RECOMMENDATION ITU-R SA.1273*

POWER FLUX-DENSITY LEVELS FROM THE SPACE RESEARCH, SPACE OPERATION AND EARTH EXPLORATION-SATELLITE SERVICES AT THE SURFACE OF THE EARTH REQUIRED TO PROTECT THE FIXED SERVICE IN THE BANDS 2 025-2 110 MHz AND 2 200-2 290 MHz

(Questions ITU-R 118/7 and ITU-R 113/9)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that systems in the space research service (SRS), space operation service (SOS) and Earth exploration-satellite service (EESS) and the fixed service (FS) share the bands 2 025-2 110 MHz and 2 200-2 290 MHz;

b) that the FS operates and plans to operate a variety of point-to-point and point-to-multipoint (P-MP) systems employing analogue and digital techniques in these bands;

c) that, because of such sharing, it is necessary to ensure that emissions from satellites do not cause unacceptable interference to FS systems;

d) that FS systems can be satisfactorily protected from the emissions from satellites by placing suitable limits on the power flux-density (pfd) produced at the surface of the Earth, in a reference bandwidth;

e) that, nevertheless, any limitations of the pfd produced at the surface of the Earth should not be such as to place undue restrictions on the design of systems in the SRS, SOS and EESS services;

f) that the performance degradation for a fixed service system depends on the sum of the degradations due to emissions from all space stations that are visible to it;

g) that the band 2 025-2 110 MHz is used for Earth-to-space links for both low-Earth orbiting (LEO) and geostationary satellite orbit (GSO) spacecraft; the band is also used for space-to-space links, typically for radiocommunications from data relay satellite (DRS) spacecraft to LEO spacecraft;

h) that the band 2 200-2 290 MHz is used for space-to-Earth links for both LEO and GSO spacecraft; this band is also used for space-to-space links, typically for radiocommunications from LEO spacecraft to DRS spacecraft;

j) that for systems in the SRS, SOS and EESS, techniques are employed to reduce the radio-frequency spectral power density of satellite emissions,

recommends

1 that in the band 2 200-2 290 MHz the maximum pfd produced at the surface of the Earth by emissions from a space station operating in the space-to-Earth direction, for all conditions and methods of modulation, should not exceed:

– –130 dB(W/m^2) in any 1 MHz for angles of arrival less than 5° above the horizontal plane;

– –130 + 0.5 (δ – 5) dB(W/m^2) in any 1 MHz for angles of arrival δ (degrees) between 5° and 25° above the horizontal plane;

– –120 dB(W/m^2) in any 1 MHz for angles of arrival between 25° and 90° above the horizontal plane;

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* This Recommendation was jointly developed by Radiocommunication Study Groups 7 and 9, and future revisions should be undertaken jointly.

2 that in the band 2 200-2 290 MHz the maximum pfd produced at the surface of the Earth by emissions from a space station in LEO operating in the space-to-space direction, for all conditions and methods of modulation, should not exceed:

– –127 dB(W/m^2) in any 1 MHz for angles of arrival less than 5° above the horizontal plane;

– –127 + 0.5 (δ – 5) dB(W/m^2) in any 1 MHz for angles of arrival δ (degrees) between 5° and 25° above the horizontal plane;

– –117 dB(W/m^2) in any 1 MHz for angles of arrival between 25° and 90° above the horizontal plane;

3 that in the band 2 025-2 110 MHz the maximum pfd produced at the surface of the Earth by emissions from a DRS in GSO, for all conditions and methods of modulation, should not exceed:

– –130 dB(W/m^2) in any 1 MHz for angles of arrival less than 5° above the horizontal plane;

– –130 + 0.5 (δ – 5) dB(W/m^2) in any 1 MHz for angles of arrival δ (degrees) between 5° and 25° above the horizontal plane;

– –120 dB(W/m^2) in any 1 MHz for angles of arrival between 25° and 90° above the horizontal plane;

3.1 that the value of –130 dB(W/m^2) in any 1 MHz may need to be exceeded in rare occasions by up to 6 dB but for not more than 5% of the time to compensate for background interference;

4 that the above limits relate to the pfd and angles of arrival which would be obtained under free-space propagation conditions;

5 that Annex 1 should be referred to for additional guidance relating to this Recommendation.

NOTE 1 – In deriving § 2 of *recommends*, it has been determined that space-to-space transmissions of the space radiocommunication services control the sharing environment with the FS.

ANNEX 1

Interference considerations from the SRS, SOS and EESS into the FS in the bands 2 025-2 110 MHz and 2 200-2 290 MHz

1 Introduction

This Annex provides additional consideration in support of the pfd values given in § 1, 2 and 3 of *recommends*. The values presented in this Annex have been derived either from a calculation of the effects of continuous interference from the emissions of geostationary DRS or from Monte Carlo simulations of the effect of emissions from geostationary DRS satellites and LEO satellites on FS stations using the principles of Recommendations ITU-R F.1107 and ITU-R F.1108. Orbital locations for DRS satellites were obtained from Recommendation ITU-R SA.1275; FS system parameters were obtained from Recommendations ITU-R M.1143 and ITU-R F.759, and the orbital characteristics of the LEO satellite space science services satellites were derived from the Report of the Space Science Services Steering Group (Annex 4 to Document 7B/26-9D/54 dated 16 November 1994).

Paragraph 2 summarizes the results applicable to the emissions of GSO satellites in the band 2 200-2 290 MHz. Paragraph 3 summarizes the results applicable to the emissions of LEO satellites in the band 2 200-2 290 MHz, and § 4 applies to the emissions of DRS satellites in the band 2 025-2 110 MHz. Each paragraph contains its own conclusion that supports the value of pfd in the associated *recommends*.

