RECOMMENDATION ITU-R IS.1143

SYSTEM SPECIFIC METHODOLOGY FOR COORDINATION OF NON-GEOSTATIONARY SPACE STATIONS (SPACE-TO-EARTH) OPERATING IN THE MOBILE-SATELLITE SERVICE WITH THE FIXED SERVICE

(Question ITU-R 202/2)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that certain space-to-Earth mobile-satellite service (MSS) allocations are shared on a co-primary basis with the fixed service (FS) in the range 1-3 GHz;

b) that non-geostationary-satellite orbit (GSO)-MSS systems have individually unique system characteristics particularly in relation to orbital parameters, transmission characteristics, altitude, and elevation angle;

c) that these characteristics may permit opportunities for enhanced sharing with fixed services, when the thresholds set forth in Recommendation ITU-R IS.1141 are exceeded;

d) that analytical methods, interference criteria, and system characteristics exist describing the FS systems in the shared bands,

recommends

1 that the system specific methodology described in Annex 1 be used to assess the need for coordination of non-GSO-MSS networks (space-to-Earth) with FS assignments:

– in the frequency bands 1 492-1 525 MHz, 1 525-1 530 MHz, 2 160-2 170 MHz, 2 170-2 200 MHz, 2 483.5-2 500 MHz and 2 500-2 535 MHz;

– when the thresholds set forth in Recommendation ITU-R IS.1141 are exceeded, on the basis of the reference FS parameters provided in Annex 2 and the criteria referred to in Annex 1.

2 that, in detailed coordination activities, the methodology given in Annex 3 may be used to assess the level of interference into actual FS links.

ANNEX 1*

A system specific methodology to be used in determining the need for coordination of NGSO MSS systems in the space-to-Earth MSS allocations with the FS

1 Introduction

An administration with existing or planned terrestrial FS networks is considered to be potentially affected by emissions from non-GSO MSS space stations if the relevant coordination threshold criteria for analogue FS and/or digital FS systems given in Recommendation ITU-R IS.1141 are exceeded.

* The standard computational programme needs to be further developed with joint participation of Radiocommunication Study Group 8 (mobile satellite) and Radiocommunication Study Group 9 (fixed) experts. The methodology in this Annex may also need to be updated to reflect the results of this development work.

The standard computation programme (SCP) needs to be developed for use in a detailed assessment of the need to coordinate frequency assignments to transmitting non-GSO MSS space-stations with frequency assignments to receiving FS stations in a FS network of a potentially affected administration. The SCP takes into account more specific characteristics of the non-GSO MSS system and reference FS characteristics. Throughout this Annex, mention of FS characteristics are understood to imply reference characteristics.

The SCP requires as input a characterisation of the reference FS system as well as that for the non-GSO MSS satellite system as described in § 2.

The SCP computes using the methodology as described in § 3 on the basis of the above data relevant statistics of interference caused by the non-GSO MSS constellation to the given reference FS system.

If the applicable maximum interference criteria given in § 4 are not exceeded then (unless otherwise subsequently advised by the administration responsible for the FS systems), coordination is not considered to be necessary.

2 FS and MSS data requirements

2.1 Worst FS pointing azimuth determination

For a given non-GSO MSS constellation and for a victim FS station at a given latitude, it is possible to determine the worst azimuth pointing direction for the FS station in terms of maximum potential for receiving interference from the non-GSO constellation. For a given administration the SCP is exercised for the worst FS trend-line azimuth pointing direction for a suitable sample of latitudes (e.g. every 5°) covering the latitude range covered by the territory of that administration. Alternatively various trend-lines representing all azimuth directions (for example in 5° or 10° increments) could be considered, if required.

