz and 94.1-95 GHz allocations are segmented into unequal portions that may result in FS deployments (i.e. link density) at 90 GHz that are different than those at 70/80 GHz.

On this basis, applying a simple FS mirror-mask of the 86-92 GHz band for the 92-94 GHz band may not be assumed at this time and could require further studies.

3.5 Comparative analysis

Studies 1, 2 and 3 consider the compatibility between FS and EESS based on different assumptions/methodologies and some comprehensive elements are necessary for having an accurate understanding before drawing general conclusions.

Study 1 (in Annex A, completed by Annex A1) derives FS maximum unwanted emission level/mask to ensure the EESS (passive) protection criteria is met.

Studies 2 and 3 (in Annexes B and C respectively) are based on current FS power/frequency parameters and/or deployments and demonstrate that under these conditions, the EESS (passive) is protected.

3.5.1 FS links density

The following table summarizes the FS link density scenarios considered in the three studies:

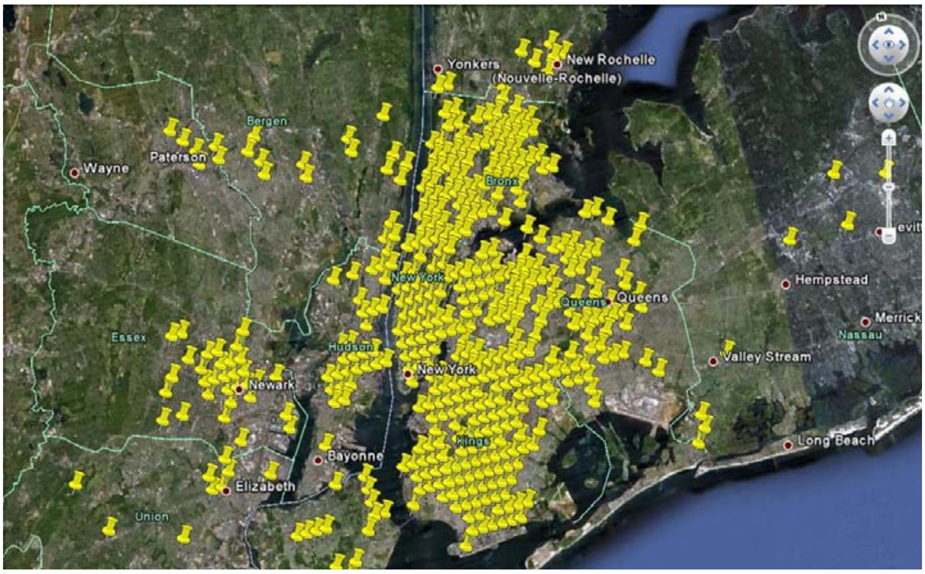
	Study 1 (Annex A)	**Study 1 (Annex A1)**	**Study 2 (Annex B)**	**Study 3 (Annex C)**
Urban (hot spots)	0.5 links/km²	0.1 to 0.5 links/km²	0.1 to 0.19 links/km²	0.1464 to 0.2382 links/km² [1)]
Rural (outside hot spots)	0.06 links/km²	0.01 to 0.06 links/km²	0.01 to 0.02 links/km²	

[1)] Study 3 used actual licensed deployments not calculated averaged densities. In particular these deployments already show some hot spot deployments with FS densities up to 1.2 links/km² (see Fig. 3B below, 1 259 stations within 1 044 km²).

This table shows that the FS link density assumptions considered in the three studies are broadly similar.

FIGURE 3B

Existing FS deployment in the vicinity of New York (US)



3.5.2 FS links elevations

The following table summarizes the FS link elevation scenario considered in the three studies:

	Study 1 (Annex A)	Study 1 (Annex A1)	Study 2 (Annex B)	Study 3 (Annex C)
High elevation links	0.39% of links with elevation higher than 20°	0.1 to 0.5 % of links with elevation between 30° and 45°	± 30° (normally distributed)	Less than 2% of links with elevation between 20° and 65°

This table shows that the FS link density assumptions considered in the 3 studies are similar in that they consider a majority of FS links with elevation below 30° whereas they differ with regards to high elevation FS links.

In addition, it can be highlighted that typical incident angles of EESS are below 60°, leading to EESS main beam elevation angles above 30°. Therefore, limiting the FS elevation statistic below 30° could reduce the calculated maximum interference since it leads to excluding from the results some cases of possible FS and EESS main beam alignment. It is however recognized that the number of such cases will be low and not likely to have an impact on the results.

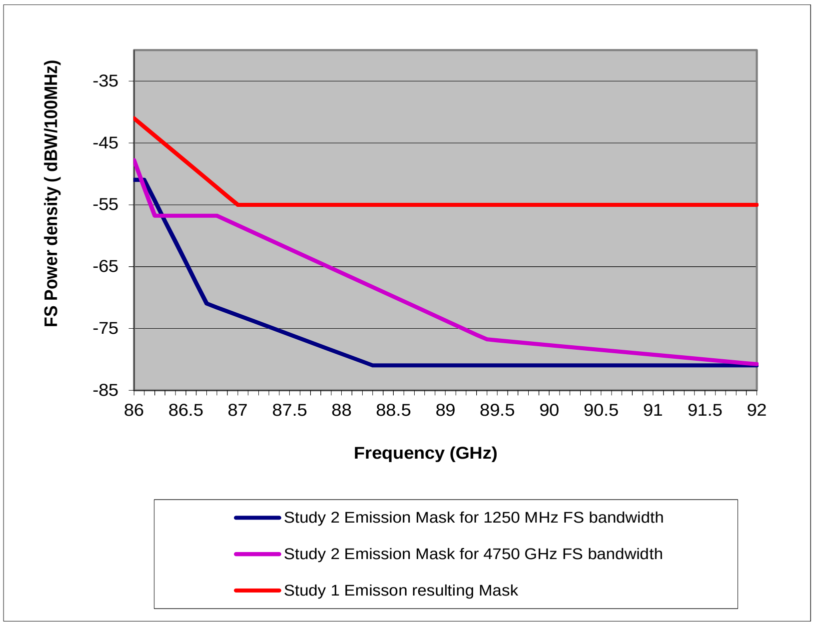
3.5.3 OOB FS emissions in the 86-92 GHz band

Study 1 derives a FS maximum unwanted emission mask in the band 86-92 GHz, starting with −41 dBW/100 MHz at 86.05 GHz and decaying to −55 dBW/100 MHz at 87 GHz (see Fig. 3-A).

Study 2 is based on actual FS in band maximum power (−10 dBW) and derives relative unwanted emission levels in the adjacent 86−92 GHz band to assess the potential interference to EESS (passive). On this basis Study 2 demonstrates that the potential interference is below the EESS (passive) protection criteria specified in Recommendation ITU-R RS.1029 with a minimum margin of 4 dB.

FIGURE 3C

Comparison of maximum unwanted emissions levels used in Study 2 with results of Study 1



When comparing maximum unwanted emission levels used in Study 2 with the results of Study 1 in terms of maximum FS unwanted emissions levels in the adjacent 86-92 GHz band, as in Fig. 3C, it can be seen that the maximum emission levels used in Study 2 are well below the resulting mask of Study 1. Since the emission levels used in Study 2 are based on current FS equipment capabilities, this figure also shows that the mask derived from Study 1 (−41/−55 dBW/100 MHz) is not constraining to current FS equipment.

Study 3 is based on an existing FS deployment in one administration and simulates the interference that such FS network would produce to EESS (Passive). Unlike Studies 1 and 2, parameters of Study 3 are based on the statistics of the existing network, in particular in terms of centre frequency, bandwidth and output power (see details in Annex C). Study 3 hence does not make use of a single set of FS links parameters but one can derive the typical FS link parameters used in Study 3:

Frequency	82.5-83.5 GHz
Bandwidth	1 250 MHz.
Power	−10 dBW
Emission mask based on Annex C1	

On this basis, the unwanted FS emission in the 86-86.1 GHz band used in Study 3 is, for most links, −54 dBW/100 MHz. Under these conditions, Study 3 depicts simulations results that are below the EESS (passive) protection criteria with a minimum margin of 4.5 dB. It can also be noted that this level is below the mask derived from Study 1.

Therefore it appears that a maximum FS unwanted emission level of −49.5 dBW/100 MHz (−54 dBW/100 MHz + 4.5 dB) in the 86-92 GHz band would meet the EESS (passive) protection criteria.

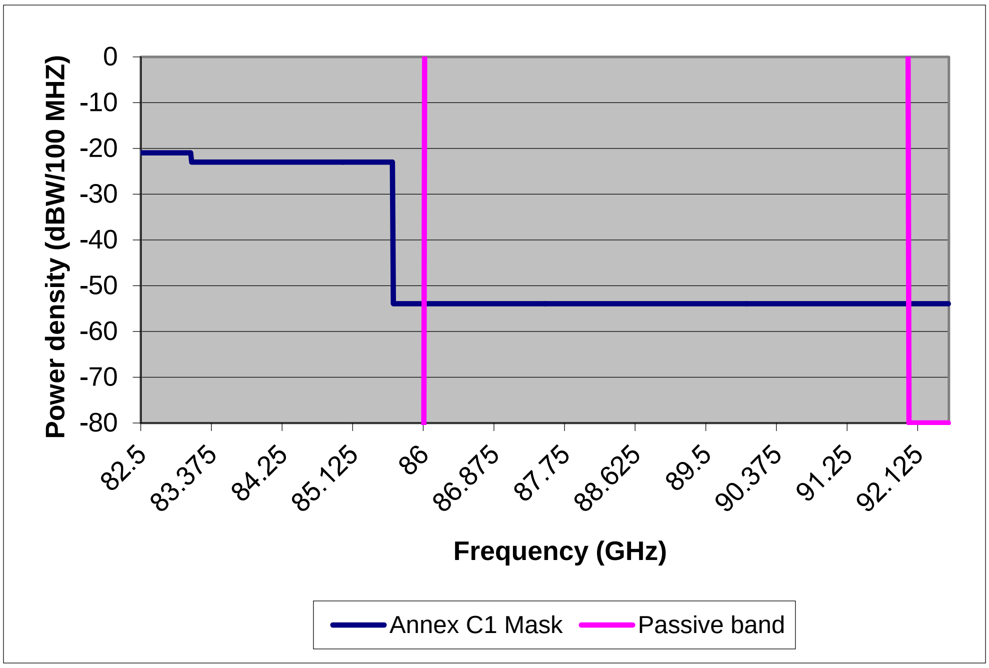
3.5.4 Additional consideration on Annex C1 mask

The emission mask specified in Annex C1 is frequency and bandwidth dependent and as such leads to different unwanted emissions levels into the 86-92 GHz passive band.

For example, for a 1 250 MHz bandwidth FS links operated around 82.5 GHz, the emission mask specified in Annex C1 is described in Fig. 3D, leading to a maximum unwanted emission level in the passive band of −54 dBW/100 MHz.

FIGURE 3D

Annex C1 Emission mask (F = 82.5 GHz B = 1 250 MHz)



FS equipments operating between 83.5 GHz and 86 GHz would have unwanted emission levels of −23 dBW/100 MHz.

This mask was considered in Annex C study for calculation purposes only and is not intended to be proposed as a regulatory mask.

3.6 Conclusion

Compatibility studies between Fixed Service (FS) operating in the bands 81-86 GHz and 92-94 GHz and EESS (passive) operating in the 86-92 GHz band have been considered in various technical studies presented in Annexes A , B and C of this Report.

These studies are based on different assumptions and methodologies leading to following conclusions:

Study 1 derives the following maximum unwanted emission mask/levels for the FS in the 81-86 GHz/92-94 GHz bands based on the EESS (passive) protection criteria for the adjacent 86-92 GHz band;

– −50 dBW/100 MHz in the 86-92 GHz band.

– An unwanted emission mask in the band 86-92 GHz, starting with −41 dBW/100 MHz at 86.05 GHz and decaying to −55 dBW/100 MHz at 87 GHz can be utilized to provide an operational interference level that is equivalent to the interference caused by an emission mask of −50 dBW/100 MHz flat across the 86-92 GHz band. Utilizing such an emission mask better meets the needs of FS operation at the band edge compared to the flat limit given above.

– Considering the FS in the 92-94 GHz band, taking into account that the propagation conditions, the EESS sensor characteristics and FS characteristics are similar to the band 81-86 GHz, a similar "mirror mask" starting with −55 dBW/100 MHz at 91 GHz and increasing to −41 dBW/100 MHz at 91.95 GHz is also adequate to ensure protection of EESS (passive) in the 86-92 GHz band.

Studies 2 and 3 are based on actual FS power/frequency parameters and demonstrate that under these conditions, the EESS (passive) protection criterion specified in Recommendation ITU-R RS.1029 is met.

Overall, it has been demonstrated that a maximum FS unwanted emission level of around −50 dBW/100 MHz in the 86-92 GHz band would meet the EESS (passive) protection criteria. The unwanted emissions produced by current FS equipment are, in most cases, already below above mentioned levels.

4 Summary of compatibility studies between RAS and FS

The study contained in Annex D addresses the impact of in band and unwanted emissions of FS operating in the bands 71-76 GHz, 81-86 GHz and 92-94 GHz on RAS in shared and adjacent bands:

a) Protection of radio astronomy service (RAS) stations operating in the bands76-77.5 GHz from unwanted emissions of fixed service stations operating in the band 71-76 GHz;

b) Protection of RAS stations operating in the bands 79-81 GHz and 86-92 GHz from unwanted emissions of fixed service stations operating in the bands 81-86 GHz and 92-94 GHz;

c) Protection of RAS stations operating in the bands 81-86 GHz and 92-94 GHz from in band emissions of fixed service stations operating in the same bands

A separation distance between the RAS station and the FS station should be considered depending on the FS station orientation as well as the environment, such as terrain elevation. The required separation distance should therefore be determined on a case-by-case basis. In view of the limited distances calculated in this study, it may be considered that the protection of RAS will be limited to a national matter.

ANNEX A

Considerations on compatibility between the FS in the 71-76 GHz, 81-86 GHz and 92-94 GHz bands and the EESS in the 86-92 GHz band

1 Fixed service characteristics

1.1 FS transmitter characteristics

Typical FS applications in the 71-86 GHz range are expected to operate with bandwidths lower than 1 250 MHz and are expected to be deployed in urban and suburban areas.

In order to consider the aggregate effect of several thousand FS links on EESS (passive) sensors, FS antennas have been modelled using the pattern given in Recommendation ITU-R F.1245.

1.2 Typical FS deployment and assumptions taken in studies

FS stations operating in the bands 71-76 GHz and 81-86 GHz are assumed 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°.

Based on the analysis in Annex A2, a density of 0.5 links per km^2 per frequency channel was assumed in this Study but is limited to areas with high population densities (hot spots). Twenty 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^2using a squared roll-off distribution.

Annex A1 of the present study provides additional information considering typical FS deployment and shows in particular that, based on current deployment of more than 2 800 FS stations in one Administration, a density of FS stations of 0.5 links per km^2 is far being a worst case and can hence be considered as typical.

2 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

2.1 EESS characteristics and protection criteria

Recommendation ITU-R RS.1861 provides characteristics of EESS passive sensors operating below 275 GHz. Relevant EESS (passive) systems and corresponding characteristics are given in Annex E.

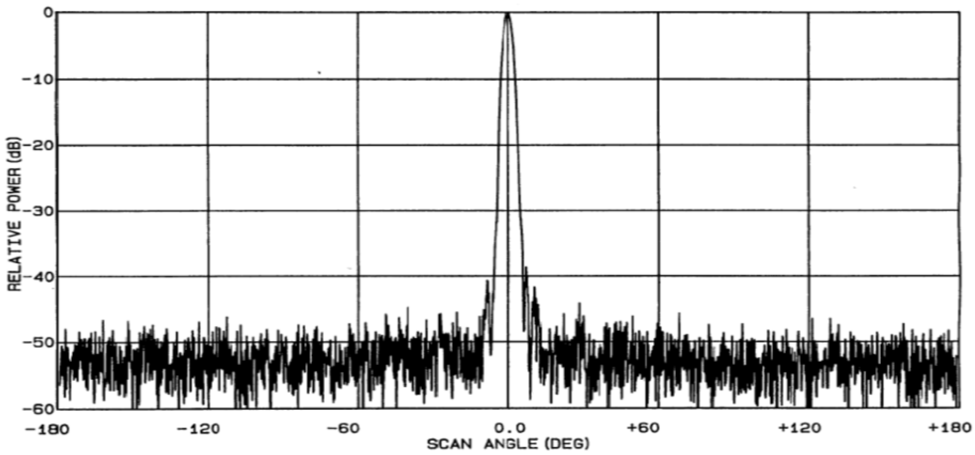
In addition Recommendation ITU-R RS.1029 provides the protection criterion for EESS operating in the frequency range 86-92 GHz which is a maximum received allowable power of −169 dBW in 100 MHz (see red spot in Figs. 6 to 8). This level may be exceeded for less than 0.01% of the time (for a 0.01% level, the measurement area is a square on the Earth of 2 000 000 km^2, unless otherwise justified).

EESS receive filters frequency response is assumed to provide sufficient attenuation outside of the 86-92 GHz to allow limiting the compatibility analysis within the 86-92 GHz band.

Passive sensors are designed to have a high main beam efficiency resulting in slightly wider main beam and lower side-lobe levels. A typical antenna pattern for AMSU-A is shown in Fig. 4.

FIGURE 4

Typical AMSU-A antenna pattern around 89 GHz



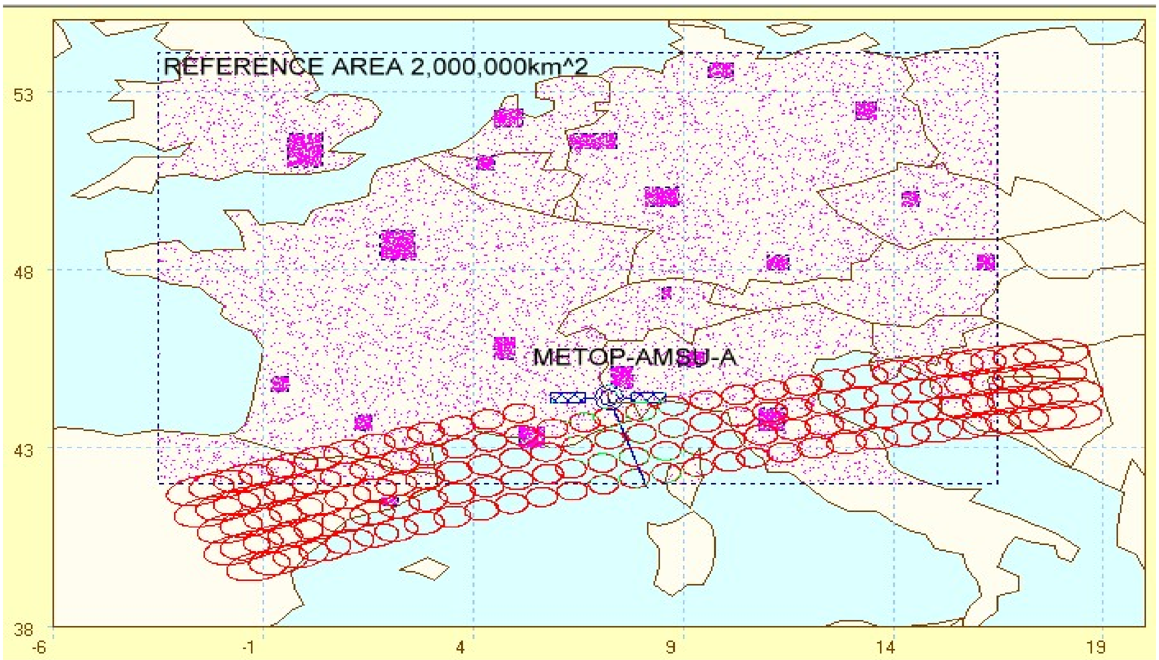
This makes sensors slightly more vulnerable to interference received in the main lobe but much more robust against interference received via side lobes. Recommendation ITU-R RS.1813 provides relevant EESS sensors antenna patterns to be used for interference assessment.

