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Radiocommunication Sector of ITU

Recommendation ITU-R F.1509-4 (01/2018)

Technical and operational requirements that facilitate sharing between point-to-multipoint systems in the fixed service and the inter-satellite service in the band 25.25-27.5 GHz

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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R F.1509-4*

**Technical and operational requirements that facilitate sharing
between point-to-multipoint systems in the fixed service and
the inter-satellite service in the band 25.25-27.5 GHz**

(Question ITU-R 118/7)

(2001-2009-2013-2015-2018)

Scope

This Recommendation provides maximum e.i.r.p. density of transmitting hub and subscriber point-to-multipoint stations in the fixed service towards the direction of the geostationary-satellite orbit to enable sharing with the inter-satellite service in the frequency band 25.25-27.5 GHz. The reference e.i.r.p. density in this Recommendation takes into account the need for transmission at the minimum necessary level while taking into account use of automatic transmitter power control (ATPC) at the fixed service (FS) stations for precipitation events.

Keywords

Data relay satellites, orbital locations, e.i.r.p., spectral density

Abbreviations

ATPC	Automatic transmitter power control
DRS	Data relay satellite
e.i.r.p.	Equivalent isotropically radiated power
FS	Fixed service
GSO	Geostationary-satellite orbit
POCS	Proximity operations communication system

Related ITU Recommendations

Recommendation ITU-R F.758	System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference.
Recommendation ITU-R F.1249	Technical and operational requirements that facilitate sharing between point-to-point systems in the fixed service and the inter-satellite service in the band 25.25-27.5 GHz.
Recommendation ITU-R F.1336	Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz.
Recommendation ITU-R SA.609	Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites.

* This Recommendation was jointly developed by Radiocommunication Study Groups 7 and 5, and future revisions should be undertaken jointly.

Recommendation ITU-R SA.1018	Hypothetical reference system for systems comprising data relay satellites in the geostationary orbit and user spacecraft in low Earth-orbits.
Recommendation ITU-R SA.1155	Protection criteria related to the operation of data relay satellite systems.
Recommendation ITU-R SA.1276	Orbital locations of data relay satellites to be protected from the emissions of fixed service systems operating in the band 25.25-27.5 GHz.

The ITU Radiocommunication Assembly,

considering

- a) that the band 25.25-27.5 GHz is allocated to the fixed, mobile and inter-satellite services on a primary basis;
- b) that in addition to point-to-point fixed service (FS) systems, point-to-multipoint (P-MP) FS systems are planned to operate in the 25.25-27.5 GHz band;
- c) that space-to-space radiocommunication links in the inter-satellite service are used in the 25.25-27.5 GHz band;
- d) that space-to-space links are established between low-orbiting user satellites and geostationary data relay satellites (DRS) and also proximity operations communication system (POCS) between users in proximity of low-orbiting space stations;
- e) that these links, particularly the space-to-space links of a DRS network, are designed to operate with margins on the order of 2 dB to 4 dB;
- f) that satellite links are susceptible to interference from the emissions of fixed service systems within a field-of-view that is of large geographical extent;
- g) that specifying particular orbital locations to be protected rather than the orbital arc will impose less burden on the fixed service for band sharing, particularly for those stations located at high latitudes,

recognizing

- a) that the protection criteria for POCS links may be found in Recommendation ITU-R SA.609, and the protection criteria for DRS links may be found in Recommendation ITU-R SA.1155;
- b) that a limited number of DRS networks, as described in Recommendation ITU-R SA.1018, are either deployed or in the implementation phase in the geostationary orbit, at orbital locations given in Recommendation ITU-R SA.1276-5 (see Note 1);
- c) that Recommendation ITU-R F.758 provides a large variety of fixed wireless system parameters generalized by representative systems for specific frequency ranges,

recommends

1 that for each transmitter of a hub station of a P-MP FS network operating in the 25.25-27.5 GHz band (see Annex 1 for the background of the e.i.r.p. limits):

1.1 the e.i.r.p. spectral density of the emission in the direction of any geostationary-satellite orbit (GSO) location specified in Recommendation ITU-R SA.1276 should not exceed the following values in any 1 MHz band for the elevation angle θ above the local horizontal plane (see Notes 1, 2 and 3):

$$+8 \text{ dBW} \quad \text{for } 0^\circ \leq \theta \leq 20^\circ$$

$$+14 - 10 \log(\theta/5) \quad \text{dBW} \quad \text{for } 20^\circ < \theta \leq 90^\circ$$

