

RECOMMENDATION ITU-R M.1143-3*

System specific methodology for coordination of non-geostationary space stations (space-to-Earth) operating in the mobile-satellite service with the fixed service

(Questions ITU-R 201/8 and ITU-R 118/9)

(1995-1997-2003-2005)

Scope

This Recommendation describes methodologies and reference fixed system characteristics for implementation of the System Specific Methodology (SSM) of Appendix 5 of the Radio Regulations (RR), which allows a detailed assessment of the need to coordinate frequency assignments for non-geostationary (non-GSO) space stations (space-to-Earth) and receiving systems in the fixed service (FS). The Recommendation also describes a possible methodology for use in bilateral coordination of non-GSO mobile-satellite service (MSS) transmitting space stations with stations of the FS.

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 (non-GSO) MSS systems have individually unique system characteristics particularly in relation to orbital parameters, transmission characteristics, altitude, and elevation angle;
- c) that consideration of the characteristics mentioned in *considering* b) may help in facilitating sharing with FS, when the thresholds set forth in the Radio Regulations (RR) are exceeded;
- d) that analytical methods, interference criteria, and system characteristics exist describing the FS systems in the shared bands,

recommends

- 1 that when the thresholds set forth in RR Appendix 5 are exceeded, 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 1 518-1 525 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;
- 2 that, in detailed coordination, the methodology given in Annex 3 may be used to assess the level of interference into actual FS links.

* The revision of this Recommendation was jointly prepared by Radiocommunication Study Groups 8 and 9, and any further revision will also be undertaken jointly.

Annex 1*

System specific methodology to be used by the standard computation program (SCP) in determining the need for coordination of non-GSO 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 RR Appendix 5 are exceeded.

The 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 of one constellation (single-entry) 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 specific reference FS systems of those given in Annex 2 to be used should correspond to the types of actual FS systems in use in the administration concerned.

The SCP requires as input a characterization 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 might not be necessary.

2 FS and MSS data requirements

2.1 Position of FS station and determination of worst FS pointing azimuth

For a given administration the SCP is exercised for a suitable sample of latitudes (e.g. every 5°) covering the latitude range covered by the territory of that administration. 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. The SCP is thus exercised for the worst FS trend-line azimuth pointing direction.

The formulae to be used for the calculation of the worst azimuth can be found in § 5 of Appendix 3 to Annex 1 of Recommendation ITU-R S.1257.

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

2.2 Analogue FS system data

It is assumed that there are $M = 13$ co-frequency 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 $D = 600$ 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 $V = \pm 12.5^\circ$. 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 Recommendation ITU-R F.1245.

The characteristics of the reference analogue FS system are taken to be as given in Appendix 2 to Annex 2, or if available, as obtained from FS data notified by the administration to the Radiocommunication Bureau (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 Recommendation ITU-R F.1245.

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.

2.4 Non-GSO MSS data

Full information on the following parameters is required to characterize non-GSO/MSS networks:

- centre frequency,
- number of spot beams,
- maximum power of one satellite,
- spot beam characteristics.

The detailed list of parameters is given in Appendix 1 to Annex 1.

Full information is required on the maximum e.i.r.p. density/4 kHz and 1 MHz in any active beam of any satellite with potential carrier frequency overlap with the assumed FS receiver at all sample points during the time that 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.

In general if a code division multiple access/frequency division multiple access (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 time division multiple access (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.

Part 1 of Appendix 2 to Annex 1 provides a default/baseline methodology for modelling satellite spot beam loading. Part 2 of Appendix 2 to Annex 1 provides a detailed methodology for modelling of satellite spot beam loading for CDMA and TDMA systems in cases where the necessary traffic data for the MSS system is made available. Since projections of MSS traffic data for that system are required, the application of Part 2 of Appendix 2 to Annex 1 methodology will normally require consultation with concerned administrations.

For all types of non-GSO MSS systems (TDMA, FDMA, or CDMA), all visible satellites of the constellation should be considered in the computation of aggregate interference to the victim FS station, but traffic should be distributed among these satellites.

3 Methodology for calculating interference

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

3.1 Calculation loop

The programme calculates the position and velocity vectors of the satellites of the non-GSO 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 from all visible and appropriately selected MSS satellites. If the FS receiver bandwidth does not completely overlap the MSS signal the interfering power is then scaled by the bandwidth factor. In the analogue case, this interfering power is scaled to 4 kHz.