2.2 Analogue FS system data

It is assumed that there are $M = 51$ analogue stations on a route centred at a given latitude with a trend-line corresponding to the worst azimuth for the given non-GSO MSS constellation. The routes span a distance of $D = 2\,500$ km with stations spaced exactly $d = 50$ km apart. The azimuth angle for each station is specified by the given worst azimuth trend-line angle and a variable angle that is uniformly distributed between $V = \pm 12.5°$. Each FS station is assumed to use a high gain antenna pointed at the next station at an elevation angle of 0°. The point-to-point FS station antenna gain conforms to the antenna pattern having averaged sidelobe levels as defined in Note 6 of Recommendation ITU-R F.699.

The characteristics of the reference analogue FS system are taken to be as given in Annex 2 or if available as obtained from FS data notified by the administration to the BR and filed in the BR database.

2.3 Digital FS system data

Only one digital FS receiver is required for the analysis as opposed to a complete route. The FS station is positioned at a given latitude pointing in the worst azimuth direction. The FS station is assumed to use an antenna at an elevation angle of 0°. The FS station antenna gain conforms to the antenna pattern having averaged sidelobe levels as defined in Note 6 of Recommendation ITU-R F.699.

The characteristics of the reference digital FS system are taken to be as given in Appendix 1 to Annex 2 or if available as obtained from FS data notified by the administration to the BR and filed in the BR database.

Point-to-multipoint systems, which use antennas that are omnidirectional in azimuth, may also need to be considered in some bands. The antenna patterns to be used for these systems are under study in Radiocommunication Working Party 9B. The need to include these systems in the SCP requires further study.

2.4 Non-GSO MSS data to be used

The following data (in addition to Appendix 3 to Annex 2 data) is to be supplied by the administration responsible for the non-GSO MSS system.

2.4.1 Full information to characterize the orbital elements of each satellite in the non-GSO constellation (i.e. orbital altitude, orbital inclination, right ascension of ascending node, argument of perigee, mean anomaly, mean motion and epoch) in accordance with an appropriate reference inertial coordinate system.

2.4.2 Full information to characterize the antenna pattern (maximum gain, antenna roll-off pattern and polarization) of each spot beam of each satellite in the non-GSO MSS constellation. The MSS spot beam antenna pattern may for example be characterized by a parabolic roll-off with a floor, any of the applicable satellite antenna patterns of the Second Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and on the Planning of Space Services Utilizing It (Geneva, 1988) (WARC-ORB-88) or the World Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service (Geneva, 1977) (WARC-BS-77) or as given in Recommendation ITU-R S.672.

2.4.3 Full information on the maximum e.i.r.p. density/4 kHz or 1 MHz in any active beam with potential carrier frequency overlap with the assumed FS receiver of any satellite at all sample points in time any given satellite is visible to the FS system. This information should implicitly reflect the intra-satellite and inter-satellite frequency reuse plans as well as satellite spot beam traffic loading taking into account the expected geographical distribution of traffic for the MSS system.

A suitable file interface for inputting such data to the SCP needs to be developed along with the methodology for application.

In general if a CDMA/FDMA access scheme is employed on the non-GSO MSS constellation, then potentially all beams of all visible satellites may operate co-frequency. However if a TDMA/FDMA or FDMA access scheme is employed on the non-GSO MSS constellation, then only a subset of beams on visible satellites will operate co-frequency.

2.4.4 In the absence of such information § 2.4.3, each spot beam of each satellite is to be assumed to have frequency overlap with the FS receiver and to be loaded to a level given by:

a) either the absolute worst case maximum MSS traffic loading (MAX) for any spot beam (which would result in a considerable overestimation of interference power into the FS system);

b) or the mean MSS loading (MEAN) for any spot beam obtained by dividing the total instantaneous maximum satellite traffic capacity by the number of spot beams on the satellite (which would underestimate the effect of interference power into the FS system);

c) or by a random variation between the above MAX and MEAN levels (which would mediate between § a) and § b) to more accurately reflect the effect of interference power into the FS system).

