RECOMMENDATION ITU-R M.1319-1*

THE BASIS OF A METHODOLOGY TO ASSESS THE IMPACT OF INTERFERENCE FROM A TIME DIVISION MULTIPLE ACCESS/FREQUENCY DIVISION MULTIPLE ACCESS (TDMA/FDMA) MOBILE-SATELLITE SERVICE (MSS) SATELLITE SYSTEM OPERATING IN THE 2 GHz RANGE ON THE PERFORMANCE OF LINE-OF-SIGHT FIXED SERVICE RECEIVERS**

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

(1997-2000)

The ITU Radiocommunication Assembly,

considering

a) that the frequency bands 2 170-2 200 MHz in all Regions and 2 160-2 170 MHz in Region 2 are allocated to the MSS (space-to-Earth) and the FS on a co-primary basis;

b) that transmissions from MSS satellites could cause unacceptable interference to line-of-sight FS receivers operating in these bands;

c) that interference involves time-varying phenomena such as interference geometry, propagation conditions, and MSS traffic;

d) that simulation is the most common way to evaluate such interference;

e) that the impact and acceptability of such interference in most cases can be assessed in detailed bilateral coordination by studying via computer simulation the C/N, C/I and $C/(N + I)$ statistics as described in Recommendation ITU-R M.1143;

f) that there is a need as called for in Resolution 716 (Rev.WRC-2000) to develop and provide to administrations the necessary tools in a timely manner to assess the impact of interference in the detailed coordination of mobile-satellite systems;

g) that assistance in using such tools is particularly needed by administrations in developing countries,

recommends

1 that the methodology in Annex 1 be used as a basis for developing computer simulation tools for use in detailed bilateral coordination pursuant to RR No. S9.11A between concerned parties to enable a detailed assessment of the impact of interference from a TDMA/FDMA MSS satellite system in the 2 GHz MSS allocations to analogue and digital line-of-sight FS systems, taking into account the specific characteristics of the MSS and FS systems concerned (see Notes 1, 2 and 3).

NOTE 1 – The application of the methodology in this Recommendation will require the development of algorithms or calculation procedures to address the implementation of the considerations described. The use or adaptation of these algorithms or procedures in any bilateral coordination would be subject to agreement by the concerned parties.

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

** Further study is needed for MSS networks using code division multiple access (CDMA).

NOTE 2 – In countries where a large number of FS systems are in operation, it may be sufficient to apply the analysis to a representative set of existing FS systems, using actual FS parameters, especially taking into account those FS systems that are likely to be most sensitive to interference. The most sensitive FS systems are usually those oriented close to the worst-case azimuth direction; this direction can be established based on the orbital characteristics of the MSS system. However, this is a matter that will require agreement between the concerned parties.

NOTE 3 – In the case of GSO MSS systems the calculations are significantly simplified, since there is no need to simulate the orbital mechanics of the MSS constellation, however the potential of interference from multiple GSO MSS satellites may need to be considered when evaluating the impact of interference.

ANNEX 1

1 Introduction

Sharing between MSS and FS involves time varying phenomena such as interference geometry, propagation conditions, etc. Simulation is the most common way to evaluate interference between MSS and FS systems. The output of such simulations is typically in the form of C/I, C/N and $C/(N+I)$ statistics presented usually as a cumulative distribution function, for example as described in Recommendation ITU-R M.1143 (Annex 3).

The relevant baseband performance objectives for a given digital and analogue FS system can generally be translated into a required $C/(N+I)$ (see Note 1 below). For example for a digital FS system, the baseband specification is usually a bit-error ratio (BER) requirement not to be exceeded for a certain percentage of time. The baseband BER requirement can, from reference curves such as those provided in Recommendation ITU-R SF.766 or actual modem specifications, be translated into a required E_b/N_0 value, which in turn can be translated into a $C/(N+I)$ requirement at the input to the receiver. In a similar way the baseband requirements for analogue frequency division multiplex/frequency modulation (FDM/FM) and TV-FM FS systems in terms of total baseband noise or baseband S/N can be translated into a $C/(N+I)$ requirement at the input to the receiver.

