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Annex 27 to Joint Task Group 4-5-6-7 Chairman's Report

WORKING DOCUMENT TOWARD PRELIMINARY DRAFT
NEW REPORT ITU-R M.[BSS-MS]

Sharing and compatibility studies between IMT systems and BSS systems in the frequency band 1 452-1 492 MHz

1 Introduction

The frequency band 1 452-1 492 MHz is allocated on a primary basis to the broadcasting, broadcasting-satellite, fixed and mobile services.

As of 24th July 2014, there are 1178 filings of broadcasting-satellite service (BSS) networks from 27 administrations in the band 1 467-1 492 MHz:

- 1 037 as advanced publication;
- 138 in coordination phase;
- 3 notified networks from Australia (ASIABSS), Russian Federation (SADKO-1) and United States (AFRIBSS).

[Several countries are already using this frequency band under the mobile service for systems based on International Mobile Telecommunication (IMT) technology, as defined in Recommendation ITU-R M.1457, or are considering to introduce them in this frequency band.]

Many administrations have submitted the coordination request of satellite networks for application in this band. Consequently, in considering potential identification to IMT, there was a need to perform sharing and compatibility studies between potential IMT systems and BSS systems.

The studies in this document are covering only co-channel sharing.

2 Background

WARC-92 allocated the band 1 452-1 492 MHz on a co-primary worldwide basis to the broadcasting satellite service (sound) (BSS(S))[1], RR No. **5.345** limits the use of band 1 452-1 492 MHz by the BSS and BS, to digital audio broadcasting.

[1] Subject to the provisions of RR Resolution **528 (WARC-92)**.

Satellite broadcasting, including the band 1 452-1 492 MHz is governed by Resolution **507**, the *resolves* of which stipulates that:

- “stations in the broadcasting-satellite service shall be established and operated in accordance with agreements and associated plans adopted by world or regional administrative conferences, and/or world or regional radiocommunication conferences, as the case may be, in which all the administrations concerned and the administrations whose services are liable to be affected may participate”
- “during the period before the entry into force of such agreements and associated plans the administrations and the Radiocommunication Bureau shall apply the procedure contained in Resolution **33 (Rev.WRC-03)**”

Resolution **528 (Rev.WRC-03)** limits the current use of the broadcasting-satellite allocation to the upper 25 MHz for digital audio broadcasting. *Resolves* 3) and 4) stipulates that:

3) “in the interim period, broadcasting-satellite systems may only be introduced within the upper 25 MHz of the appropriate band in accordance with the procedures contained in Sections A to C of Resolution **33 (Rev.WRC-03)**, or in Articles **9** to **14**, as appropriate (see resolves 1 and 2 of Resolution **33 (Rev.WRC-03)**). The complementary terrestrial service may be introduced during this interim period subject to coordination with administrations whose services may be affected”
4) “the calculation methods and the interference criteria to be employed in evaluating the interference should be based upon relevant ITU-R Recommendations agreed by the administrations concerned as a result of Resolution **703 (Rev.WARC-92)*** or otherwise”

In the current situation:

a) Coordination of BSS systems with terrestrial services is pursuant to RR No. **9.11**. Appendix **5** of the RR only includes overlapping bandwidth as the criteria for triggering coordination.

b) Coordination of transmitting terrestrial stations with BSS is pursuant to RR No. **9.19**[2], taking into account the criteria referred to in RR Appendix **5**.

c) For countries listed in RR No. **5.342** the coordination of BSS networks under RR No. **9.11** is based on Recommendation ITU-R M.1459 with respect to terrestrial aeronautical telemetry systems.

Note : some administrations consider that in carrying out the studies in relation to any frequency band under the agenda item of any WRC, such studies shall not modify the regulatory environments and conditions in force and applicable to the incumbent service. Any contrary action would be in contradiction and contravene the principles enshrined in the Radio Regulations.

2 “for any transmitting station of a terrestrial service or any transmitting earth station in the fixed-satellite service (Earth-to-space) in a frequency band shared on an equal primary basis with the broadcasting-satellite service, with respect to typical earth stations included in the service area of a space station in the broadcasting-satellite service.”

3 Technical characteristics

3.1 User equipment of the mobile service

[Recommendation ITU-R M.1646 “Parameters to be used in co-frequency sharing and pfd threshold studies between terrestrial IMT-2000 and BSS (sound) in the 2 630-2 655 MHz band” contains in particular the interference criterion that was used to protect IMT from BSS space stations.

This interference criterion was assessed in terms of I_{sat}/N_{th}, where:

- I_{sat} is the level of aggregate interference from BSS (sound) systems;
- N_{th} is the thermal noise at any IMT receiver.

A value of I_{sat}/N_{th} = –10 dB is recommended as a trigger value for sharing studies with the view to protect IMT stations from BSS (sound) (see *recommends* 2 of Recommendation ITU-R M.1646). Because of the similarities between the two sharing situations (i.e. protect IMT from BSS stations covering a very wide area), the same value is proposed to be used in the band 1 452-1 492 MHz. Because of the omnidirectional nature of the BSS(sound) terminals, BSS(sound) systems cannot share the same frequency over the same geographical area therefore the level of aggregate interference from BSS (sound) systems is assumed to be predominantly caused by only one satellite and I_{sat} is therefore not apportioned.

Other parameters are taken from *recommends* 3 of Recommendation ITU-R M.1646 because they are considered applicable to future IMT user equipment in the band 1 452-1 492 MHz.]

TABLE 1

IMT system characteristics

Parameters	Values	Units
Maximum noise figure	9	dB
Thermal noise level (N_0=kTB)	–135	dB(W/MHz)
I_{sat}/N_{th}	-6 or –10[3]	dB
Antenna gain	–3	dBi
Body loss	4	dB

3.2 Receivers of base stations of the mobile service

Table 2 summarizes base station receiver characteristics of the mobile service used in the study, which are based on Report ITU-R M.2039 and Report ITU-R M.2292.

[3] Different protection criteria correspond to different interference situations: I/N = -6 dB (corresponding to 1 dB reduction of the receiver sensitivity) is applicable to cases where interference affects one or a few cells, or when the IMT-2000 system is interference limited. In other cases I/N = -10 dB (corresponding to 0.4 dB reduction of the receiver sensitivity) is applicable.

TABLE 2

Base station receiver characteristics in the mobile service

Parameters	Values	Units
Noise figure	5	dB
Thermal Noise Level (N_0=kTB)	–139	dB(W/MHz)
I_{sat}/N_{th}	-6 or –10	dB
Antenna gain (including feeder losses)	13-15	dBi
Antenna down tilt	3-6	Degree

3.3 Typical parameters of BSS (sound) systems for compatibility study with IMT systems on the 1 452-1 492 MHz frequency band

Based on the Recommendation ITU-R S.1432, the *I*/*N* ratio of -12.2dB is proposed as the protection criteria to be used in compatibility studies between BSS (sound) systems and IMT systems.

Table 3 provides some example of GSO BSS (sound) system carrier characteristics.

TABLE 3

BSS (sound) system carrier characteristics

Carrier type	1	2
Occupied bandwidth	1.836 MHz	1.485MHz
Noise bandwidth	2.57 MHz	1.71 MHz
Out of Band Emission (OoB)	-27 dB[4]	

Table 4 provides some example of typical characteristics of the BSS (sound) earth stations.