2.2 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 5 shows an overview of the assumed hot spot distribution and background density.

FIGURE 5

Dynamic analysis configuration for AMSU-A



An unwanted emission power level of −28 dBW in 100 MHz was assumed in the simulations.

Figure 6 shows the results for the AMSU-A and Fig. 7 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°, an interference excess of 8 dB can be expected. 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 6

Interference statistics for AMSU-A

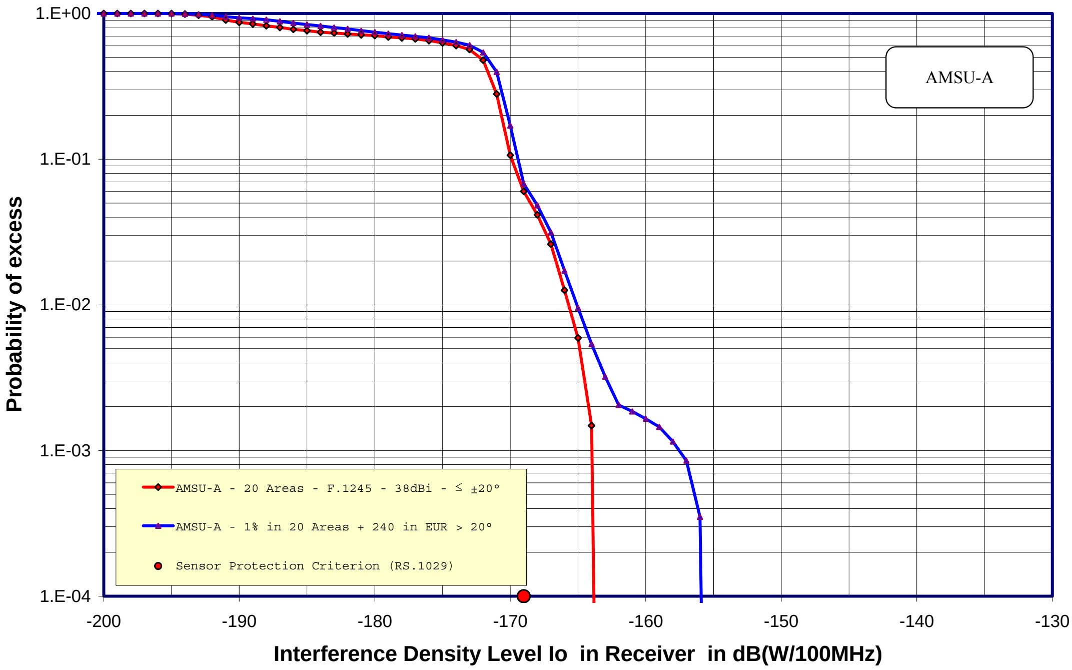


FIGURE 7

Interference statistics for MHS

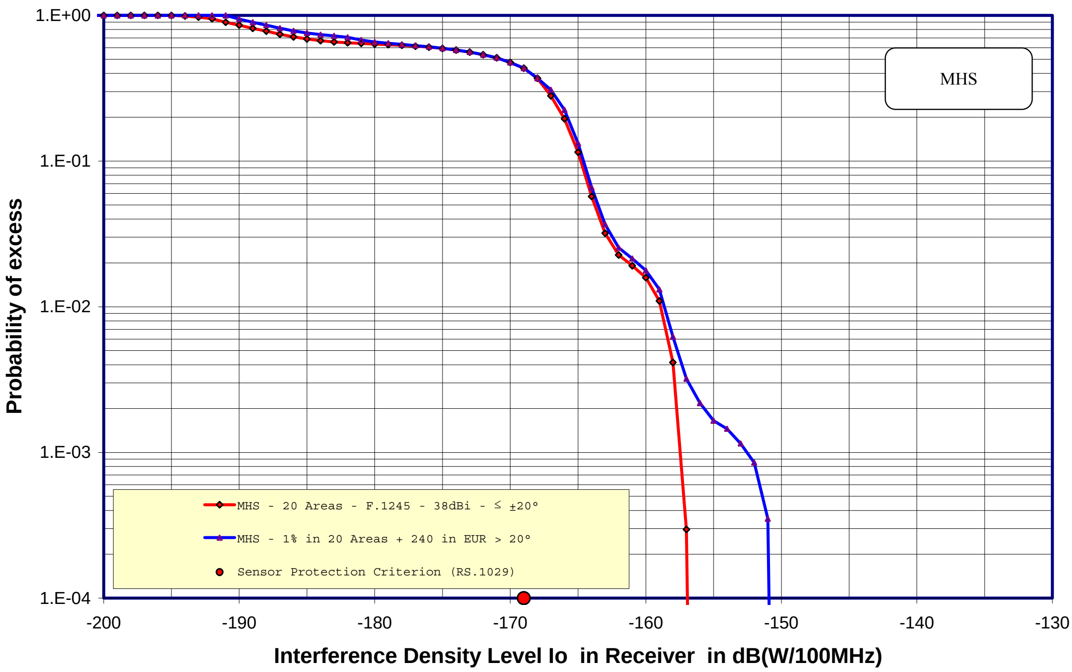


FIGURE 8

Interference statistics for CMIS

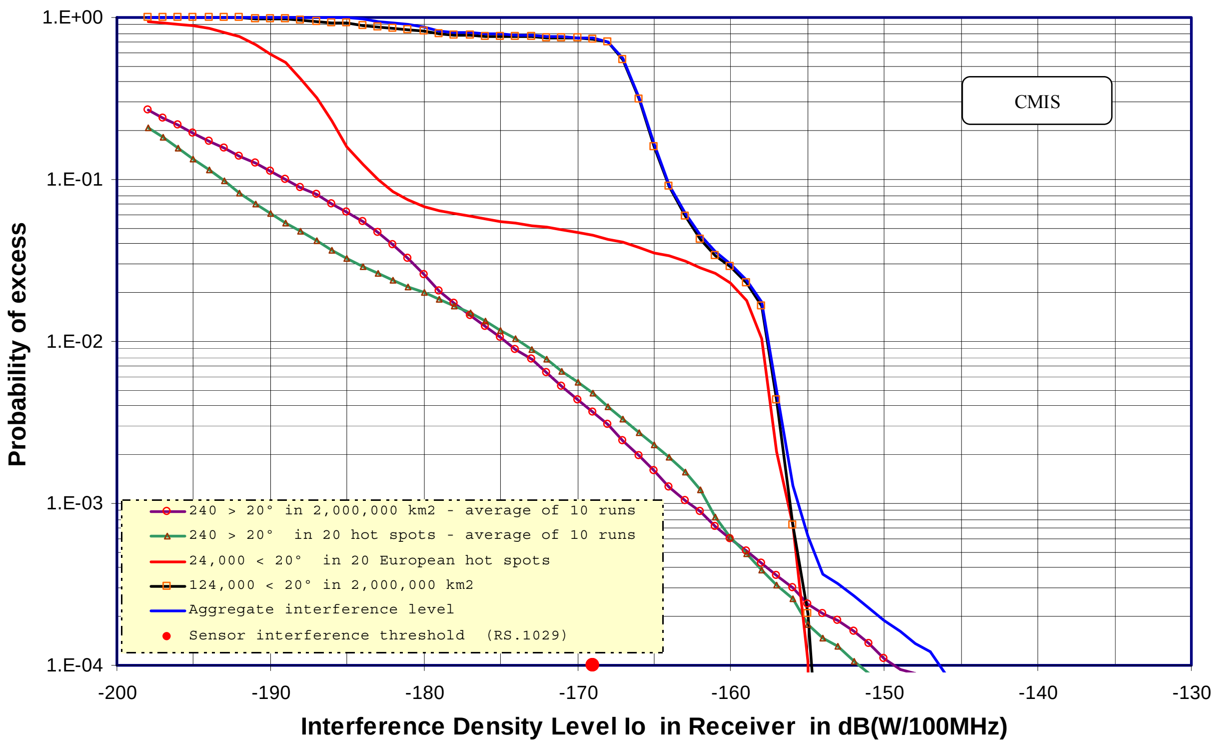


Figure 8 shows a summary of the results for the CMIS sensor for the 1% scenario for elevation angles above 20° in hot spots and 0.24% in other areas. An average of 1.3 dB for attenuation due to propagation losses and signal blocking was taken into account. The red curve shows the aggregate interference 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 124 000 stations) distributed over the reference area of 2 000 000 km^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 hot spots or outside are also shown in Fig. 8 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. From the simulations, a maximum power density level of around −42 dBW/100 MHz is required if only low elevation links would be deployed. 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.

2.3 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 20 degrees can significantly increase the interference levels as main beam coupling may occur. From the simulations, the required level to protect passive sensors from FS links deployed below elevation angles of 20° 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 two different levels for unwanted emission limits is not considered practical in view of two 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 two 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 FS unwanted emission power level at the band edge, provided that the average FS unwanted emission over a 3 GHz channel in the band 86-89 GHz does not exceed the aggregate value obtained with a level of −50 dBW/100 MHz.

To further reduce any potential burden on the FS, an alternative possible single mask is proposed starting with −41 dBW/100 MHz at 86 GHz and decaying to −55 dBW/100 MHz at 87 GHz.

It should be noted that a second technical analysis as given in Annex B, starting with FS parameters and expected unwanted emission power levels provide additional support to the adequacy of these conclusions.

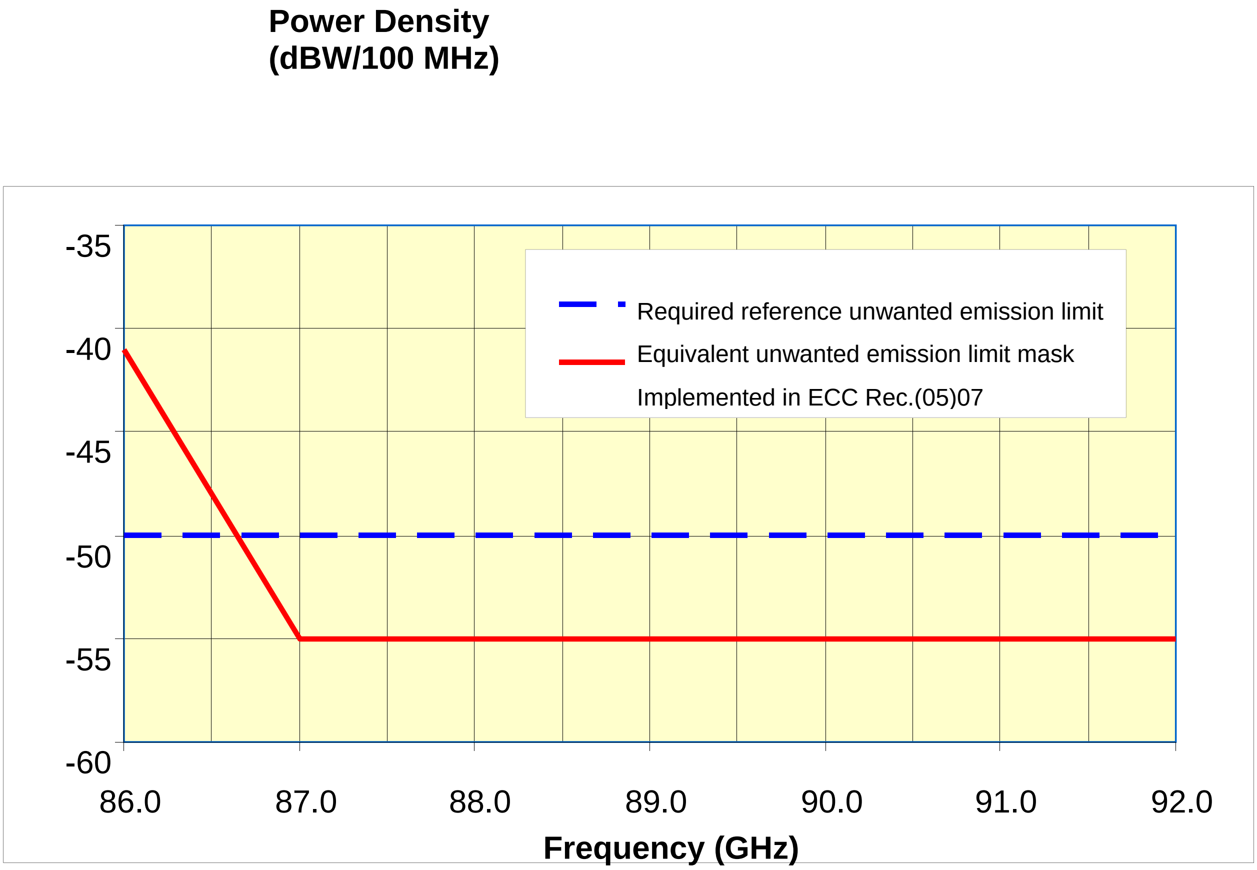
2.4 Conclusions

A single unwanted emission level of −50 dBW/100 MHz without any further restrictions on the FS will provide adequate protection to EESS (passive) while allowing flexibility for deployment of FS stations.

An alternative unwanted emission mask as shown in Fig. 9 below 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/100 MHz at 87 GHz.

FIGURE 9

Unwanted emission specifications for FS systems



2.5 Impact on the FS in the 81-86 GHz of the proposed unwanted emission limits in the band 86-92 GHz for the protection of EESS

For satisfactory compliance of limits in the 86-92 GHz band for the protection of EESS, it is assumed that FS would have to implement certain mitigation techniques which include relevant placement of FS carriers according to their bandwidth from the EESS band edge (86 GHz) or additional filtering or combination of both.

It is currently and widely recognized that compliance with the above mentioned alternative mask is not binding to the FS.

2.6 Analogue analysis related to FS in the 92-94 GHz band

Annex A/Appendix 1 similarly considers the compatibility between FS operating in the 92-94 GHz band and EESS (passive) sensors in the 86-92 GHz band.

Based on the fact that the FS characteristics and deployment scenarios are likely to be the same as in the bands 81-86 GHz and that the propagation conditions and the EESS sensor characteristics are the same as already used, this Annex C allows to conclude that the above technical analysis conclusions are valid for FS in the 92-94 GHz band.

Therefore, similar conclusions applies as a single unwanted emission level of −50 dBW/100 MHz will provide adequate protection to EESS (passive) while allowing flexibility for deployment of FS stations and that an alternative unwanted emission mask (so-called “mirror-mask” compared to the one depicted in Fig. 9 above) starting with −55 dBW/100 MHz at 91 GHz and increasing to −41 dBW/100 MHz at 92 GHz would provide similar protection to EESS (passive).

3 Conclusions

Annex A and Annex A/Appendix 1 assess the impact of unwanted emissions of FS operating in the bands 71-76 GHz, 81-86 GHz and 92-94 GHz on passive services in shared and adjacent bands.

The following results were achieved:

Active service	Passive service	Conclusion
FS in the bands 81-86 GHz and 92-94 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/100 MHz at 87 GHz (see § 2.4). The same “mirror mask” is applied for FS operating in the 92-94 GHz band (see § 2.6 and Annex A/Appendix1). For the impact of these limits on FS (see § 2.5)

Appendix 1 to Annex A

Consideration of compatibility between the FS in the 92-94 GHz band and the EESS in the adjacent 86-92 GHz band

1 Introduction

The technical analysis developed in the present Study is limited to FS systems operated in the 81-86 GHz band. However, it should be kept in mind that the goal is also to achieve the protection of passive services from interference from unwanted emissions of active services in adjacent bands and it would be irrelevant to consider the protection of EESS from unwanted emissions of FS deployed in the band 81-86 GHz without taking into account the case of FS systems deployed above 92 GHz that also have the potential to produce unwanted emissions in the 86-92 GHz band.

2 Basis for the unwanted emission mask derived in the study

As shown in Annex A, unwanted emission power limit is a function of:

− the FS station antenna pattern;

− the density of FS stations deployed in hot spots (urban/sub-urban areas);

− the maximum elevation angle of FS stations;

− the antenna gain and footprint, and protection criterion of the EESS sensor.

With regard to the antenna pattern of FS, it was agreed to use Recommendation ITU-R F.1245. The documentation from one European manufacturer provided in Annex shows that the FS links at

92-95 GHz will use the same antennas as for the 70/80 GHz or even 40.5-43.5 GHz bands, with antenna gains up to 50 dB. With regard to the density of FS stations, it should be noted that, in absence of available operational data, only theoretical values were taken for the density of FS links in the bands 71-76 and 81-86 GHz, based on the calculation of mutual interference between FS systems (methodology described in Annex A1) As stated in Annex A “a density of 0.5 links per km² per frequency channel was assumed in this study but is limited to areas with high population densities (hot spots).” Since the output power and e.i.r.p. are the same for the frequency bands 81-86 GHz and 92-95 GHz and the applications are the same in both bands, the methodology will give the same results for all frequency bands, 0.5 FS links/km², limited to hot spots.

With regard to the maximum elevation angle of FS stations, it has been shown that the distribution curve of elevation angles has no impact on the simulation results, but that the maximum elevation angle does. Annex A states that:

“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.”

Still from information available from one European manufacturer, the hop length for FS links above 92 GHz is roughly the same as for FS links below 86 GHz and the applications are also the same. Therefore, the maximum elevation angles used in operational deployments will also be the same.

With regard to the EESS sensor characteristics, it is obvious they are the same whether we consider unwanted emissions from FS above 92 GHz or below 86 GHz.

Finally, it should be noted that the difference between 81-86 GHz and 92-94 GHz equipment is of the order of less than 10 % of relative bandwidth. Therefore the radio frequency technology should be physically very similar.

3 Conclusion

Based on the above elements tending to demonstrate that the situation pertaining to FS in the 92-94 GHz band will be more than likely similar to the one in the 81-86 GHz in terms of FS characteristics and deployment scenarios, propagation conditions and EESS sensor characteristics, one can expect that conclusions related to the 81-86 GHz band remain valid for the 92-94 GHz band.