2.4.5 For non-GSO MSS systems which employ CDMA/FDMA, all visible satellites could be considered in the computation of aggregate interference to the victim FS station. For non-GSO MSS systems which employ TDMA/FDMA or FDMA, one satellite randomly selected of visible satellites or the highest elevation angle satellite could be considered in the computation of aggregate interference to the victim FS station.

Further study will be required to define § 2.4.3, 2.4.4 and 2.4.5.

3 Methodology for calculating interference

The SCP simulate the interference into the FS network from the non-GSO satellite constellation(s) as follows.

The programme calculates the position and velocity vectors of the satellites of the NGSO satellite system and stations of FS system at each time instance.

At each time sample the SCP calculates the total interfering power at each victim FS station from all active spots with active carrier frequency overlap to the given FS station receiver bandwidth from all visible and appropriately selected MSS satellites. The aggregate interference power from all active spot beams of all visible satellites visible to the FS station(s) is determined using the following equation:

$$I = \sum_{k=1}^{M} \sum_{i=1}^{N} \sum_{j=1}^{S} \frac{E_{ijk}}{L_{ik}} G^3(\alpha_{ijk}) \; G^4(\theta_{ik}) \; \frac{B_w}{B_i} \frac{1}{F_k} \frac{1}{P_{ik} \; A} \tag{1}$$

where:

I:	interference power (W)
i:	1 of N visible satellites to the current k^{th} FS station
j:	1 of S of active spot beams on the visible selected MSS satellite with frequency overlap to the current FS station receiver
k:	1 of M FS stations on a FS route
E_{ijk} :	maximum e.i.r.p. density per reference bandwidth input to the antenna for the j^{th} active spot beam in its boresight direction of the i^{th} visible selected satellite (W/reference bandwidth)
B_i:	reference bandwidth for the interfering signal from the j active spot beam of the i^{ths} visible selected satellite (kHz)
$G^3(\alpha_{ijk})$:	antenna discrimination of the j^{th} active spot beam of the i^{th} visible selected satellite towards the k^{th} FS station
α_{ijk}:	angle between the boresight pointing vector j^{th} active spot beam of the i^{th} visible selected satellite to the k^{th} FS station (degrees)
L_{ik}:	free space loss at the given reference frequency from the i^{th} visible selected satellite to the k^{th} FS station
$G^4(\theta_{ik})$:	k^{th} FS station's antenna gain in the direction of the i^{th} visible selected satellite
θ_{ik}:	angle between the k^{th} station's antenna pointing vector and the range vector from the k^{th} station and the i^{th} visible selected satellite (degrees)
B_w:	receiver bandwidth of the victim FS station
A:	averaging factor to take into account MSS carrier frequency, power or time variability
F_k:	feed loss for the k^{th} FS station
P_{ik}:	polarization advantage factor between i^{th} MSS satellite and k^{th} FS station.

The averaging factor A may be applicable to reflect dynamic frequency, time or power variations in MSS traffic levels in a given reference bandwidth (due to for example use of voice activation, duty cycle, power control etc. as appropriate for the concerned non-GSO MSS system). Further study is required in this respect.

The polarization advantage P_{ik} of 3 dB is to be used only if the range vector from the k^{th} FS station to the i^{th} MSS satellite is within the 3 dB beamwidth of the FS antenna pointing vector.

4 Applicable interference criteria

4.1 Analogue FS

The SCP calculates the interference statistics based on the aggregate interference noise power accumulated over all stations as calculated at each sample point. The interference statistics indicate the probability that the aggregate received interference noise power exceeds a given interference level.

The methodology of Annex 3 of Recommendation ITU-R F.1108, which is based in part on Recommendation ITU-R FS.766 may be used for this purpose with the following parameters:

N_t: thermal noise power introduced in a 4 kHz telephony channel at a station = 25 pW psophometrically weighted at a point of zero relative level (pW0p)

T: station receiving system noise temperature (K)

L_f: feeder loss (dB).