TABLE 4

BSS (sound) system earth station characteristics

Receiver type	A	B	M1	M2
Maximum antenna gain	5 dBi	11 dBi	2 dBi	2 dBi
Radiation pattern	Figure 1	Figure 2	Figure 3	Figure 4
G/T	−19.5 dB/K	−12 dB/K	−22.5 dB/K	−22.5 dB/K
Adjacent channel selectivity (ACS)	35 dB[2]			

Table 5 provides some examples of typical GSO BSS (sound) satellite transponder e.i.r.p. levels per carrier type corresponding to the different receivers. Future BSS systems may have other parameters.

4 Refer to Recommendation ITU-R BO.1504.

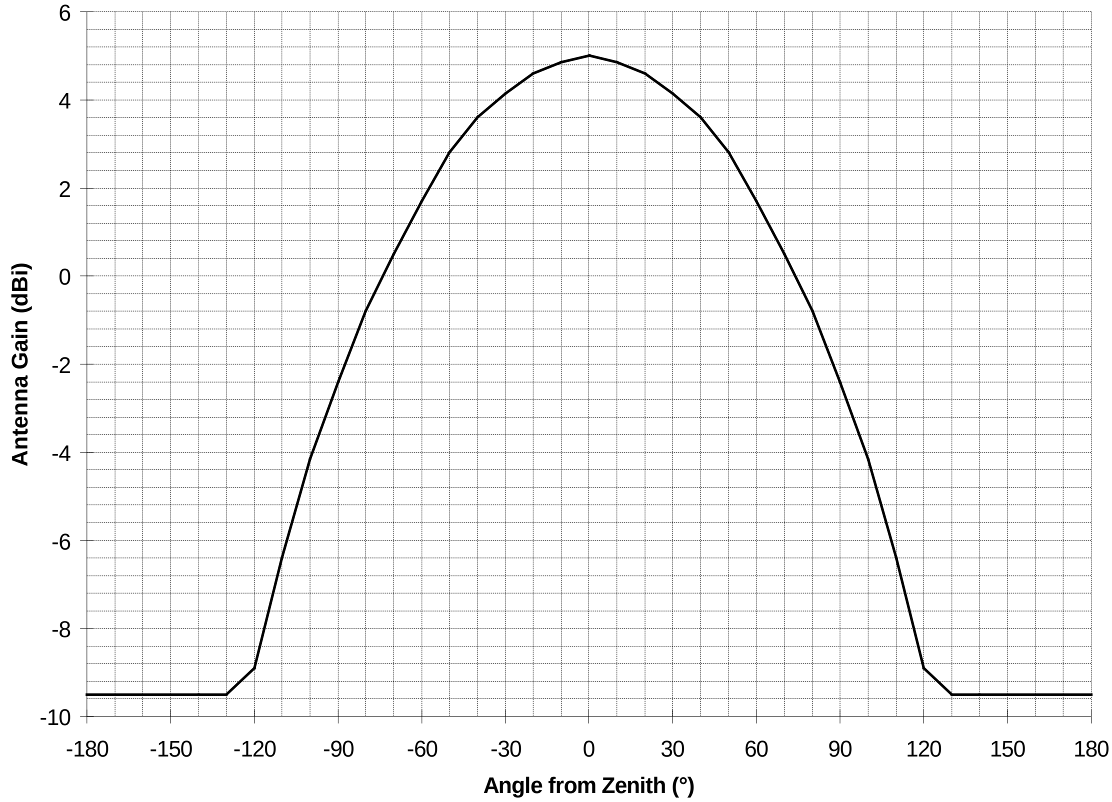
TABLE 5

Satellite transponder e.i.r.p. levels per carrier (dBW)

Carrier type / Receiver type	1	2
A	49.7	52.5
B	42.2	45.0
M1	52.7	55.5
M2	52.7	55.5

FIGURE 1

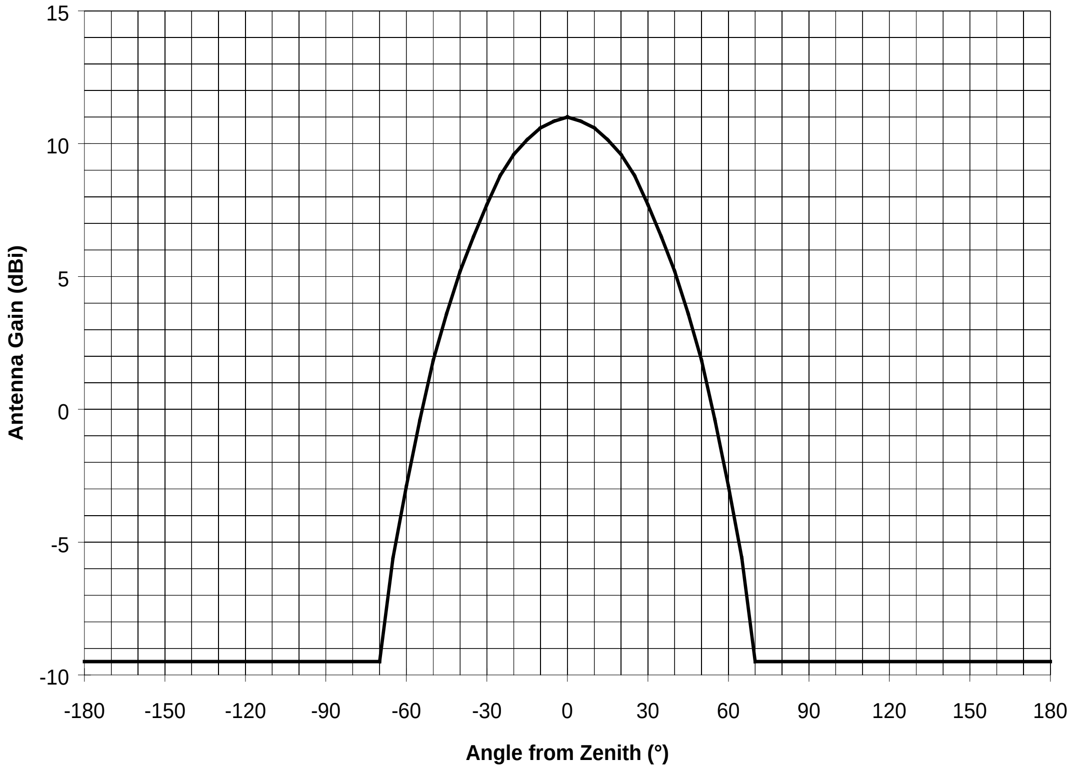
Type A antenna co-polar radiation pattern diagram (vertical plane)



Plane is rotationally symmetric in the horizontal plane.