NOTE 1 – While the performance of radio-relay systems should, in principle, be related to a quantity that can be described as $C/(N+I)$, the validity of such relationships depends on having the appropriate value for the total equivalent system noise, N.

These equivalent radio-frequency performance objectives can be plotted on the cumulative distribution plots of $C/(N+I)$ and compared with the simulation curves of C/N and $C/(N+I)$ to assess if the interference from MSS satellites is acceptable or not.

The method described herein, although it requires significant computer simulation is relatively straightforward to implement in software, since all calculations and comparisons are undertaken in the radio-frequency domain. The methodology herein should generally be used in the detailed coordination phase between administrations, when coordination is required and triggered in application of RR No. S9.11A in order to determine whether or not the interference can be accepted in the context of actual FS system information and the relevant ITU-R performance and availability objectives.

When assessing an MSS network using TDMA/FDMA, the aggregate interfering signal power within a reference bandwidth of 1 MHz (or less) for fixed stations should be assumed to be generated only by the individual network under consideration, under the assumption that the emissions of these MSS systems would not be interleaved within any 1 MHz segment of spectrum.

2 Methodology

2.1 Generation of target $C/(N + I)$ requirements for FS system

The relevant baseband performance objectives for a given digital and analogue FS system can generally be translated into a required $C/(N + I)$ as indicated below.

Recommendation ITU-R F.393 specifies performance requirements for analogue FDM/FM FS systems in terms of total baseband noise in a given telephone channel for various percentages of time. These baseband requirements for the reference circuit can be translated through the standard C/N versus S/N FM equation into equivalent $C/(N + I)$ requirements.

Recommendation ITU-R F.555 specifies performance requirements for analogue TV/FM FS systems in terms of required S/N in a given video channel for various percentages of time. These baseband requirements for the reference circuit can be translated through the standard C/N versus S/N FM equation into equivalent $C/(N + I)$ requirements.

Recommendations ITU-R F.634, ITU-R F.695, ITU-R F.696, ITU-R F.697 and ITU-R F.557 specify network performance objectives (NPO) (error performance objectives and availability) for the existing digital systems in high, medium and local grade of the integrated services digital network (ISDN) in terms of required BER for various percentages of time. These baseband requirements for the reference circuit can be translated through standard reference curves provided in Recommendation ITU-R SF.766 into equivalent $C/(N + I)$ requirements.

Generation of target $C/(N + I)$ requirements for new digital FS systems should be based on Recommendations ITU-R F.1092 and ITU-R F.1189 and the subsequent revisions.

The actual FS receiver modem characteristics should be used, where available, in the translation from baseband performance objective to $C/(N + I)$. Where this information is not available, theoretical characteristics from Recommendation ITU-R F.766 can be used, and an implementation margin should be agreed between the parties.

2.2 Generation of C/I, C/N and $C/(N + I)$ statistics for FS system

Step 1: Calculation at each time step of received carrier level, C, at each receive FS station in a multi-hop FS route with multipath fading taken into account on that particular hop.

a) The received carrier level, C, at each station is calculated from the associated transmit FS station e.i.r.p., the free space loss corresponding to the particular path length and multipath fading propagation loss applicable to that particular hop, the receive FS antenna gain and receive FS feed losses.

b) Multipath fading is taken into account using a random fade depth predictor, whose output is consistent with the statistical distribution derived from the Recommendation ITU-R P.530 multipath fading model. The random fade predictor generates fade depths at each relevant time step in the simulation, such that the statistical distribution of fades generated is consistent with the distribution predicted for that path. The fade depth predictor requires information on the path length, path inclination, frequency and a number of geoclimatic factors specified in the above Recommendation appropriate to the particular geographical location of the FS hop. The time step specified for the fade depth predictor can in general be different from that required for interference assessment, since the latter is usually a more slowly varying process. For typical 2 GHz digital FS systems it is normally not necessary to include an allowance for other types of fading.