In order to assess if coordination is triggered or not the distribution of interference power is compared with respect to the two point interference objective mask, consisting of a long-term and a short-term interference objective given in Recommendation ITU-R F.357.

4.2 Digital FS system

For the digital FS case the SCP calculates the fractional degradation in performance FDP for the digital station as in Annex 2 of Recommendation ITU-R F.1108:

$$FDP = \sum_{I_i = min}^{max} \frac{I_i \; f_i}{N_T} \tag{2}$$

where:

I_i: interference power in FS receiver bandwidth B_w

f_i: the fractional period of time that the interference power equals I_i

N_T: station receiving system noise power level = k T B_w (W)

where:

k: Boltzmann's constant

T: station receiving system noise temperature (K)

B_w: FS receiver bandwidth (kHz)
(usually B_w = 1 MHz).

In order to assess if coordination is triggered or not with respect to digital FS systems, the computed FDP is compared with respect to the applicable criterion of 25%.

ANNEX 2

Reference characteristics of fixed service systems in the 1-3 GHz band for use in sharing analyses with other services

1 Introduction

The following Appendices provide the characteristics of FS systems, operating in the 1-3 GHz band, which can be used to perform analysis of sharing between stations in the FS and other services. Where applicable both typical and the most sensitive parameters are detailed.

Appendix 1 – Characteristics of digital point-to-point systems

Appendix 2 – Characteristics of analogue point-to-point radio-relay systems

Appendix 3 – Characteristics of point-to-multipoint systems.

It should be noted that digital FS systems are typically more sensitive to interference than analogue systems and that new installations of FS systems will primarily be digital. Sharing analysis should therefore concentrate on, but not be limited to, digital system characteristics and required protection levels.

It should be further noted that the parameters for troposcatter systems are detailed in Recommendation ITU-R F.758, Table 6 for 1.7-2.45 GHz band, and Table 7 for the 2.45-2.69 GHz band.

2 Use of automatic power control in digital systems

Automatic power control (APC) has been implemented to facilitate intra-service sharing and coordination based on lower transmit power. During fade conditions the power level is increased for a short duration to overcome the effect of the fade condition. There are two problems associated with the use of APC to overcome interference. First, it does not appear likely that the potential total interference time from non-GSO networks would be considered a short-term event. Therefore, any intra-service coordination based upon lower power levels would be inappropriate. The higher power levels that would need to be used for coordination purposes between FS systems would make sharing much more difficult. Additionally, the higher transmit power of the FS would make other inter-service sharing issues, including interference into non-GSO network uplinks, more difficult. The second and perhaps more significant problem is that there is currently no practical method for sensing interference that would cause APC to activate. An increase in a link margin beyond current engineering practices is not considered an appropriate method to improve resistance to interference and may make other inter-service sharing issues more difficult.

APPENDIX 1

TO ANNEX 2

Characteristics of digital point-to-point systems

Three different digital systems are described in Table 1 which should be used for compatibility studies as they represent three different uses of FS systems:

– 64 kbit/s capacity used for example for outside-plant (individual subscriber connection);

– 2 Mbit/s capacity used for example for professional subscriber connection or local part of the inside-plant;

– 45 Mbit/s capacity used for example for trunk network.

These interference values (for long-term interference) correspond to a degradation in the receiver threshold of 1 dB or less.

As indicated in Recommendation ITU-R F.758 (Annex 2, § 4, Note 1), it must be noted that in order to simplify Table 1, only the interfering carrier level corresponding to the 1×10^{-3} BER is included. Equally important are the 1×10^{-6} and 1×10^{-10} BER objectives, used in the evaluation of permissible degradation. Typically, the carrier level corresponding to 1×10^{-6} BER is around 4 dB higher than that for 1×10^{-3} BER; the carrier level difference between 1×10^{-6} and 1×10^{-10} BER points is also about 4 dB.

It must be pointed out that when considering maximum power-spectral density for a long-term interference, the three values are about the same (only 4 dB difference) and similar to those given in Recommendation ITU-R F.758.