FIGURE 2

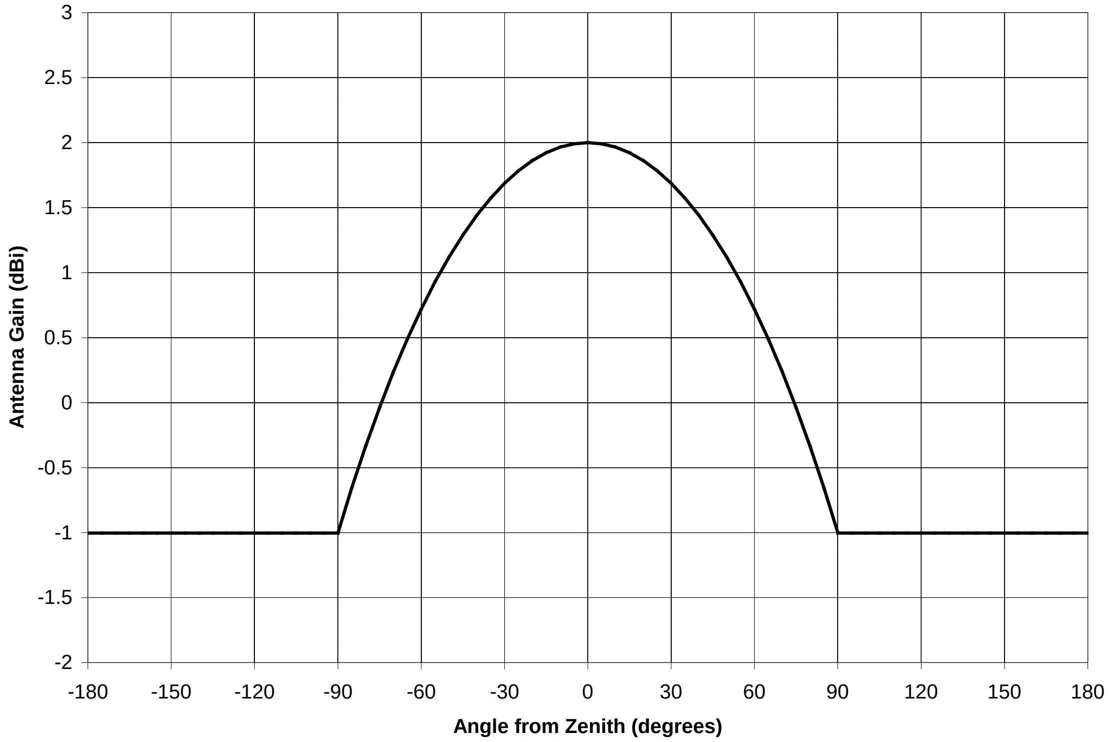
Type B antenna co-polar radiation pattern diagram (vertical plane)



Plane is rotationally symmetric in the horizontal plane.

FIGURE 3

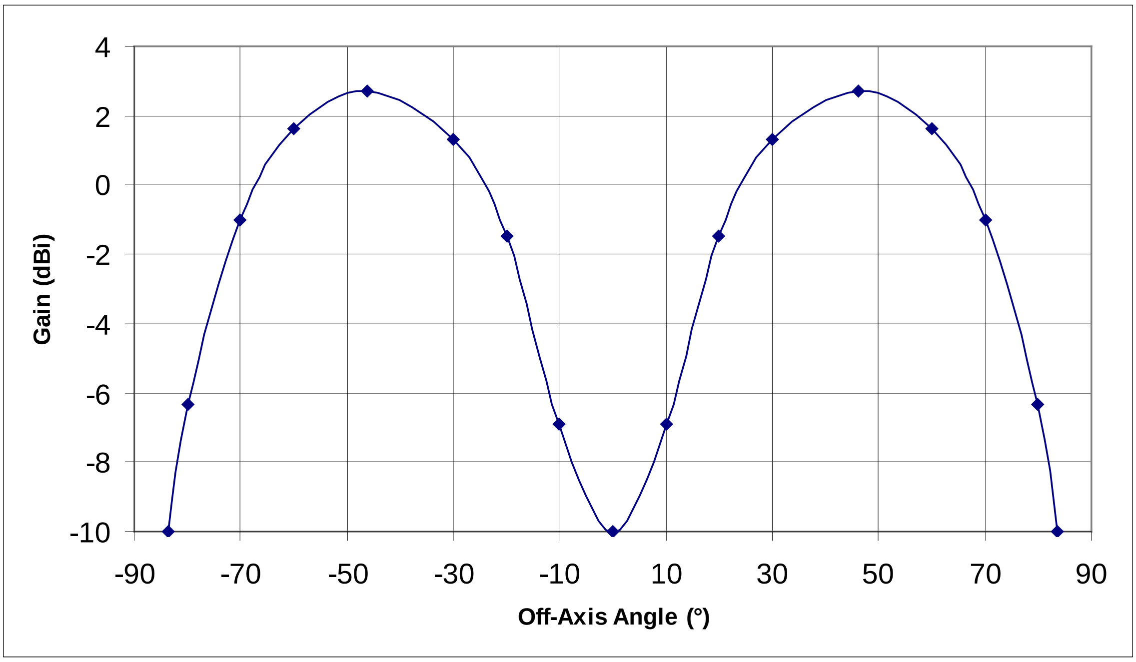
Type M1 antenna co-polar radiation pattern diagram (vertical plane)



Plane is rotationally symmetric in the horizontal plane.

FIGURE 4

Type M2 antenna co-polar radiation pattern diagram (vertical plane)



Plane is rotationally symmetric in the horizontal plane.

4 Analysis of the protection criteria

4.1 Interference from BSS into mobile service

4.1.1 User equipment

The study is aimed at deriving the pfd level to protect user equipment (UE).

The maximum allowable pfd level can be calculated at 1 492 MHz using the following equation:

PFD(dBW/m²/MHz)= 24.9 + Thermal noise (dBW/MHz) + I_{sat}/N_{th}(dB) - Antenna Gain (dBi) + Body loss (dB)

Based on the parameters of section 3.a), the pfd for the protection of UE is **-**113.1 dB(W/m²) in 1 MHz for any angle of arrival. The I/N criterion used in the calculation is -10 dB[5], taking into account the statistical nature of body loss which may in some case be 0 dB.

Based on the above technical parameters, the above interference criterion, which are presented via maximum allowable pfd level for the protection of IMT would be exceeded in the BSS coverage area. Therefore, the co-frequency co-coverage sharing between BSS and IMT is not feasible.

4.1.2 Base stations

Study 1

Note : No consensus was reached on the possibility to derive a pfd level in the band 1 452-1 492 MHz from the pfd limit applicable in the band 2.6 GHz.

The study is aimed at deriving the pfd level to protect mobile service base stations.

The maximum allowable pfd level is derived based on the results of the studies carried out under WRC-07 agenda item 1.9.

The pfd values at the Earth's surface produced by emissions from a space station in the light of protecting terrestrial services including IMT systems were studied and the derived values in the studies as shown below were reflected into Table **21-4** of the Radio Regulations:

–136 dBW/m^2 in 1 MHz for a vertical arrival angle of 0 – 5°;

–136 + 11/20(δ – 5) dBW/m^2 in 1 MHz for a vertical arrival angle of 5 – 25°,

–125 dBW/m^2 in 1 MHz for a vertical arrival angle of 25 – 90°.

