

RECOMMENDATION ITU-R SF.1572*

Methodology to evaluate the impact of space-to-Earth interference from the fixed-satellite service to the fixed service in frequency bands where precipitation is the predominant fade mechanism

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

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that emissions from space stations in the fixed-satellite service (FSS) operating in geostationary orbit (GSO) and sharing the same spectrum as the fixed service (FS) may produce interference in receiving stations of the FS;
- b) results obtained using a statistical approach compared to a worst-case analysis may lead to a more efficient use of the spectrum than results from criteria developed using worst-case analysis;
- c) that sharing methodologies should take into consideration the performance requirements and deployment characteristics of FS systems being used and planned for use in these frequency bands;
- d) that in spectrum where precipitation is the predominant fade mechanism it is desirable to have an interference evaluation tool using C/N , C/I and $C/(N + I)$ statistics to determine impact on availability;
- e) that such an interference evaluation tool may have application in bands above about 17 GHz to assist administrations in performing sharing studies,

recommends

- 1 that the methodology as described in Annex 1 can be used for developing computer simulation tools which evaluate the impact of interference from FSS systems to digital FS systems operating in frequency bands above 17 GHz.

* The methodology in Annex 1 concentrates on interference from GSO FSS systems. Further studies are required in order to ensure that this methodology is generally applicable to interference from non-GSO FSS systems.

ANNEX 1

1 Introduction

The methodology described in this Annex provides a model for an analysis of all of the FS system parameters and local geoclimatic parameters of both point-to-point (P-P) and point-to-multipoint (P-MP) systems, which may contribute to the susceptibility of FS receivers to interference from FSS downlinks.

1.1 Definitions

In the frequency bands where precipitation is the predominant fade mechanism, FS design objectives are determined by availability performance rather than error performance. For the purpose of this Recommendation, the term “designed availability” is considered based upon severely errored second (SES) threshold taking into account that in these frequency bands the percentage of events with consecutive SESs less than 10 s is negligible. Hereafter the designed availability for any FS link is estimated by the percentage of time in an average year that a receiver signal, C/N , falls below the threshold, C/N_{th} , which corresponds to SES events. Throughout this Annex, unavailability (100% – availability) is indicated by the symbol $p_D(\%)$.

Designed availability for P-MP system – The design availability is the percentage of time in an average year that the carrier-to-total noise plus interference, $C/(N + I)$, into a reference subscriber located at the maximum radius of a P-MP cell will receive at or above the threshold C/N_{th} .

Designed availability for P-P – The design availability is the percentage of time in an average year that the carrier-to-total noise plus interference, $C/(N + I)$, into the receiver will receive at or above the threshold C/N_{th} .

Reference subscriber for a P-MP system – The receiver which is located at the maximum distance from the transmitting hub antenna which is used to calculate the transmit power necessary to achieve the designed availability. In P-MP systems, which are modelled with subscriber antennas that have heights, which follow a statistical distribution, the height of the reference receiver is the most probable height. In such a P-MP system model, a hub antenna to which just sufficient transmitter power is delivered to achieve the designed availability on a link to the reference receiver, will not have sufficient transmit power to meet the designed availability of 100% of all possible subscribers. This is due to a combination of lesser hub antenna gain and greater free space loss in the direction of subscribers also at or near the maximum distance from the hub antenna. Additional power delivered to the hub antenna would be required for all possible subscribers to achieve their designed availability in a P-MP system characterized by subscriber antennas that have heights, which follow a statistical distribution.

Four types of modulations employed by FS systems are referred to in this Annex. These types of modulation are: quadrature phase shift keying (QPSK) and three different types of quadrature amplitude modulation (16-QAM, 64-QAM and 256-QAM).

2 Types of FS systems analysed for susceptibility to GSO FSS interference

Based on the systems described in Recommendation ITU-R F.758, there are two distinctly different implementations of FS systems.