Therefore, similar conclusions applies as a single unwanted emission level of −50 dBW/100 MHz will provide adequate protection to EESS (passive) while allowing flexibility for deployment of FS stations and that an alternative unwanted emission mask (so-called “mirror-mask”) starting with −55 dBW/100 MHz at 91 GHz and increasing to −41 dBW/100 MHz at 92 GHz would provide protection to EESS (passive).

Appendix 2 to Annex A

100Mbps + 8E1 point-to-point wireless mm-wave link with total throughput 155 Mbit and fibre optics interface

PPC-100FE/8E1 is wireless point-to-point link that provides mm-wave radio connectivity for the following mm-wave bands: 40.5-43.5 GHz, 57.0-65.0 GHz, 71-76 GHz and 81-86 GHz, and 92-95 GHz. The main channel is full-duplex 100 Mbit Fast Ethernet plus 8xE1 additional channels transmitting simultaneously. The total link throughput is 155 Mbit which is coming to uplink port of optical mux "100 Mbps + 8E1". The link kit shipment includes two optical multiplexers "100 Mbps + 8E1" among two mm-wave radios (one for each side of the link).

Applications of point-to-point PPC-100FE/8E1 Links

For PPC-100FE/8E1 model the primary application is interconnection between base station sites in cellular networks (GSM / GPRS / UMTS). PPC-100FE/8E1 provides an ideal intranet-intranet and intranet-public network connection solution as wells as any LAN/WAN connection where there is a requirement to combine data and voice services in one link.

Other general purpose applications are the following:

− Wireless full duplex connection link for remote LAN segments at corporate and university campuses;
− FSO (atmospheric laser) and fibre optics channel back-up;
− Multipurpose fixed wireless communications for any field use.

PPC-100FE/8E1 links are featured with remote management and parameter monitoring capabilities. To communicate with the link for SNMP and parameter control, there is a special twisted pair cable patch which has to be connected to any RJ-45 socket within LAN, deployed in the building. This allows remote SNMP management and remote parameter monitoring of PPC-100/STM-1 links from a central location.

These "100 Mbps + 8E1" point-to-point millimetre wave radio systems are available with a choice of three different sizes of compact parabolic Cassegrain antenna − 30 cm, 45 cm, and 60 cm.

Depending of the link frequency, these antennas deliver operating distances from about 1.5 mile to 9.5 miles (2.5 km to 15 km) for fair-weather conditions.

PPC-100/STM-1 point-to-point link specifications

System parameters				
Frequency band	42 GHz [Q-band]	60 GHz [V-band]	70-80 GHz [E-band]	94 GHz [W-band]
Bandwidth	40.5-43.5 GHz	57-64 GHz	71-76 / 81-86 GHz	92-94.0, 94.1-95 GHz
Max distance* km) for different size antennas • for 30 cm • for 45 cm • for 60 cm	7.8 11.2 13.0	1.7 2.1 2.3	N/A N/A 7.1	5.5 6.7 8.1
Capacity	155 Mbps duplex			
Modulation type	ASK			
Rx sensitivity	−95 dBW	−95 dBW	−94 dBW	−93 dBW
Frequency stability	15 ppm/630 kHz	15 ppm/900 kHz	20 ppm/1 600 kHz	20 ppm/1 900 kHz
Output power **	50 mW	18 / 34 / 55 mW for 30/45/60cm antennas respectively	50 mW	50 mW
AGC range	60 dB [AGC]			
Network management	SNMP			
Parameters monitoring	Proprietary adapter in ODU with software application [Windows 98/2000/XP]			
Remote monitoring	Software			
Data and aux. interface				
Data interface	STM-1 [SC/PC optical connector]			
SNMP and diagnostics port	IP 65 environmental RJ-45 connector with UTP cable patch, RS-485 port (optional)			

Antenna				
Antenna type	Parabolic Cassegrain type antenna with radome (choice of sizes with diameter 30 cm, 45 cm or 60cm)			
Antenna gain/beamwidth				
• for 30 cm antenna	38 dB/1.6°	42 dB/1.0°	43.5 dB/0.9°	45 dB/0.7°
• for 45 cm antenna	42 dB/1.0°	45 dB/0.7°	46.5 dB/0.6°	48 dB/0.5°
• for 60 cm antenna	44 dB/0.7°	47 dB/0.5°	50 dB/0.4°	50 dB/0.4°
Power/environment				
Power supply AC input	88-132 / 176-264 Volts, 50/60 Hz [with manual voltage range switch]			
Transceiver power consumption	20 W [+15W heating]		35 W [+15W heating]	
DC power	48 to 60 Volts DC			
Power connector	SNMP-Ethernet / Power connector IP-65 [optional IP-68]			
Operational temperature	−40°C to 50°C (−40°F to 122°F)			
Humidity	0 to 95%, non-condensing			
Physical dimensions				
Outdoor unit size	w/o antenna 330 × 350 × 460 mm			
Weight (ODU w/o antenna)	14 kg			

Annex A1

Additional considerations on compatibility between the FS in the 81-86 GHz and 92-94 GHz bands and the EESS in the 86-92 GHz band

1 Introduction

This Annex provides additional considerations related to FS typical deployment characteristics (density and elevations) and further simulation results taking into account new assumptions for FWS in the frequency band in 71-76/81-86 GHz and 92 GHz.

From the simulation results, it can be seen that even by restricting the overall number of FS links, the elevation angles of FS stations to 45° and the percentage of elevation angles above 30° to very low percentages, the conclusions presented in the Annex A on the coexistence between fixed service operating in 71-76/81-86 GHz bands with the passive services are unchanged.

2 Additional simulations

Further simulations were run with the following assumptions:

- the CMIS sensor;
- a reference power density of 0 dBW/100 MHz for the FS station;
- a reference area of 2 000 000 km² as specified in Recommendation ITU-R RS.1029;
- 20 hot spots with an area of 1 000 km² (1 200 was considered in Report ITU-R F.2239);
- a background deployment representative of rural areas;
- 0.1 or 0.5 Tx/km² in hot spots;
- 0.01 or 0.05 Tx/km² in rural areas;
- the majority of elevation angles below 30°, no elevation angle above 45°;
- 0.5% or 0.1% of elevation angles above 30°.

It should be noted that these simulations are valid for FS deployed in the 81-86 GHz and 92-94 GHz bands.

Simulation limitation

It should be noted that, first, the simulation was run over 17 days with a time step of 0.4 seconds. In order to get a greater number of sensor positions, the sensor rotation was modified from 189.6°/s to 36°/s. In spite of that, a certain number of pixel are missed (not seen), which may include a FS link with a high elevation angle. The simulation tool used was run with time steps down to 32 ms, thus offering a more detailed view of the simulation.

Additional simulations were run over a single satellite pass over Europe, but with a time step of 1.2 ms similar to the sensor integration time, and the actual rotation speed of the conical scan sensor. The results are shown in Fig. 12 for one single passage.

FIGURE 10

Simulation geometry and FS deployment

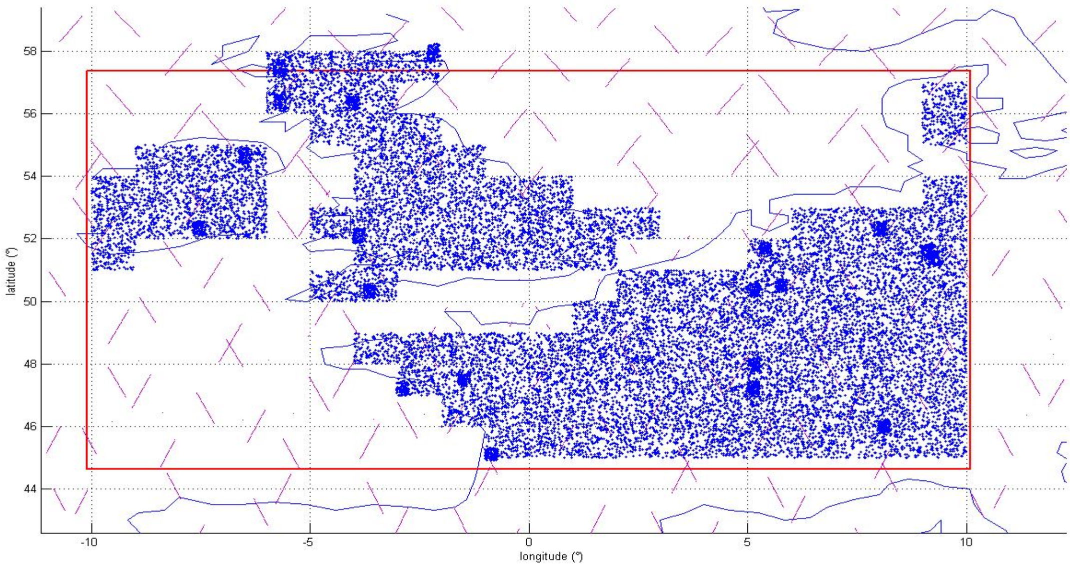
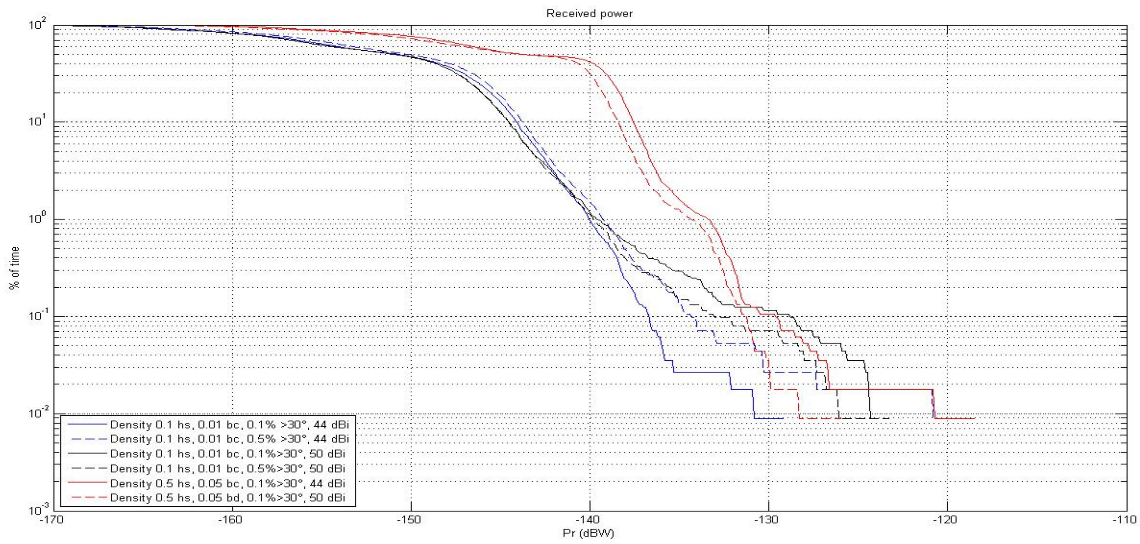


FIGURE 11

Simulation results over 17 days



The simulation results show that:

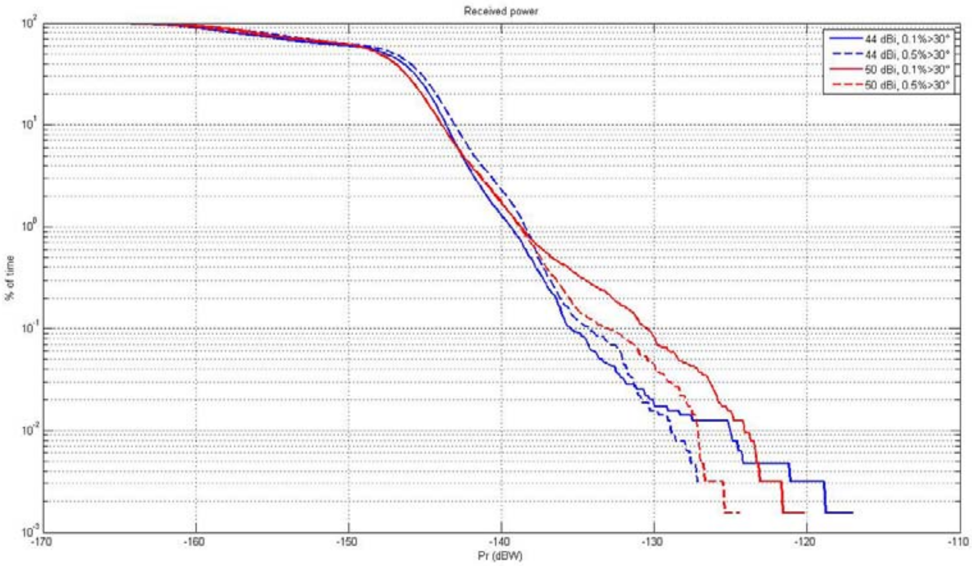
– the maximum interference level for 0.01% of the time and a power level of 0 dBW is −121 dBW/100 MHz, 48 dB above the protection criterion, which means that the power density should be reduced to −48 dBW/100 MHz consistent with the −50 dBW/100 MHz given in Annex A;

– this maximum value is reached in two cases, irrespective of the density of terminals per hot spot (respectively in rural environment) is 0.1 (0.01) or 0.5 (0.05) and of the ratio of terminal elevations higher than 30° (0.1 or 0.5%);

– the terminal density has indeed an impact on the shape of the overall curve, but not necessarily on the maximum interference level for 0.01% of the time;
– the FS antenna gain does not seem to have a big impact on the results since results for an antenna gain of 50 dBi can sometimes be better than those for an antenna gain of 44 dBi.

FIGURE 12

Simulation results over 1 single passage



When considering a single passage and a time step of 1 ms similar to the sensor integration time, it is possible to focus on the short term events. However in this case the percentage of time is calculated only over one satellite passage and thus gives different results than in Fig. 11. However, it confirms that there is not really an influence of the maximum antenna gain, or of the percentage of high elevation angles.

Impact of the density of FS links

For urban hotspots, calculations were made for two figures of FS density, 0.1 and 0.5 Tx/km^2. A density of 0.1 Tx/km^2 is considered more representative of some current FS deployment whereas 0.5 Tx/km^2 is a more conservative value taking into account the possible future larger deployment of FS.

For rural area, calculations were made for two figures of FS density, 0.01 and 0.06 Tx/km^2. A density of 0.01 Tx/km^2 is considered more representative of some current FS deployment whereas 0.06 Tx/km^2 is more conservative value taking into account the possible larger deployment of FS.

The FS density parameter is one of the key contributors to the interference level. In theory, a decrease by a factor of 5 of the density of FS links in hot spots would lead to a decrease by 10log(5) or 7 dB of the interference level and therefore a relaxation of the required unwanted emission mask by 7 dB. This is confirmed by a general shift of the cdf curves.

However, this is not necessary the case for the percentage of time of 0.01% since at such low percentage of time, the interference is more than likely controlled by one single FS link. This is confirmed by the additional simulations above for which it happens that one single FS pointing at high elevation angles is sufficient to increase the interference level by 5 to 10 dB. For example, in one case with a density of 0.1 per hot spot and 0.01 for the background, the interference level is similar to the one found in Annex A with densities 5 times higher.

In addition to these findings, it should also be highlighted that the application of the methodology presented in Annex A1 to derive the maximum density of FS links that may be deployed in a given area without mutual interference leads to different density values when considering different reference areas and FS bandwidth.

Indeed, for a rather small hot spot representative of a small city of 20 km², the density of FS links may be up 5.5 Tx/km². For a hot spot of 200 km² representative of the EESS sensor pixel, the density of FS links is between 0.5 and 1.2 Tx/km²,

The following tables provide different FS densities for various values of the reference area and FS bandwidth:

TABLE 1

1 576 km² reference area

FS bandwidth	***I/N* = −6 dB** **Density/km² (number)**	***I/N* = 0 dB** **Density/km² (number)**
1.250 GHz	0.13 (205)	0.19 (299)
4.750 GHz	0.18 (284)	0.26 (410)

TABLE 2

200 km² reference area

FS bandwidth	***I/N* = −6 dB** **Density/km² (number)**	***I/N* = 0 dB** **Density/km² (number)**
1.250 GHz	0.49 (98)	0.79 (158)
4.750 GHz	0.75 (150)	1.22 (444)

TABLE 3

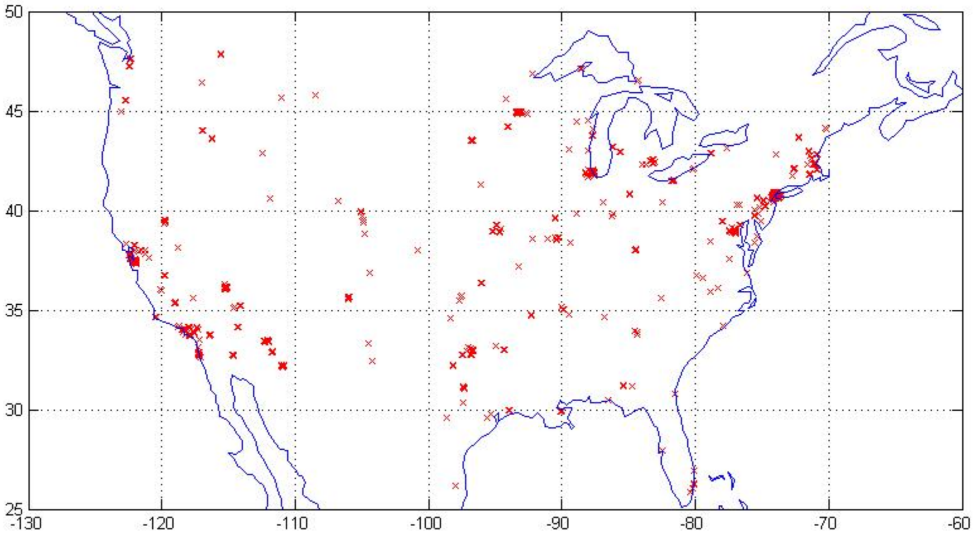
20 km² reference area

FS bandwidth	***I/N* = −6 dB** **Density/km² (number)**	***I/N* = 0 dB** **Density/km² (number)**
1.250 GHz	2.90 (58)	3.86 (77)
4.750 GHz	3.75 (75)	5.52 (110)

These tables show that what can be considered realistic for a given reference area may be largely exceeded for another one. It is clear that the unwanted emission mask for the protection of EESS should not be based on a best-case deployment in one single specific area since it may lead to interference exceeding the EESS protection criterion when the passive sensor is looking at smaller cities with higher densities of FS links.