These values are based on the base station antenna pattern using Recommendation ITU-R F.1336-1 with a *k* value of 0.2, while the latest considerations in *recommends* 3.1 of Recommendation ITU-R F.1336 assume improved base station antenna patterns. Furthermore, the antenna down tilt values recently reported in Report ITU-R M.2292 is in the range 3-6 degrees, which would be larger as those assumed in the studies under WRC-07 agenda item 1.9. Taking into consideration the recent development of antenna characteristics of IMT base stations, the pfd values could be relaxed by 3 dB for low arrival angles and 4-11 dB for high arrival angles, respectively, compared to those derived under WRC-07 agenda item 1.9. With respect to the difference in frequency between 2.6 GHz (for WRC-07 agenda item 1.9) and 1.4 GHz (for WRC-15 agenda item 1.1), stringent value by 5 dB from corresponding pfd values considered in the 2.6 GHz band should be applied for

[5] The I/N criteria for IMT-2000 is -10 dB and the I/N criteria for IMT-Advanced is -6 dB.

pfd values in the 1.4 GHz band. Isat/Nth applied for IMT base stations is -6 dB, as reported in the Report ITU-R M.2292, which relaxes interference threshold level for IMT base stations by 4 dB. Those differences are summarized in the Table 6 below.

TABLE 6

Summary for differences between parameter values of WRC-07 agenda item 1.9 and latest parameter values

Parameters	Low arrival angle	High arrival angle
Antenna pattern	+ 3 dB	+ 4 – 11 dB
Frequency difference	– 5 dB	– 5 dB
Isat/Nth	+ 4 dB	+ 4 dB
Total	+ 2 dB	+ 3 – 10 dB

“ + ” indicates improvement from values in WRC-07 agenda item 1.9 and “ - ” indicates degradation from those values.

Based on these considerations, the interference criteria for the protection of base stations in the mobile service can be derived as follows:

–134 dBW/m^2 in 1 MHz for a vertical arrival angle of 0 – 5°,

–134 + 12/20(δ – 5) dBW/m^2 in 1 MHz for a vertical arrival angle of 5 – 25°,

–122 dBW/m^2 in 1 MHz for a vertical arrival angle of 25 – 90°.

Study 2

The study is aimed at deriving the pfd level to protect mobile service base stations.

The maximum allowable pfd level can be calculated at 1 492 MHz using the following equation:

PFD(dBW/m²/MHz) = 24.9 + Thermal noise (dBW/MHz) + I_{sat}/N_{th}(dB) - Antenna Gain (dBi) + Antenna discrimination (dB)[6]

Based on the parameters provided in section 3.b) and Report ITU-R M.2292, the pfd mask for the protection of IMT base stations is as follows:

–132 dBW/m^2 in 1 MHz for a vertical arrival angle of 0 – 5°,

–132 + 16/20(δ – 5) dBW/m^2 in 1 MHz for a vertical arrival angle of 5 – 25°,

–116 dBW/m^2 in 1 MHz for a vertical arrival angle of 25 – 90°.

Based on the above technical parameters, the above interference criteria, which are presented via maximum allowable pfd level for the protection of IMT would be heavily exceeded in the BSS coverage area. Therefore, the co-frequency, co-coverage sharing between BSS and IMT is not feasible.

[6] Values of antenna discrimination should be determined for high elevation angle (25^o) and low elevation angle (0^o), respectively.

4.2 Protection of the BSS receiving earth stations from a single IMT base station

When an IMT system is deployed co-frequency and co-coverage with BSS the required separation distances from IMT-Advanced base stations and/or user equipment to protect BSS receiving earth stations would make it very difficult to deploy these two high-density applications in the same geographical area. Thus sharing may be feasible under certain circumstances in case of adjacent territories.

To define specific separation distances or path loss required the maximum allowable pfd level could be used as interference criteria. The pfd level for the protection of earth stations from interference from the horizon can be calculated on the basis of an I/N of -12.2 dB and the characteristics of BSS receiving earth stations above. It results in the following maximum interfering pfd:

Receiver type	A	B	M1	M2
Maximum interfering pfd from an IMT stations	-121 (dBW/m²/MHz)	-123 (dBW/m²/MHz)	-130 (dBW/m²/MHz)	-121 (dBW/m²/MHz)

These values are only slightly lower than the value for the protection of IMT SDL terminal (-113 dBW/m²/MHz) taking into account that this calculation does not account for other losses such as body loss for user equipment (i.e. M1).

Therefore, when IMT system is deployed co-frequency in neighbouring countries, coordination between countries will not be significantly more difficult than when coordinating different SDL networks at the border.

4.3 Considerations on aggregated interference

A study on the impact of aggregated interference is provided in Annex 1. It shows that the cumulative interference from IMT networks can exceed the single-entry interference by a value ranging from 0 to 23 dB. In practice, the value will depend on the relative location between the IMT deployment area and the test point, i.e. on the field strength required to protect a type of BSS receiving earth stations. The detailed analysis in Annex 1 showed that for the levels of single entry interference, as well as for levels of aggregate interference, comparable to the protection criteria of BSS earth stations the aggregated interference margin could be approximated by the value of 20 dB.

5 Summary

Co-frequency sharing between BSS and IMT is not feasible in the same area.

The sharing and compatibility for adjacent frequency bands (in the same and in adjacent territories) between IMT and BSS was not studied.

Some studies in this report consider co-frequency sharing studies between BSS and IMT in adjacent territories

With respect to the interference from IMT to BSS, the results of these studies are:[Based on current technical studies, in the case of implementation of IMT networks on adjacent territory to the BSS service area, the maximum pfd values produced by each IMT base station at the edge of the BSS service area to protect BSS earth stations is in the range of -139 to -150 dBW/m²/MHz if aggregated interference is taken into account and is in the range of -119 to -130 dBW/m²/MHz if aggregated interference is not taken into account].

[With respect to the interference from BSS satellite to IMT, based on current technical considerations, the power flux-density value of BSS satellite to protect user equipment of the mobile service, including IMT, in the band 1 452-1 492 MHz is -113 dB(W/(m^2.MHz)).]

[The power flux-density value of BSS satellite to protect base stations terminals of the mobile service, including IMT, in the band 1 452-1 492 MHz is:

–134 dBW/m^2 in 1 MHz for a vertical arrival angle of 0 – 5°,

–134 + 12/20(δ – 5) dBW/m^2 in 1 MHz for a vertical arrival angle of 5 – 25°,

–122 dBW/m^2 in 1 MHz for a vertical arrival angle of 25 – 90°.]

Annex: 1

ANNEX 1

Protection of the BSS receiving earth stations from aggregated interference

IMT base station will reuse the same frequency which could lead to aggregate interference higher than from single IMT base station which should be taken into account in the protection criteria for BSS receiving earth stations.

When assessing the interference from IMT networks to BSS receiving earth station it necessary to evaluate the interference field strength of IMT base stations in the test points at the territory of other country. One study has assessed the change of the interference field strength taking into account the aggregate interference from base stations in the IMT network compared to the single-interference source for typical implementation of IMT network in the border areas.

The calculation of the increment of the cumulative interference field strength from the IMT network in relation to a field strength from a single interference source should be carried out in the following order:

1) Select country A and country B.

2) Model a network of IMT base stations with typical parameters (see Table 1) within the territory of the country A along the border with country B at a distance up to X km from the border.

3) Create test points in the territory of country B at the border and inland in increments of, for example 10 km, up to a total distance of Dt km.

4) At each test point calculate:

a = the highest interference field strength from a single base station;

b = cumulative interference field strength from all base stations in IMT network.

5) Plot on the same graph the distributions of the variables a and b as observed in respective test points (expressed as a percentage of test points).

6) Plot the distribution of the variable (*b - a)* as observed in respective test points, by the number of test points (expressed as a percentage of test points).

