



Recommendation ITU-R S.2029
(12/2012)

**Statistical methodology to assess time-
varying interference produced by
a geostationary fixed-satellite service
network of earth stations operating with
MF-TDMA schemes to geostationary
fixed-satellite service networks**

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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 S.2029

**Statistical methodology to assess time-varying interference produced by
a geostationary fixed-satellite service network of earth stations
operating with MF-TDMA schemes to geostationary
fixed-satellite service networks**

(Question ITU-R 208/4)

(2012)

Scope

This Recommendation provides a statistical methodology to assess time-varying interference resulting from a geostationary network of earth stations, operating with MF-TDMA schemes, over a geostationary-satellite orbit fixed-satellite service network. The methodology considers the potential interference to another GSO FSS network. Furthermore, the methodology can be used to adjust the power levels of the interfering terminals such that the performance objectives of the interfered-with satellite network are not impacted.

The ITU Radiocommunication Assembly,

considering

- a) that FSS GSO satellites are well suited to provide broadband communication applications including Internet and data services;
- b) that satellite networks use a variety of network topologies and multiple access schemes, including the multi-frequency time division multiple access (MF-TDMA) scheme;
- c) that through the use of efficient modulation and coding, higher satellite e.i.r.p. levels, and other techniques, some networks can support full mesh (point-to-point) connectivity with small aperture terminals;
- d) that it is necessary to protect networks of the FSS from any potential interference from these terminals;
- e) that it would be useful to have methodologies to assess the time-varying interference from a GSO FSS network to another GSO FSS network;
- f) that it would be useful to have methodologies for assessing interference levels to satellite networks resulting from earth stations operating with MF-TDMA schemes;
- g) that many of the technical characteristics of these networks which affect performance and orbit spectrum/utilization have time-varying characteristics which are best modelled by stochastic processes,

noting

- a) that maximum permissible levels of inter-network interference from GSO networks to GSO/FSS networks operating in the same frequency band are provided in Recommendation ITU-R S.1323;
- b) that maximum permissible levels of inter-network interference and the methodology for determining this interference, from non-GSO systems and to GSO/FSS networks operating in the same frequency band are provided in Recommendation ITU-R S.1323;
- c) that time invariant interference is typically estimated using the $\Delta T/T$ method, described in Recommendation ITU-R S.738;

d) that methodologies to estimate the off-axis e.i.r.p. density levels and to assess the time-varying interference towards adjacent satellites resulting from pointing errors of a vehicle mounted earth station are provided in Recommendation ITU-R S.1857,

recommends

- 1 that the methodology given in the Annex should be used to assess the time-varying interference due to multiple earth stations operating in a MF-TDMA scheme;
- 2 that the methodology provided should be used to determine the off-axis emission levels of the interfering earth stations such that these satisfy the performance objectives of the interfered-with satellite network;
- 3 that the methodology provided should be used so that the type of MF-TDMA networks described in this Recommendation would not create interference to other FSS networks operating in the same frequency bands beyond the level accepted by administrations;
- 4 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – The methodology given in the Annex provides a statistical approach to assess the potential interference impacts of an MF-TDMA network to a neighbouring co-frequency GSO FSS network.

NOTE 2 – The parameters and the examples provided in the Annex represent a hypothetical system that operates in the 20/30 GHz frequency band. However, the methodology may also be used for other frequency bands after appropriate modifications of some parameters.

NOTE 3 – The methodology of this Recommendation does not apply to networks operating with code division multiple access (CDMA) schemes.

NOTE 4 – To verify that the mathematical model described in the methodology truly represents the time-varying characteristics of an MF-TDMA network, it may be useful to obtain the statistical characteristics of operational networks.

NOTE 5 – The apportionment of short-term interference for the MF-TDMA GSO/FSS networks considered in this Recommendation may be mutually agreed through the process of coordination.

NOTE 6 – The time allowance and the short-term interference criteria for GSO/FSS networks may be a subject for further study.

Annex

Statistical methodology to assess time-varying interference produced by a geostationary fixed-satellite service network of earth stations operating with MF-TDMA schemes to geostationary fixed-satellite service networks

1 Introduction

In recent years, the demand for satellite-based two-way Internet services has increased significantly. These services, especially for residential and small business users, are provided using small aperture satellite terminals. Typically, a single satellite network may consist of a large number of small aperture terminals deployed over a wide geographical area. According to the location within the

satellite footprint, the varying weather conditions, and the user's data rates, these terminals may operate on a range of aperture sizes and may require different transmit power levels. To utilize network resources efficiently, these networks may employ time- and frequency-division multiple access methods. A particular characteristic of small aperture terminals is that they have large antenna beamwidths and hence may produce uplink interference towards adjacent satellites if the transmit power levels are not adjusted properly. Additionally, some small terminals mounted on air/sea vessels, trains, or ground vehicles as well as stationary terminals may produce antenna pointing errors which may result in potential interference that must be mitigated. These combined effects contribute to a time-varying interference pattern from the network of terminals to a victim receiver in another satellite network.

This Annex presents a statistical approach to determine the interference to a GSO network from another GSO network consisting of multiple terminals operating using a time-division multiple access scheme and antenna pointing errors. The Annex discusses a long-term interference criterion and criteria to satisfy the short-term performance objectives, it provides some examples to illustrate the impacts on the neighbouring satellite network, and it presents a step-by-step approach on how to compute the resulting interference. The methodology presented may be useful to determine the off-axis emission levels of the interfering terminals such that these satisfy the short-term and long-term performance objectives of the victim satellite system.

