RECOMMENDATION ITU-R SF.1484*

MAXIMUM ALLOWABLE VALUES OF POWER FLUX-DENSITY AT THE SURFACE OF THE EARTH PRODUCED BY NON-GEOSTATIONARY SATELLITES IN THE FIXED-SATELLITE SERVICE OPERATING IN THE 37.5-40.5 GHz AND 40.5-42.5 GHz BANDS TO PROTECT THE FIXED SERVICE

(Questions ITU-R 217/9 and ITU-R 250/4)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that the band 37.5-40.5 GHz is allocated to the fixed-satellite (FS) and the fixed-satellite service (FSS) (space-to-Earth) on a co-primary basis;

b) that the band 40.5-42.5 GHz is allocated to the FS and the FSS (space-to-Earth) on a co-primary basis in Regions 2 and 3 and in certain countries in Region 1;

c) that it is necessary to ensure that emissions from satellites do not cause unacceptable interference to FS systems in the bands 37.5-40.5 GHz and 40.5-42.5 GHz;

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

e) that the current and anticipated FS system characteristics in the band 37.5-40.5 GHz are different from those in the band 40.5-42.5 GHz;

f) that any limitations of the pfd produced at the surface of the Earth should not place undue restrictions on the design of geostationary (GSO) and non-GSO FSS systems;

g) that Resolution 133 (WRC-97) requested ITU-R to determine, in time for WRC-2000, whether the pfd limits included in Article S21 of the RR for the 37-40 GHz range adequately protect terrestrial services from FSS networks;

h) that Resolution 129 (WRC-97) invited ITU-R to undertake, as a matter of urgency, studies of appropriate criteria and methodologies for sharing between the FSS and other services with allocations in the band 40.5-42.5 GHz;

j) that some FS systems employing small net fade margins may not be fully protected from interference from FSS systems without unduly constraining those systems;

k) that several non-GSO satellite systems have been advance published in the 37.5-40.5 GHz and 40.5-42.5 GHz bands, and that the largest number of spacecraft in any one of the published non-GSO satellite systems is 99 spacecraft,

recommends

1 that in the bands 37.5-40.5 GHz and 40.5-42.5 GHz, the maximum allowable pfd at the surface of the Earth from any one non-GSO satellite should not exceed, in any 1 MHz band:

1.1 for the band 37.5-40.5 GHz:

-120	$dB(W/m^2)$	for	$\theta \leq 5°$
$-120 + 0.75(\theta - 5)$	$dB(W/m^2)$	for	$5° < \theta \leq 25°$
-105	$dB(W/m^2)$	for	$25° < \theta \leq 90°$

where θ is the angle of arrival (degrees above the horizontal);

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 3 (Working Party (WP) 3M), 4 (WP 4A) and 9 (WP 9B and WP 9A).

1.2 for the band 40.5-42.5 GHz:

–115	dB(W/m^2)	for	$\theta \leq 5°$
$-115 + 0.5(\theta - 5)$	dB(W/m^2)	for	$5° < \theta \leq 25°$
–105	dB(W/m^2)	for	$25° < \theta \leq 90°$

where θ is the angle of arrival (degrees above the horizontal);

2 that the aforementioned limits relate to the pfd which would be obtained under assumed free-space propagation conditions;

3 that the information contained in Annex 1 should be used as guidance for the use of this Recommendation for the band 37.5-40.5 GHz;

4 that the information contained in Annex 2 should be used as guidance for the use of this Recommendation for the band 40.5-42.5 GHz;

5 that further study be conducted before the values in *recommends* 1 may be applied to any non-GSO FSS system with a larger number of spacecraft than the number identified in *considering* k).

ANNEX 1

Potential interference from non-GSO FSS systems into the FS systems in the band 37.5-40.5 GHz

1 Introduction

This Annex presents the potential interference from non-GSO FSS systems into point-to-point and point-to-multipoint (P-MP) FS systems. In this study, LEO V1 (low Earth orbit (LEO)), LEO V2 (medium Earth orbit (MEO)), LEO V3 (MEO) satellite networks are used as the non-GSO FSS systems. The study covers the band 37.5-40.5 GHz.

2 Technical characteristics of non-GSO FSS systems

The satellite system parameters of LEO V1, LEO V2 and LEO V3 are shown in Table 1.

TABLE 1

Non-GSO FSS system orbital parameters

Parameters	LEO V1	LEO V2	LEO V3
Number of satellites	72	15	32
Number of orbital planes	12	3	4
Number of satellites/plane	6	5	8
Altitude (km)	1 350	10 355	10 355
Inclination angle (degrees)	47	50	50
Period of orbit	6 761 s	6 h	6 h

3 FS system parameters and interference criteria

3.1 FS system parameters

The FS system parameters have been taken from Recommendation ITU-R F.758.

– Point-to-point systems: In the simulation, the following parameters are used:
  – FS receiver antenna gain: 44 dBi and 45 dBi;
  – Receiver noise figure: 6 dB to 8 dB;
  – FS elevation angle: 0° to 60°;
  – FS antenna radiation patterns: Recommendations ITU-R F.1245 and ITU-R F.699;
  – FS azimuth angle: simulations based on worst-case azimuth.
– Point-to-multipoint systems:
  – FS receiver antenna gain (Hub or central station): 16 dBi;
  – FS antenna elevation angle (Hub or central station): 0°;
  – Receive noise temperature: 1 740 K;
  – End user terminal: the above characteristics of point-to-point FS systems are considered to be representative.

3.2 Interference criteria

3.2.1 Long-term criterion

The long-term *I*/*N* criterion for aggregate interference from FSS space stations into the FS system is:

Criterion C1: *I*/*N* not to exceed –10 dB for more than 20% of the time.

3.2.2 Short-term criteria

The following range of short-term *I*/*N* criteria have been considered:

Criterion C2: *I*/*N* not to exceed 9 dB for more than 0.01% of the time.

Criterion C3: *I*/*N* not to exceed 13 dB for more than 0.0003% of the time.

The above short-term criteria are based on an assumed fade margin of 14 dB. For FS systems with a higher fade margin, the short-term criteria can be relaxed.

For systems with a fade margin in excess of 20 dB, a short-term criterion is:

Criterion C4: *I*/*N* not to exceed 20 dB for more than 0.001% of the time is acceptable.

For FS systems which operate with a fade margin less than 14 dB, the above short-term criteria would have to be tightened.

For FS systems with a fade margin of 10 dB, the interference criterion is:

Criterion C5: *I*/*N* not to exceed 5 dB for more than 0.012% of the time.

4 Interference from non-GSO FSS systems to FS system receivers

4.1 Interference analysis

The *I*/*N* at the FS system receiver, can be calculated as:

$$\frac{I}{N}(\text{dB}) = 10\log\left(\sum_{i=1}^{n} 10^{\left(\frac{pfd_i + G_{FS}(\alpha_i)}{10}\right)}\right) - 10\log\left(\frac{4\pi}{\lambda^2}\right) - 60 - L_{atm} - N_0 - L_{pol}$$

where:

n: total number of satellites in the non-GSO FSS satellite constellation

pfd_i: power flux-density (dB(W/(m^2 · MHz))) from the i-th satellite

$G_{FS}(\alpha)$: FS receive antenna gain in the direction of the non-GSO FSS satellite

L_{atm}: atmospheric loss

N_0: thermal noise density (dB(W/Hz))

L_{pol}: polarization isolation.