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:

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

where:

- I : interference power (W)
- i : 1 of N satellites being considered in the interference calculation for the k -th FS station
- j : 1 of S active spot beams on the visible selected MSS satellite with frequency overlap to the current FS station receiver, taking account of the satellite spot beam frequency reuse pattern
- k : 1 of M FS stations on a FS route
- E_{jk} : 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_{ij} : reference bandwidth for the interfering signal from the j -th active spot beam of the i -th 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 (4 kHz or 1 MHz)

- 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_{ijk} : polarization advantage factor between j -th spot beam of the 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_{ijk} is to be used only if the i -th MSS satellite is within the 3 dB beamwidth of the k -th FS station antenna and the k -th FS station is within the 3 dB beamwidth of the j -th spot beam of the i -th MSS satellite. P_{ijk} can be calculated according to the formula of Note 7 of Recommendation ITU-R F.1245.

An improvement of the simulation run time can be obtained by excluding from the interference calculation beams for which α_{ijk} is greater than a given “exclusion” angle.

3.2 Size and number of steps in the calculation loop

On the one hand the duration of the program must be as quick as possible so that the user does not have to wait a long time for the results, on the other hand it is necessary to have enough samples at appropriate time intervals to have accurate results, taking into account all the interference received at the receiver of the fixed station.

3.2.1 Time increment

The following formulae are used, and the derivation of the formulae are fully detailed in Appendix 3 to Annex 1. As the satellite speed is about the same at the equator and at higher latitudes, the calculation of simulation time step Δt is made for a satellite at the equator taking into account the Earth's rotation, satellite inclination and FS station antenna elevation. The worst azimuth for fractional degradation of performance (FDP) or the azimuth of horizontal movement is not used in calculation of Δt .

$$\omega = \sqrt{(\omega_s \cos I - \omega_e)^2 + (\omega_s \sin I)^2}$$

$$\theta_\epsilon = \arccos\left(\frac{R}{R + h} \cos \epsilon\right) - \epsilon$$

$$\Delta t = \frac{\Phi_{3dB}}{N_{hits} \omega} \frac{\sin \theta_\epsilon}{\cos \epsilon}$$

where:

- ω : satellite angular velocity in Earth fixed coordinates (geocentric geosynchronous reference coordinate system)
- ω_s : satellite angular velocity in space fixed coordinates (geocentric heliosynchronous reference coordinate system)
- ω_e : Earth rotation angular velocity at the equator
- I : satellite orbit inclination
- θ_ϵ : geocentric angle between FS station and satellite

- R : Earth radius
- h : satellite altitude
- ε : FS antenna elevation angle
- $\Phi_{3\text{dB}}$: FS station 3 dB beamwidth
- N_{hits} : number of hits in FS station 3 dB beamwidth ($N_{\text{hits}} = 5$)
- Δt : simulation time step.

3.2.2 Precession rate and total simulation time

As time evolves, the subsatellite point of an MSS satellite circular orbit traces out a path on the surface of the Earth. After a number of complete orbits, this path will return to the same, or almost the same, point on the surface of the Earth. The elapsed time for this occurrence is the repeat period of the satellite. For some constellations, a repeat period can be defined based on another satellite of the constellation returning to the same point. In these cases the elapsed time between the two occurrences can be taken as the repeat period of the constellation.

Some constellations have short repeat periods of several days (typically less than one week) whereas other constellations have very long periods, such as many months. These great differences require special consideration because FS systems must meet performance requirements in any month. Two ways of handling these discrepancies were identified.

For constellations with repeating periods of less than one week, the solution could be to use the repeating period of the constellation as the total simulation time and to run the program for several values of the right ascension (initial position of the ascending node of orbital plane number 1) ranging from a longitude of 0° to a longitude equalling the angular distance between two consecutive orbital planes. This would ensure that the worst case from the FS point of view would be identified. Further study is needed to assess the value of the longitude incremental step, which is related to the number of time increments during which a satellite is within the main beam of a FS station (see § 3.2.1).

For constellations with very long repeat periods, using this period as the total simulation time could lead to correspondingly long central processing unit (CPU) running time. Furthermore the paths on the Earth surface would be uniformly distributed and the longitude resolution (longitudinal distance between two neighbour paths) would be unnecessarily small. In such cases one should use an artificial precession rate which would lead to a longitude resolution of the same order of magnitude as the longitude incremental step described in the previous case. The artificial precession rate would induce an artificial constellation period, significantly shorter than the real one, thus reducing the CPU running time. However, it is necessary to evaluate simulation results for several one month periods within the repeat cycle to assess the variability of the FDP on a month-to-month basis.

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.