2.1 P-MP system

The P-MP system is characterized by a central or “hub” transmitting antenna that radiates omnidirectionally in the horizontal plane (azimuth) and directionally in the vertical plane (elevation). The hub antenna radiation pattern is accomplished by combining a number of sector antennas together and may be given a negative elevation angle bias in order to maximize coverage from a high point on the top of a tall building or tower. The user or “subscriber” antennas, in contrast, are directive and for computational purposes may be assumed to be axially symmetric. The distribution of subscribers over a specified range of possible values of hop length may be statistically modelled or user defined. Some of today’s modern, third generation P-MP systems operate on up to three modulations simultaneously such as: QPSK, 16-QAM, 64-QAM and 256-QAM. Such a configuration allows a higher traffic capacity per sector, which is essential to make the networks more economical. The result is that in every cell site, up to three concentric rings may exist where the same minimum availability objective is encountered. This means that a much larger number of subscribers that receive higher capacities have higher average elevation angles than in P-MP cells and are modelled using a single modulation scheme throughout the whole cell. Subscribers operating at the higher modulation levels in the inner-most rings are inherently subject to higher power flux-density (pfd) levels from satellites operating in the GSO due to having higher elevation angles than those subscribers in the outer rings. The overall impact from FSS interference on the availability of such a P-MP system may be statistically modelled by weighting either the number of subscribers (independent of the capacity) in each of the rings or by weighting the number of subscribers of equivalent capacity by post processing the availability data obtained from analysing each of the rings individually.

Applying the methodology over a large range of possible deployment scenarios allows the sensitivity of P-MP systems to a variety of FS system parameters, including FS receiver antenna diameter, receiver system noise figure, P-MP cell characteristics and geoclimatic factors, to be assessed parametrically.

2.2 P-P system

This type of system is characterized by randomly oriented microwave links having a wide range of hop lengths and elevation angles. When considering the impact of interference from the FSS systems into a P-P FS network, the impact of the FSS interference is examined into both ends of the FS link.

A subset of P-P systems is that of an implementation of a P-MP system or a “star” configured network where the traffic may or may not be asymmetrical (i.e. higher capacity from centrally located transmitter to the subscriber). In this case, a higher proportion of P-P receivers will have higher elevation angles, much like that of the receivers in a P-MP network and thus have an increased susceptibility to interference from space-to-Earth links. In the “star” type configuration of a P-P network, the distribution of subscribers over a specified range of possible values of hop length may be specified in the same way as for a P-MP network.

In some FS deployments, it may be possible to encounter hybrid developments consisting of P-P (both random and star configurations), and P-MP deployments that are optimized based on network efficiency considerations. In all such cases, the dominant interference scenario is the FSS interference into the FS subscriber receiver.

3 General considerations

3.1 P-MP systems

The P-MP cell geometry and the hub and subscriber antenna patterns affect the statistical distribution of the levels of interference over the population of possible receivers as well as their susceptibility to interference. Also, in frequency bands above 17 GHz, long-term attenuation by atmospheric gases, the effects of scintillation and short-term attenuation due to rain, which are in turn affected by geoclimatic factors related to latitude, are important in determining the susceptibility of subscriber terminals to space-to-Earth interference from FSS satellites. The effect of each of these factors on the susceptibility of subscriber terminals to interference from GSO FSS satellites can be parametrically determined.

3.2 Fixed P-P systems (including star configuration)

In P-P systems, in the frequency bands above 17 GHz, a number of factors including receive antenna diameter, elevation angle and system fade margins contribute to the susceptibility of receiving terminals to external interference. System fade margin in a P-P system is dependent on the hop distance and by the same geoclimatic factors and in a similar manner as for P-MP systems.

4 Assumptions

The methodology presented in this Annex makes certain assumptions.