In the simulations, each non-GSO FSS system is assumed to operate at the pfd levels of –115/–105 dB(W/(m^2 · MHz)) down to 0° angle of arrival. Furthermore, it is assumed that the FS receiver receives multiple sources of interference from all the satellites in view at any given time.

At frequencies above 20 GHz, attenuation due to atmospheric gases becomes increasingly significant. Attenuation due to atmospheric gases has been addressed in Recommendation ITU-R SF.1395, which defines the following formulae for attenuation at 37.5 GHz at latitudes above 45°:

$$L_{atm} = 14.44 / \left[1 + 0.7365\theta + 0.01542\theta^2 + h\left(0.2202 + 0.2754\theta\right) + 0.07416h^2\right]$$

where:

h: antenna altitude above sea level (km)

θ: elevation angle above the horizon (degrees).

4.2 Simulation results

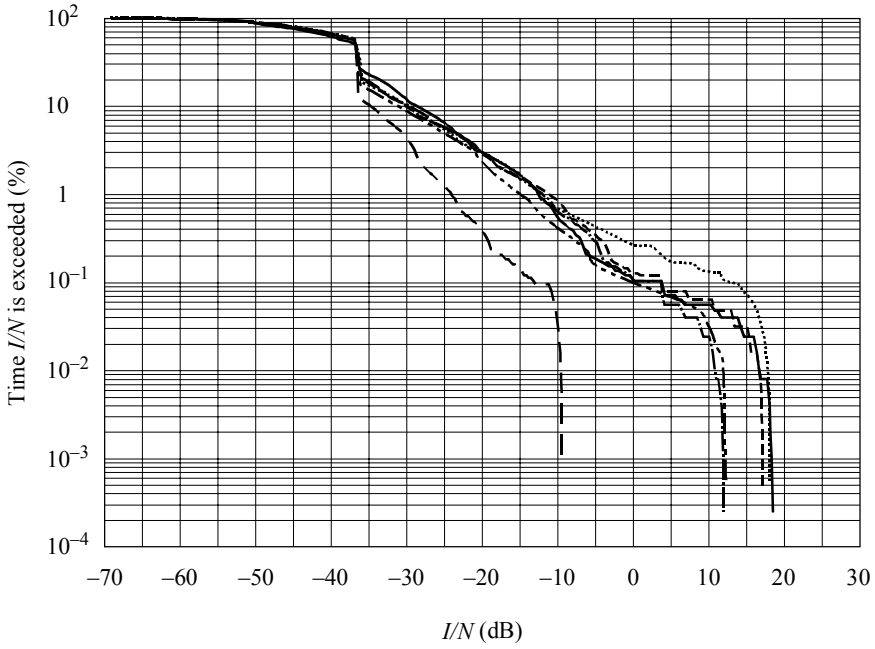
A 48-hour period simulation was performed for 15 non-GSO LEO V2 satellites, 72 non-GSO LEO V1 satellites and 32 non-GSO LEO V3 satellites with a time step of 1 s. In the simulations, the calculated interference level, *I*, is based on the worst-case azimuth angle of LEO V2 and LEO V3. The worst-case azimuth is chosen to ensure that the non-GSO satellite passes through the main beam causing in-line interference to the FS receiver.

4.2.1 Interference from LEO V2 system into point-to-point FS receiver

In this simulation, the pfd mask of –115/–105 dB(W/(m^2 · MHz)) is applied to all non-GSO LEO V2 satellites. It was assumed that the LEO V2 system operated down to 0° elevation angle. It was also assumed that the non-GSO FSS earth terminal with multiple antennas, or more than one non-GSO FSS user, communicates to all non-GSO FSS satellites in view and uses the same frequency. The results are shown in Fig. 1.

FIGURE 1

Percentage of time *I/N* at FS receiver at worst-case azimuth is exceeded (G_{FS} = 44 dBi, Recommendation ITU-R F.699, NF = 8 dB)



Each criterion is considered with respect to the above results:

Criterion C1 (long term): The criterion is met in all cases.

Criterion C2 (short term): The criterion is met for elevation angles less than about 15°.

Criterion C3 (short term): The criterion is met for elevation angles less than about 15°.

Criterion C4 (short term): The criterion is met in all cases.

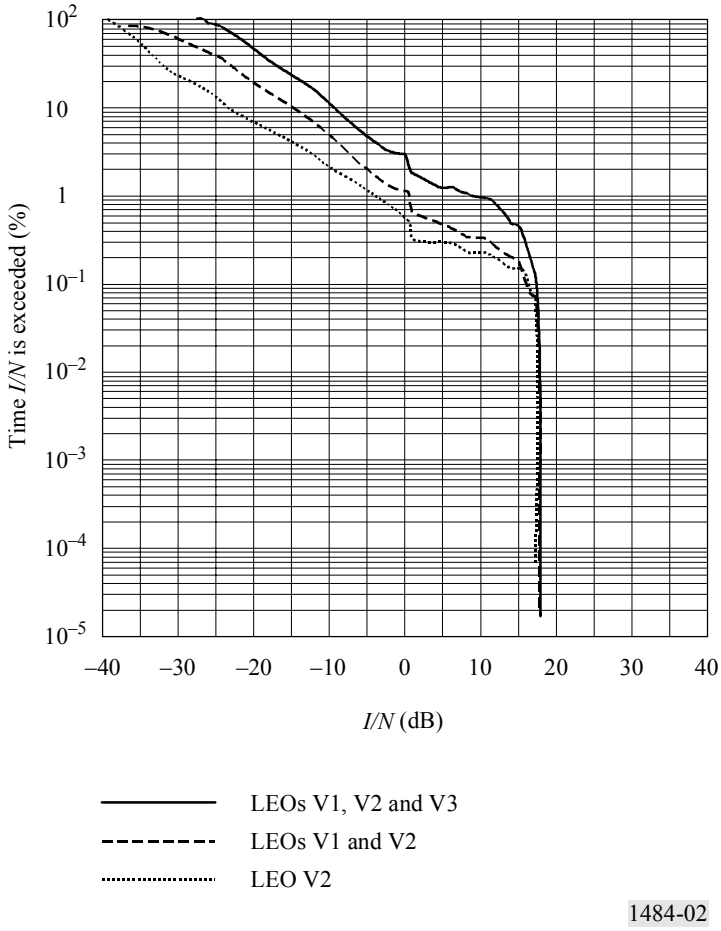
Criterion C5 (short term): The criterion is met for elevation angles less than about 10°.

4.2.2 Interference from three non-GSO FSS systems into point-to-point FS receiver

This case analyses the contributions of single and multiple (two and three) non-GSO satellite systems in the *I*/*N* of an FS receiver. The FS antenna radiation pattern in Recommendation ITU-R F.1245 is employed and the elevation angle of 30° is considered. The result is in Fig. 2, which shows the cumulative distribution of the *I*/*N* at the FS receiver with a NF of 8 dB.

FIGURE 2

Percentage of time *I/N* at FS receiver at worst-case azimuth is exceeded (FS antenna patterns are based on Recommendation ITU-R F.1245; NF = 8 dB, G_{FS} = 44 dBi, elevation angle = 30°)



Each criterion is considered with respect to the results shown in Fig. 2:

Criterion C1 (long term): The criterion is met.

Criterion C2 (short term): The criterion is exceeded by about 9 dB.

Criterion C3 (short term): The criterion is exceeded by about 5 dB.

Criterion C4 (short term): The criterion is met.