2 Pfd levels applicable to geostationary satellite emissions in the band 2 200-2 290 MHz

A number of GSO satellites operating in the ground network of the space science services use the band 2 200-2 290 MHz (space-to-Earth) for tracking, telemetry and command verification (TTC) either on an operational or on a contingency basis. Scientific satellites tend to use the band operationally, whereas if the band is used by application satellites, such as fixed-, broadcasting-, or mobile-satellites, it tends to be on a contingency basis. Data gathered on a number of such GSO satellites have indicated that their numbers vary over a ten year span to the year 2005 between 87 and 117. At a particular orbit location there will only be a few assignments and there will be significant spans of the GSO orbit where there are no assignments existing or planned. The e.i.r.p. of 96% of existing GSO satellite assignments is less than +10 dBW, resulting in a total pfd of less than –153 dB(W/m^2) on the surface of the Earth. Taking into account the necessary bandwidths of the GSO satellites, with the exception of only a few assignments, the e.i.r.p. density of the GSO satellite transmissions is less than –10 dB(W/4 kHz), resulting in a pfd on the surface of the Earth of less than −173 dB(W/m^2) in any 4 kHz (–149 dB(W/m^2) in any 1 MHz) for all angles of arrival.

Based on this data, it may be concluded that emissions from GSO satellites in the band 2 200-2 290 MHz are not significant sources of potential interference to the FS. To ensure that sufficient flexibility is afforded DRS applications in future while also protecting the FS, a pfd level equivalent to –154/–144 dB(W/(m^2 · 4 kHz)) as identified in the Radio Regulations No. S21.16, Table S21-4 for the band 2 200-2 300 MHz (Mask A) and referenced to 1 MHz will be adequate for sharing of this band.

3 Pfd levels applicable to LEO satellite emissions in the band 2 200-2 290 MHz

3.1 Simulation studies considered the downlink interference from 24 DRS-LEO combinations, where each DRS was treated as transmitting/receiving simultaneously to/from two LEOs (while they were visible). All DRS-LEO combinations were considered as operating together and co-channel. The transmission parameters used for the modelling are summarized in Table 1.

TABLE 1

Satellite transmission parameters used for the modelling

	DRS	LEO
Power density into antenna (dB(W/Hz))	–57.7	–83.5 (1)
Transmit gain (dBi)	34.7	28.5
Receive gain (dBi)	36.0	28.5
Antenna pattern	Recommendation ITU-R S.672 (–20 dB sidelobe)	Recommendation ITU-R S.672 (–20 dB sidelobe)

(1) Based on a quoted e.i.r.p. density of –55 dB(W/Hz).

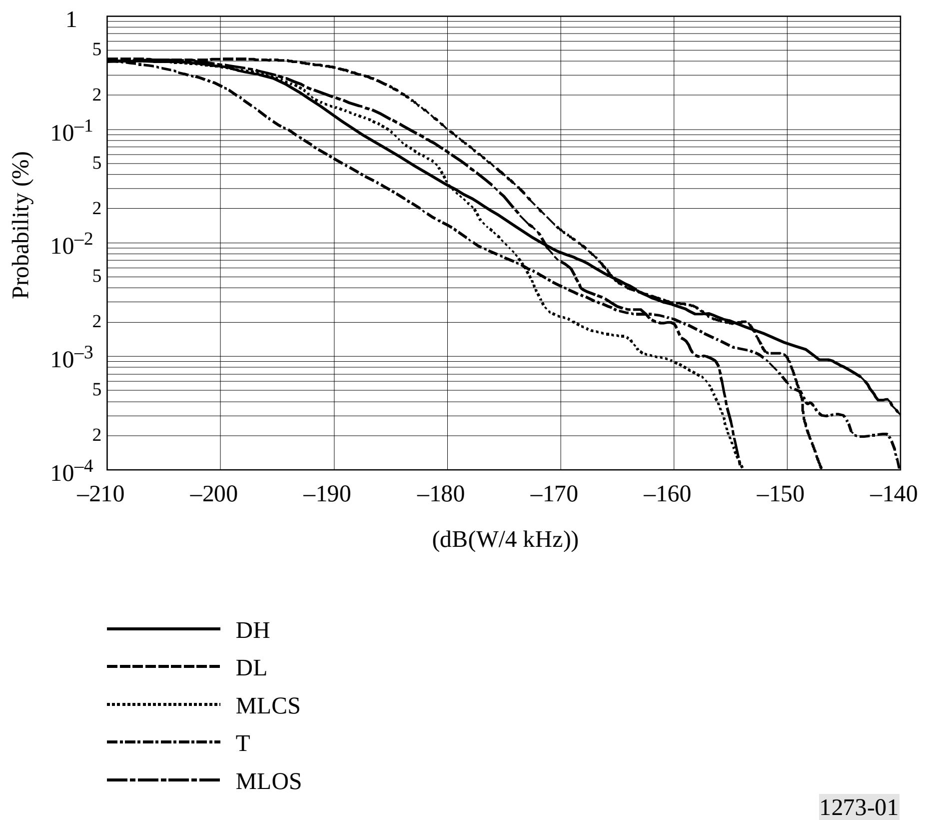
The interference was simulated into a variety of fixed systems. As the only element of the receive system that will alter the value of received interference is the antenna, it was necessary only to model interference into each antenna type, rather than each system type. Consequently interference was modelled only into system types DH (digital high capacity), DL (digital low capacity), MLCS (digital point-to-multipoint central station), MLOS (digital point-to-multipoint out station) and T (analogue or digital tropospheric), representing 33 dBi dish, Yagi, omnidirectional, flat-plate and 45 dBi dish antennas, respectively.

Interference was calculated at each of 60 locations (at 20° and 50° North, and at 30° longitude increments) and for 8 FS antenna azimuths at each location. For the results presented, the two worst-case results were then selected for each system type (excluding those locations far from land).

Figure 1 shows that the Yagi antenna (DL system) experiences the most severe interference at approximately −184 dB(W/4 kHz) for 20% of the time. This is, however, well within the long-term performance objective (20%) for most fixed link systems, i.e., around –170 dB(W/4 kHz). This protection level corresponds to a degradation in FS receiver threshold of approximately 1 dB (see Recommendation ITU-R F.759).