c) In some cases, FS hops may not have first Fresnel Zone clearance. In such cases, it is appropriate to add an additional loss factor to the free space loss and multipath fading loss. This factor should be based on measured data, where available.

d) In cases where statistically valid measured propagation data is available for individual FS hops, this data could be used in place of the propagation models given in a), b) and c) above, on agreement between the concerned parties. It may be possible in some cases, e.g. based on measured data, to take into account diurnal and/or seasonal variations in multipath fading propagation behaviour.

e) Consideration should be given to including in the total noise, *N*, an allowance for intra-system and intra-service interference within the FS, as well as contributions from other co-primary (non-MSS) services (see Note 1 below). The value of this allowance should be determined by the concerned parties. It should be noted that Recommendation ITU-R F.1094 specifies that the maximum allowable value of error performance and availability degradation to digital FS systems due to emissions from services sharing frequencies on a primary basis should not exceed 10% of NPO.

NOTE 1 – Included in the total equivalent noise, in addition to the contributions to account for thermal noise and receiver noise for the receivers, are factors to account for intra-service interference and additional factors depending on the type of FS system. For digital systems, factors may be needed for receiver implementation imperfections where ideal modem characteristics are used. For analogue FM radio-relay systems used for telephony, factors are needed to account for intermodulation distortion noise and for contributions from such systems components as multiplexers/demultiplexers, and entrance links. For analogue radio-relay systems used for television, consideration of additional factors may be needed.

Step 2: Calculation at each time step of the interfering signal power, *I*, at each receive FS station in a multi-hop FS route due to each interfering TDMA/FDMA MSS carrier within the FS carrier occupied bandwidth from each spot beam of each visible MSS satellite, taking into account MSS satellite spot beam, receive FS antenna discrimination, MSS satellite spot beam power/traffic loading and frequency plans.

a) The orbital positions of each MSS satellite can be predicted by an orbit predictor taking into account the actual or forced precession of the orbits. The orbital position of a GSO satellite is fixed at a given longitude in the geostationary orbit.

b) The free space loss on the interfering path from each visible MSS satellite to each visible FS station can be computed knowing the range vector magnitude.

c) Each MSS satellite spot beam on each MSS satellite can be characterized by reference patterns or by actual measured or predicted antenna patterns.

d) For each MSS satellite spot beam per satellite, the satellite spot beam antenna gain towards each FS station can be computed knowing the instantaneous relative position of the MSS satellite with respect to the FS station and the pointing direction of the particular satellite spot beam;

e) Each receive FS antenna can usually be described by the Recommendation ITU-R F.1245 pattern or by the actual antenna pattern or formula. In the case of GSO MSS systems, Recommendation ITU-R F.699 may be more appropriate.

f) For each receive FS station the receive antenna gain towards the visible satellite can be computed knowing the instantaneous relative position of the MSS satellite with respect to the FS station and the pointing direction of the particular FS antenna.

g) Based on predicted realistic diurnal and geographic subscriber traffic distributions and system dependant satellite spot beam traffic allocation, the total traffic carried in each spot beam of each MSS satellite can be identified by the MSS party using proprietary or representative algorithms. Based on the system dependant internal frequency reuse constraints for the MSS satellite system, the nominal frequency plan applicable to each spot beam of each MSS satellite can similarly be identified if necessary.

h) For each receive FS station, the interfering power from all TDMA/FDMA MSS carriers in any spot beam of any visible MSS satellite which overlaps the FS occupied carrier bandwidth can be accumulated taking into account MSS satellite spot beam antenna discrimination, FS antenna discrimination and range loss. It may suffice to take into account MSS satellite spot beams whose boresight is within a certain off-axis angle from the vector to the victim FS station.

i) Since MSS satellite systems and FS systems will usually employ circular and linear polarizations respectively, it is relevant to consider the available polarization discrimination. Specifically if the MSS spot beam pointing vector and the receive FS antenna boresight vector are within a specified angular range (typically within the 3 dB beamwidths of both antennas), a polarization advantage can be computed taking into account information on the actual cross-polar patterns of the MSS satellite spot beam and FS antennas or alternatively Recommendation ITU-R F.1245 can also be used for this purpose. In the case of GSO MSS systems, Recommendation ITU-R F.699 may be more appropriate.