1.2 the e.i.r.p. spectral density of the emission should not exceed the following values in any 1 MHz band for the elevation angle θ above the local horizontal plane:

$$+14 \text{ dBW} \quad \text{for } 0^\circ \leq \theta \leq 5^\circ$$

$$+14 - 10 \log(\theta/5) \quad \text{dBW} \quad \text{for } 5^\circ < \theta \leq 90^\circ$$

1.3 during conditions when precipitation attenuation is experienced between the FS hub transmitting and receiving stations, the transmitting hub station may use automatic transmit power control (ATPC) to increase its transmitted power, by an amount not exceeding the precipitation attenuation such that its e.i.r.p. spectral density in the direction of any GSO location specified in Recommendation ITU-R SA.1276 does not exceed +17 dBW in any 1 MHz band;

2 that the e.i.r.p. spectral density of the emission of each subscriber station of a P-MP FS network operating in the band 25.25-27.5 GHz should comply with *recommends* 2 and 3 of Recommendation ITU-R F.1249;

3 the following Notes 1, 2, 3 are part of this Recommendation.

NOTE 1 – Recommendation ITU-R SA.1276-5 identifies the following geostationary DRS orbital positions: 9°E, 10.6° E, 16.4° E, 16.8° E, 20.4°E, 21.5° E, 47° E, 59° E, 77° E, 80° E, 85° E, 89° E, 90.75° E, 95° E, 113° E, 121° E, 133° E, 160° E, 167° E, 171° E, 176.8° E, 177.5° E, 12° W, 16° W, 32° W, 41° W, 44° W, 46° W, 49° W, 62° W, 139° W, 160° W, 164.2° W, 167.5° W, 170° W, 171° W, and 174° W.

When Recommendation ITU-R SA.1276 is revised so that new DRS orbital locations are added, the protection of the space stations in these new orbital slots in revision to this Recommendation applies only to FS stations installed after the enforcement date of the revised Recommendation ITU-R SA.1276.

NOTE 2 – The e.i.r.p. spectral density radiated towards a geostationary DRS location should be calculated as the product of the transmitted power spectral density and the gain of the omnidirectional or sectoral antenna in the direction of the DRS. In the absence of a radiation pattern for the hub-station antenna, the reference radiation pattern of Recommendation ITU-R F.1336 should be used. The calculation should take into account the effects of atmospheric refraction and the local horizon. A method for calculating the separation angles is given in Annex 2.

NOTE 3 – In the case of a hub-station employing single frequency operation in which the same frequency is used for both transmission and reception on a time-division basis, the e.i.r.p. spectral density limit in *recommends* 1.1 can be relaxed by $7 \log(1/\delta)$ dB, where δ ($0 < \delta < 1$) is the proportion of time when a hub-station is transmitting signals. However, this relaxation should not exceed 3 dB even for a small δ .

Annex 1

An assessment of the spatial and temporal distribution of interference to DRS systems and POCS from the emissions of P-MP hub stations in the FS in the band 25.25-27.5 GHz

1 Introduction

This Annex provides an assessment obtained by computer simulation, of the spatial and temporal distribution of interference to DRS at specific orbital locations, and POCS from the emissions of a global deployment of hub stations of P-MP FS systems in the band 25.25-27.5 GHz. These P-MP FS systems are frequently referred to as local multipoint distribution service (LMDS) systems. For this analysis, the peak-of-beam e.i.r.p. spectral density at each hub station is assumed to be +8 dB(W/MHz) which is indicated as a typical value for hub stations of point-to-multipoint systems in Report ITU-R F.2108. A single LMDS transmitting station operating with an e.i.r.p. spectral density of +8 dB(W/MHz) does not exceed the protection level given in Recommendation ITU-R SA.1155 regardless of its geographic location with respect to the orbital location of a DRS. The protection level of -148 dB(W/MHz) is not to be exceeded for more than 0.1% of an orbital period. However, the aggregate effect of multiple co-channel LMDS transmitting stations within an urban population centre can, under some geometric conditions, cause interference in excess of the DRS protection level.