TABLE 1

Capacity	64 kbit/s	2 Mbit/s	45 Mbit/s
Modulation	4-PSK	8-PSK	64-QAM
Antenna gain (dB)	33	33	33
Transmit power (dBW)	7	7	1
Feeder/multiplexer loss (dB)	2	2	2
e.i.r.p. (dBW)	38	38	32
Receiver IF bandwidth (MHz)	0.032	0.7	10
Receiver noise figure (dB)	4	4.5	4
Receiver input level for a BER of 1×10^{-3} (dBW)	–137	–120	–106
Maximum long term interference – Total power (dBW) – Power spectral density (dB(W/4kHz))	 –165 –174	 –151 –173	 –136 –170

Fixed service antenna pattern

Recommendation ITU-R F.699 should be used.

APPENDIX 2

TO ANNEX 2

Characteristics of analogue point-to-point radio-relay systems

The types of analogue point-to-point systems operating in the 1-3 GHz bands comprise telephony, FM-TV and ENG links. A reference set of characteristics has been extracted from Tables 5, 6 and 7 of Recommendation ITU-R F.758, Table 1 of Recommendation ITU-R F.759 and from Recommendation ITU-R SF.358 which details the analogue hypothetical reference circuit currently used for ITU-R sharing studies.

1 Typical FS analogue characteristics operating in the 1-3 GHz bands

Antenna envelope characteristic: see Recommendation ITU-R F.699

Antenna gain: 33 dBi

e.i.r.p.: 36 dBW

Receiver noise figure (referred to input of receiver): 8 dB

Long-term interference limit per link (20% of time): –170 dB(W/4 kHz)

2 ITU-R analogue hypothetical reference circuit characteristics

Hop length: 50 km

Number of hops: 50

Antenna gain: 33 dBi

Feeder loss: 3 dB

Receiver noise figure (referred to input of receiver): 8 dB

Total route baseband noise power limit: 1 000 pW0p.

APPENDIX 3

TO ANNEX 2

Characteristics of point-to-multipoint systems

The information presented below summarizes typical and worst-case basic parameters for use in sharing studies between point-to-multipoint (P-MP) systems and other systems, in the range 1-3 GHz.

Basic sharing parameters for P-MP systems in the frequency range 1-3 GHz.

The characteristics of P-MP systems currently being deployed for local access use by at least one administration are summarized in Table 4. These systems are designed to operate in the 2 025-2 110 MHz and 2 200-2 290 MHz bands.

The characteristics of another example P-MP system are summarized in Table 5 and Fig. 1. These systems are designed to operate in the bands 2 076-2 111 MHz and 2 300-2 400 MHz.

In the absence of further information regarding the outstation antenna pattern, the reference pattern of Recommendation ITU-R F.699 should be assumed.

Pending the development of a recommendation for the reference radiation pattern for omnidirectional antennas, it is suggested that the following pattern be used:

$$G(\theta) = G_0 - 12(\theta / \varphi_3)^2 \quad \text{dBi} \quad \text{for} \quad 0° \leq \theta < \varphi_3 \tag{3a}$$

$$G(\theta) = G_0 - 12 - 10 \log (\theta / \varphi_3) \quad \text{dBi} \quad \text{for} \quad \varphi_3 \leq \theta < 90° \tag{3b}$$

where:

G_0 : maximum gain in the horizontal plane (dBi)

θ : radiation angle above the horizontal plane (degrees)

φ_3 : (degrees) is given by :

$$\varphi_3 = \frac{1}{\alpha^2 - 0.818} \quad \text{degrees} \tag{4a}$$

$$\alpha = \frac{10^{0.1 G_0} + 172.4}{191.0} \tag{4b}$$

Equations (3a) and (3b) have been derived on the assumption that the omnidirectional antenna is an *n*-element linear array radiating in the broadside mode, and that the elements are spaced $3\lambda/4$.