Step 3: Calculation of the total equivalent noise power N – The thermal noise at each FS receive station can be calculated from knowledge of the FS system noise temperature taking into account the receiver noise figure, the feed losses and the antenna noise temperature.

Step 4: Calculation at each time step of C/I (due to all relevant interfering MSS active carriers from each relevant spot beam of each visible MSS satellite), C/N and $C/(N+I)$ at each receive FS station.

Step 5: Calculation at each time step of C/I, C/N and $C/(N+I)$ by inverse addition of the C/N, C/I and $C/(N+I)$ values calculated in Step 4 at each FS receive station, and calculation of the overall C/N, C/I and $C/(N+I)$ at the terminal FS receive station in the particular FS system.

Step 6: The above steps are repeated for each time step over a statistically valid period consistent with a full or equivalent orbital cycle period of the MSS satellite constellation and a representative period for the FS multipath fading behaviour. (In the case of GSO satellites this will be equal to the representative period for multipath fading.) One method to check for statistical validity is to ensure that statistics at the required level are not significantly influenced by additional time steps. Application of the additional methods of Recommendation ITU-R F.1108 may also be useful for this evaluation.

Step 7: If there are multiple FS systems in the country concerned, which may be affected by the MSS satellite system, it may be possible to carry out Steps 1 to 6 above in parallel for each such FS system during the simulation.

Step 8: Finally, for each FS system considered, the cumulative distribution of C/I, C/N and $C/(N+I)$ can be plotted. The C/N (in the absence of interference) and $C/(N+I)$ curves can then be compared with the relevant ITU-R target performance objectives.

NOTE 1 – For non-GSO MSS satellites, the time step chosen for the interference assessment should be sufficiently small to allow for multiple samples of non-GSO MSS satellite visibility within the main-beam of the particular FS stations to be considered. The selection of appropriate time step is a function of the orbital parameters of the non-GSO MSS satellite constellation, the location of the FS stations and the FS antenna beamwidths.

NOTE 2 – For non-GSO MSS satellites, the simulation period should be sufficiently long to allow for a complete cycle period of the non-GSO MSS satellite to be considered. For consideration of the effects of the uniformity of interference from a non-GSO MSS satellite constellation in a month, the guidance of Annex 5 to Recommendation ITU-R F.1108 may be useful. Taking these factors into account, for non-GSO MSS satellite constellation which exhibit a relatively slow orbital precession, it may be preferable to establish a forced precession rate to allow for simulation of the complete cycle period within a reasonable elapsed simulation time.

NOTE 3 – FS performance objectives specified in all the relevant ITU-R Recommendations are only applicable during available time, where availability is defined by the relevant ITU-R Recommendations. During periods of propagation induced unavailability, it is not relevant to consider the impact of interference. However this factor can be ignored in the present methodology if the interference from the MSS system allows the FS system to meet all of its requirements for ITU-R error performance objectives.

NOTE 4 – Convolution of the C and I distributions with N can also be used to generate a $C/(N+I)$ distribution for a single hop FS system. For non-GSO MSS, see also the Annex 6 of Recommendation ITU-R F.1108.

2.3 Consideration of analysis

Step 1: If the performance objectives in the applicable ITU-R Recommendations are met for each FS system considered in the presence of the incremental performance degradation induced by interference by MSS satellite system, it should facilitate satisfactory completion of the technical aspects of frequency coordination.

Step 2: In some cases, it may be necessary to conduct further studies to determine if interference from MSS satellite system is acceptable or not, prior to consideration of other burden sharing measures.