FIGURE 1

Interference from LEO into various FS systems



The long-term interference into the 33 dBi dish, omnidirectional and flat-plate antennas is similar, at around 9 dB less than that into the Yagi.

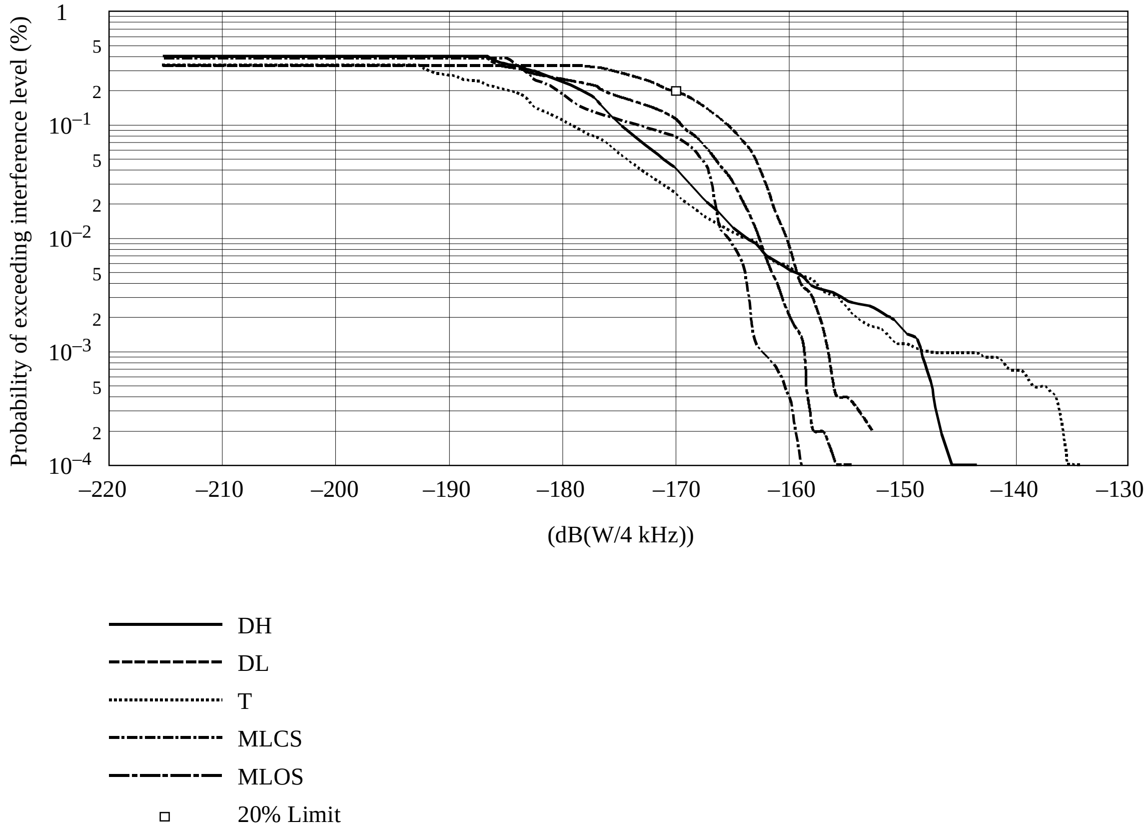
The narrow beamwidth of the 45 dBi gain tropospheric antenna ensures that it receives very low levels of long-term interference, but occasional alignments result in high short-term interference levels.

These low levels of interference generally would be expected as the LEO antenna will point away from the earth for the majority of the orbit.

3.2 Deterministic simulations (see Fig. 2) have also shown that, with 24 LEO spacecraft at 800 km altitude (98° inclination) and at 350 km altitude (28.5° inclination) working to 12 DRS satellites, and with unfavourable FS antenna azimuth pointings, the long-term (20% of the time) FS protection criteria are marginally met using a pfd mask with levels approximately 2 to 3 dB greater than –154/–144 dB(W/(m^2 · 4 kHz)). Low-power P-MP systems, which employ relatively low-gain antennas, are marginally protected in both the long and short term at these pfd levels.

FIGURE 2

Worst-case LEO interference to FS systems



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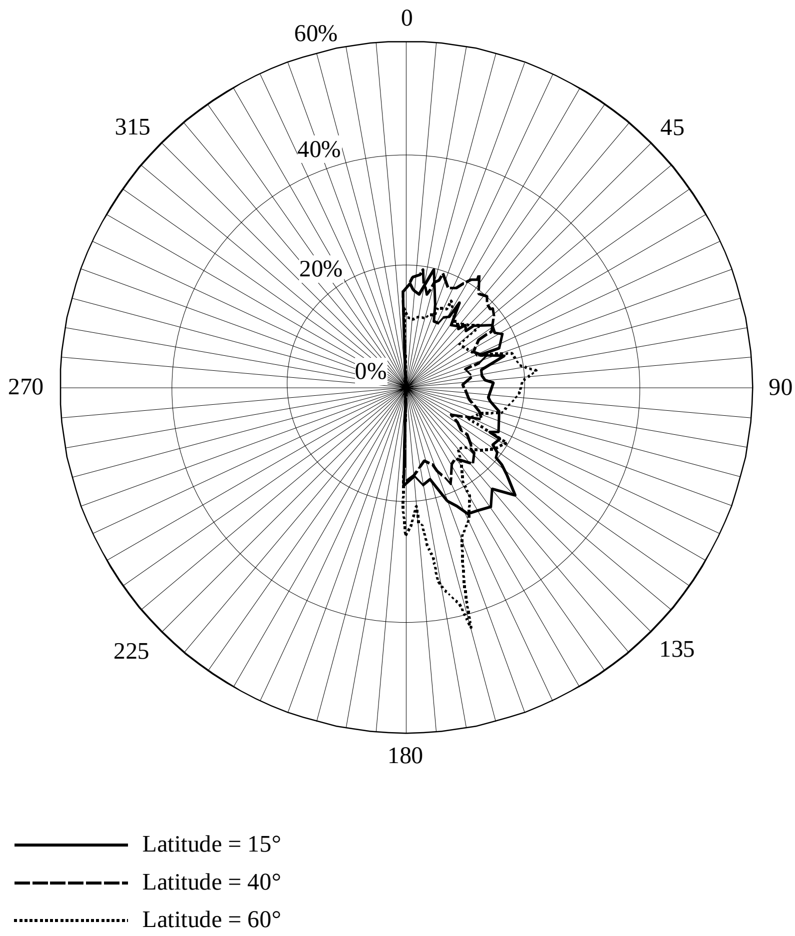
3.3 Another analysis was performed using the methodology of Recommendation ITU-R F.1108. It was assumed that the digital stations were centred at a given latitude, employed high gain antennas at 0° elevation angles. The azimuth angle of each station receiving antenna varied between 0° and 180°. The FS characteristics are summarized as follows:

FS Antenna Pattern:	Recommendation ITU-R F.699
Antenna Gain:	33 dBi
Feeder Losses:	2 dB
Receiver Noise Temperature:	290 K
Receiver Noise Figure:	4 dB.

The simulation study employed a total of 15 non-GSO satellites in various orbits. Pfd values ranging from −148 dB(W/(m^2 · 4 kHz)) at elevation angles less than 5° to –135 dB(W/(m^2 · 4 kHz)) for elevation angles greater than 25° were assessed. The results (see Fig. 3) show that 7.2% of the FS stations experienced a fractional degradation in performance (FDP) greater than 25%. Stations experiencing the greatest degradation are located at the higher latitude of 60° used in the simulation.

FIGURE 3

FDP as a function of azimuth angle for digital radio-relay station located at 15°, 40° and 60° latitude



For PFD = – 148 to – 135 dB(W/($m^2 \cdot$ 4 kHz)), 7,2% of stations exceed 25% FDP criterion.
G_0 = 33 dBi

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3.4 Other studies were performed to establish the adequacy of various pfd masks to protect the FS. Digital point-to-point characteristics were used for the FS as follows:

FS Antenna Pattern:	Recommendation ITU-R F.699
Antenna Gain:	33 dBi
Feeder Losses:	2 dB
Receiver Thermal Noise:	–164 dB(W/4 kHz)
Polarization Discrimination:	3 dB.

A 3 dB polarization discrimination was applied only for mainbeam-to-mainbeam coupling. Space diversity was assumed for the FS stations. The study employed the simulation method described in Recommendation ITU-R F.1108 to determine the FDP of FS systems. The simulations took account of the effects of atmospheric refraction and absorption as contained in Recommendation ITU-R P.834. Two FS station latitudes were selected at 20° N and 50° N.

Two sets of satellite parameters were selected, namely 6 satellites at 333 km and 28.5° inclination, and 8 satellites at 800 km and 98° inclination. The pfd levels were varied in conformance with three different masks identified in the Radio Regulations No. S21.16, Table S21-4, namely:

Mask A: –154/–144 dB(W/(m^2 · 4 kHz)) for the band 2 200-2 300 MHz

Mask B: –152/–137 dB(W/(m^2 · 4 kHz)) for the band 2 500-2 690 MHz

Mask C: –152/–142 dB(W/(m^2 · 4 kHz)) for the band 3 400-4 200 MHz.

In addition, simulations were performed for slightly greater pfd levels namely, 2 dB greater than Mask C. In summary the results demonstrated:

– The pfd levels of Mask A will potentially introduce peak FDPs in the range of 6% to 7.5%.

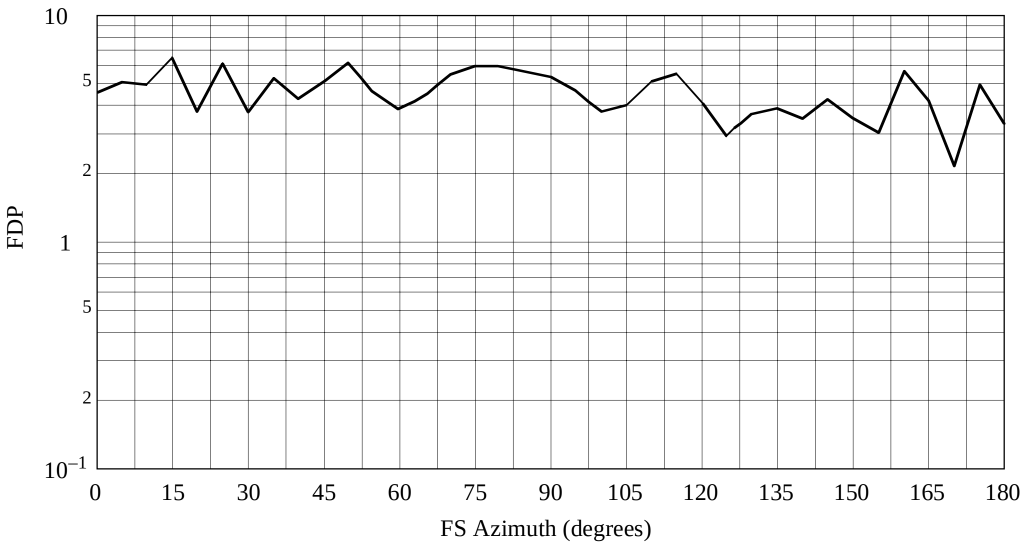
– The pfd levels of Mask C produce little change from Mask A for FS stations at low latitudes and LEO satellites operating at 98° inclination (see Fig. 4). However, the same FS stations are impacted greater by the satellites at 28.5° inclinations. The peak FDP for these stations increased to about 12%. For FS stations located at 50° N, the peak FDP has approximately doubled from the levels of Mask A (see Fig. 5).

– The pfd levels of Mask B again produce little change in FDP for the case of low latitude FS stations and LEO satellites operating at 98° inclination, relative to Mask A or Mask C. In addition, while the impacts on the same FS stations are slightly greater from the satellites at 28.5° inclinations, the peak FDP remains unchanged at 12%. For FS stations located at 50° N latitude, the peak FDP has increased marginally to 18%.