Example of density of FS links in hot spots in the US

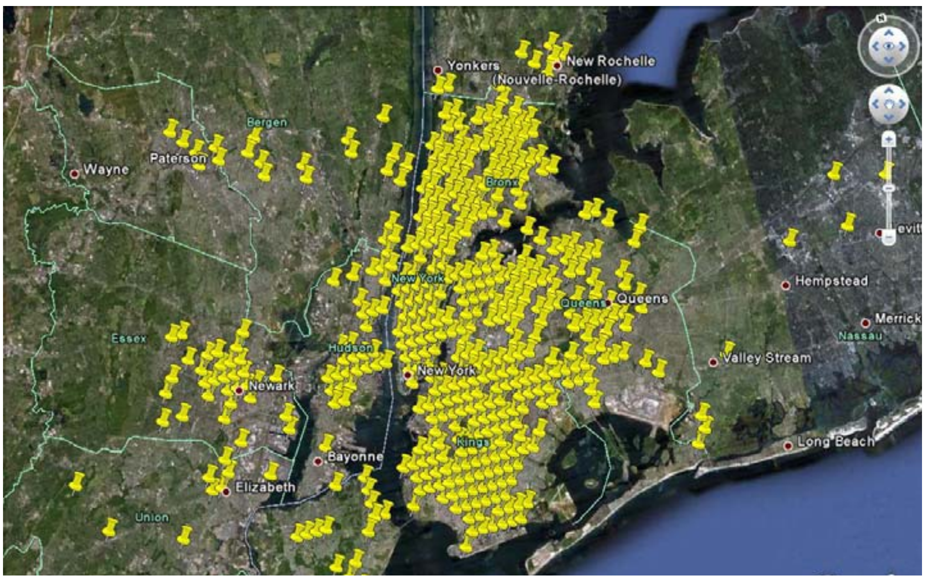
From the US FCC database, there are currently 2 935 FS stations currently in operation or planned in the USA, already presenting quite a number of hot spot spread over the US territory as depicted in the figure below.



Specifically addressing the case of New York (see figure below), there are 1 259 FS stations deployed in an area of 29 km × 36 km, 1 044 km², 5 times the CMIS pixel dimension.

This corresponds to a density of 1.2 stations per km² in this area, i.e. 2.4 times higher than what is considered in Annex A (i.e. 0.5 stations/km²). The density of 0.5 cannot therefore be considered as a worst case or overestimating possible future FS deployment.

It is not expected that significant variations will appear in the density of links in cities from one country to the other and one can therefore assume that the density of 0.5 Tx/km² in hot spots is obviously an average case and not a worst case.



Impact of the elevation angle

Based on data from the 37-38 GHz band in some European countries, links have an elevation angle lying from 0 to 30°. In these same countries, some of the FS links can be above 30°. It should be noted that the likelihood of links above 30 deg is very low.

The simulation runs have considered different cases: 0.5% of elevation angles above 30°, and 0.1% of elevation angles above 30°. In all cases, the elevation was limited to 45°.The percentage of links with an elevation higher than 30° has actually no impact. On all cases simulated with random location of cities and FS stations within cities and in the background, it happens from time to time that one single FS station causes interference exceeding the protection criterion, with a level similar to the one determined in Annex A.

With a density of 0.5 Tx/km² in hot spots and 0.05 Tx/km² in rural areas, even 0.1% of FS links with an elevation angle above 30° is sufficient to get an interference level similar to the levels found in Annex A.

Typical total emission power and associated antenna gain values of FS stations

The following values have been extracted from the preliminary draft revision of Report ITU-R F.2107.

System-wide	
Frequency band (GHz)	71-76/81-86
Transmitter	
Output power (dBm)	17-20
EIRP (dBm)	70 (typical), 75 (max for sharing studies) 85 (absolute max)[1]
Antenna	
Antenna type	Parabolic
Antenna gain (dBi)/beamwidth (degrees) ** 60 cm 45 cm 30 cm	 50/0.4 46.5/0.6 43.5/0.9
Antenna polarization	Vertical or horizontal (field selectable)
Receiver	
Noise figure (dB)	≤ 11
Sensitivity at 10^{-6} BER (dBm)	−61.5 *

** For antenna gains less than 50 dBi, the EIRP must be reduced by 2 dB for every 1 dB reduction in gain below 50 dBi.

* Data sheets of existing receivers specify a sensitivity (BER=10^{-6}) ranging from −62 dBm to −57 dBm. The sensitivity (BER = 10^{-6}) of −61.5 dBm is derived by using the theoretical S/N (BER = 10-6) values provided in Recommendation ITU-R F.1101 with the coding gain and implementation losses assumed mutually compensating.

It should be noted that the in-band power has no impact on the studies as the aim is to derive an unwanted emission mask from the protection criteria of the EESS sensor. The in-band output power is fully relevant when assessing the impact of this unwanted emission mask on the FS transmitter in terms of potential additional filtering or guard bands.

The maximum antenna gain has an impact only for elevation angles higher than 30°. The additional simulations above show that the impact is marginal for a percentage of time of 0.01%.

Conclusions

In view of the elements including additional density calculation and the additional simulations provided in this document, one can show that the conclusions as given in Annex A remain valid.

Nor the restriction of elevation angles to values up to 45° neither the reduction of the percentage of elevation angles with elevations higher than 30° provide improvement of the situation and hence a change in the required unwanted emission mask.

Annex A2

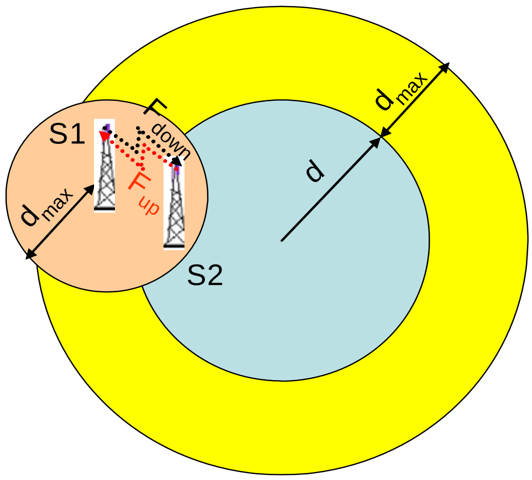
Estimation of the maximum density of FS links

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. It is set up in a radius of d_{max} centred around the first station (see Fig. 13).

FIGURE 13

First link



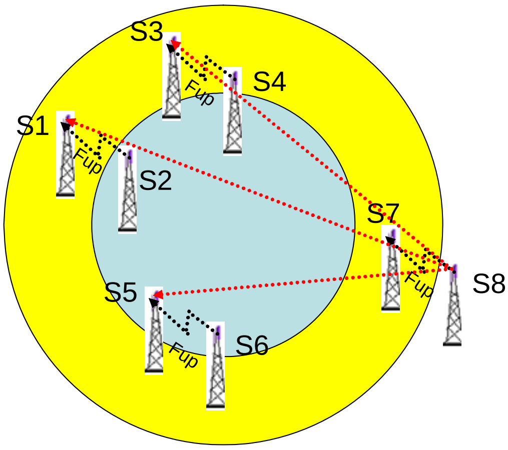
The power at the receiver is assumed to be 3 dB above the sensitivity, and the power at the Tx is calculated taking into account the oxygen absorption (see Recommendation ITU-R P.676 [3]) and the rain fading (see Rec. ITU-R P.530 [4]). It should be mentioned that this methodology considers free-space 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 Recommendations ITU-R P.837 [5] and ITU-R P.838 [6] (zone "K" is assumed in the simulations).

Step 2: Step 1 is repeated to set up new links. (See Fig. 14.)

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 14

Interference from the new transmitter at each existing receivers

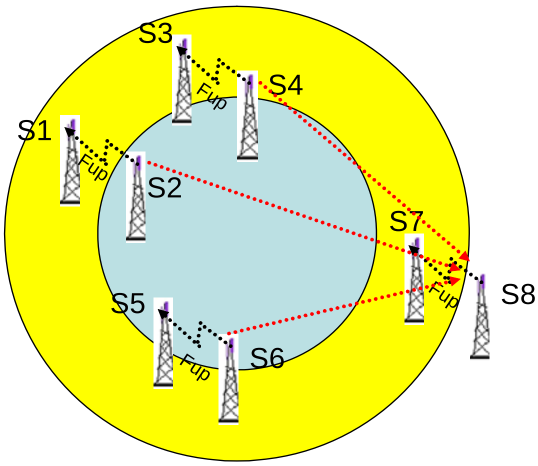


Then, the aggregate interference is calculated.

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 Fig. 15).

FIGURE 15

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: 55 dBi
− Antenna pattern: Recommendation ITU-R F.1245
− Noise level: −114 dBW in 250 MHz
− Hop length: 50 m - 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).

TABLE 4

Results of simulations

Total number of stations	Total number of stations in $d + d_{max}$	Total number of stations in d	Total number of Rx at 86 GHz stations in d	Density of stations in $d + d_{max}$	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

It leads to the conclusion that an estimation of FS links density could be 0.5 Tx/km^2.

Annex B

Compatibility study between the fixed service in the 81-86 GHz band and Earth exploration-satellite service (passive)in the 86-92 GHz band

1 Introduction

This study aims to take into account more realistic information on typical fixed service deployment characteristics such as station density and elevation angles with a view to developing a near realistic worst-case interference scenario to address the potential for impact from the fixed services operating in the 81-86 GHz band into the EESS (passive) measurements in the adjacent 86-92 GHz band.

During the development of this study EESS receive filter frequency response characteristics were not taken into account which may provide further additional mitigation from FS interference to the EESS in the adjacent band. Further information on EESS receive filter frequency response could provide even better representation of the actual compatibility environment for these bands.

2 Methodology

Link density, elevation angles and antenna gain

The FS deployment scenario assumed a maximum link density of 0.19 links/km^2. This was calculated using a similar methodology to that presented in Annex A2 (Methodology), which calculates the maximum number of FS links that can be deployed in an area on an interference limited basis. This method has been adjusted to calculate the density across the total 81−86 GHz band as opposed to the density per single channel.

A number of the assumptions used in the calculations have been revised. The antenna gain has been reduced from 55 dBi to 44 dBi based on actual manufacturer data, and that most of the current actual fixed service deployments in 81-86 GHz have an antenna gain of 44 dBi. Recommendation ITU-R F.699 antenna pattern was used as this is more appropriate for an intra-service scenario. In Annex A an intra-service FS I/N value of 0 dB is assumed. A more representative value of −6 dB is more commonly used in typical fixed link planning and assignment scenarios. For clarity both of these values have been used in the analysis to show a range of results. Finally, the final figure for density has been taken as an average over 1 000 runs of the method, rather than the maximum value from 10 runs in order to give a more repeatable result.

A normal distribution of elevation angles for fixed links was considered of ±30 degrees. Practical data from this and other bands suggests the vast majority of link elevations will be less than 20 degrees, yet the possibility of links as high as 30 degrees elevation has been considered here as a worst case to account for the possibility of short distance urban links at high elevation.

3 Scenarios

The analysis considered two scenarios of FS deployments:

Scenario 1 covered a worst-case high density deployment across an urban area and a surrounding lower density, and Scenario 2 covered a wide scale deployment with urban hotspots and a combined lower density over an area of 2 000 000 km^2.

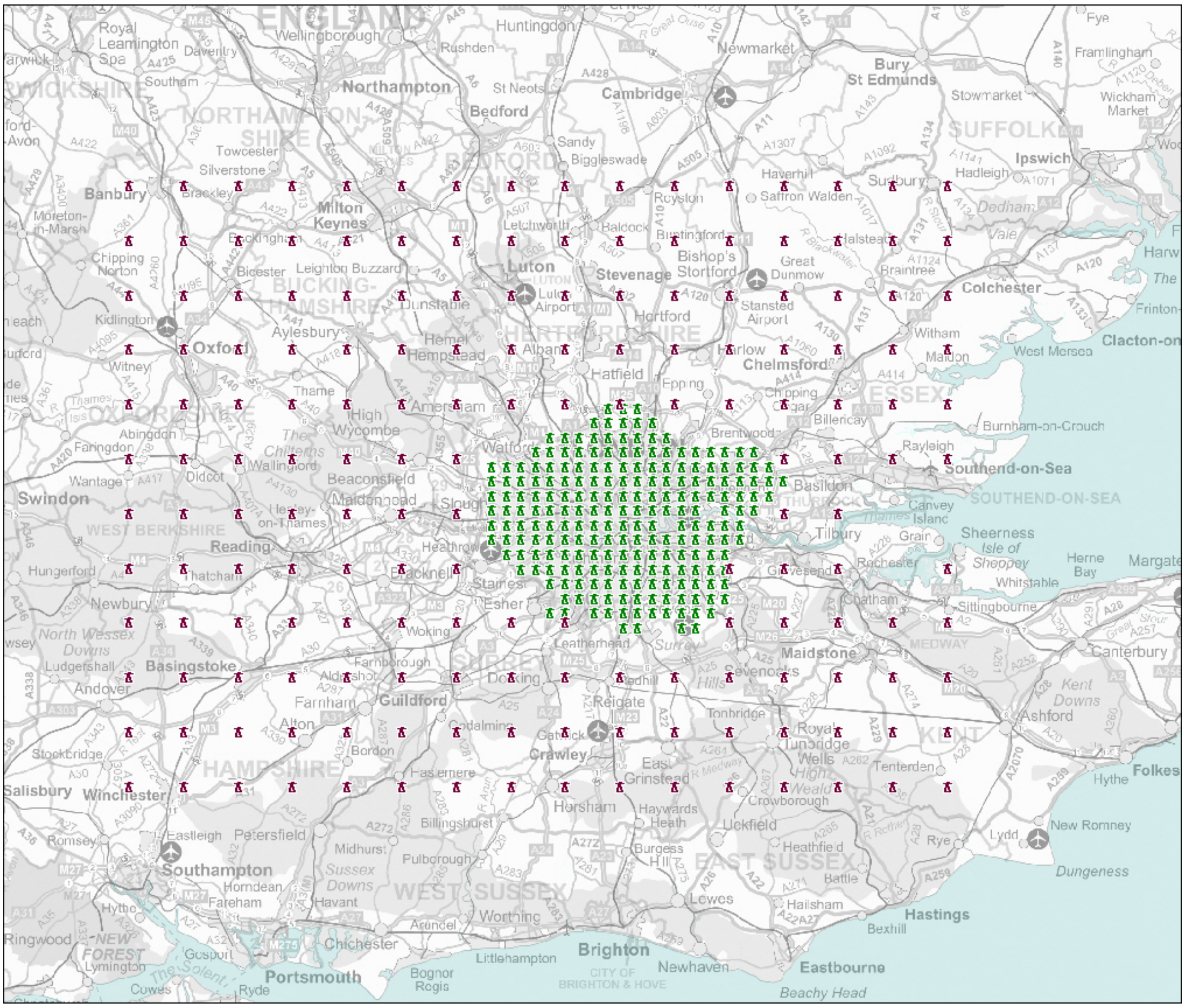
The urban scenario (Scenario 1) was chosen as the worst case of interference can be expected to occur as the EESS sensor moves over a high density urban FS deployment. Analysis over wider rural areas will not show any increase in interference and therefore a full FS deployment over the 2 000 000km^2 area referenced in Recommendation ITU-R RS.1029 is not necessary. In the case of cross-track scans, the satellite is positioned so that the edge of the sensor sweep is over the urban area, which gives the worst case in terms of alignment of main beams. However, for completeness a second scenario which uses a deployment over the full 2 000 000 km^2 reference area was also considered to confirm the worst-case results from Scenario 1.

Scenario 1

The scenario considered a regular grid of fixed links deployed on a statistical basis over Greater London and the surrounding area as shown below. It should be noted that although London was chosen as a location for Scenario 1, similar statistical deployment over any geographical area would give similar results.

FIGURE 16

FS Transmitter locations



A high density deployment was considered in the urban Greater London area (approx. 1 500 km^2), and a lower density in the surrounding rural area (approx. 28 500 km^2). The urban density was calculated according to the methodology and assumptions above, and varies with planning assumptions and channel bandwidth. The rural density was calculated relative to the urban density by a factor of 0.09 based on worst-case ratio of urban to rural densities in the 38 GHz band.

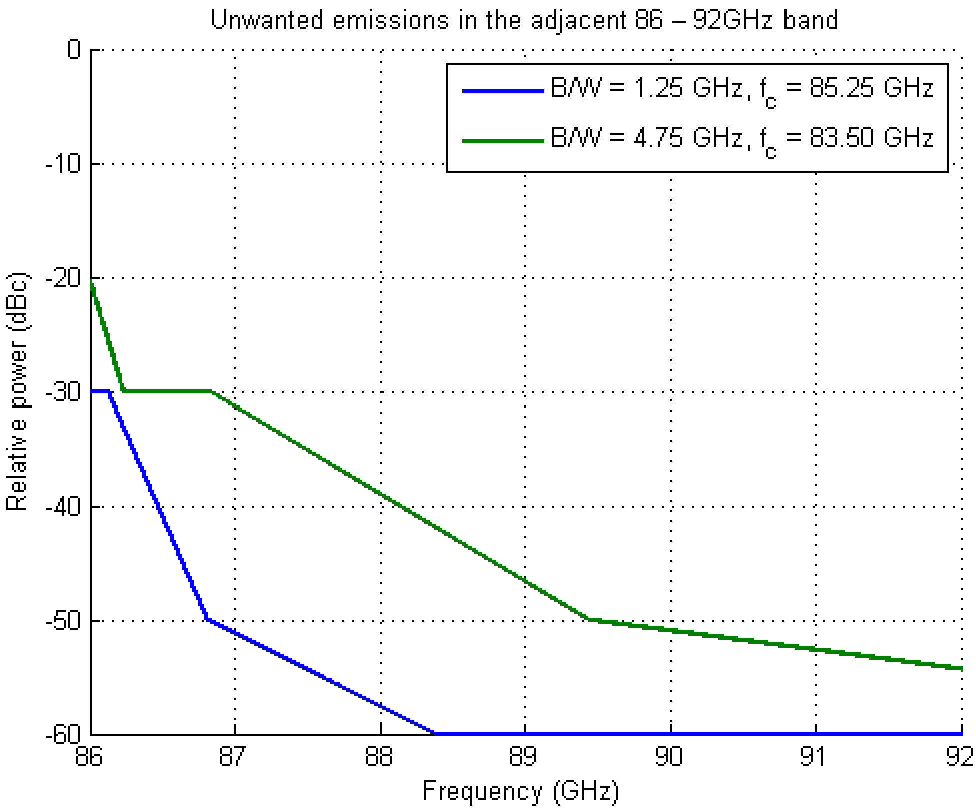
The main FS parameters are given below:

TABLE 5

Main FS parameters

FS frequency range (channel edges):	81.125−85.875 GHz
Antenna pattern:	Recommendation ITU-R F.1245-1
Antenna gain[1]:	44 dBi (applied to 86% of links) 51 dBi (applied to 14% of links)
Max Tx power:	−10 dBW
Unwanted emissions[2]:	See Fig. 17
Link elevation:	±30 degrees (approximately normally distributed)

FIGURE 17



Four different FS deployments were considered, with varying channel bandwidth and value of *I*/*N* as follows:

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[1] The distribution of antenna gain values is based on registered links in one administration at the date of the study.

[2] Unwanted emissions are based on ETSI Tx output power density mask for these bands.