Criterion C5 (short term): The criterion is exceeded by about 13 dB.

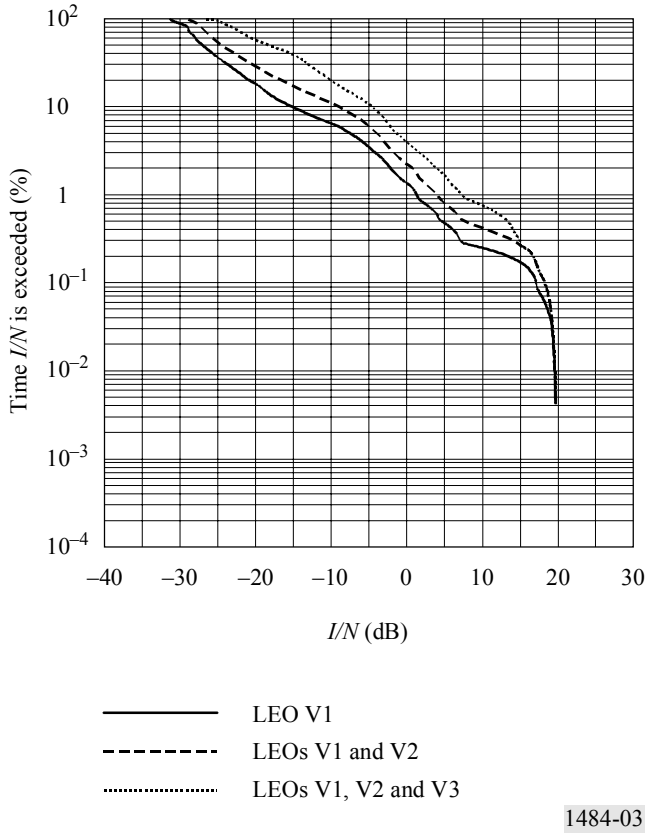
4.2.3 Interference from three non-GSO FSS systems into point-to-point FS receiver

This case also analyses the contributions of single and multiple (two and three) non-GSO satellite systems in the *I*/*N* of an FS receiver. The FS antenna radiation pattern in Recommendation ITU-R F.699 is employed and the FS elevation angle of 30° is considered. The result is in Fig. 3, which shows the cumulative distribution of the *I*/*N* at the FS receiver with a NF of 6 dB.

Each criterion is considered with respect to the results shown in Fig. 3.

FIGURE 3

Percentage of time *I/N* at FS receiver at worst-case azimuth is exceeded (FS antenna patterns are based on Recommendation ITU-R F.699; G_{FS} = 44 dBi, NF = 6 dB; elevation angle = 30°)



Each criterion is compared with the results shown in Fig. 3:

Criterion C1 (long term): The criterion is met.

Criterion C2 (short term): The criterion is exceeded by about 11 dB.

Criterion C3 (short term): The criterion is exceeded by about 7 dB.

Criterion C4 (short term): The criterion is met.

Criterion C5 (short term): The criterion is exceeded by about 15 dB.

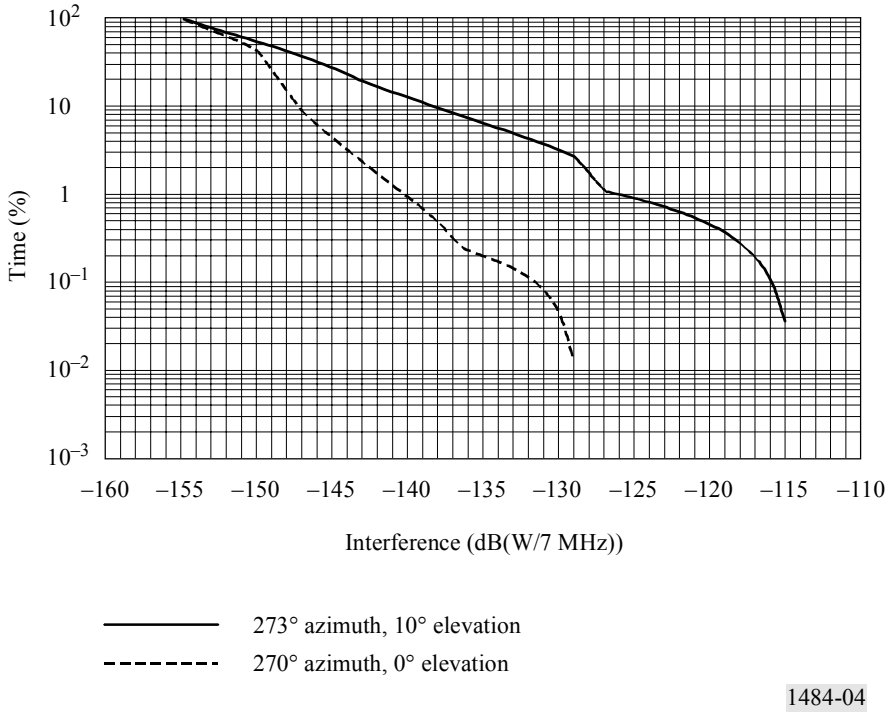
4.2.4 Interference from LEO V1 system into point-to-point FS receiver

In this example, interference from the LEO V1 system into a point-to-point FS receiver is considered. The FS receiver is at a latitude of 52° N and elevation angles of 0° and 10° are modelled, with the antenna pattern given by Recommendation ITU-R F.699 and maximum gain 45 dBi. The results are shown in Fig. 4, with the interference power scaled to a reference bandwidth of 7 MHz.

Each criterion is compared with the results shown in Fig. 4.

FIGURE 4

Cumulative distribution of interference from LEO V1 into point-to-point FS receiver (G_{FS} = 45 dBi, NF = 7 dB, Recommendation ITU-R F.699)



All the criteria for the 0° elevation case are met. For the 10° elevation case, each criterion is considered with respect to the results shown in Fig. 4 (for an FS system with a NF of 7 dB).

	Interference power criterion referenced to 7 MHz bandwidth	
Criterion C1 (long term)	–138.5 (20% time)	The criterion is met
Criterion C2 (short term)	–119.5 (0.01% time)	The criterion is exceeded by about 5 dB
Criterion C3 (short term)	–115.5 (0.0003% time)	The criterion is met
Criterion C4 (short term)	–108.5 (0.001% time)	The criterion is met
Criterion C5 (short term)	–123.5 (0.012% time)	The criterion is exceeded by about 8 dB