To perform this calculation the following parameters of IMT base stations have been used.

TABLE 1

Parameters for IMT base stations

Parameter	Scale	Value
Maximum e.i.r.p. per sector for 10 MHz	dBm	61.00
Average base station activity	dBm	50%
Average e.i.r.p. per sector for 10 MHz	dBm	58.00
Antenna gain(Giso)	dBi	15.00*
Polarization discrimination	dB	3
Antenna height above ground	m	30.00
Antenna tilt, downside	Degrees	3
Main beam by 3 dB loss in H plane	Degrees	65
Main beam by 3 dB loss in V plane	Degrees	Rec. ITU-R F.1336. Annex 8 of this Recommendation and a k-value of 0.7

Parameter	Scale	Value
MS network type		Rural
Frequency	MHz	1452
Inter-site distance	km	7.5

*- the antenna gain is 3 dB lower than the value in Report ITU-R M.2290 for this frequency range

Figure 1 shows an example of an IMT network, located along the border of the neighbouring state (blue dots indicate the place of base stations sites) and covering the close-to-border part of the country. The evaluation of the increase of the cumulative interference field strength from an IMT network over the maximum interference field strength from one base station was carried out at the test points established in the territory of the neighbouring country (black dots). Figure 2 shows an example of the reverse situation – when the IMT network is located in the opposite country.

FIGURE 1

Example 1 – IMT base stations sites (blue circles) within the borders of one country and the test points (black circles) on the territory of another country

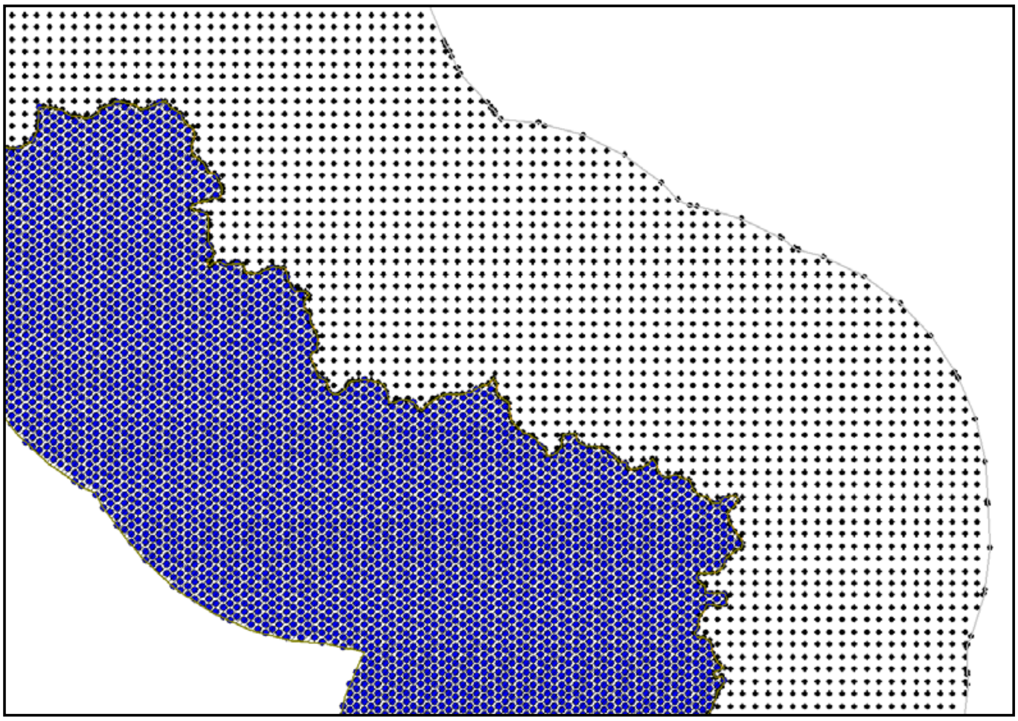
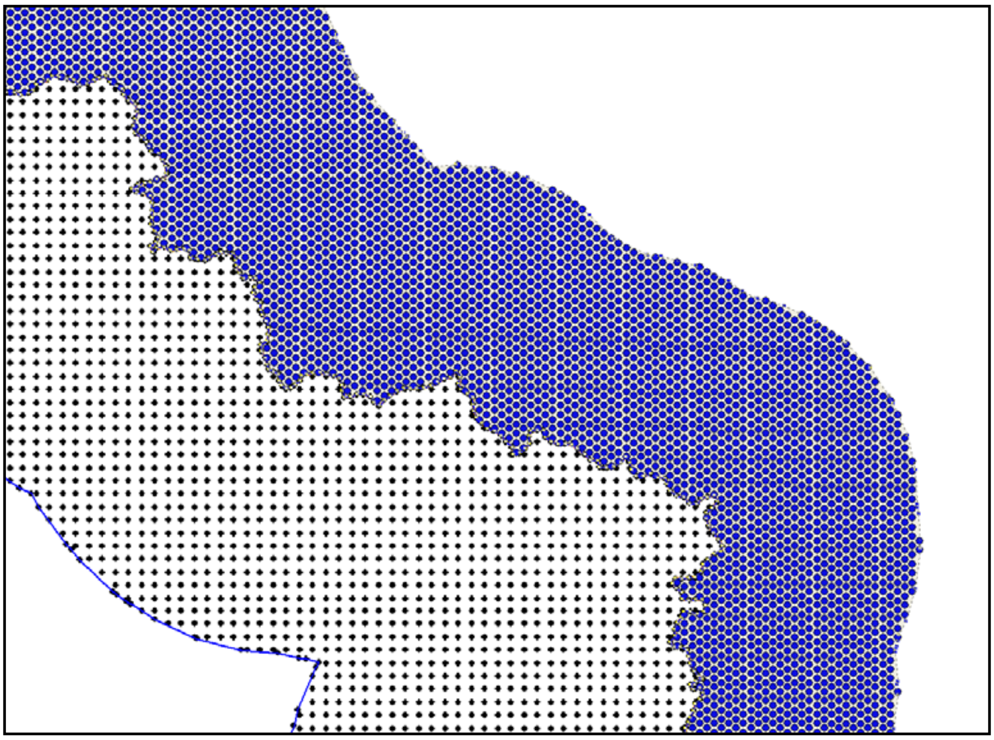


FIGURE 2

Example 2 – IMT base stations sites (blue circles) within the borders of second country and the test points (black circles) on the territory of first country



The distribution of the interfering fields in the test points of Example 1 shown in Figure 3, and for Example 2, is shown in Figure 4.