TABLE 6

Simulated FS parameters

Simulation	FS B/W (GHz)	FS *I*/*N* (dB)	Urban density (Tx/km^2)	Rural density (Tx/km^2)	Total links
1	1.25	−6	0.14	0.01	391
2	4.75	−6	0.1	0.01	336
3	1.25	0	0.19	0.02	634
4	4.75	0	0.14	0.01	391

Four EESS sensors were included in the analysis. Their main parameters are given in Table 7:

TABLE 7

Simulated sensor parameters

Sensor	Sensor type	Scan type	Antenna gain (dBi)	Antenna beamwidth (deg)	Min. elevation angle (deg)
a	AMSU-A	Cross-track	34.4	3.3	32.5
b	AMSR-E	Conical	60.5	0.18	35.5
c	MHS	Cross-track	47	1.1	31
d	ATMS	Cross-track	37.9	2.2	26.75

Scenario 2

Scenario 2 considers analysis across an area of 2 000 000 km^2, as specified by Recommendation ITU-R R S.1029. A density of 0.01 links/km^2 is assumed across the reference area (i.e. the 'rural' density figure used in Scenario 1), resulting in 20 000 links in total. Additionally a layer of 15 urban deployments is included, each with 300 links. It results in 24 500 links in total. The approach taken involves calculating the aggregate EIRP by elevation angle towards the EESS satellite from a randomly located group of FS transmitters within a 100 km × 100 km square. This level is applied as a gain pattern to a grid of 200 equally spaced test points. A similar approach is used for the urban layer, using 15 40 km × 40 km test points at locations corresponding to major European cities.

4 Results

Scenario 1

Results for maximum and average interference level into the first 100 MHz of the EESS band (i.e. 86-86.1 GHz) are given below. This will give the highest level of interference into the EESS band. Interference into the entire 6 GHz has also been recorded but is found to be lower than the level at the band edge in all cases.

TABLE 8

Main simulation results

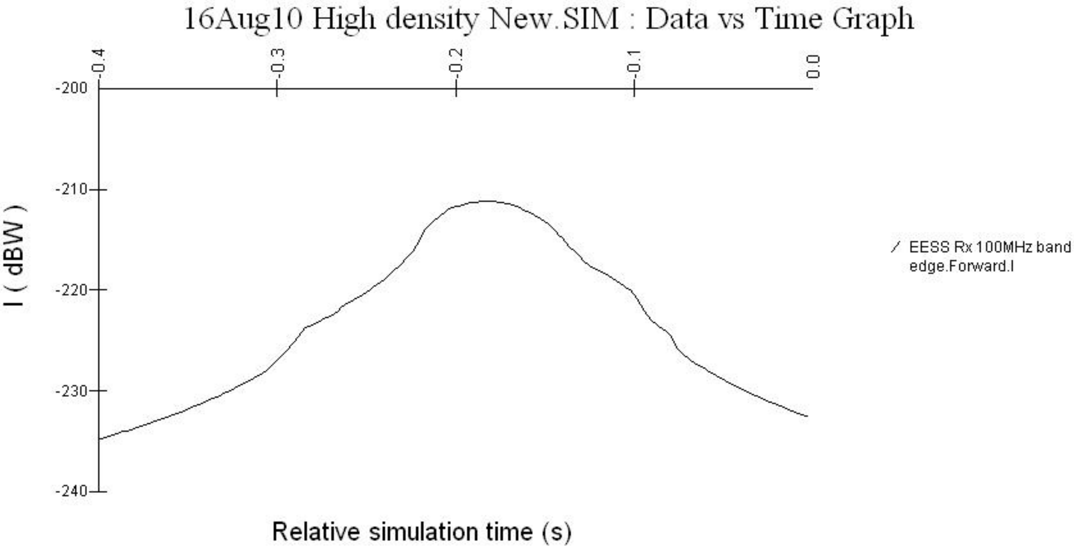
Simulation	Max *I* into band edge (dBW/100 MHz)	Average *I* into band edge (dBW/100 MHz)
1a	−211.39	−225.71
1b	−201.72	−225.73
1c	−208.45	−220.19
1d	−211.18	−220.83
2a	−203.27	−215.87
2b	−190.59	−212.28
2c	−197.34	−207.51
2d	−200.58	−209.34
3a	−211.2	−224.44
3b	−195.71	−223.59
3c	−203.87	−216.22
3d	−209.03	−218.11
4a	−186.13	−199.66
4b	−173.54	−196.58
4c	−179.42	−191.37
4d	−183.59	−193.00

As can be seen, there are no cases where the threshold of −169 dBW is exceeded. The highest value of *I* is −173.54 dBW, in simulation 4b, for the maximum FS density and bandwidth, and the worst-case EESS sensor in terms of antenna gain (AMSR-E).

The average values of I are significantly lower. This is explained by the time variation as the senor moves across its sweep, as shown below for simulation 3a:

FIGURE 18

Simulation 3a: plot of I vs. time

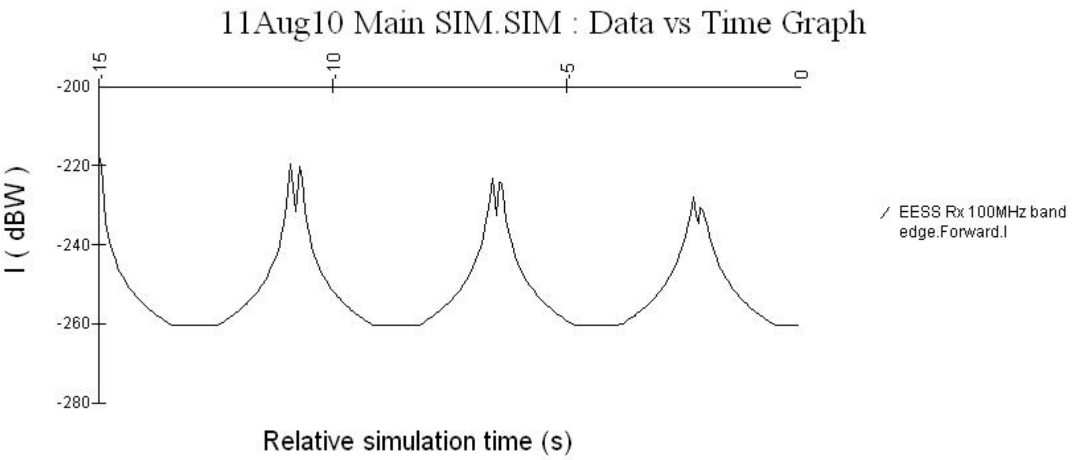


The peak corresponds to the sensor moving directly over London. As it moves further away, interference decreases.

Longer timeframes can also be examined, as in Fig. 19 for simulation 1a, which shows three successive sensor sweeps.

FIGURE 19

Simulation 1a: plot of I vs. time over multiple sweeps



As can be seen, the peaks decrease over time as the satellite moves further north in its orbit. The interference floor of −260 dBW as the sensor beam moves away from the fixed link deployment show that any contributions to interference from the sensor beam side lobes can be assumed to be negligible, and it is main beam interference that dominates.

The cumulative distributions of *I* for all simulations are shown below:

FIGURE 20

CDF of *I* for AMSU-A (sensor 'a')

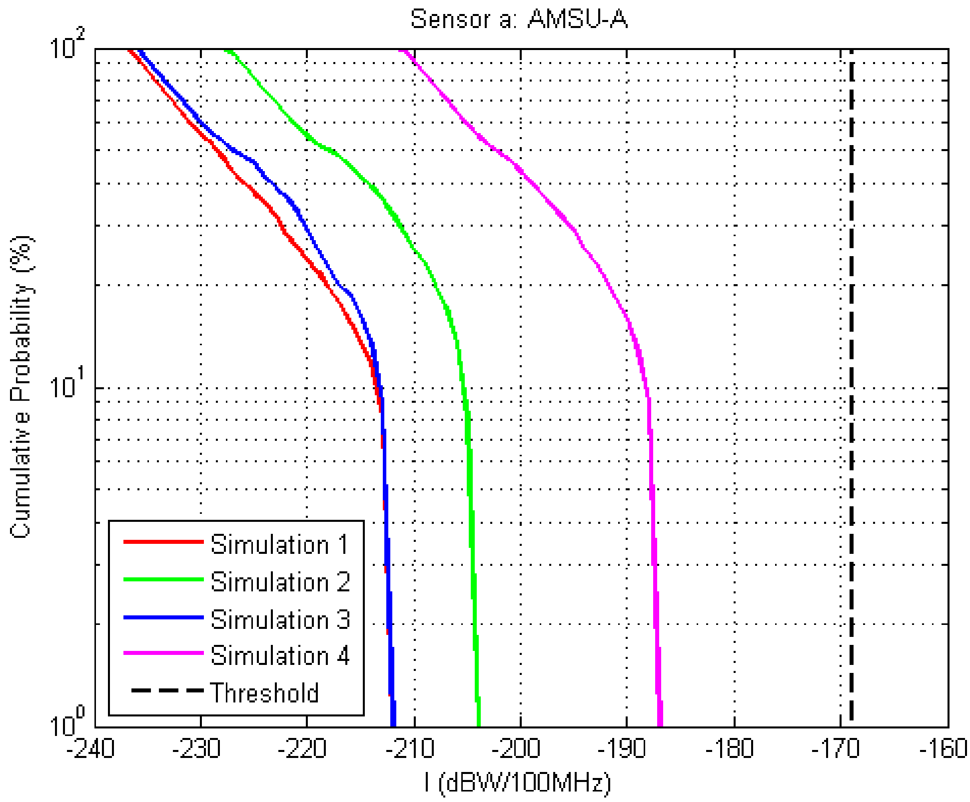
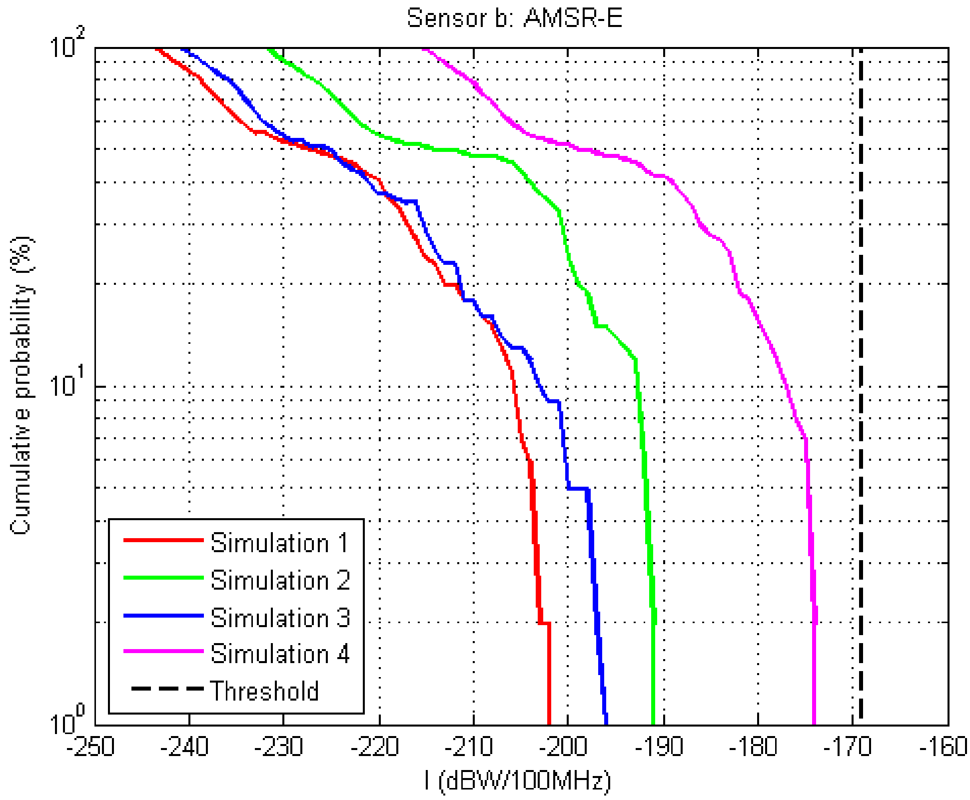


FIGURE 21

CDF of *I* for AMSR-E (sensor 'b')



The above plot shows that even for the worst-case sensor it is highly unlikely that the threshold will be breached.

FIGURE 22

CDF of *I* for MHS (sensor 'c')

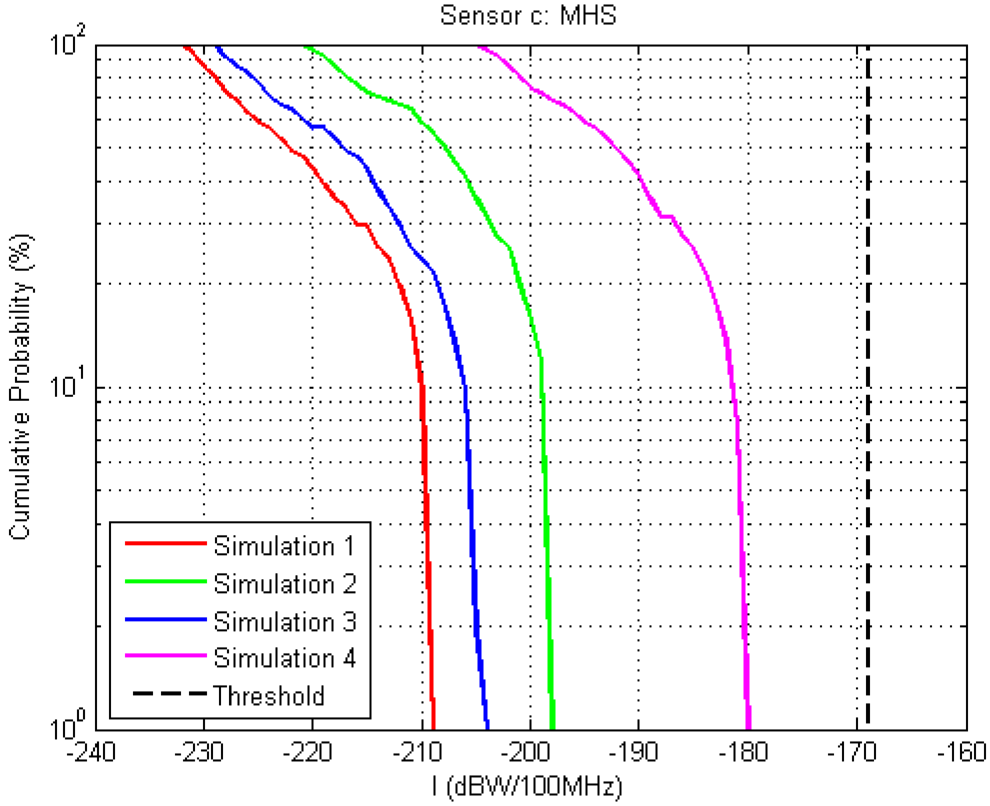
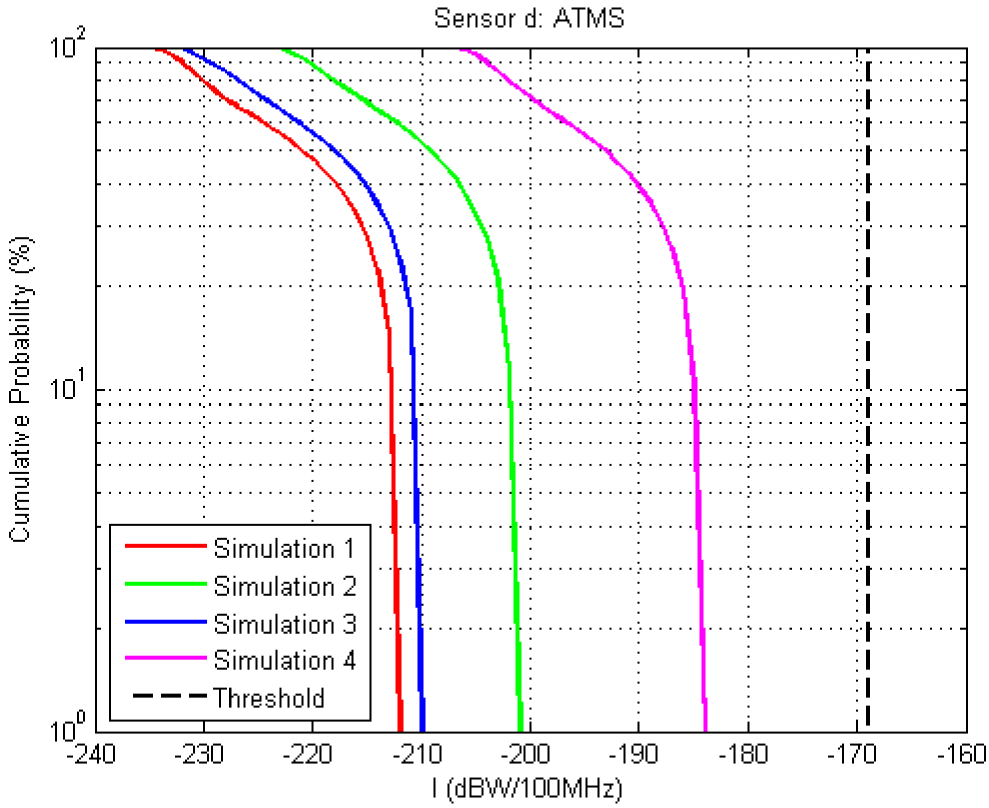


FIGURE 23

CDF of *I* for ATMS (sensor 'd')



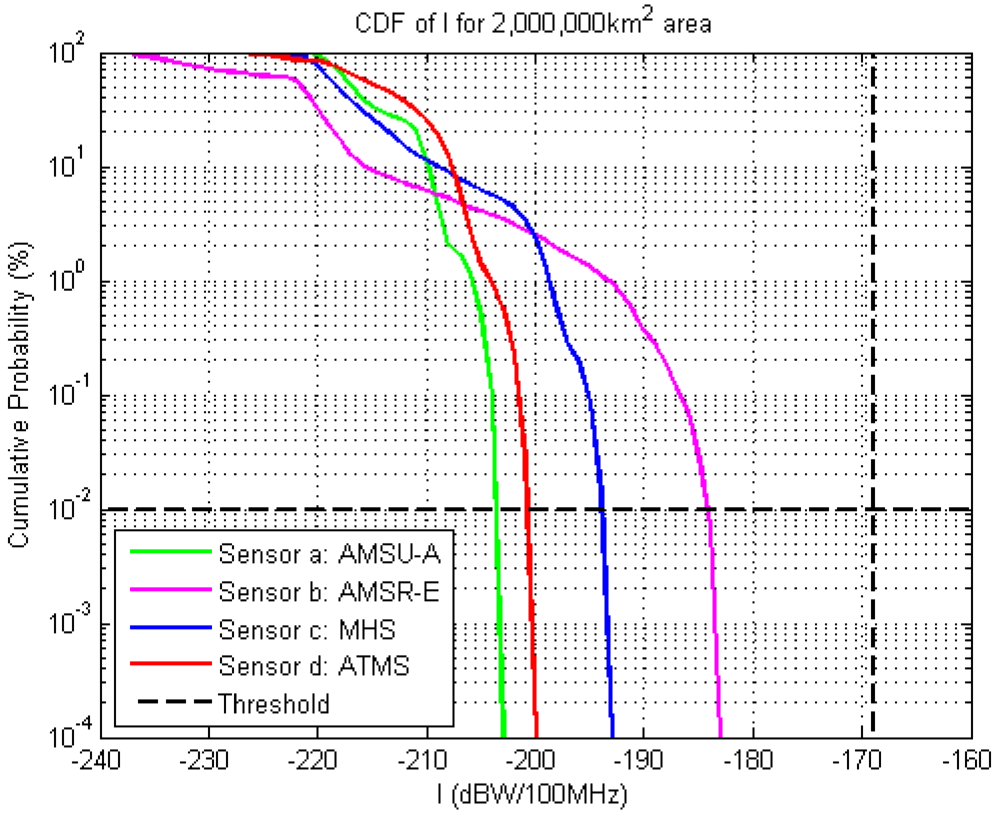
It should be noted that while the above plots do not go down to the 0.01% probability level, the results indicate no variation below the 1% level – i.e. the criteria is met 100% of time.