Section 2 describes the approach used and the assumptions made to evaluate the spatial and temporal distribution of the interference to DRS. In this Annex, two studies, Study A and Study B, are presented in § 3 and § 4, respectively. In Study A, an e.i.r.p. spectral density of +8 dB(W/MHz) was assumed, whereas in Study B, an e.i.r.p. spectral density of +14 dB(W/MHz) was used. Section 3 presents the spatial distribution of the interference to DRS at specific orbital locations. It shows that when the e.i.r.p. spectral density of the emissions in the local horizontal plane from a service area containing 29 hub stations visible to the DRS and operating at +8 dB(W/MHz), the interference to DRS can be as high as 9 dB in excess of the recommended interference level. Also in § 3 are the results of dynamic simulations to determine the temporal characteristics of interference to DRS while tracking a low-orbiting user satellite with the orbital characteristics of the international space station. It is shown that, for a small number of orbits with ascending nodes that result in the user satellite being aligned with urban population centres that appear on or near the Earth's limb, the duration of the interference can exceed a period of time that is greater than 0.1% of an orbital period of the user satellite. Section 4 presents the result of Study B. Section 5 describes a simple means to extend the results of this study to LMDS deployments that use smaller cells. Section 6 discusses interference into POCS. The results show that, based on an e.i.r.p. spectral density of +14 dB(W/MHz), the aggregate interference from LMDS hub stations into the receiver antennas of the POCS fall well below the protection criterion of -147 dB(W/MHz) at all times. Section 7 gives the conclusions of the study and proposes characteristics to facilitate sharing between space science services, inter-satellite service systems and P-MP FS systems.

2 Approach

Computer simulations have been used to evaluate the spatial and temporal distribution of interference to DRS systems from the emissions of a potentially large number of high density P-MP FS systems assumed to be operated in the 25.25-27.5 GHz band. The basic approach embodied in the simulation is to deploy a number of LMDS hub stations in urban population centres and to then determine the spatial and temporal interference resulting from this deployment. To determine the spatial distribution, the aggregate interference to a DRS at a specified orbital location is computed as the

high-gain receiving antenna of the DRS is scanned in roll and pitch. The approach is described in § 2.1. The approach used to determine the temporal characteristics of the interference are described in § 2.2. In both cases, the simulation takes into account: the e.i.r.p. spectral density and gain of the LMDS transmitting station in the direction of the DRS; atmospheric absorption; path loss; and, the gain of the DRS receiving antenna in the direction of the interfering LMDS station.

2.1 Spatial distribution

LMDS stations are expected to be deployed in a cellular configuration in urban population centres to serve businesses, government and homes with moderate to high capacity interactive or broadcast type digital communications services. These services might include Internet access, voice, data and video. For the purpose of this analysis, it is assumed that the aggregate co-channel emissions from an LMDS service area may be modelled as a single station that uses a transmitter with the power spectral density equal to the sum of the power spectral density at the input to each LMDS hub station in the service area, and that a single transmitting antenna provides an acceptable representation of the distribution of the e.i.r.p. spectral density above the local horizontal plane.

It has been assumed for these simulations that the e.i.r.p. spectral density of the emissions of each hub station is +8 dB(W/MHz)¹ and that the aggregate LMDS emission from a single service area is proportional to the number of hub stations in the urban population centre.

The specific model used for the simulation is as follows. The power received from a distant transmitting station can be written as:

$$P_r = \frac{P_t G_t G_r}{l_1 l_2 l_3} \quad (1)$$

where:

- P_r : received power spectral density at the output of an antenna in a specified frequency band (stated as a power spectral density for the purpose of this analysis (W/MHz))
- P_t : transmitted power at the input to an antenna in the same frequency band specified for received power (stated as a spectral density for the purpose of this analysis (W/MHz))
- G_t : gain of the transmitting antenna in the direction of the receiving station relative to an isotropic radiator (numeric)
- G_r : gain of the receiving antenna in the direction of the transmitting station relative to an isotropic radiator (numeric)
- l_1 : free-space propagation loss (numeric)
- l_2 : loss in excess of free-space due to several stationary and time-dependent atmospheric effects (numeric)
- l_3 : polarization coupling loss (numeric), equal to unity if the transmitting and receiving antennas are co-polarized².

¹ For this analysis, a peak of beam hub emission of +8 dB(W/MHz) is assumed at 0° elevation angle and in all azimuths from the hub. It is also assumed that the adjacent antenna sectors operate at the same frequency employing orthogonal linear polarizations.

² For main-beam alignment between a linearly polarized transmit antenna (as normally used in the FS) and circularly polarized satellite receiver antennas, l_3 is assumed to be 2.