– The low and high arrival angle pfd was increased 2 dB from the levels contained in Mask C. In the case of FS stations at low latitudes and LEO satellites at 98° inclination, the FDP increased to about 10%. In addition, for LEO satellites at 28.5° inclinations, the peak FDP doubled to about 25% (see Fig. 6). For FS stations at 50° N, the peak FDP increased to 32% (see Fig. 7).

FIGURE 4

FDP as a function of azimuth angle for a digital radio-relay station located at 20° N, antenna elevation = 0.5° from 8 satellites at 800 km altitude and 98° orbit inclination



Low/high angle pfd = – 152/ – 142 dB(W/(m^2 · 4 kHz)) at 5°/25° angles of arrival

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FIGURE 5

FDP as a function of azimuth angle for a digital radio-relay station located at 50° N, antenna elevation = 0.5° from 8 satellites at 800 km altitude and 98° orbit inclination

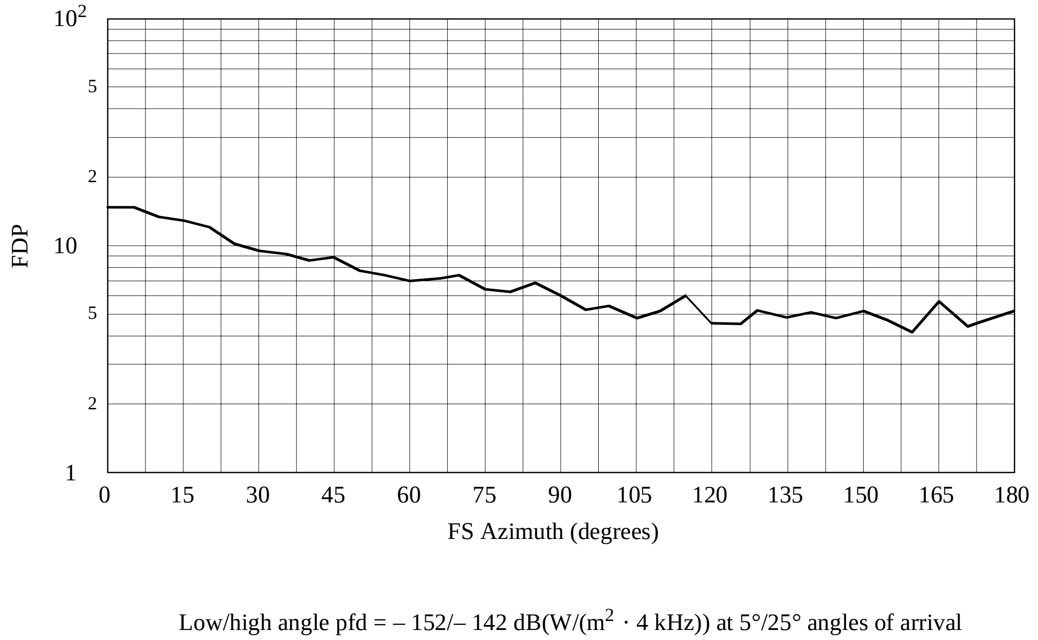

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FIGURE 6

FDP as a function of azimuth angle for a digital radio-relay station located at 20° N, antenna elevation = 0.5° from 6 satellites at 333 km altitude and 28.5° orbit inclination