The reference radiation pattern given in equation (3) has been found to adequately approximate the theoretical radiation pattern for omnidirectional antennas with a maximum gain in the horizontal plane ranging from 10 dBi to 13 dBi. Further study is required to demonstrate the adequacy of the pattern for antennas with gains outside the range given above and to compare the reference pattern with measured antenna patterns.

TABLE 2

Typical characteristics

Parameter	Central station	Outstation
Antenna type	Omni/Sector	Dish/Horn
Antenna gain (dBi)	10/17	20 analogue 27 digital
e.i.r.p. (max.) (dBW) – analogue – digital	 12 24	 21 34
IF bandwidth (MHz)	3.5	3.5
Maximum permissible long-term interference power (20% time) – Total (dBW) – dB(W/4 kHz) – dB(W/MHz)	 –142 –170 –147	 –142 –170 –147

TABLE 3

Worst-case characteristics

Parameter	Central station	Outstation
Antenna type	Omni/Sector	Dish/Horn
Antenna gain (dBi)	13/21(1)	27/12
e.i.r.p. (max.) (dBW) – analogue – digital	 23 24	 23 34
IF bandwidth (MHz)	6(2)	6(2)

(1) A 2 dBi antenna is used in some countries in the band 1 452-1 492 MHz.

(2) 6 MHz bandwidths used by AMDSB MVDS systems in the United States of America in the frequency bands 2 150-2 162 MHz and 2 500-2 690 MHz.

TABLE 4

Characteristics of an example CDMA local access radio system

Frequency band (GHz)	2	
System type	Fixed point-to-multipoint (CDMA)	
RF transmission rate (kbit/s)	2 048	
Modulation	QPSK	
	Central station	Outstation
Transmit power (dBW)	–10.0 (per outstation)	–10.0
Antenna polarization	Vertical	Vertical
Antenna maximum gain (dBi)	10	9
Feeder loss (dB)	3.5	0
Maximum e.i.r.p. (dBW)	–3.5/outstation(1)	–1.0(2)
Receiver IF bandwidth (MHz)	3.2	3.2
Receiver thermal noise (dBW)	–134.0	–134.0
Receiver threshold (BER 1×10^{-7})(3) (dBW)	–135.0	–135.0
Maximum long-term interference power (dB(W/MHz))	–150.0	–150.0
Availability target	99.99% of time	99.99% of time
Typical fade margin (dB)	< 20	< 20
Path length (km)	1-15	1-15

(1) Maximum e.i.r.p.: 8.5 dBW.

(2) Automatic power control is employed, therefore typical powers may be 0-20 dB less.

(3) Typical signal level for a system with 15 outstations.

TABLE 5

Characteristics of an example multipoint distribution system

Frequency bands (MHz)		2 076-2 111 and 2 300-2 400	
System type		Fixed point-to-multipoint	
Modulation		Not specified – mainly PAL-B	
Channel bandwidth (MHz)		7	
Emission mask		See Fig. 1	
	Main station	Repeater station	Outstation
e.i.r.p. (max.) (dBW)(1)	30(1)	< 30(1)	Receive only
Antenna type	Omnidirectional in horizontal plane	Directional	Directional

(1) Transmission power at angles of elevation of 5° or more above the horizontal plane must not exceed the following e.i.r.p. limits:

– 100 W at 5°, decreasing linearly to 31.6 W at 10°;

– 31.6 W between 10° and 15°;

– 31.6 W at 15°, decreasing linearly to 10 W at 20°;