FIGURE 3

Distribution of the interfering field strength at the test points of Example 1 for a single interferer and cumulative interference

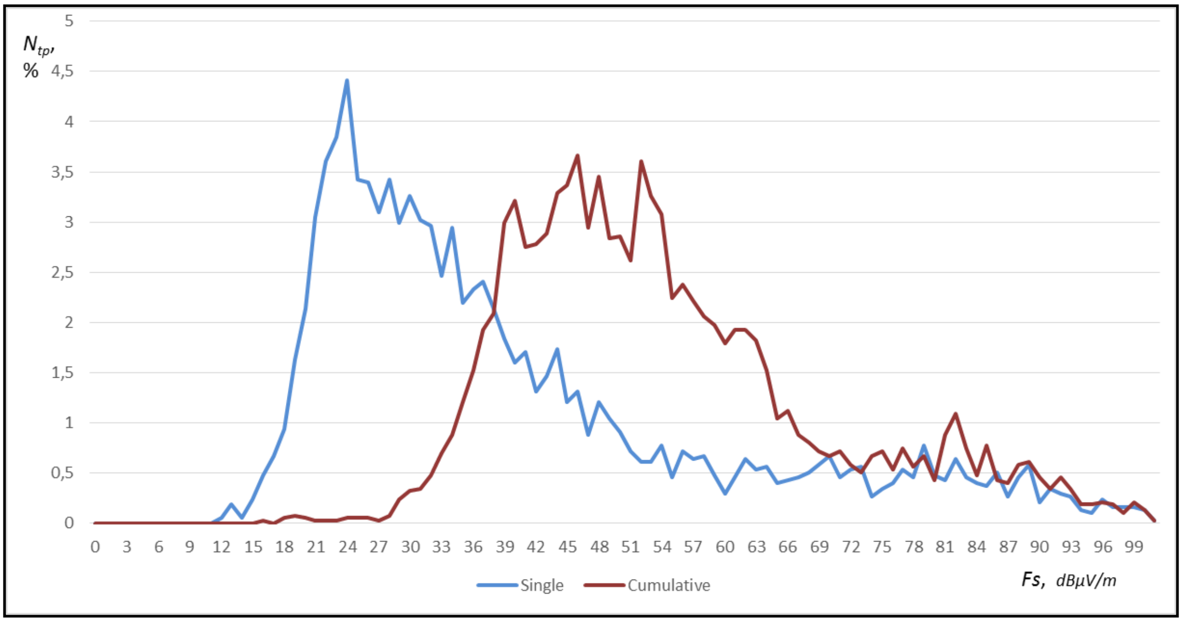
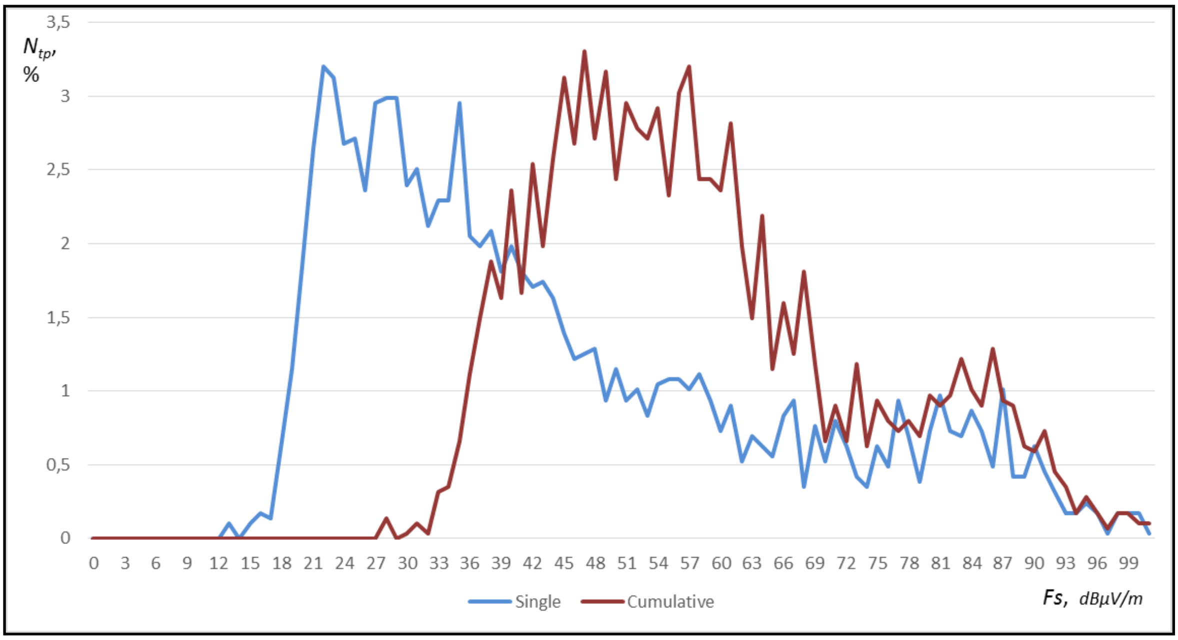


FIGURE 4

Distribution of the interfering field strength at the test points of Example 2 for a single interferer and cumulative interference



The resulting distribution of the increments of the total strength of the interfering field with respect to the maximum field strength of the interfering signal from one station is shown in Figures 5 and 6. Figures 5 and 6 show the results for the case of using an omnidirectional receiving antenna.

FIGURE 5

Distribution of the difference in interfering field strength from IMT base stations when comparing a single interference with cumulative interference in Example 1