Scenario 2

The CDF of *I* into the first 100 MHz of the EESS band (86−86.1 GHz), is shown below for all sensors:

FIGURE 24

CDF of *I* for Scenario 2



As in Scenario 1, the threshold of −169 dBW/100 MHz is never breached. The interference levels are lower than those for Scenario 1. This is expected, as Scenario 1 is expected to represent the worst case.

Other considerations

The above simulations do not take into account the receive filtering of the EESS sensor. It should be noted that most sensors operate with a bandwidth less than 6 GHz, and would therefore be expected to attain some level of roll-off at the band edge providing further mitigation from interference from FS. Therefore further information on this would have facilitated even better representation of the compatibility environment for these bands.

5 Conclusions

This study shows that for currently available information on typical FS parameters and expected realistic fixed service link densities the impact on the EESS sensors considered is acceptable i.e. the cumulative interference level is below the sensor protection criterion defined in Recommendation ITU-R RS.1029. This has been shown for both scenarios considered.

Annex C

Compatibility analysis between Earth exploration-satellite service (EESS) (passive) systems operating in the 86-92 GHz band and fixed service (FS) systems operating in the adjacent 81-86 GHz band

1 Introduction

This study assesses the impact of unwanted emissions from the currently licensed FS stations in North America. It presents a realistic interference scenario for addressing the potential for impact from the FS operating in the 81-86 GHz band into the EESS (passive) measurement in the adjacent 86-92 GHz band.

2 Theoretical fixed service link density

The link densities in Annexes A and B are 0.5 links/km^2/250 MHz and 0.19 links/km^2/1.25 GHz, respectively. Both these link densities were determined by following the methodology in Annex A1 (Method Annex A1), which considers rain fading (see Recommendation ITU-R P.530) as an FS-to-FS interference mitigation factor. However, when determining the FS deployment density, rain fading should not be considered since interference analysis between two FS links should be performed using a worst case (meaning no rain fading).

Method Annex A1 was repeated with the assumptions provided in Table 9 and no rain fading.

TABLE 9

Simulation assumptions

Number of consecutive failures	20
Frequency	86 GHz
Max Tx power	−10 dBW/1.25 GHz or 5 GHz
Maximum antenna gain	44 dBi
Antenna pattern	Recommendation ITU-R F.699-7
Noise level	−114 dBW in 250 MHz
I/N	0 dB or −6 dB
Hop length	50 m - 2.5 km (uniform distribution)
Study area radius	8 km
FS distance from study area centre	0-8 km (uniform distribution)
FS azimuth from study area centre	0-360 deg (uniform distribution)
FS antenna height	20-100 m (uniform distribution)
FS elevation	Depends on link's Tx/Rx antenna heights
Oxygen absorption	ITU-R P.835-4 and Annex 2 of Recommendation ITU-R P.676-7

Table 10 presents the average link densities over 10 runs of Method A1 for four different FS deployment scenarios, with varying channel bandwidth and value of *I*/*N*.

TABLE 10

Simulated average FS link densities for a study area radius of 8 km

Scenario	FS BW (GHz)	FS *I*/*N* (dB)	Average density (links/km^2)
1	1.25	−6	0.1464
2	5	−6	0.2339
3	1.25	0	0.1781
4	5	0	0.2382

With no rain fading, interfering signals from the FS are no longer attenuated or weakened by atmospheric rain, snow or ice. Thus, the coverage distances of these interfering signals will be greater and less FS links can be deployed within the study area. In addition, the pixel size for an EESS sensor at an altitude of 850 km is specified to be 201 km^2 (8 km radius) in Report ITU-R SM.2092. With these realistic assumptions, much lower FS link densities were calculated than in Annexes A and B. This is important because the aggregate interference level into EESS (passive) is sensitive to the FS link density.

3 Interference assessment

For this study, rather than model the FS deployment based on the simulated average FS link density in § 2, publicly available data on stations licensed in North America was assembled in a format that allowed the construction of a simulation model in which the FS stations have the same characteristics as the licensed stations in terms of locations, powers, centre frequencies, bandwidths, antenna pointing azimuths/elevations (based on Tx/Rx coordinates/heights) and maximum antenna gains. Based on actual deployments, this scenario allows for a realistic assessment of interference. An FS reference antenna pattern based on Recommendation ITU-R F.1245-1 was used in the simulations.

It should be noted that the average FS link density in § 2 was determined assuming only co-channel interference (i.e. a single centre frequency transmitting at maximum power). However, in a real FS deployment scenario (such as this), more than one centre frequency is assigned to an area in order to reduce power/interference and increase coverage/capacity with careful network planning and frequency reuse. Consequently, it is possible to see areas in this real FS deployment scenario with FS link densities greater than the simulated average FS link density in § 2.

The unwanted emission power falling within the 86-92 GHz EESS (passive) band was then calculated for each station by integrating the power spectral density (psd) of emissions over the first 100 MHz (86-86.1 GHz) of the EESS (passive) band based on the out-of-band emission mask provided in Annex C1[3], and the centre frequency, necessary bandwidth and maximum antenna gain

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[3] The mask provided in Annex C1 is taken from one administration's current national regulation. It is used only for calculation purposes and is not intended to be proposed as a regulatory mask to ensure protection of EESS (passive).

of the licensed frequency assignment.

Figure 25A illustrates this deployment of transmitting FS stations, as well as three passive sensor measurement areas covering the administration for which interference statistics are developed by the simulation model. The individual dots represent the 2 850 frequency assignments of FS stations included in the licensed station database for the 81-86 GHz band. Figures 25B, 25C, 25D, 25E and 25F provide the distribution of these FS stations' centre frequencies, bandwidths, powers, maximum antenna gain, and antenna point elevations, respectively.