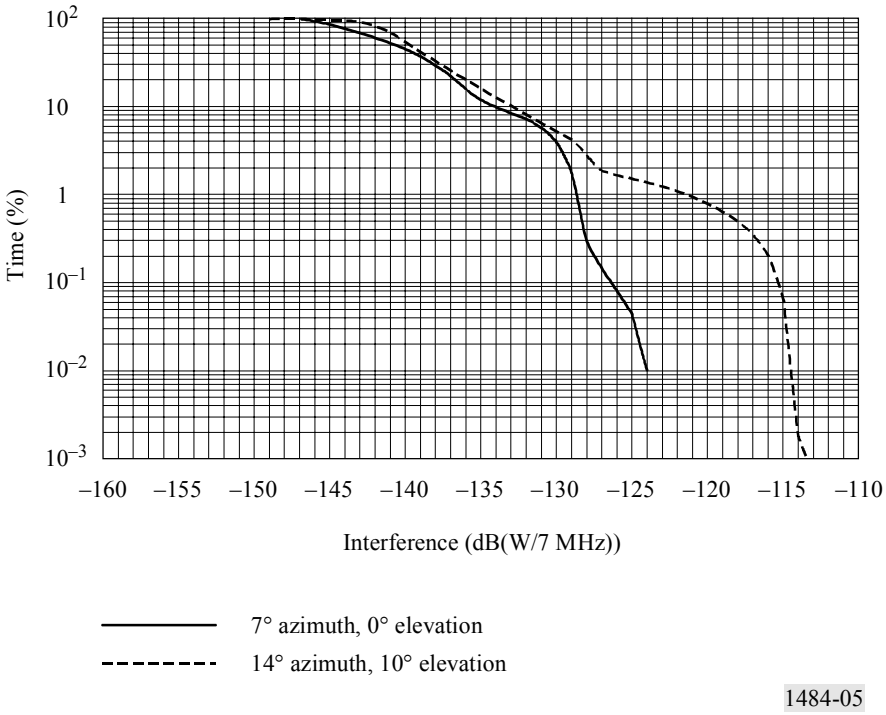
Criteria C2 and C5 are exceeded by 5 dB and 8 dB respectively. However, the polarization advantage was not considered in this simulation. By subtracting 3 dB polarization advantage, and adjusting the results for an antenna gain of 44 dBi, the criteria are exceeded by approximately 1 dB and 4 dB respectively.

4.2.5 Interference from a 288 satellite non-GSO satellite constellation

To consider the effect of non-GSO FSS systems with large constellations, a further simulation considered the interference from a constellation of 288 satellites. The point-to-point FS link receiver elevation angle of 0° and 10° is considered. The antenna radiation pattern of the FS antenna given by Recommendation ITU-R F.699 was used. The results are shown in Fig. 5.

FIGURE 5

Interference from a 288 satellite non-GSO satellite constellation to a FS receiver (G_{FS} = 45 dBi, Recommendation ITU-R F.699, NF = 7 dB)



For the 10° elevation case, each criterion is considered with respect to the results shown in Fig. 5 (for an FS system with a NF of 7 dB).

	Interference power criterion referenced to 7 MHz bandwidth	
Criterion C1 (long term)	–138.5 (20% time)	Exceeded by about 2 dB
Criterion C2 (short term)	–119.5 (0.01% time)	Exceeded by about 5 dB
Criterion C3 (short term)	–115.5 (0.0003% time)	Criterion is met
Criterion C4 (short term)	–108.5 (0.001% time)	Criterion is met
Criterion C5 (short term)	–123.5 (0.012% time)	Exceeded by about 8 dB

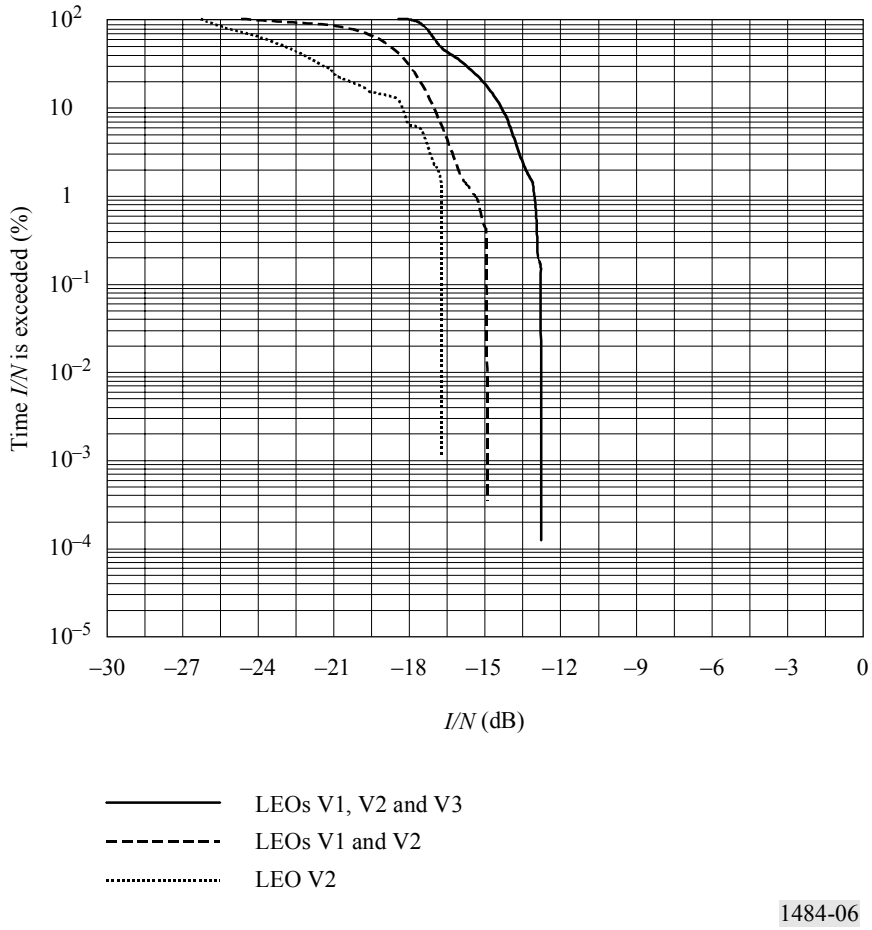
4.2.6 Potential interference from three non-GSO FSS systems into P-MP FS receivers

Figure 6 shows the cumulative distribution of the *I/N* into an FS hub station receiver due to a single non-GSO FSS system, due to two non-GSO FSS systems, and due to three non-GSO FSS systems. In the worst-case interference, the *I/N* at the FS receiver is less than –13 dB. If the FS 6 dB receiver NF is used, the worst-case interference ratio, *I/N*, is still less than –12 dB, which is well below the provisional FS interference criterion.

In general, the elevation angle of P-MP FS hub station receivers is less than 0° (downtilt). Therefore the actual interference levels at the receiver are significantly lower than those shown in Fig. 6. In Fig. 6, all criteria are met.

FIGURE 6

Percentage of time *I/N* at FS hub receiver, due to 1, 2 and 3 non-GSO FSS systems is exceeded (G_{FS} = 45 dBi, Recommendation ITU-R F.1245)



The interference susceptibility of P-MP subscriber stations considered in this simulation is assumed to be the same as that of point-to-point stations as the equipment characteristics are similar. Thus the simulation presented in § 4.2.1 also applies to P-MP subscriber receivers.

5 Conclusions

The current pfd limits, (–115/–105 dB(W/(m^2 · MHz))) when applied to non-GSO FSS systems, are adequate to protect FS systems operating in the band 37.5-40.5 GHz with a fade margin of more than 20 dB, based on a high gain antenna (44 dBi).

Due to the low antenna gain, the current pfd limits are adequate to protect P-MP hub stations, even with low fade margins.

For point-to-point FS systems with 14 dB fade margin and high gain antennas, the current pfd limits only protect the FS when operating with an elevation angle less than 15°.

For the point-to-point FS systems with 10 dB fade margin and high gain antenna, the current pfd limits only protect the receiver operating with low elevation angles (less than 10°). A tightening of the low arrival angle pfd limits by 5 dB (to –120/–105 dB(W/(m^2 · MHz))) would protect most FS links with 10 dB fade margin and high elevation angles (≥ 10°), but would not unduly constrain non-GSO FSS systems.