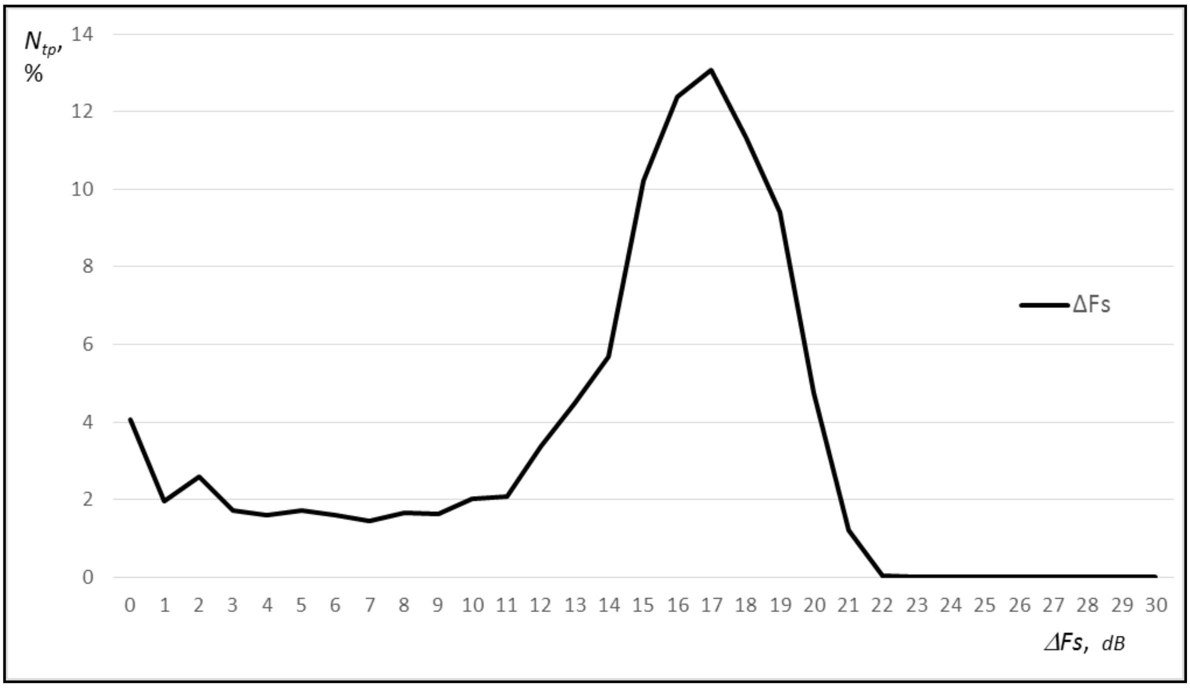
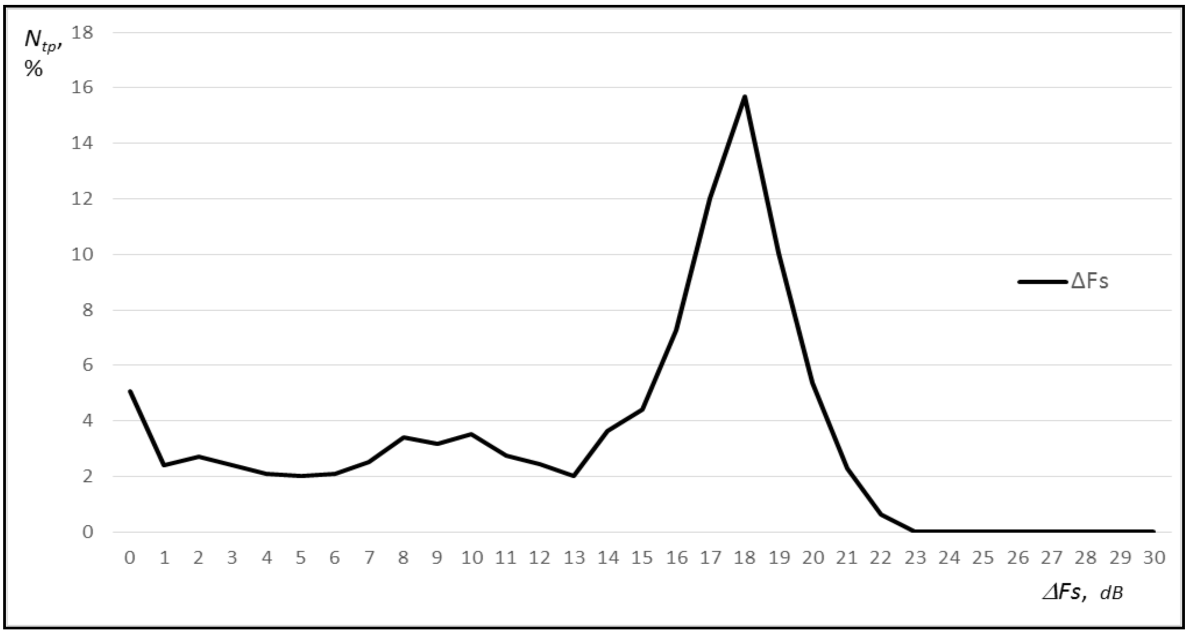


FIGURE 6

Distribution of the difference in interfering field strength from IMT base stations when comparing a single interference with cumulative interference in Example 2



The figure 6 shows that the aggregated interference margin could vary from 0 dB up to 23 dB and may be well approximated by a 20 dB aggregate interference margin to cover most of the cases of aggregated interference. To specify the appropriate value to protect a BSS earth station further analysis is needed. Specifically the distribution of the difference between a single interference level and aggregated interference level is required for points with the single entry interference level corresponding to the protection criteria of a BSS earth station. To derive such distributions the cross correlation function between single entry level variable and aggregated interference variable should be analysed. Such a 2D function of correlation is calculated and shown on Figure 7 for Example 2.

To define distributions of the difference in single vs aggregated interference level, the protection criteria of a BSS earth station should be recalculated into field strength levels. Assuming 0 dBi antenna gain and the frequency of 1 452 MHz such a conversion will lead to:

- the level of -119 dBW/m²/MHz corresponding to 37 dBµV/m/10 MHz
- the level of -130 dBW/m²/MHz corresponding to 26 dBµV/m/10 MHz

To acquire the distribution of aggregated interference level as observed at points with a level of single entry interference of around 26 dBµV/m the values of the 2D function in Figure 7 should be taken across the line corresponding to a single entry interference of 26 dBµV/m. This line is shown in red in the Figure 7. Similarly to acquire the distribution of aggregated interference level as observed in points with level of single entry interference of around 37 dBµV/m the values of 2D function on Figure 7 should be taken across the line corresponding to single entry interference of 37 dBµV/m. This line is also shown in red on the Figure 7. Based on that rule the distributions of aggregated interference variation are shown in Figures 8 and 9 for levels 26 dBµV/m and 37 dBµV/m/10 MHz correspondingly.

On these specific distributions the proposed aggregated interference margin of 20 dB has been shown as well. For both cases the proposed margin is a couple of dBs above the most probable value, but still below the worst case detected. However taking into account that this margin is proposed for coordination purposes, the conservative approach is more appropriate.

To check whether this situation is the same for points which are 20 dB below the single entry level the last distribution is shown in Figure 10 for the case of a -119 dBW/m²/MHz protection criterion corresponding to 17 dBµV/m/10 MHz. This line is also shown in the Figure 7, but in green. This case illustrates the observed aggregate interference levels reaching the established protection criterion when an actual single entry interference is practically 20 dB below this level. Based on that it could be concluded that for the protection criteria levels defined to protect BSS earth stations the aggregation interference effect does exist and could be approximated by the margin of 20 dB.

FIGURE 7

Distribution of the correlation between single-entry interference levels and aggregated interference levels in Example 2 (expressed as a percentage of test points)