FIGURE 25A

Current 81-86 GHz licensed FS station deployment in North America

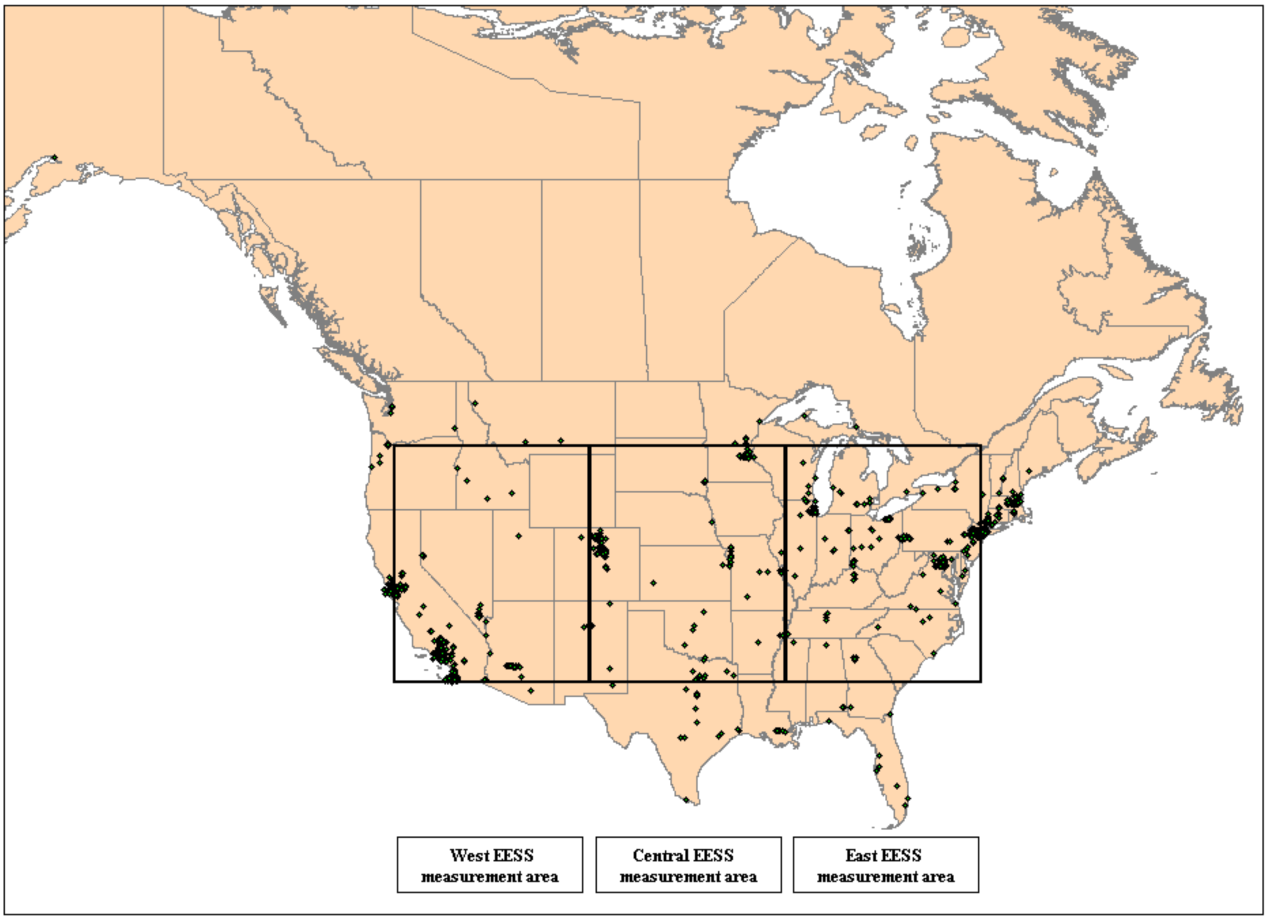


FIGURE 25B

Distribution of FS centre frequencies

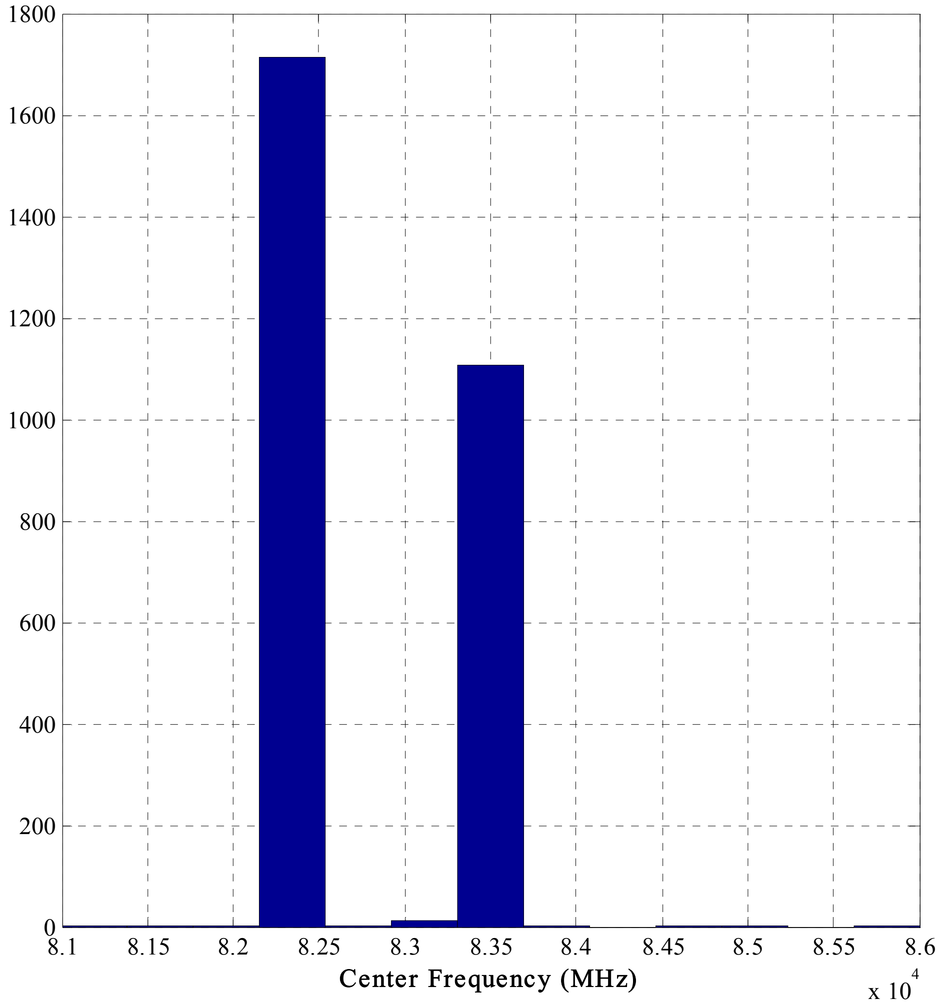


FIGURE 25C

Distribution of FS bandwidths

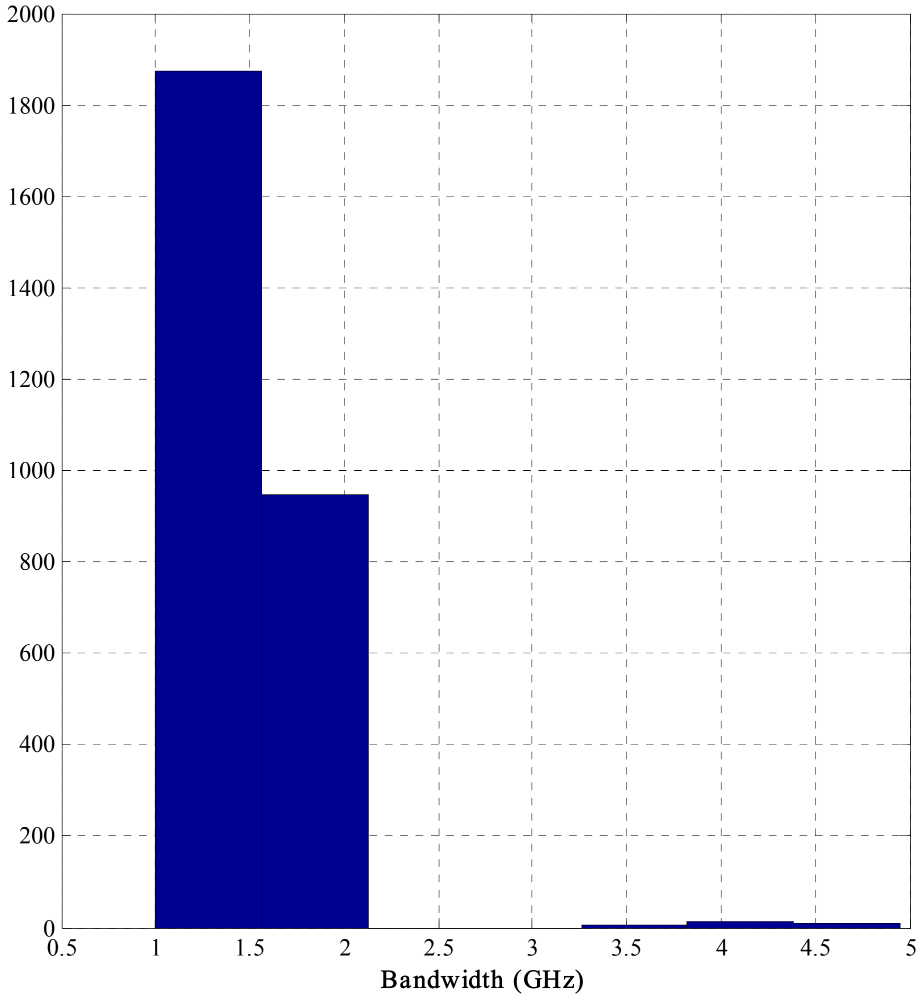


FIGURE 25D

Distribution of FS powers

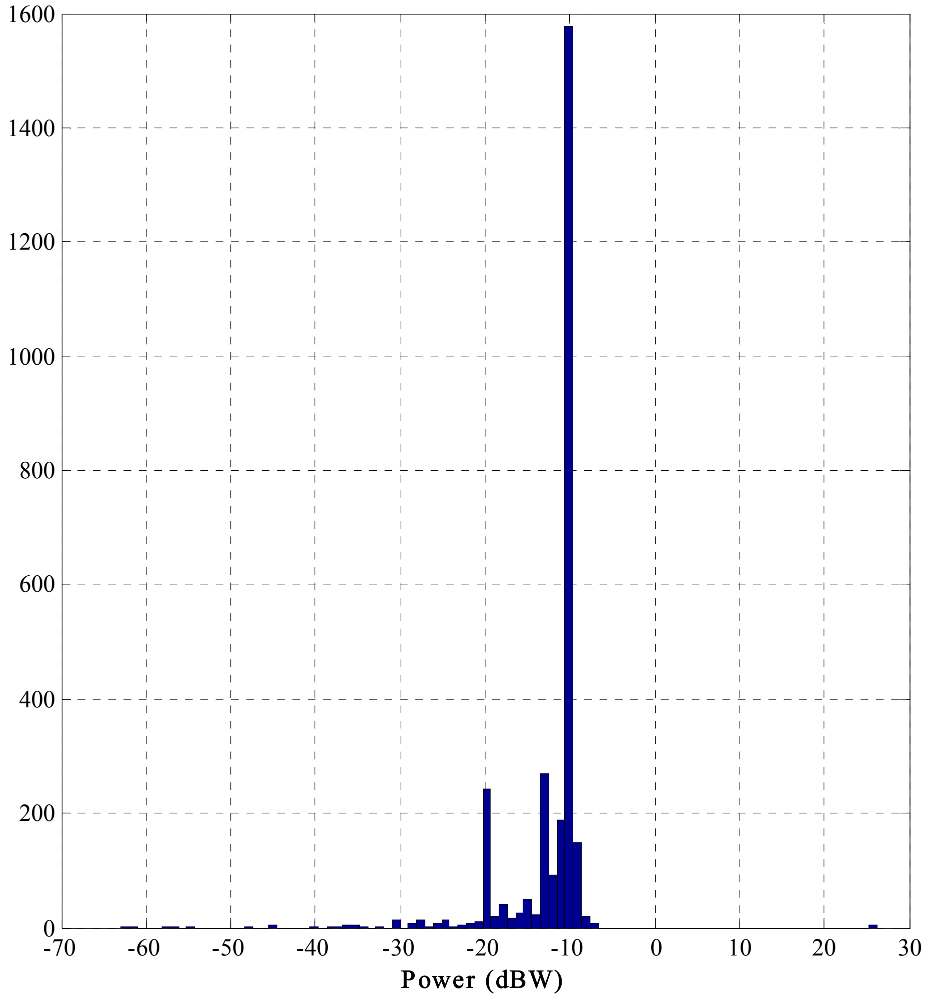


FIGURE 25E

Distribution of FS maximum antenna gains

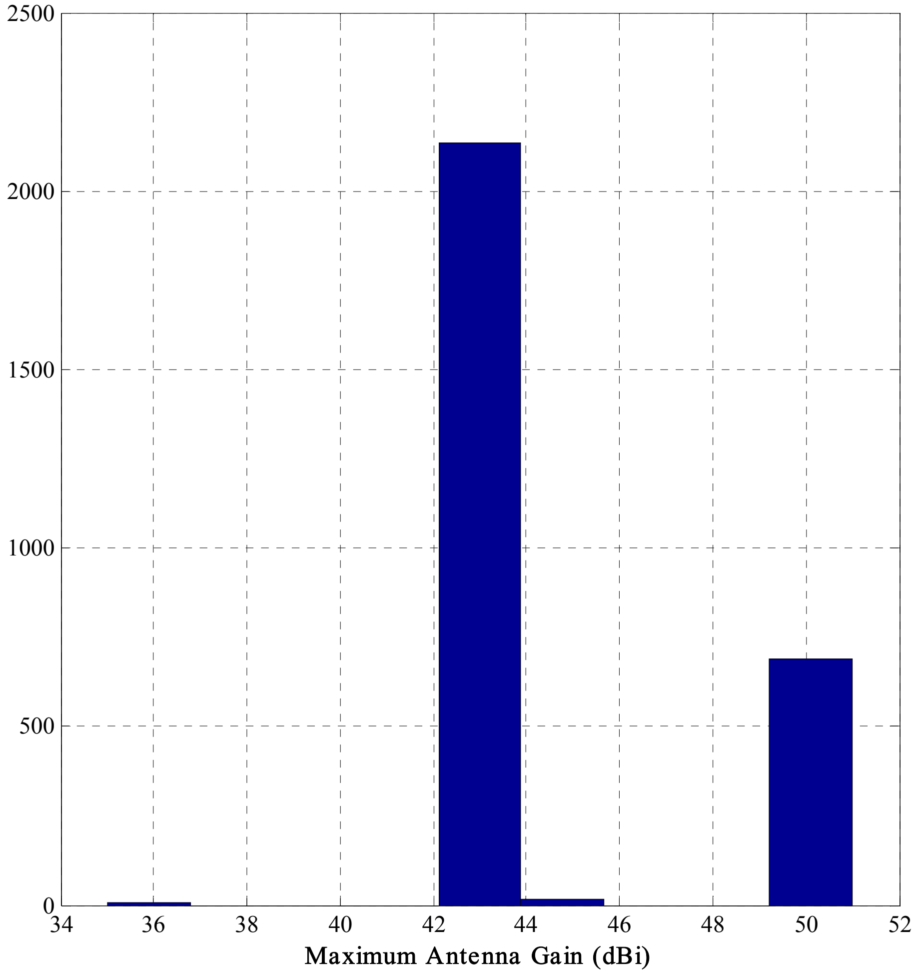
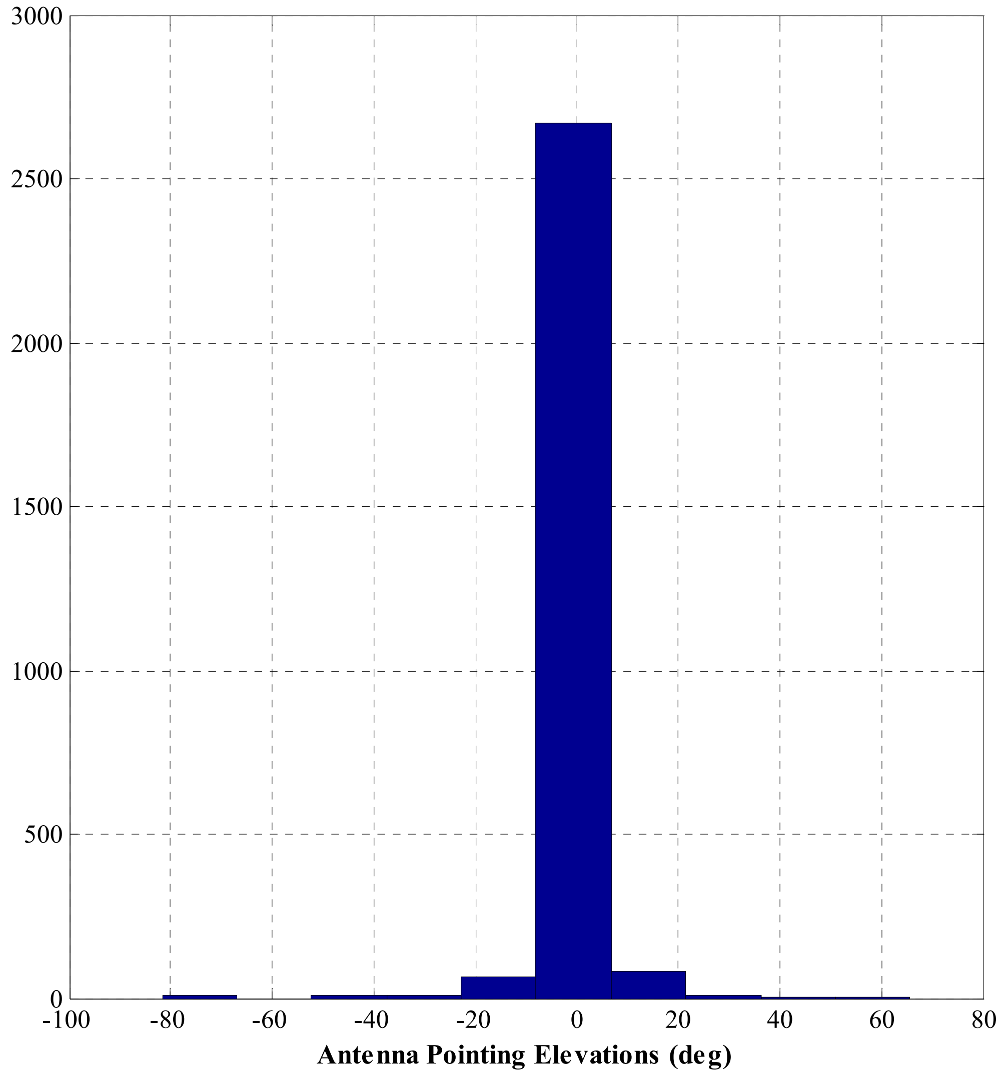


FIGURE 25F

Distribution of FS antenna pointing elevations



Simulations for this deployment model were conducted for the three adjacent, but non-overlapping, measurement areas between 32.524° and 45.476° North latitude and between 73.898° and 122.102° West longitude as illustrated in Fig. 25. Each of these areas, designated as the East, Central and West measurement areas, has an area of 2 000 000 km^2.

The simulations were conducted for the EESS sensors listed in Table 11.

TABLE 11

Simulation sensor parameters from Annex A2

Sensor type	Scan type	Altitude (km)	Antenna gain (dBi)	Off-nadir pointing angle (deg)	Swath width (km)
AMSU-A	Cross-track	833	34.4	±48.33	2 343
ATMS	Cross-track	824	37.9	±52.725	2 500
AMSR-E	Conical	705	60.5	A: 47.5, B: 47	1 450
CMIS	Conical	828	56	46.8	1 700

The sensor antenna side-lobe pattern is assumed to conform to the reference antenna pattern specified in Recommendation ITU-R F.1245-1. Recommendation ITU-R RS.1029-2 provides the protective criterion for EESS (passive) operating in the frequency range 86-92 GHz which is a maximum received allowable power of −169 dBW in 100 MHz. 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). Interference from FS links into a passive EESS sensor is evaluated under free space propagation conditions, plus an additional loss for atmospheric (gaseous) absorption from Annex 2 of Recommendation ITU-R P.676-7. The temperature, pressure and surface water vapour content were generated using Recommendation ITU-R P.835-4.

Simulations were run to produce cumulative density functions (CDFs) over a grid of 10 000 evenly spaced EESS sensor sub-points. At each sub-point, the beam steps through 30 pointing azimuth angles limited by the swath width in Table 11 and 30 pointing angles evenly spaced between the off-nadir pointing angle in Table 11 for conical and cross-track scans, respectively. Each beam step is considered a sample point within the measurement area. The CDFs of the interference from the FS stations into the first 100 MHz (86-86.1 GHz) of the EESS (passive) band are shown in Figs. 26, 27 and 28 for each of the three measurement areas analysed.

FIGURE 26

FS interference CDFs − East measurement area

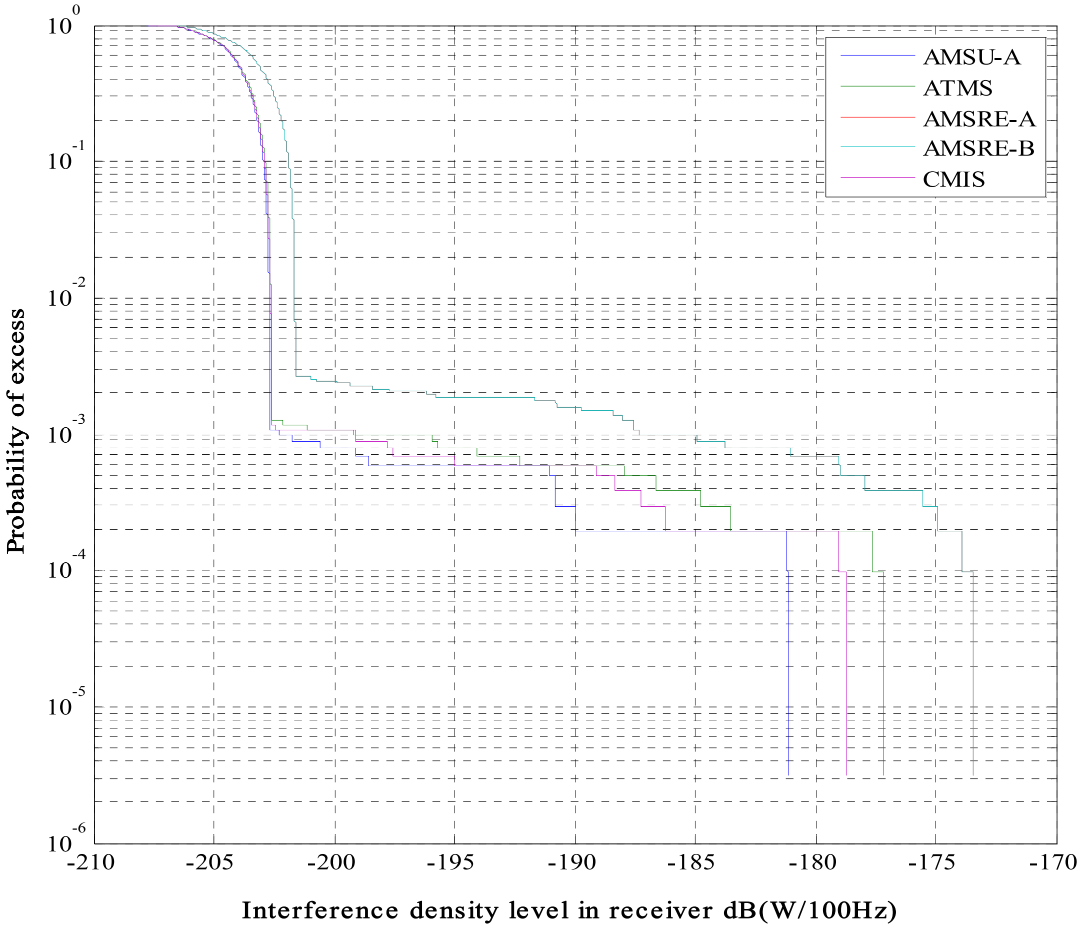


FIGURE 27

FS interference CDFs − Central measurement area

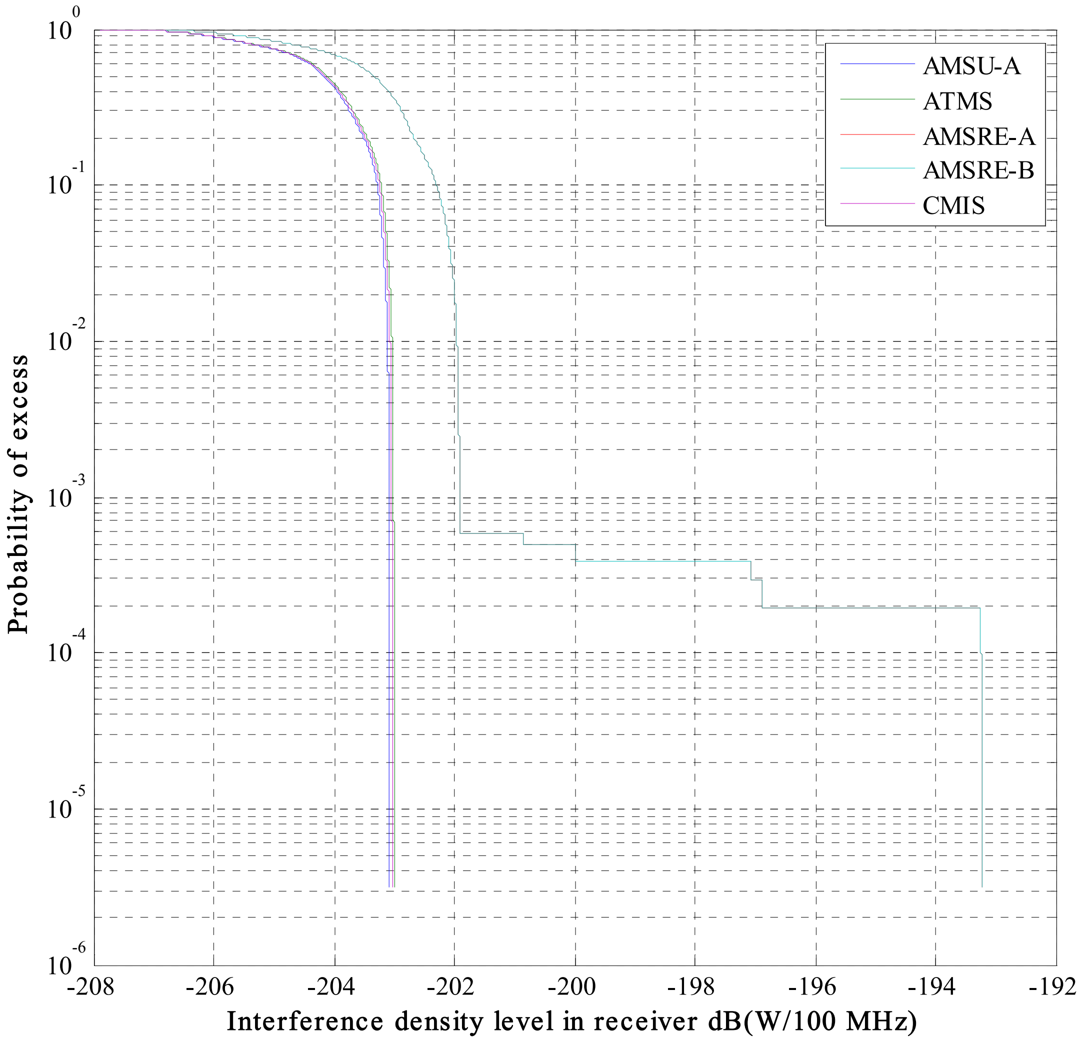
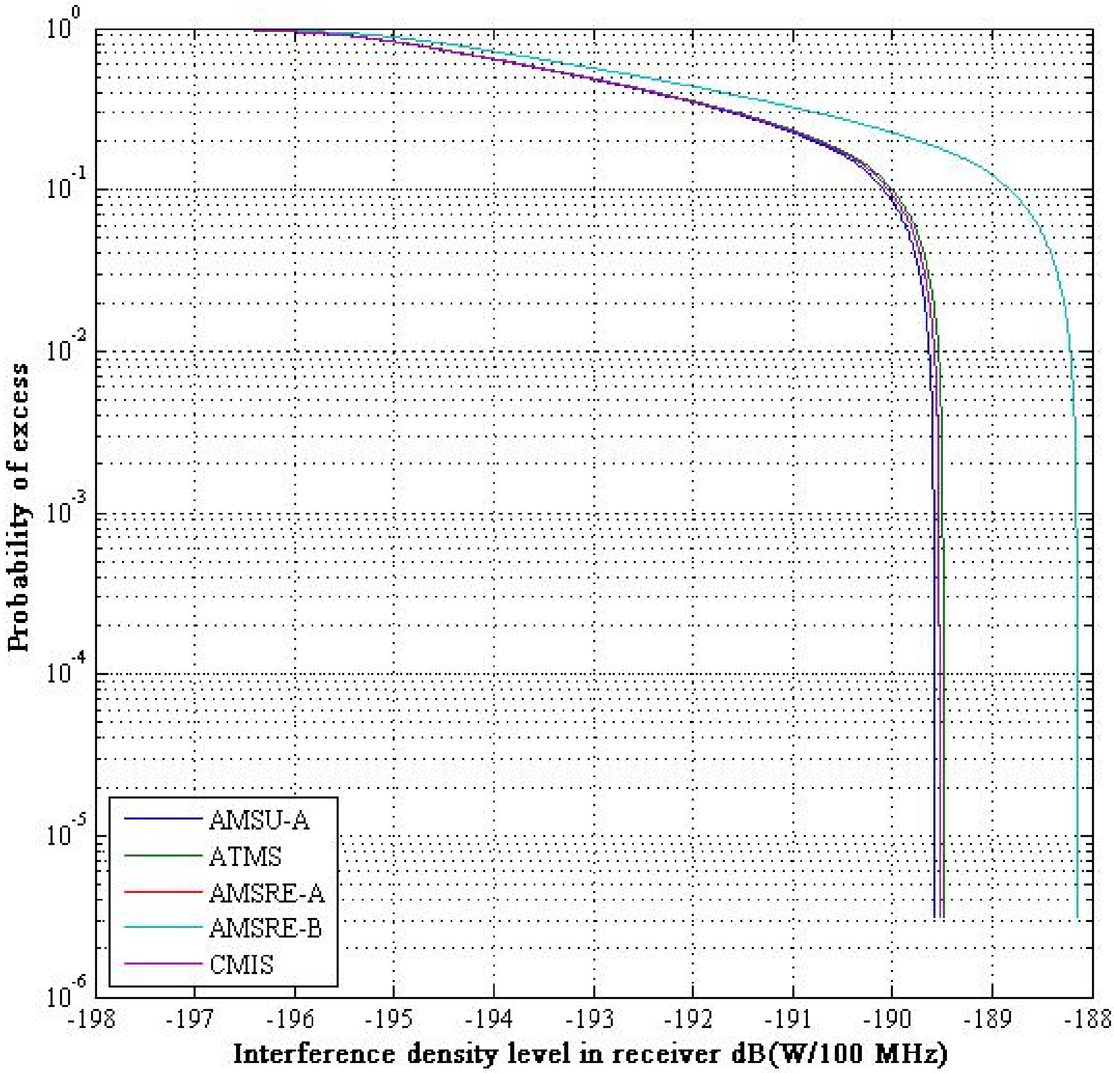


FIGURE 28

FS interference CDFs − West measurement area



4 Conclusion

The results of the simulations indicate that the EESS protective criterion specified in Recommendation ITU-R RS.1029-2 are not exceeded for the EESS sensors. In the worst case, the aggregate interference level of −173.4694 dBW/100 MHz is approximately 4.5 dB lower than the EESS (passive) interference threshold of −169 dBW/100 MHz. This difference is attributed to the centre frequencies, bandwidths, powers and maximum antenna gains used for the simulation, as well as, the lower FS link density.