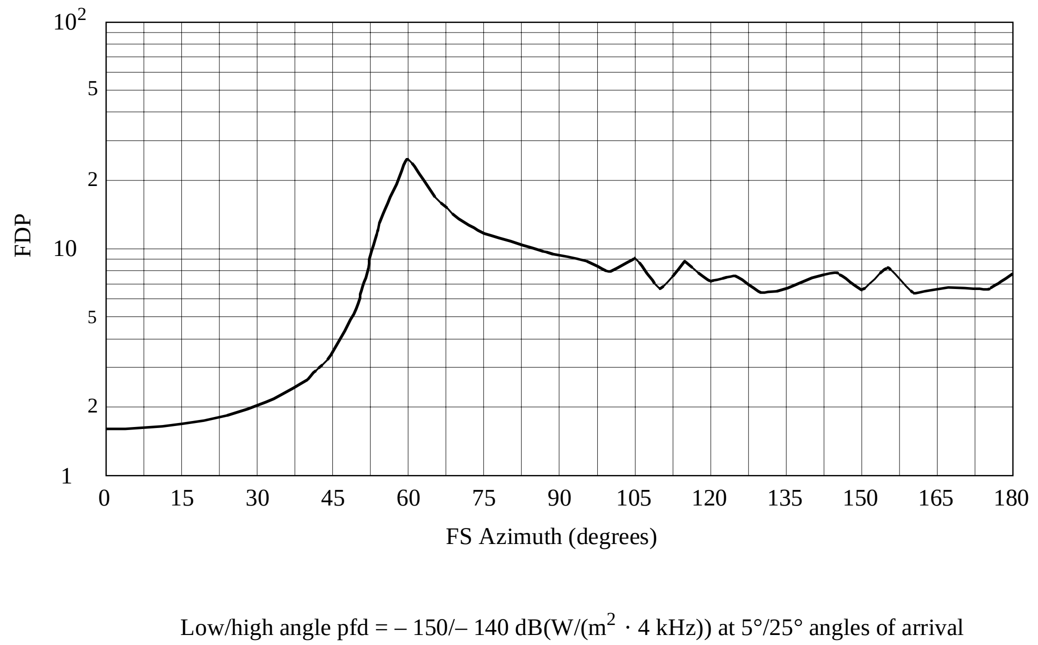

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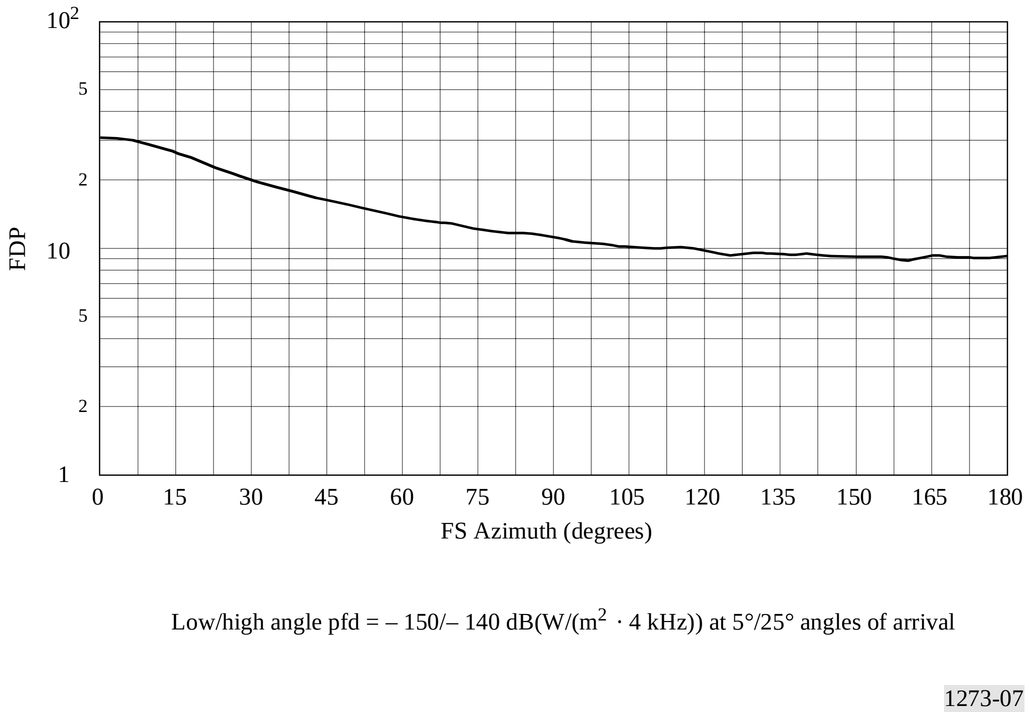
FIGURE 7

FDP as a function of azimuth angle for a digital radio-relay station located at 50° N, antenna elevation = 0.5° from 6 satellites at 333 km altitude and 28.5° orbit inclination



3.5 Conclusions related to the band 2 200-2 290 MHz

Studies of bandsharing between space stations in LEO and FS stations in the band 2 200-2 290 MHz have demonstrated that pfd levels significantly greater than Mask A will produce unacceptable performance conditions for the FS. For example, at pfd increases of 4 dB or greater than Mask A, the FS performance degradations approach 25% for large portions of available FS azimuths. However, at modest pfd increases up to about 3 dB, the performance degradations should be acceptable. Although marginally exceeding the FS bandsharing objectives, these levels in practice should be acceptable since a number of ameliorating elements may be present such as relative channel bandwidths, channel occupancy, and satellite transmission activity factors. In addition, since the majority of new FS stations will be digital, a 1 MHz reference bandwidth will be acceptable to protect the FS. A pfd level (converted to 1 MHz) ranging from –127 dB(W/(m^2 · MHz)) at elevation angles less than 5° to –117 dB(W/(m^2 · MHz)) for elevation angles greater than 25° should provide the necessary protection to the FS while allowing operational flexibility for existing and planned LEO satellites.

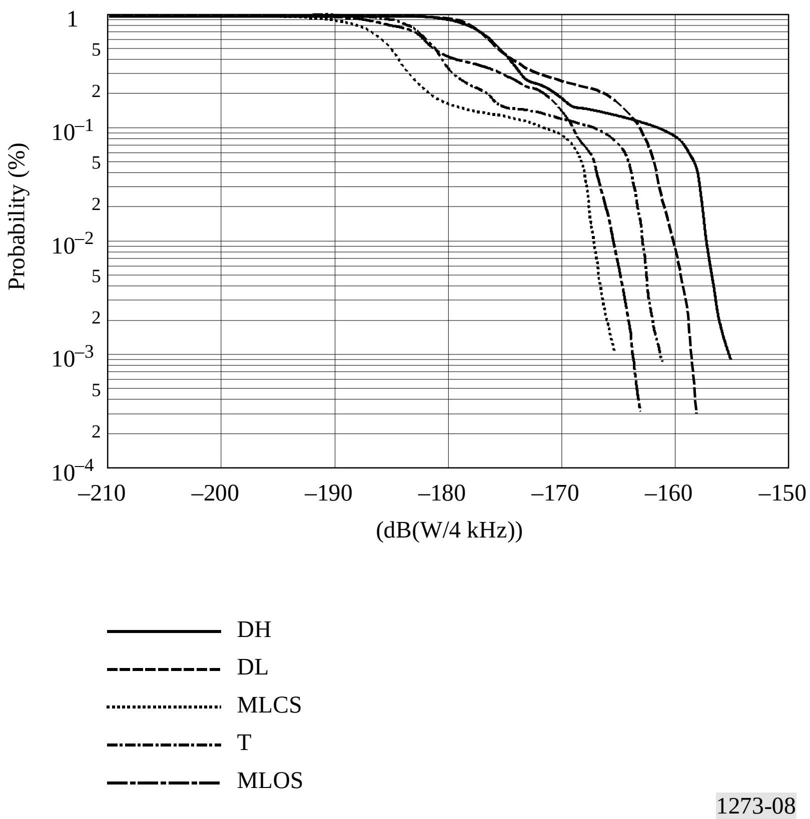
4 Pfd levels applicable to GSO DRS emissions in the band 2 025-2 110 MHz

4.1 In the same analysis that was performed under § 3.1, interference was also simulated from the DRS constellation. In terms of the various interference reduction factors, account was taken of three factors, namely, FS channelization, FS DRS position avoidance (see Note 1), and improved FS antenna performance. Figure 8 shows the expected interference from this simulation.

NOTE 1 – The orientation of FS stations was allocated randomly. An inspection of their pointing showed that none of the stations were directed within 1.5° of any of the DRS GSO orbital locations.