The following maximum pfd levels would provide an acceptable balance of the need to protect the FS systems but would not unduly constrain non-GSO FSS systems (see Note 1):

–120	dB(W/(m^2 · MHz))	for	$\theta \leq 5°$
–120 + 0.75(θ – 5)	dB(W/(m^2 · MHz))	for	$5° < \theta \leq 25°$
–105	dB(W/(m^2 · MHz))	for	$25° < \theta \leq 90°$

However, for non-GSO FSS systems with large satellite constellations (i.e. more than 80 satellites), preliminary studies have shown that the FS systems may require additional protection.

NOTE 1 – Some FS systems employing small fade margins and which operate at elevation angles greater than 10° may not be fully protected from interference from FSS systems, without unduly constraining FSS systems.

ANNEX 2

Potential interference from non-GSO FSS systems into FS systems in the band 40.5-42.5 GHz

1 Introduction

This Annex presents the potential interference from non-GSO FSS systems into FS systems in the band 40.5-42.5 GHz.

2 Technical characteristics of non-GSO FSS systems

The system parameters of LEO V2 and LEO V4 are shown in Table 2.

TABLE 2

Non-GSO orbital parameters

Parameters	LEO V2	LEO V4
Number of satellites	15	99
Number of orbital planes	3	11
Number of satellites/plane	5	9
Altitude (km)	10 355	1 600
Inclination angle (degrees)	50	55
Period of orbit	6 h	Not available

In addition, studies have been carried out to examine the interference resulting from non-GSO systems with a large constellation. Simulations using a 288 satellite constellation have been performed.

3 FS system parameters and interference criteria

3.1 FS parameters

The following FS system characteristics were used in the analyses.

– FS systems with directional antennas:
  – FS directional antenna gain: 33 dBi;

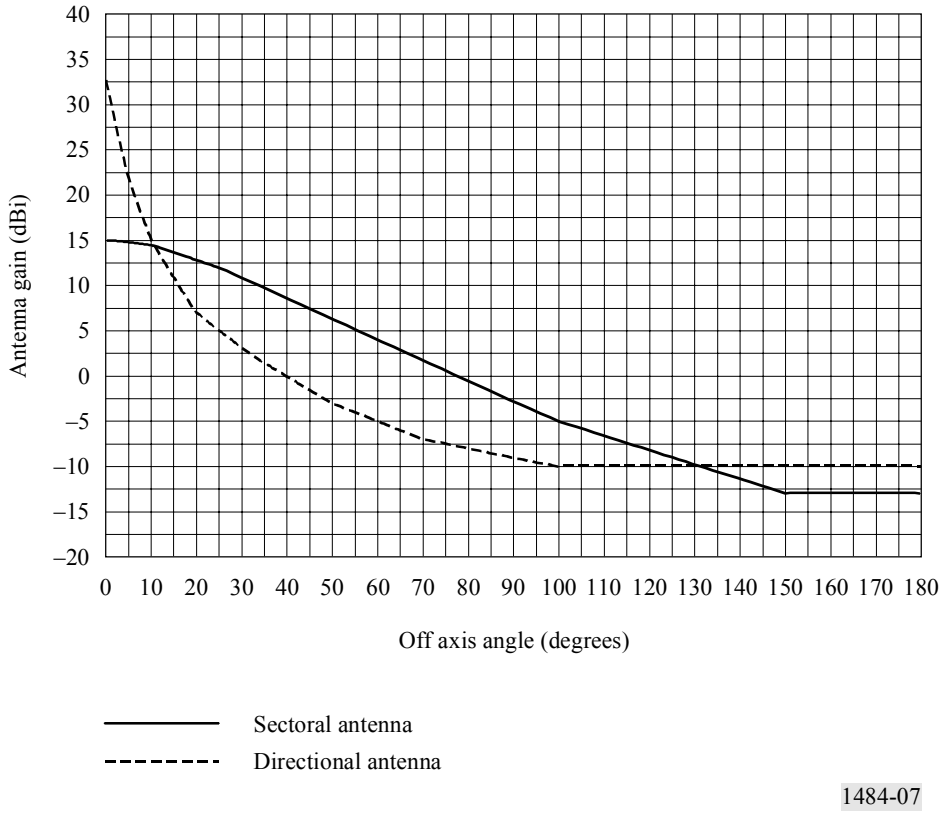
- Receiver noise figure: 7 dB and 8 dB;
- FS elevation angle: 0° to 60°;
- FS azimuth angle: simulations based on worst-case azimuth.

– FS systems with sectoral antennas:
  - FS receiver antenna gain: 15 dBi;
  - 3 dB beamwidth: 60° in azimuth plane, 18° in elevation plane;
  - FS antenna elevation angle: 0° to 20°;
  - Receive noise temperature: 1 740 K.

The antenna radiation patterns are shown in Fig. 7.

FIGURE 7

FS antenna radiation pattern envelopes



The link fade margin varies from 10 to 30 dB. For the network to subscriber links a margin of 10 to 30 dB may be assumed. However, on the return path from the end user to the central station, automatic transmit power control (ATPC) may be used.

3.2 Interference criteria

3.2.1 Long-term criterion

The long-term criterion *I*/*N* for aggregate interference from FSS space stations into the FS system is:

Criterion C1: *I*/*N* not to exceed –10 dB for more than 20% of the time.

3.2.2 Short-term criteria

The following range of aggregate short-term *I/N* criteria have been considered:

Criterion C2: *I*/*N* not to exceed 9 dB for more than 0.01% of the time.

Criterion C3: *I*/*N* not to exceed 13 dB for more than 0.0003% of the time.

The above short-term criteria are based on an assumed fade margin of 14 dB. For FS systems with a higher fade margin, the short-term criteria can be relaxed.

For FS systems with a fade margin in excess of 20 dB, a short-term criterion of:

Criterion C4: *I*/*N* not to exceed 20 dB for more than 0.001% of the time is acceptable.

For FS systems which operate with a fade margin less than 14 dB, the short-term criteria would have to be tightened.

For FS systems with a minimum fade margin of 10 dB, the interference limit of:

Criterion C5: *I*/*N* not to exceed 5 dB for more than 0.012% of the time.

For short-term interference into sectoral FS antennas, it is assumed that fading of the wanted and interfering signals may not be correlated and that ATPC may be applied to the wanted signal. No fade margin can therefore be assumed and the short-term interference limit is therefore the same as the long-term limit, i.e.:

Criterion C6: *I/N* not to exceed –10 dB for more than 0.06% of the time.

4 Interference from non-GSO FSS systems to FS receivers

4.1 Interference analysis

The *I*/*N* at the FS receiver, can be calculated as:

$$\frac{I}{N}(\text{dB}) = 10\log\left(\sum_{i=1}^{n} 10^{\left(\frac{pfd_i + G_{FS}(\alpha_i)}{10}\right)}\right) - 10\log\left(\frac{4\pi}{\lambda^2}\right) - 60 - L_{atm} - N_0 - L_{pol}$$

where:

n: total number of satellites in the non-GSO FSS satellite constellation

pfd_i: power flux-density (dB(W/(m^2 · MHz))) from the i-th satellite

$G_{FS}(\alpha)$: FS receive antenna gain in the direction of the non-GSO FSS satellite

L_{atm}: atmospheric loss

N_0: thermal noise density (dB(W/Hz))

L_{pol}: polarization isolation.

In the simulations, each non-GSO FSS system is assumed to operate at the pfd levels of –115/–105 dB(W/(m^2 · MHz)) down to 0° elevation. Furthermore, it is assumed that the FS receiver receives multiple sources of interference from all the satellites in view at any given time.