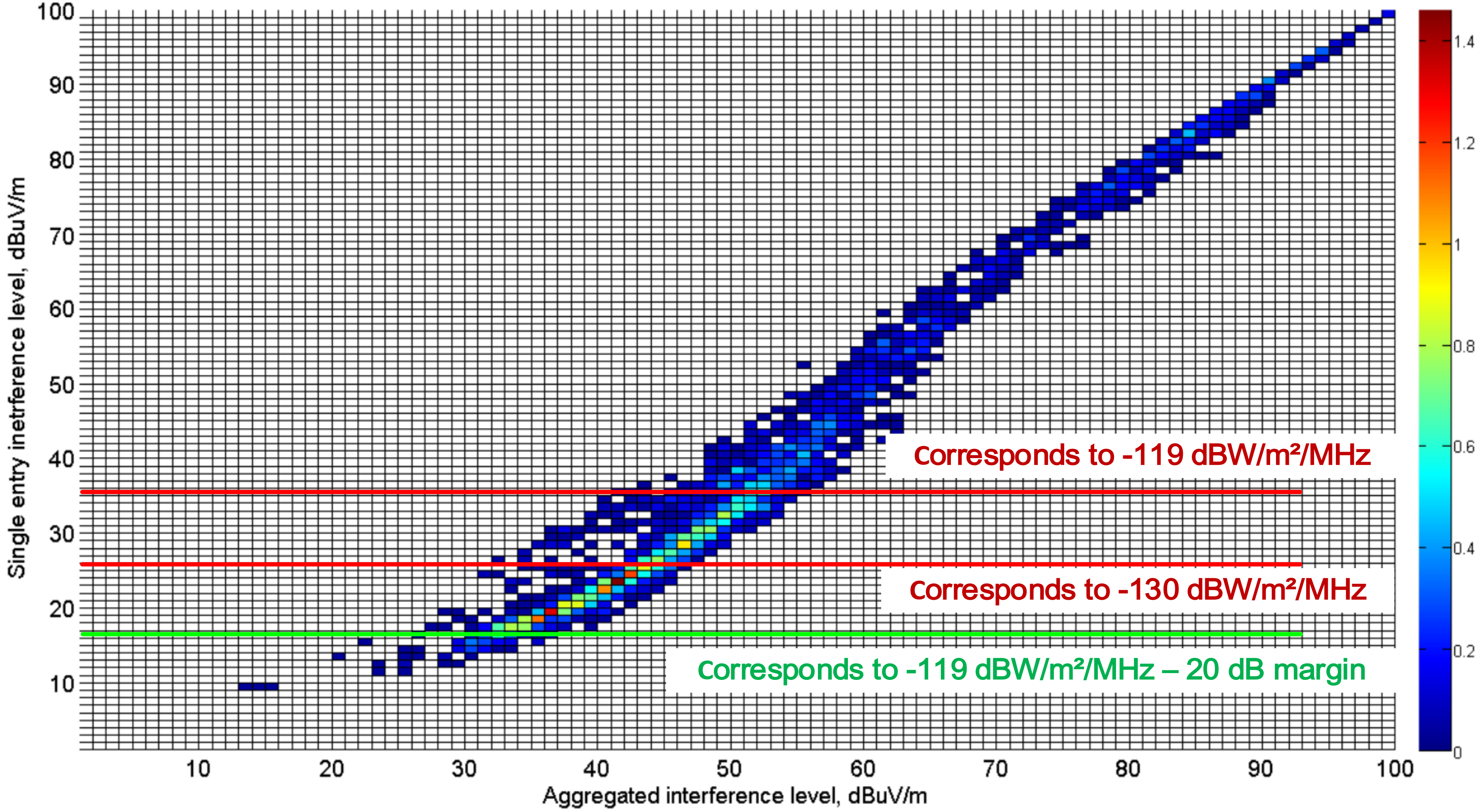


FIGURE 8

Distribution of the difference in interfering field strength from IMT base stations when comparing a single interference with cumulative interference in Example 2 as observed at the test point with the single entry level of around 37 dBµV/m

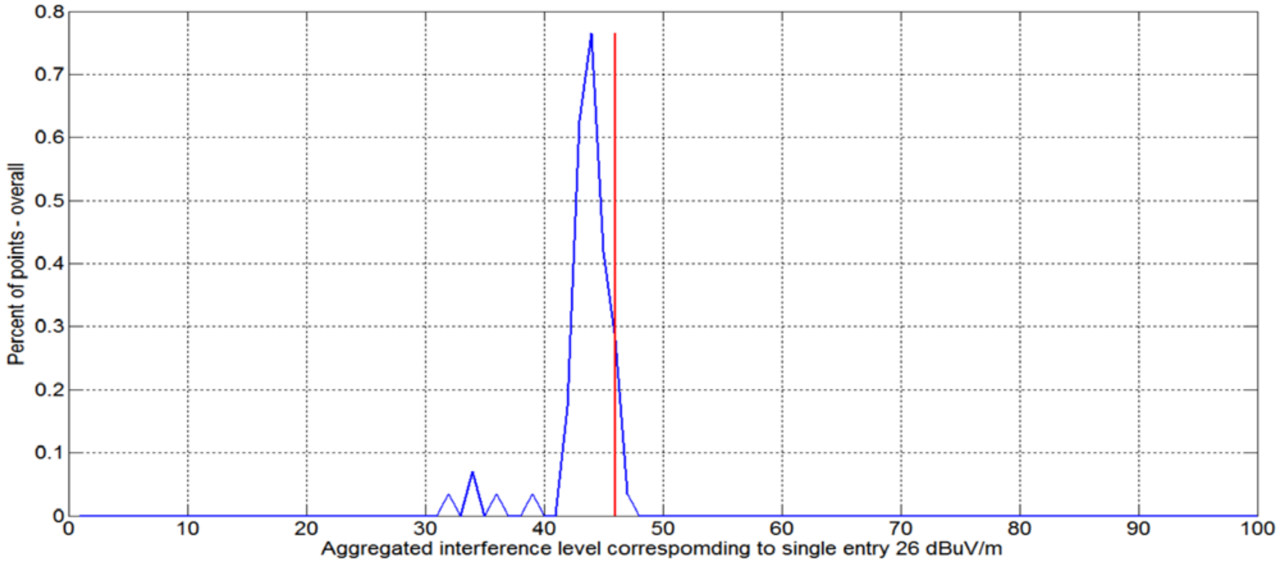


FIGURE 9

Distribution of the difference in interfering field strength from IMT base stations when comparing a single interference with cumulative interference in Example 2 as observed at the test point with the single entry level of around 26 dBµV/m

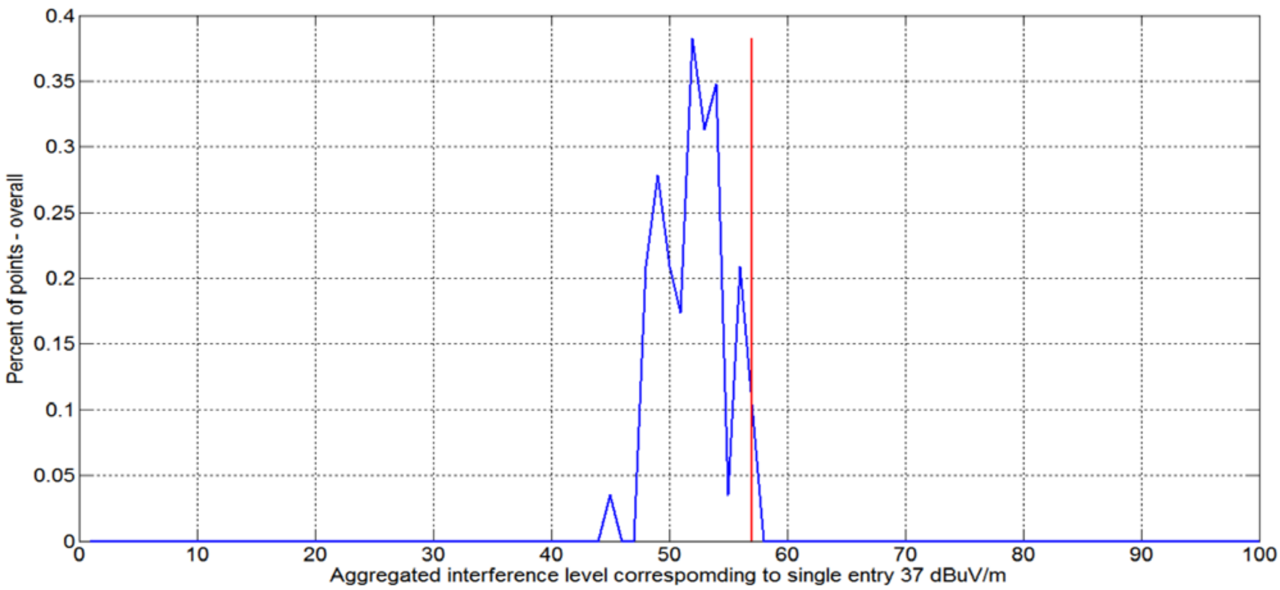


FIGURE 10

Distribution of the difference in interfering field strength from IMT base stations when comparing a single interference with cumulative interference in Example 2 as observed at the test point with the single entry level of around 17 dBμV/m