FIGURE 8

Interference from DRS into various FS systems



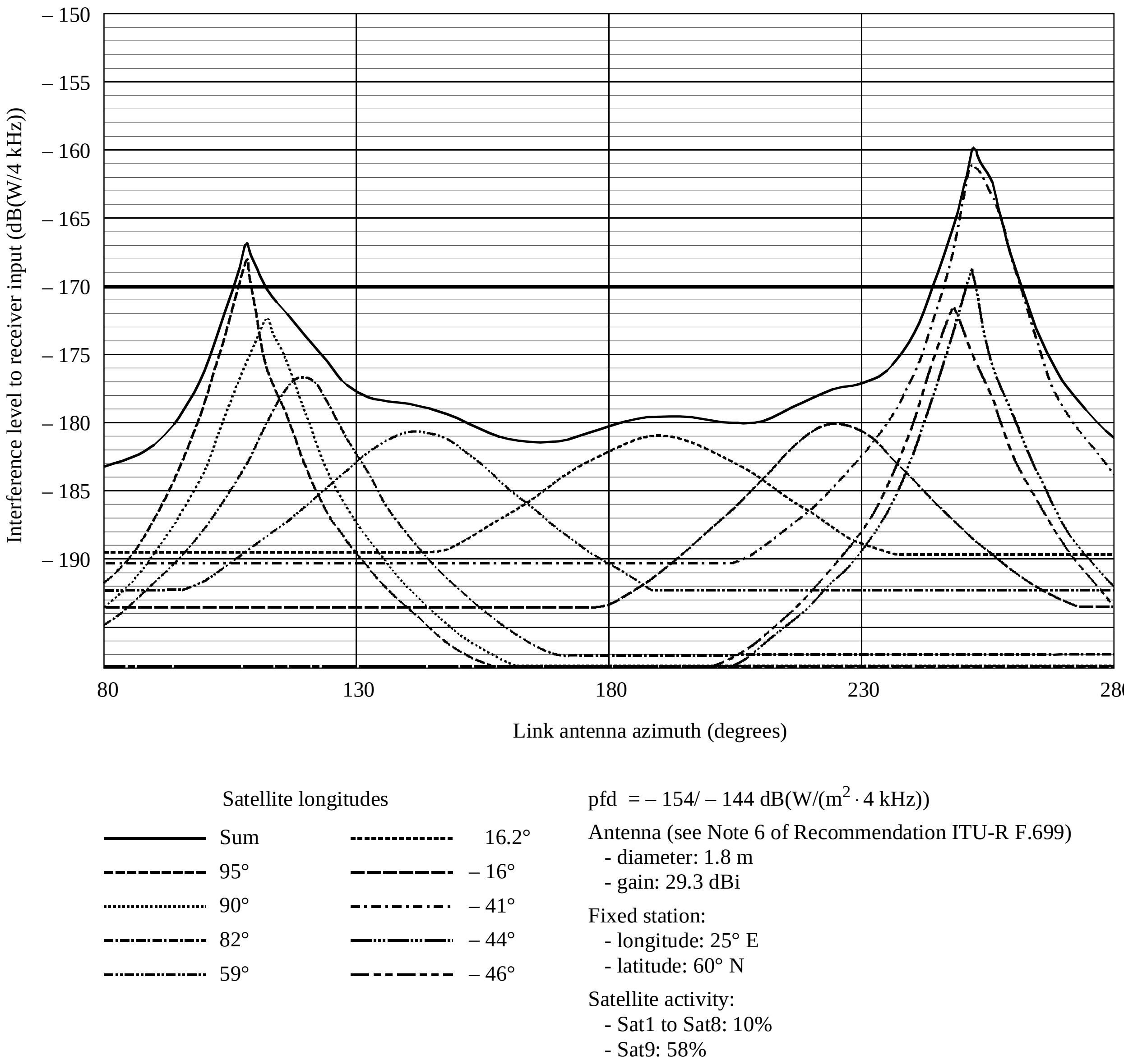
The levels can be seen to lie slightly below or near the –170 dB(W/4 kHz) level for 20% of the time in all cases except that of the Yagi (DL), which exceeds the limit by some 5 dB. Long-term interference levels into the tropospheric antenna are again low, at some 7 dB below the limit, while the low gain and zenith-pointing null of the omnidirectional antenna ensure even lower interference levels.

4.2 A study was also performed to determine the aggregate interference from all visible DRS satellites into a FS receiver located at 60° N latitude. The DRS space stations were assumed to transmit with a pfd Mask A. Orbital positions of the DRS were taken from Recommendation ITU-R SA.1275. FS parameters were taken from Recommendation ITU-R M.1143. The FS antenna radiation pattern employed Note 6 of Recommendation ITU-R F.699. A typical antenna size of 1.8 m was used instead of a 33 dBi antenna.

As DRS systems employ circular polarization, a 3 dB polarization discrimination was used in the calculation of main beam interference. A 2 dB feeder loss for the FS station was also employed. The FS station antenna was positioned at 25° E longitude and 60° N latitude and rotated in 5° steps between 80° and 280° azimuth directions.

Results indicated that to ensure that an interference level of –170 dB(W/4 kHz) is not exceeded, 81% of available azimuth directions would need to be avoided by the FS. However, this assumed that all visible DRS space stations were transmitting continuously. Recognizing that this will not be the case for many DRS applications with respect to a given FS station, a further analysis has shown that if one space station was active for a significant time period and all other DRS space stations active for much shorter periods of time, approximately 19% of available azimuth directions would need to be avoided. Further, in cases where the DRS orbital location is known, the worst case avoidance needed would decrease to 13%. This situation is shown in Fig. 9.

FIGURE 9



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4.3 Another study assessed the suitability of pfd limits contained in Mask A, Mask B and Mask C to protect the FS. The DRS orbit locations were taken from Recommendation ITU-R SA.1275. The network simulation used to determine the interference from the DRS space stations employed most of the assumptions in the Monte Carlo method described in Recommendation ITU-R F.1107. In this study a non-uniform/non-symmetrical distribution of DRS satellites was the only significant departure from Recommendation ITU-R F.1107. A latitudinal trend of 52.5° N and a reference longitude of 97° W were assumed.