At frequencies above 20 GHz, attenuation due to atmospheric gases becomes increasingly significant. Attenuation due to atmospheric gases has been addressed in Recommendation ITU-R SF.1395, which defines the following formula for attenuation at 40.5 GHz at latitudes above 45°:

$$A = 18.92 / \left[1 + 0.6577\theta + 0.04678\theta^2 - 0.001484\theta^3 + 0.1139\times10^{-4}\theta^4 + h(0.22 + 0.2811\theta) + 0.06507h^2\right]$$

where:

h: antenna altitude above sea level (km)

θ: elevation angle above the horizon (degrees).

FS systems may use linear or circular polarization, and it is assumed that the FSS systems will use circular polarization only. Therefore, if linear polarization is assumed for the FS, the isolation is 3 dB. If circular polarization is assumed for the FS, the polarization varies from 0 dB to 30 dB. Polarization isolation can only be assumed for main beam coupling.

4.2 Simulation results

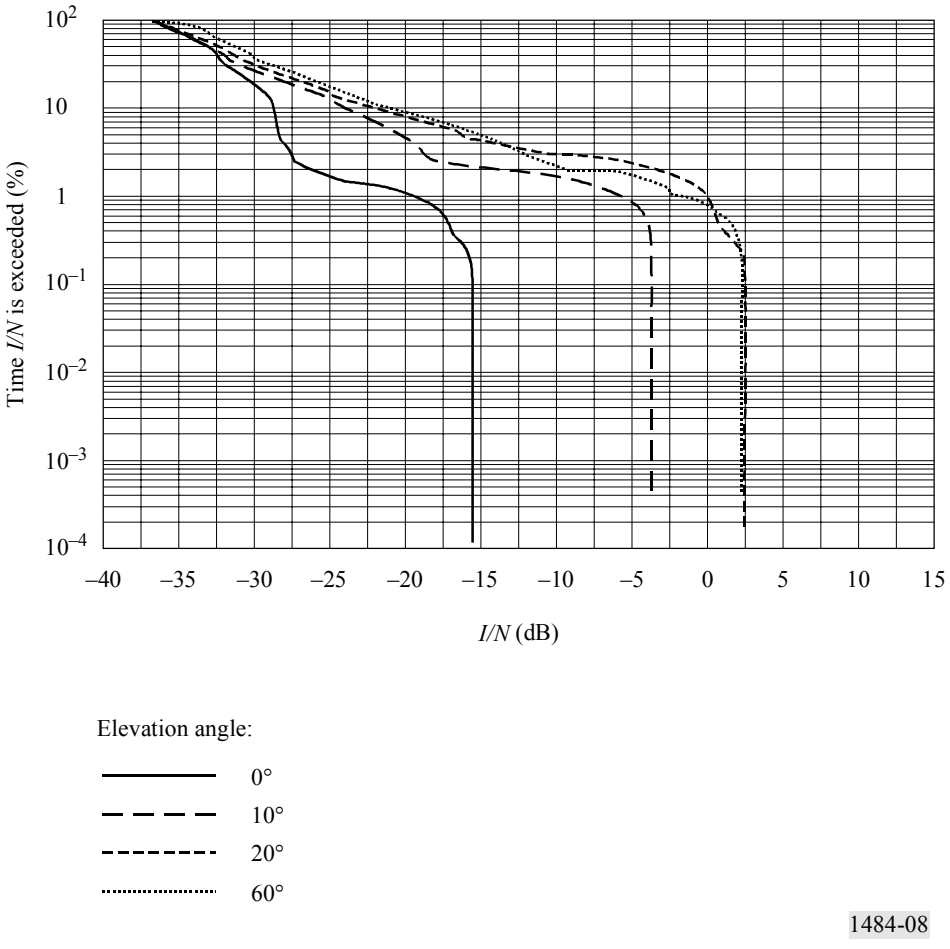
Simulations were performed for the LEO V2 and LEO V4 systems. The worst-case azimuth was chosen to ensure that the non-GSO satellite passes through the main beam causing in-line interference to the FS receiver.

4.2.1 Interference from LEO V2 system into FS receiver with 33 dBi antenna gain

In this simulation, the pfd mask of –115/–105 dB(W/(m^2 · MHz)) is applied to all non-GSO LEO V2 satellites. It was assumed that the LEO V2 system operated down to 0° elevation angle. It was also assumed that the non-GSO FSS earth terminal with multiple antennas, or more than one non-GSO FSS user, communicates to all non-GSO FSS satellites in view and uses the same frequency. Where boresight to boresight alignment occurs, 3 dB polarization is assumed. The results are shown in Fig. 8.

FIGURE 8

Percentage of time *I/N* at FS receiver at worst-case azimuth is exceeded (polarization isolation = 3 dB)



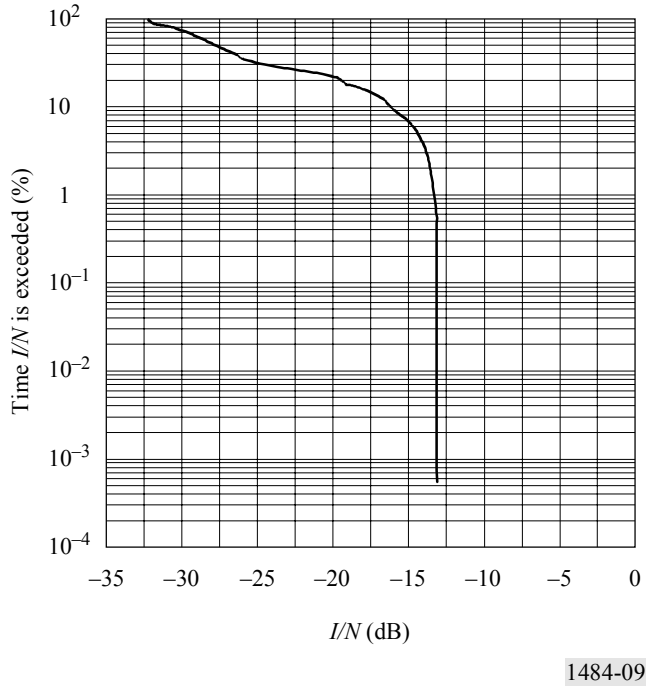
In this scenario, all relevant criteria are met.

4.2.2 Interference from LEO V2 into FS receiver with sector antenna

Figure 9 shows the cumulative distribution of the interference from the LEO V2 constellation into the FS receiver antenna. An FS antenna elevation angle of 20° is assumed. The NF is 10 dB.