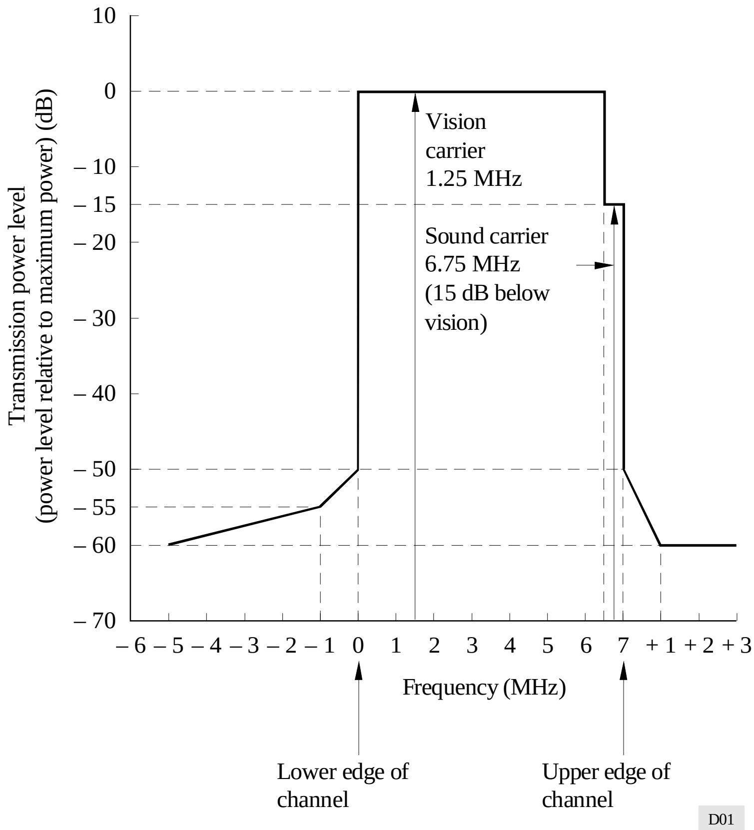
– 10 W between 20° and 90°.

NOTE 1 – Coordination level for protection of MDS receivers anywhere within service area is –146.2 dB(W/(m^2 · 4 kHz)).

Figure 1 shows the emission mask. The location shown for video and sound carriers applies when analogue PAL television signal is transmitted. Other signal formats are permitted, including video and data transmission using digital modulation, if they conform to this emission mask.

FIGURE 1

Emission mask of envelope



ANNEX 3

Possible methodology for use in bilateral coordination

If the non-GSO MSS system parameters exceed the threshold criteria given in Recommendation ITU-R IS.1141, or referred to in this Recommendation detailed bilateral coordination will be required between the concerned administrations. In this step, actual FS parameters could be used. One possible methodology which could be used in bilateral coordination is described below in this Annex.

1 Description of a possible methodology

The CDF (cumulative distribution function) of $C/(N+I)$ on analogue or digital FS systems is evaluated. The time varying interfering carrier power from the non-GSO MSS satellite is estimated at each FS receiver using orbital dynamic simulation taking into account the non-GSO MSS satellite antenna characteristics and traffic loading modelling.

The time varying wanted received FS carrier at each FS receive station is evaluated using the FS transmission characteristics in conjunction with a model of multipath fading. If considered appropriate by both parties, Recommendation ITU-R P.530 could be used. At each simulation time step the per hop C/N and C/I are evaluated and aggregated to give the end-to-end $C/(N+I)$. The CDF of $C/(N+I)$ can then be compared directly with the applicable performance objectives for the concerned FS system to evaluate whether the degradation caused by the non-GSO MSS satellite unacceptably degrades the performance.

2 Interference criteria

This analysis would apply to both analogue and digital FS systems.

Recommendation ITU-R F.393, which refers to the total noise allowance in an analogue radio-relay system, is used as the criterion to assess the interference impact into analogue FS systems.

Recommendation ITU-R F.697, which refers to error-performance objectives of a digital radio-relay system is used as the criterion to assess the interference impact into a digital FS system in the local grade portion of the ISDN. Alternatively, for digital FS systems in the high grade portion of the ISDN, the applicability of Recommendation ITU-R F.594, appropriately apportioned to a hop, should be considered.