Results demonstrated that approximately 10% of the FS hops would experience a 1 dB degradation in receiver threshold from DRS stations operating with a pfd of Mask A. These FS stations did not employ space diversity; thus the receiver threshold would be affected by 1.7 dB should space diversity be employed. For the cases of Mask C and Mask B pfd masks, approximately 20% and 55% of the FS hops, respectively would experience a 1 dB degraded receiver threshold (no space diversity). For the case of Mask B, approximately 10% of the FS links would experience a 3 dB degradation in receiver threshold.

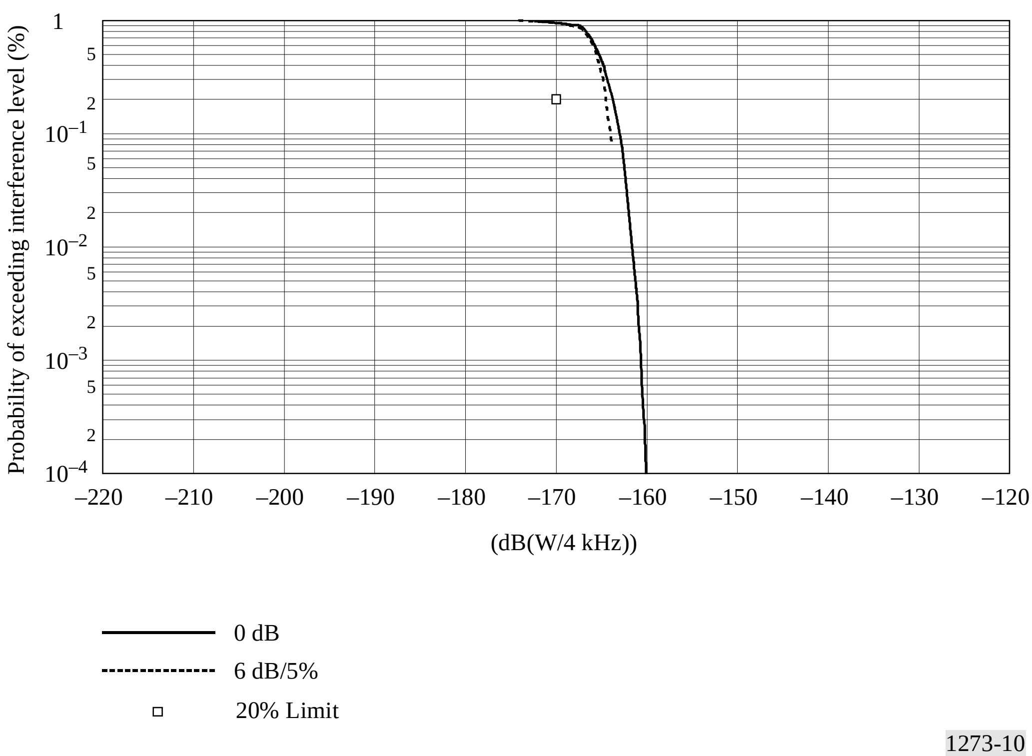
4.4 An analysis similar to § 4.3 was also performed assuming some 1 245 digital radio-relay links located near the major urban cities of the world. The United States of America was excluded from the analysis since only transportable FS stations are currently permitted in this band. The FS characteristics were the same as those in § 3.3. DRS orbit locations are given in Recommendation ITU-R SA.1275. In this study a pfd mask 4 dB higher than Mask A was employed. Results indicated that approximately 10% and 90% of the FS links would experience 3 dB and 1 dB, degraded receiver thresholds, respectively.

4.5 A study employing deterministic simulations similar to that described in § 3.1 and a pfd mask of Mask A demonstrated (see Fig. 10) that the long-term interference protection level (–170 dB(W/4 kHz)) was exceeded by between 4 and 14 dB for the worst case of random azimuth pointings. For the case of a digital high-capacity fixed link at latitude 20° N, the protection level was exceeded by 0 to 14 dB, depending upon the longitude of the FS station. However, it is recognized that the modelling of DRS satellites by a pfd mask is pessimistic since it ignores the scanning nature of the narrow (~ 3°) satellite beams, and the discrimination thereby provided. It is also noted that the constellation of 12 DRS satellites with a total of 24 beams active whenever an associated LEO spacecraft is visible is a worst case scenario. Nevertheless, it appears that some existing FS systems in unfavourable locations may suffer periodic performance and/or availability degradations during periods of high space network activity.

An increase of the pfd from each DRS by 6 dB for a random 5% of simulation samples has shown, for the case of a digital high-capacity fixed link (33 dBi antenna), that there is only a small (~ 1 dB) increase in long-term (20% of the time) interference over that due to the pfd Mask A, but at small percentages of time the increase tends towards 6 dB. As the primary FS sharing problem with the DRS constellation appears to be that of long-term interference, the proposed allowance for power control will have little additional impact on the FS and therefore is acceptable.

FIGURE 10

Effect of short-term DRS power increase



4.6 Conclusions related to the band 2 025-2 110 MHz

Studies of bandsharing between DRS satellites and FS stations in the band 2 025-2 110 MHz have demonstrated that pfd levels Mask A will be satisfactory to protect the FS in the majority of cases. An increase of the pfd from each DRS by 6 dB for a random 5% of the time introduces a small increase in the long-term interference over that due to the pfd Mask A. As the primary FS sharing condition with the DRS constellation appears to be that of long-term interference, the additional 6 dB allowance for power control will have little additional impact on the FS and therefore is acceptable from a bandsharing perspective. A pfd level (converted to 1 MHz) ranging from –130 dB(W/(m^2 · MHz)) at elevation angles less than 5° to –120 dB(W/(m^2 · MHz)) for elevation angles greater than 25°, with linear escalation between 5° and 25°, should provide the necessary protection to the FS while allowing operational flexibility for DRS satellites.