FIGURE 9

Percentage of time *I/N* at FS receiver at worst-case azimuth is exceeded (antenna gain = 15 dB, NF = 10 dB, polarization isolation = 3 dB, elevation angle = 20°)



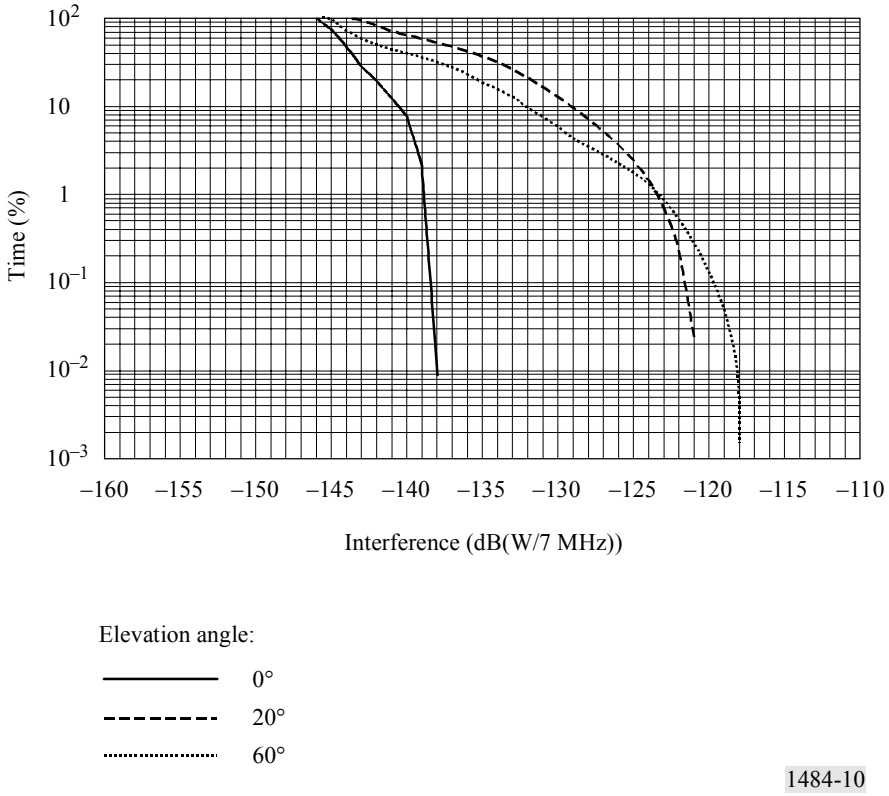
In this example, all relevant criteria are met.

4.2.3 Interference from LEO V4 system into a FS directional receiver

Figure 10 shows the cumulative distribution of interference from the LEO V4 system into an FS receiver at elevation angles of 0°, 20° and 60°.

FIGURE 10

Interference from LEO V4 system into a FS directional receiver (polarization isolation = 0 dB)



Each criterion is considered with respect to the results shown in Fig. 10 for a receiver with an assumed NF of 8 dB.

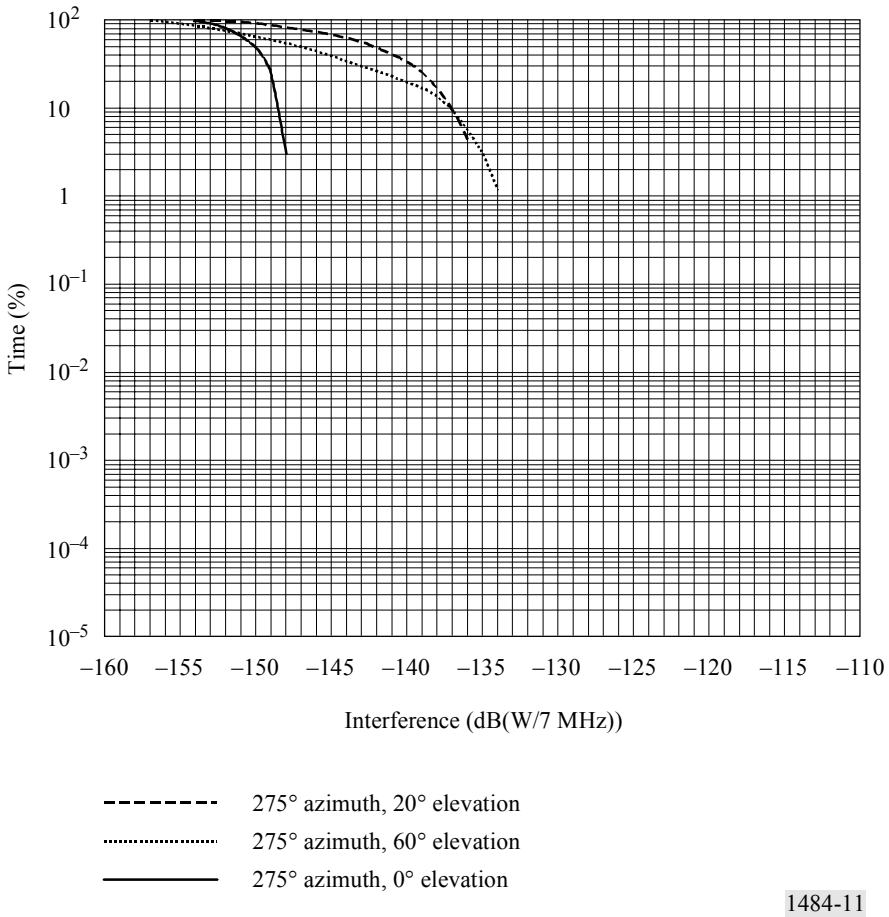
	Interference power criterion referenced to 7 MHz bandwidth	0° elevation case	20° elevation case	60° elevation case
Criterion C1 (long term)	–137.5 (20% time)	The criterion is met	Exceeded by about 5 dB	Exceeded by about 2 dB
Criterion C2 (short term)	–118.5 (0.01% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C3 (short term)	–114.5 (0.0003% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C4 (short term)	–107.5 (0.001% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C5 (short term)	–1225 (0.012% time)	The criterion is met	Exceeded by about 1 dB	Exceeded by about 2 dB

4.2.4 Interference from LEO V4 non-GSO FSS satellite constellation into a FS receiver with a sectoral antenna

Figure 11 shows the cumulative distribution of interference from the LEO V4 satellite constellation into an FS receiver with a sectoral antenna.

FIGURE 11

Interference from LEO V4 non-GSO FSS satellite constellation into a FS receiver with a sectoral antenna (polarization isolation = 0 dB)



Each criterion is considered with respect to the results shown in Fig. 11 for a receiver with an assumed NF of 8 dB.

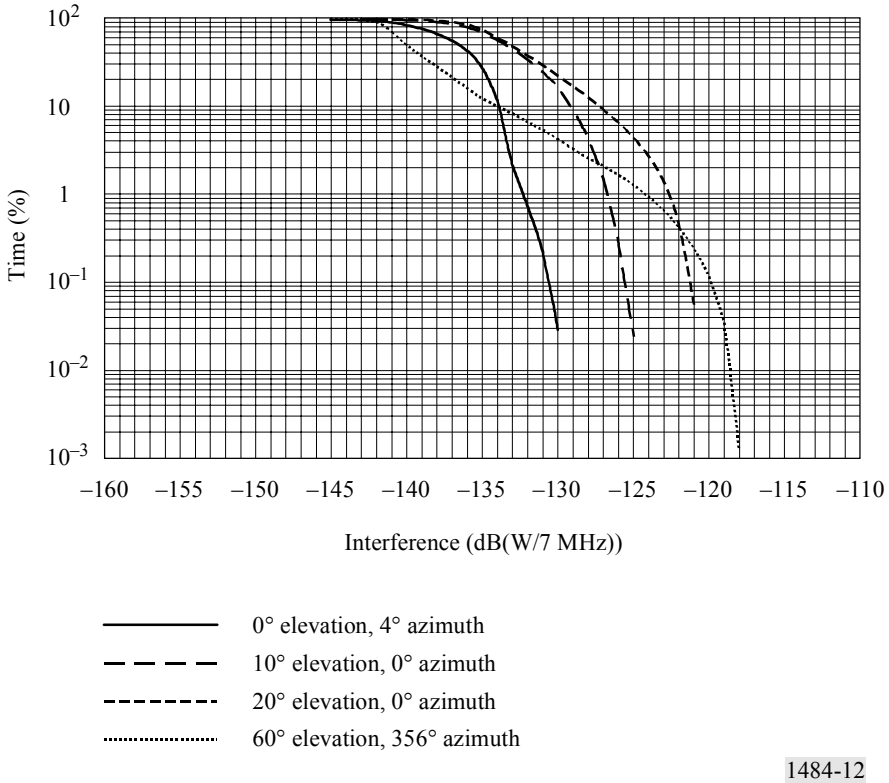
	Interference power criterion referenced to 7 MHz bandwidth	0° elevation case	20° elevation case	60° elevation case
Criterion C1 (long term)	–137.5 (20% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C2 (short term)	–118.5 (0.01% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C3 (short term)	–114.5 (0.0003% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C4 (short term)	–107.5 (0.001% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C5 (short term)	–122.5 (0.012% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C6 (short term)	–137.5 (0.012% time)	The criterion is met	Exceeded by about 1 dB	Exceeded by about 3 dB