The free-space propagation loss is:

$$l_1 = \left(\frac{4\pi d}{\lambda} \right)^2 \quad (2)$$

where:

d : distance between the transmitting and receiving stations (m)

λ : wavelength (m).

Each co-frequency transmitting station forms a radio link to the receiver. The received power from each of the n links, which are assumed to be transmitting uncorrelated signals, adds to form an aggregate received power given by:

$$P_r = \sum_{i=1}^n \frac{P_{ti} G_{ti} G_{ri}}{l_{1i} l_{2i} l_{3i}} \quad (3)$$

where the terms are as previously defined with the addition of a subscript, i , to denote each link.

The aggregate interference is the sum of the interference from each transmitting station. The interference from each station is determined based on the transmitting and receiving antenna gains, taking into account the off-axis angle of the respective antennas.

To speed the computation and taking into account that some terms are nearly constant for a single deployment area, equation (3) is further refined as:

$$P_r = \sum_{i=1}^m \frac{G_{ti} G_{ri} \sum_{j=1}^q P_{tij}}{l_{1i} l_{2i} l_{3i}} \quad (4)$$

where:

q : number of hubs in a specific deployment area

m : number of deployment areas.

Subsequent analysis showed that for the interference scenarios being simulated that the error introduced by the simplification in equation (4) is less than 1 dB.

The deployment of LMDS systems is assumed to correspond to the locations of 431 urban population centres with a population estimated by the United Nations to exceed 750 000 people by 2015 (see Urban Agglomerations, 1950-2015 (the 1996 revision), United Nations Population Division, New York, United States of America, 1996 (available on diskette)).

An empirical relationship between the radius R_p (km) of an equivalent circular area containing a total population P is given by:

$$R_p = \alpha \times P^\beta \quad (5)$$

For the United States of America, $\alpha = 0.035$ and $\beta = 0.44$ have been found to provide satisfactory results. For other areas of the world, $\alpha = 0.0155$ and $\beta = 0.44$ were found to provide a satisfactory estimate.

Equation (5) was used in the estimate of the number of hub stations required to serve an area encompassing the total population in an urban agglomeration. Assuming that each hub serves a circular area of radius R_h , the number of hubs N will be:

$$N = \text{Int} \left(\eta \left(\frac{R_p}{R_h} \right)^2 + 0.5 \right) \quad (6)$$

where:

N : number of hubs for the assumed radius of the cell

$\text{Int}()$: indicates the integer value of the argument

R_p : equivalent radius of the urban area (km)

R_h : radius of a typical LMDS cell (km)

η : deployment factor ($0 < \eta \leq 1$).

For the simulations, it was assumed that the radius of a cell was 5 km and that the deployment factor was 0.30. This value of the deployment factor takes into account economic, demographic and geographic factors and that some administrations may adopt a policy that the relevant band be not used for P-MP FS systems. The largest calculated number of hub stations obtained using the UN population database and equations (5) and (6) are 35 for New York City, United States of America and 11 for Tokyo, Japan. The methodology yields a total worldwide deployment of 944 co-frequency hub stations. Note that worldwide deployment of only co-frequency hubs is considered in this Annex.

The reference radiation pattern for the hub station antennas is based on Recommendation ITU-R F.1336. The omnidirectional pattern is obtained by using four sectoral antennas, each with gain of 15 dBi and a 90° 3 dB beamwidth in the horizontal plane. Additionally, a 3 dB polarization discrimination has been assumed to account for the linearly polarized hub station transmitting antenna and the circularly polarized DRS receiving antenna for boresight-to-boresight coupling. The reference radiation pattern of the transmitting antenna, ignoring any down-tilt, conformed to the following pattern in the vertical plane:

$$G(\theta) = G_0 - 12 \left(\frac{\theta}{\varphi_3} \right)^2 \quad \text{for } |\theta| \leq \varphi_3 \quad (7a)$$

$$G(\theta) = G_0 - 12 - 10 \log \left(\frac{\theta}{\varphi_3} \right) \quad \text{for } |\theta| > \varphi_3 \quad (7b)$$

where:

$G(\theta)$: gain relative to an isotropic antenna (dBi)

G_0 : maximum gain in the horizontal plane (dBi)

θ : elevation angle measured in the vertical plane (degrees)

φ_3 : 3 dB beamwidth in the vertical plane (degrees).

$$\varphi_3 = \frac{31\,000 \times 10^{-0.1G_0}}{90} \quad (7c)$$