4.1 Basic assumptions

The following basic assumptions, summarized below, are common to both P-MP and to P-P FS systems and are important considerations in the implementation of the methodology:

- a) The path design takes into account any performance objectives and the fade margin required to comply with the applicable recommended or desired short-term performance objectives.
- b) The impact of the interference to an FS network may be assessed, for instance as a percentage of the total possible FS receivers that achieve an availability at or above a given level of degraded availability.
- c) The portion of the GSO arc above the horizontal plane is visible to all FS receive terminals and no part of the arc in any direction is blocked from the view of any FS receive antenna.
- d) The height above mean sea level (amsl) of the entire wanted signal path is assumed to be the same for the purpose of calculating the attenuation due to atmospheric gaseous (when the option of implementing Recommendation ITU-R P.676 is used) and the long-term

attenuation due to rain (Recommendation ITU-R P.530). The height used is the average of heights of the transmitting and the receiving antenna in a P-P system and the minimum antenna height of the subscriber in a P-MP system.

- e) The maximum equivalent isotropically radiated power (e.i.r.p.) value of 55 dBW is observed. The channel bandwidth for the FS system under consideration in conjunction with the 55 dBW e.i.r.p. value will establish the maximum transmit power density limit for that FS system.
- f) FS characteristics used to model any P-P or P-MP link should be representative of typically deployed networks.
- g) FS availability is always defined based on an annual average.

4.2 P-MP assumptions

4.2.1 Intra-service (including intra-system) interference

In the most basic system model, the FS system could be assumed to have been allocated a level of intra-service interference for a reference subscriber terminal located at the edge of the P-MP cell at a specified height above ground level (agl). This assumption results in the total noise, thermal plus intra-service, being a specified level above the thermal noise level alone. Actual levels of intra-service interference can be considered, for example, if it is desired to assess the change in the impact from space-to-Earth interference (e.g. if all systems in a given region were to increase their modulation to a higher order to achieve greater capacities). Also, the methodology allows for a specific model of the FS deployment characteristics to compute the levels of intra-service interference.

4.2.2 Omni hub

In most cases, the hub antenna gain pattern envelope is circularly symmetrical in the horizontal plane and the gain of the antenna is independent of azimuth for a given angle in the vertical plane (i.e. declination angle). This assumption applies whether the hub antenna is a single omnidirectional antenna or composed of multiple sector antennas. In the case that a single sector antenna is used, the off-axis pattern in both the horizontal and the vertical plane would be required as an input to permit calculation of the gain at any given point.

4.2.3 Subscriber distribution

There are many possible ways to model the distribution of the subscribers throughout a P-MP cell including statistically described distributions such as uniform or Rayleigh, or other user defined distributions. Where possible, the selection of a model may be made through validation based on statistical data concerning actual subscriber locations. Actual data giving the relative position of a subscriber in a P-MP cell may be used when examining real links. A combination of statistical distribution and actual data can also be used.

4.2.4 Level ground

The ground elevation, amsl, throughout the entire cell may be considered to be the same as the ground elevation for the hub. Alternatively, actual data giving the ground elevation for each subscriber position is located in a P-MP cell may be used when examining links on a case-by-case basis.

4.2.5 Subscriber antenna heights

The height of subscriber antennas, agl , may be statistically modelled per Recommendation ITU-R P.1410 if the Rayleigh, σ , height for the city being modelled is known. In the case of a Rayleigh antenna height model, practical considerations should be used in truncating the height at some maximum and minimum values. Actual data giving the height of each subscriber terminal may be used when examining links on a case-by-case basis. A combination of statistical distribution and actual data can also be used.

4.2.6 0% blockage

The hub antenna is assumed to be visible to every subscriber antenna in a P-MP cell and is not blocked from the view by any building upon which other subscriber antennas may be situated even if the randomization employed by a given antenna height model would result in a closer building blocking the view of a more distant subscriber antenna.

4.2.7 No diversity

Every remote subscriber terminal is assumed to be pointed toward the same point and thus no account of a worst-case azimuth exposure is made in siting a subscriber terminal. Only in this way can the impact of GSO orbit intersection with the FS receiving antenna boresight be meaningfully established on the performance of the FS system.