4.2.5 Interference from a 288 satellite non-GSO FSS satellite constellation into a FS directional receiver

Figure 12 shows the cumulative distribution of interference from a 288 satellite constellation into a directional FS receiver with an elevation angle between 0° and 60°.

FIGURE 12

Interference from a 288 satellite non-GSO FSS satellite constellation into a FS directional receiver



Each criterion is considered with respect to the results shown in Fig. 12 for a receiver with an assumed NF of 8 dB.

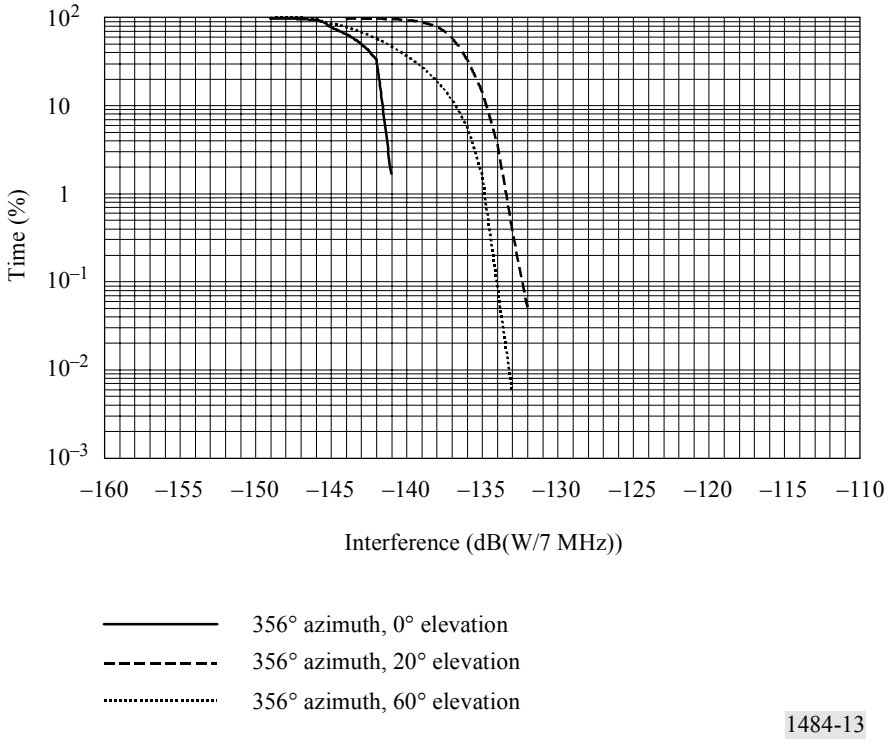
	Interference power criterion referenced to 7 MHz bandwidth	0° elevation	10° elevation	20° elevation	60° elevation
Criterion C1 (long term)	–137.5 (20% time)	Exceeded by about 3 dB	Exceeded by about 7 dB	Exceeded by about 7.5 dB	Exceeded by about 1 dB
Criterion C2 (short term)	–118.5 (0.01% time)	The criterion is met	The criterion is met	The criterion is met	The criterion is just met
Criterion C3 (short term)	–114.5 (0.0003% time)	The criterion is met	The criterion is met	The criterion is met	The criterion is met
Criterion C4 (short term)	–107.5 (0.001% time)	The criterion is met	The criterion is met	The criterion is met	The criterion is met
Criterion C5 (short term)	–122.5 (0.012% time)	The criterion is met	The criterion is met	Exceeded by about 1 dB	Exceeded by about 3.5 dB

4.2.6 Interference from a 288 satellite non-GSO FSS satellite constellation into a FS receiver with a sectoral antenna

Figure 13 shows the interference from a 288 satellite non-GSO FSS satellite constellation into a FS with a sectoral antenna.

FIGURE 13

Interference from a 288 satellite non-GSO FSS satellite constellation into a FS receiver with a sectoral antenna (polarization isolation = 0 dB)



Each criterion is considered with respect to the results shown in Fig. 13 for a receiver with an assumed NF of 8 dB.

	Interference power criterion referenced to 7 MHz bandwidth	0° elevation case	20° elevation case	60° elevation case
Criterion C1 (long term)	–137.5 (20% time)	The criterion is met	Exceeded by about 2 dB	The criterion is met
Criterion C2 (short term)	–118.5 (0.01% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C3 (short term)	–114.5 (0.0003% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C4 (short term)	–107.5 (0.001% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C5 (short term)	–122.5 (0.012% time)	The criterion is met	The criterion is met	The criterion is met
Criterion C6 (short term)	–137.5 (0.012% time)	The criterion is met	Exceeded by about 5.5 dB	Exceeded by about 4.5 dB

5 Conclusions

The following pfd levels have been examined for their suitability to protect FS systems in the band 40.5-42.5 GHz:

-115 dB(W/(m^2 · MHz)) for $\theta \leq 5°$

$-115 + 0.5(\theta - 5)$ dB(W/(m^2 · MHz)) for $5° < \theta \leq 25°$

-105 dB(W/(m^2 · MHz)) for $25° < \theta \leq 90°$

When considering interference from the LEO V2 non-GSO FSS system into the directional and sectoral antennas, all relevant criteria are met.

When considering interference from the LEO V4 non-GSO FSS system into the directional and sectoral antennas, all criteria are met when the antenna elevation angle is 0°. When the directional antenna is at elevation angles of 20° and 60°, the long-term interference criterion C1 is exceeded by 2 to 5 dB, and the short-term criterion C6 is exceeded by 1 to 2 dB. With regard to the short-term criterion, interference may be tolerable because in the majority of circumstances, FS receivers with high elevation angles will have greater fade margins. With regard to the long-term criterion C1, interference will be tolerable because in the majority of circumstances, the FS receivers with high elevation angles will have greater long-term *C*/*N* levels than those receivers at the edge of the service area.

When considering interference from the LEO V4 non-GSO FSS system into the FS sectoral antenna, the short-term criterion C6 is exceeded by 1 dB and 3 dB for elevation angles of 20° and 60° respectively. The interference will be tolerable because in practice, an additional margin will be present due to the shorter path length.

For non-GSO FSS systems with large satellite constellations, (i.e. more than 99 satellites), preliminary studies have shown that the FS may require more protection.

The above pfd limits, when applied to non-GSO FSS systems are adequate to protect FS systems of the type presented in § 3.1 of Annex 2.