Annex C1

Out-of-band emission mask

For operating frequencies in the 71-76 GHz, 81-86 GH, 92-94 GHz and 94.1-95 GHz bands, the mean power of unwanted emissions shall be attenuated below the mean output power of the transmitter as follows:

i) $A = 11 + 0.4(P - 50) + 10 \text{ Log}_{10} 500$, in any 1 MHz band, the centre frequency of which is removed from the assigned frequency by more than 50 % up to and including 250% of the authorized bandwidth.

Where:

A = Attenuation (in dB) below the mean output power level (never less than 11 dB).

P = Per cent removed from the centre frequency of the transmitter bandwidth.

NOTE − An attenuation greater than 56 dB or to an absolute power of less than -13 dBm/1MHz is not required.

ii) At least 43 + 10 Log_{10} (mean output power in watts) dB, or 80 dB, whichever is the lesser attenuation: In any 1 MHz band, the centre frequency of which is removed from the assigned frequency by more than 250 % of the authorized bandwidth.

NOTE − The mean output power used in the calculation is the sum of the output power of a fully populated channel.

Annex D

Protection of RAS stations, operating in the bands 76-77.5 GHz and 79-92 GHz from emissions of fixed service, operating in the band 71-76 GHz/81-86 GHz

1 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

1.1 RAS observations in the frequency range 76-77.5 GHz

RAS observations are performed in this frequency band worldwide.

RR No. 5.149 applies to the band 76-77.5 GHz. It has to be noted that Recommendation ITU-R RA.769-2 [1] does not provide any protection criterion for the RAS in this particular frequency band.

1.2 Considerations on the protection of the RAS station

The protection criterion used is derived from Recommendation ITU-R 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. Since the primary allocation extends only from 76 to 77.5 GHz (1.5 GHz wide), and the continuum protection criterion is given for 8 GHz, only the spectral line observations are considered in this frequency band.

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 L_0 for spectral line observations is made in the following manner:

$$P_{769} = P_{TX} + G_{TX} - L_0 \Rightarrow P_{TX} = P_{769} - G_{TX} + L_0$$

where:

P_{TX}: emission power of FS emission;

G_{TX}: antenna gain (including potential side-lobe rejection factor);

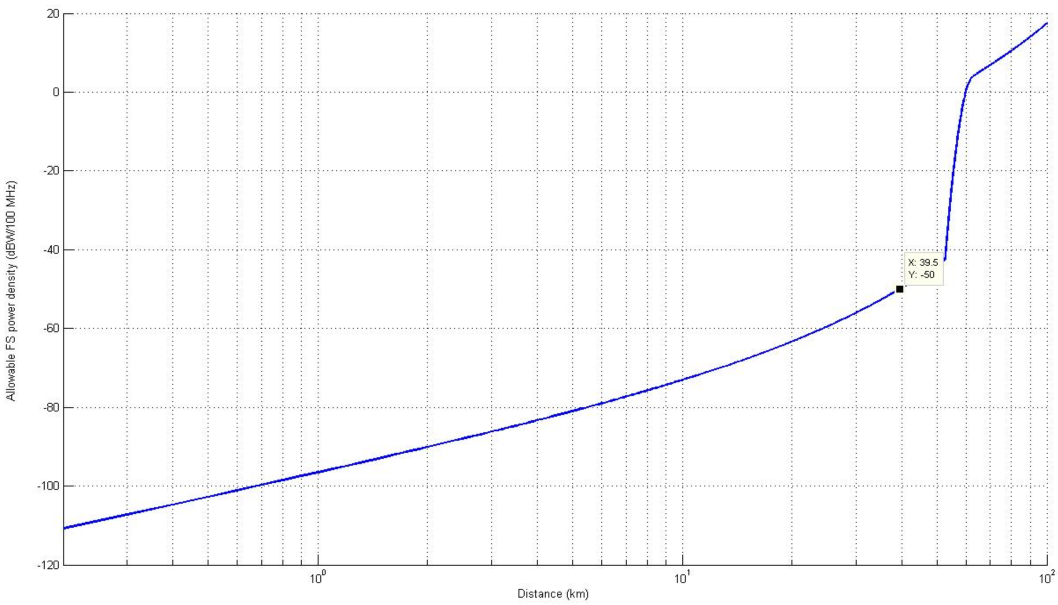
P_{769}: protection requirement given by Recommendation ITU-R RA.769 (−209 dBW/MHz);

L_0: Propagation loss given by ITU-R P.452;

For an FS antenna gain of 38 dBi, the resulting separation distance is given in Fig. 29 assuming a flat terrain, 50 m height for the RAS station and 30 m height for the FS station, depending on the FS transmitter power density at the antenna port of the FS station.

FIGURE 29

Separation distance vs. FS power density



The separation distance corresponding to an unwanted emission power of −50 dBW in 100 MHz, associated with a maximum FS antenna gain of 38 dBi is about 40 km which is over the horizon when assuming a flat terrain.

Such a separation distance is usually satisfied due to the remote location of such RAS stations. However in reality, as such RAS station may be deployed on top of mountains, such as Plateau de Bure in France or the Atacama desert in Chile, the horizon distance may be much greater than what was determined for a flat terrain.

This separation distance may be reduced when considering an FS station pointing direction different from the RAS station direction. The model in Recommendation ITU-R F.1245 provides an antenna side-lobe rejection factor of 38 dB for an offset angle greater than 16° (difference between the FS pointing azimuth and azimuth of the RAS station as seen from the FS). This will result in a relaxation of the separation distance down to 2.6 kilometres.

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 therefore be done on a case-by-case basis at national level by the concerned administration.

2 Protection of RAS stations operating in the bands 79-94 GHz from emissions of fixed service operating in the band 81-86 GHz and 92-94 GHz

2.1 RAS observations in the frequency range 79 to 92 GHz

RR No. 5.149 applies in the band 79-86 GHz and 92-94 GHz. RR No. 5.340 applies in the band 86-92 GHz.

According to Recommendation ITU-R RA.769-2 [1], in this frequency range, three types of measurements may be performed:

- Continuum observations in a reference 8 GHz bandwidth with a received power threshold level of −189 dBW in 8 GHz.
- Spectral line observations in a reference bandwidth of 1 MHz with a received power threshold level of −209 dBW in 1 MHz.
- VLBI observations in a reference bandwidth of 8 GHz with a pfd threshold level of −172 dB(W/(m^2 · Hz)).

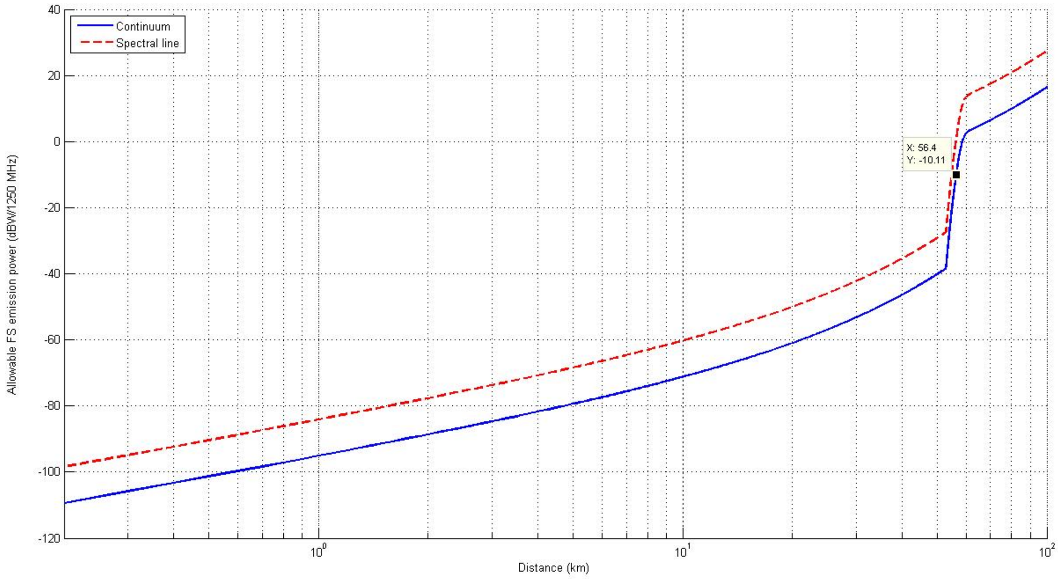
2.2 Considerations on the protection of the RAS station within the bands 81-86 GHz and 92-94 GHz from in band FS emissions

The bands 81-86 GHz and 92-94 GHz are allocated on an equal primary basis to the fixed service and radio astronomy service in all three Regions.

The same methodology as in section 1.2 is used to assess the FS emission power vs. the separation distance between the FS and RAS stations. The results are given in Fig. 30 for both continuum and spectral line observations, assuming an FS station transmitting with a 1 250 MHz bandwidth.

FIGURE 30

Separation distance vs. FS emission power



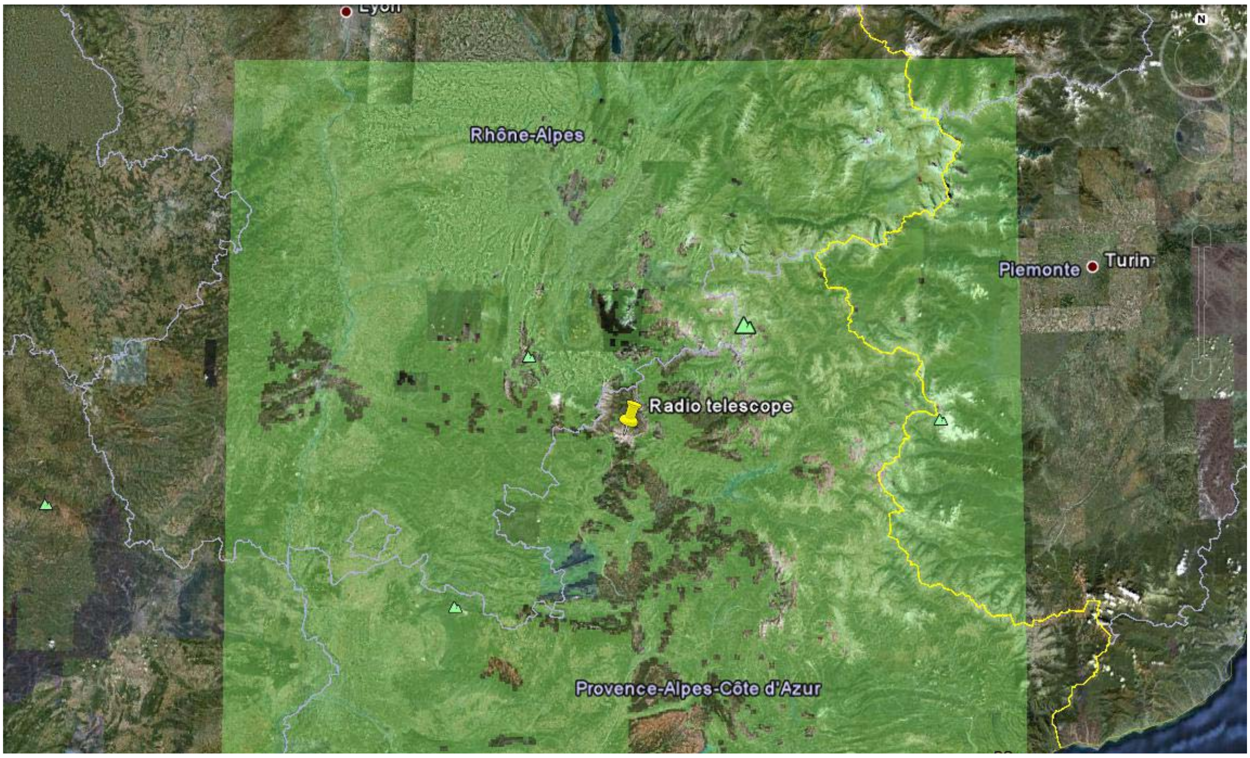
A typical FS emission power value used in studies related to the protection of EESS (passive) is −10 dBW in a bandwidth of 1 250 MHz. Associated with a maximum FS antenna gain of 38 dBi, this leads to a separation distance of around 56 km assuming a flat terrain. If the FS station orientation is such that the main beam is not pointed towards the RAS station (38 dB EIRP reduction) the separation distance will decrease to about 38 km, still assuming a flat terrain.

Figure 31 gives in green the area where FS stations with an emission power of −10 dBW could be deployed around Plateau de Bure in France, without creating any interference to the radio telescope located there. It should be noted that, while the separation distance expands up to 103 km in the south due to the high altitude of the radio telescope, the terrain shielding allows for deployments as close as 5 km to the radio telescope location.

The required separation distances will therefore depend on each particular situation and should be determined on a case-by-case basis.

FIGURE 31

Possible locations for FS stations with emission power of −10 dBW around Plateau de Bure in France

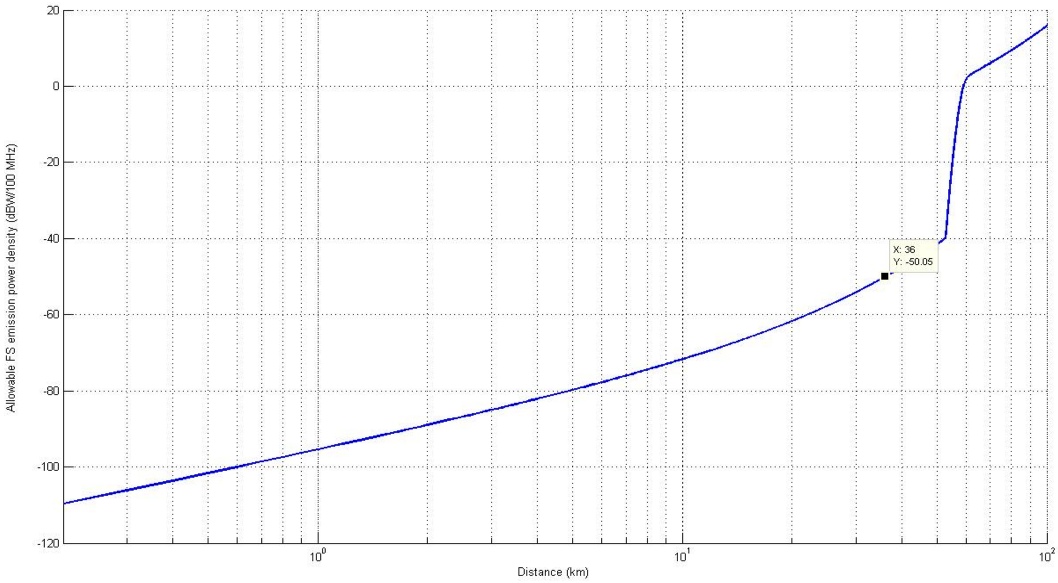


2.3 Considerations on the protection of the RAS station within the band 79-81 and 86-92 GHz from unwanted emissions of FS, operating in the bands 81−86 GHz and 92-94 GHz

The same methodology as in section 1.2 is used to assess the FS emission power density vs. the separation distance between the FS and RAS stations. The results are given in Fig. 32 for spectral line observations.

FIGURE 32

Separation distance vs. FS emission power density



The separation distance corresponding to an unwanted emission power of −50 dBW in 100 MHz, associated with a maximum FS antenna gain of 38 dBi is about 36 km which is over the horizon when assuming a flat terrain. Such a separation distance is usually satisfied due to the remote location of such RAS stations. However, in reality, as such RAS station would be deployed on top of mountains, such as Plateau de Bure in France or the Atacama desert in Chile, the horizon distance may be much greater than what was determined for a flat terrain.

This separation distance may be reduced when considering an FS station pointing direction different from the RAS station direction. **The model in Recommendation ITU-R F.1245 provides** an antenna side-lobe rejection factor of 38 dB for an offset angle greater than 16° (difference between the FS pointing azimuth and azimuth of the RAS station as seen from the FS). This will result in a relaxation of the separation distance down to 2.2 kilometres.

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 therefore be done on a case-by-case basis by the national administration.

3 Conclusions

A separation distance between the RAS station and the FS station should be considered depending on the FS station orientation as well as the environment, such as terrain elevation. The required separation distance should therefore be determined on a case-by-case basis. In view of the limited distances calculated in this study, it may be considered that the protection of RAS will be limited to a national matter.

Annex E

Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems operating below 275 GHz

TABLE 12

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°	98.85°
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	56 dBi	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 × 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:47.5°, B:47.0°	±52.725° crosstrack	44.5°	

TABLE 12 *(end)*

	Sensor 1 [CMIS]	**Sensor 2 [AMSU-A]**	**Sensor 3 [AMSR-E]**	**Sensor 4 [ATMS]**	**Sensor 5 [MADRAS]**	**Sensor 6 [MTVZA-OK]**
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°	35°
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	40.4 dBi	37.9 dBi		
Cold calibration angle (degrees re. satellite track)			115.5 deg			
Cold calibration angle (degrees re. nadir direction)		83.33°	97.0 deg	82.175°		
Sensor receiver parameters						
Sensor integration time	1.2 msec	165 msec	1.2 msec	18 msec		
Channel bandwidth	4 000 MHz centred at 89 GHz	1 500 MHz centred at 89 GHz	3 000 MHz centred at 89 GHz	2 000 MHz centred at 87-91.9 GHz		2 GHz
Horizontal resolution		40.5 km	5 km		10 km crosstrack	19 km

TABLE 13

Characteristics for METOP sensors AMSU-A and MHS

	AMSU-A	MHS
Orbit parameters		
Sensor type	Nadir scan	Nadir scan
Semi-major axis	7 189.9042 km	7 189.9042 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: 149.1 × 79.4 km	Nadir FOV: 16 km Outer FOV: 53 × 27 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	+1 037 km	+1 089 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 89 GHz
Maximum interference level (RS.1029)	−169 dBW/100 MHz	−169 dBW/100 MHz
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