4.2.8 Hub height, cell radius and hub elevation angle bias in P-MP systems

The bias angle of the hub antenna can be optimized so that the maximum gain of the hub is coincident with the most probable height for a subscriber terminal at the maximum distance from the cell centre. Alternatively, the hub elevation bias angle can be user specified. Given that a subscriber at the edge of a P-MP cell may have a height, agl , which varies over a considerable range of values, the hub antenna would have maximum gain toward only one subscriber antenna height at the maximum cell distance. When using a statistical model of antenna height, some subscribers at the edge of a cell may have insufficient margin under clear-sky conditions, in the absence of any space-to-Earth interference. If the hub antenna is biased to point toward the most probable subscriber height, the percentage of subscribers having insufficient margin, under clear-sky conditions can be minimized. The most probable subscriber height is calculated according to the antenna height probability distribution for each antenna height model. The calculation of hub antenna bias angle for optimal hub gain at the edge of the cell is given by the following expression:

$$\varphi_{Hub} = \tan^{-1}((h_{Hub} - h_{sub})/R_{max})$$

where:

h_{Hub} : height of the hub above ground level (m)

h_{sub} : most probable height of the subscriber at distance R_{max} from the hub (m)

R_{max} : maximum distance of a subscriber in a P-MP cell (m).

The most simplistic implementation of this model is for that of a hub having a 360° symmetry. For P-MP cells having individual sectors that need to have a different bias angle in order to more efficiently accommodate their respective subscriber populations, the methodology may be applied

individually to each sector and statistics for the whole cell may be calculated by weighting the results according to the number of subscribers in each sector.

4.3 P-P FS assumptions

4.3.1 Location of FS receiver

In the most simplistic implementation of the methodology, it is assumed that an FS antenna has an equal probability of being located at any azimuth for a given hop distance and elevation angle. Alternatively, when actual data is available, the azimuth and elevation angle of an FS path may be used when examining links on a case-by-case basis.

4.3.2 Maximum hop distance

The maximum possible hop distance depends upon geoclimatic factors as well as FS system design parameters such as designed availability, the C/N threshold for a given level of bit-error ratio (BER) performance and the type of modulation employed. The transmit antenna size, the designed availability, the type of modulation, the receiver noise figure and the channel bandwidth, coupled with the maximum power limit specified in § 4.1 e) will have the effect of limiting the maximum distance.

4.3.3 Minimum/maximum antenna diameter

The methodology can accommodate any size of antenna typically used in shared bands above 17 GHz.

4.3.4 Antenna height models

The same models used for modelling antenna heights for subscribers in P-MP systems can be used for modelling the antenna heights for P-P FS receivers. Given the fact, however, that there is some preferential selection involved in choosing higher buildings upon which to situate antennas for P-P networks, statistical data for antenna heights, as derived from national frequency databases, where available, may be used.

In the case of a P-P implementation of a P-MP system or a star network or a symmetrical P-P network, the same models used for modelling antenna heights for subscribers in P-MP systems can be used for modelling the antenna heights for star configured P-P FS receivers.

Note that the difference in the thresholds associated with long-term and short-term performance varies depending upon which type of modulation is being used. Links utilizing higher modulation levels with higher C/N thresholds will require higher transmit powers for links of a given distance and channel bandwidth. This fact coupled with the maximum power limit in any radio-frequency channel specified in § 4.1 e) will have the effect of limiting the maximum distance of a link for a given availability or reducing the availability achievable for a given distance.

5 Clear-sky atmospheric attenuation

5.1 Geoclimatic parameters and applicable ranges

If it is desired to test the sensitivity of specific FS system parameters and the associated geoclimatic factors with respect to interference susceptibility, the methodology can be applied parametrically over a wide range of system parameters and geoclimatic factors.