2 Long- and short-term components of interference

The interference signal at the victim receiver consists of signals that belong to a large number of transmit terminals from a single interfering network that operate using a time-division multiple access protocol. The terminals may employ antenna apertures of different sizes and may transmit at different power levels depending on their location within the footprint of the satellite beam. Additionally, these terminals may have small antenna pointing errors. Therefore, when the observation interval is sufficiently large to contain transmissions from several interfering terminals, the interference level at the victim receiver is time-varying.

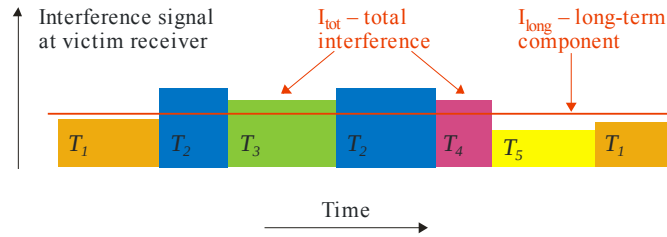
In such cases, for illustrative purposes, the interference signal at the victim receiver, I_{tot} , may be expressed as the sum of a long-term interference component, I_{long} , and a short-term interference component, I_{short} , so that $I_{tot} = I_{long} + I_{short}$. The long-term interference component is constant over short time intervals but it may exhibit small variations when observed over long time intervals (of the order of several minutes). These variations are statistical in nature resulting from the slow changing characteristics of the transmit signals. On the other hand, the short-term interference component is due to the transmissions from different terminal types and may vary over very short time intervals, for example over fractions of a second. Note that this short-term and long-term interference components are used only for illustrative purposes; interference analysis is carried out for the total interference.

Figure 1 shows the interference levels at the victim receiver due to transmissions from Terminals T_1 , T_2 , T_3 , T_4 and T_5 . In general, as shown in this figure, the interference levels and the transmission durations depend on the particular terminal. The long-term component shown here represents the average level of the interference and the short-term interference component is given by the difference between the total interference and this long-term interference component.

To quantify and limit the effects of interference, this Annex gives methods for assessing and limiting the long-term interference, short-term interference, and total interference. Specifically, long-term interference and the criteria to satisfy the short-term performance objectives are given to limit the effects of interference at the victim receiver.

FIGURE 1

Interference observed at the victim receiver due to time-division multiple access transmissions from Terminals T_1 , T_2 , T_3 , T_4 and T_5



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3 Long-term interference criterion

Assessment of time invariant interference is typically carried out using the $\Delta T/T$ method, for example as described in Recommendation ITU-R S.738. In order to make use of a similar approach consider the hypothetical situation when the interference level at the victim receiver is not time-varying: that is the e.i.r.p. density levels at the terminals are adjusted so that the interference level seen at the victim receiver is given by long-term interference level, I_{long} . Also, in this case the terminals do not produce antenna pointing errors. The long-term interference criterion in this case is expressed in terms of the $\Delta T/T$ ratio as:

$$\left(\frac{\Delta T}{T}\right)_{long} = \frac{\tilde{I}_{long} / k}{\Theta_v + \gamma_v \Theta_v^s} \quad (1)$$

where $\tilde{I}_{long}$ is defined as the ensemble-averaged interference power spectral density computed in a bandwidth of W_{long} , k is the Boltzmann constant, Θ_v is the victim receiver noise temperature referred to the output of its antenna, Θ_v^s is the noise temperature at the receiver of the victim satellite referred to the output of its antenna, and γ_v is the transmission gain from the output of the victim satellite's input antenna to the output of the victim receiver's antenna.

Clearly, when the ensemble-averaged power of the interference is a constant, the interference power-to-noise ratio considered in this hypothetical case is time invariant.

However, in practice, rather than the ensemble-average value the time-averaged value of the long-term interference component is generally available. This time average value may exhibit small variations when computed over different time intervals. This time-averaged value, $\tilde{I}_{long}$, when computed over the long-term time interval of duration T_{long} may exhibit variations because the underlying interference is a statistical process. Additionally, statistical characteristics of the terminals may change during this interval resulting in small variations about this average value. These variations can be limited by imposing constraints on the cumulative distribution function (CDF) of the variable $(\Delta T/T)_{long}$ as follows:

$$\Pr\left\{\left(\frac{\Delta T}{T}\right)_{long} > X\%\right\} < p_{long}\% \quad (2)$$

where X , p_{long} and T_{long} are system parameters.

For illustrative purposes, Recommendation ITU-R S.523-4 specifies an averaging interval of 10 min for computing the interference to PCM encoded Telephony systems. Moreover, Annex 1 of Recommendation ITU-R S.1432-1 specifies the maximum levels of interference-to-noise ratio (I/N) that may be exceeded in any month as: $(I/N) > 0$ dB for 0.005% of any month;

$(I/N) > -2.4$ dB for 0.03% of any month; $(I/N) > -10$ dB for 20% of any month; and $(I/N) > -12$ dB for 100% of any month.

4 Criteria to satisfy short-term performance objectives

In the preceding section, limits were imposed on the long-term interference. In this section, a criterion is presented to limit the total interference so that it meets the short-term performance objectives of the victim receiver. The total interference may exhibit variations over a few milliseconds. According to Recommendation ITU-R S.1323-2, victim links should contain sufficient link margins to overcome degradations due to the combined effects of propagation and time-varying interference. Degradations due to propagation effects should not account for more than 90% of the time allocated in the short-term performance objectives. Additionally, this Recommendation states that time-varying interference “should be responsible for at most 10% of the time allowance for the BER (or C/N value) specified in the short-term performance objectives of the desired network and corresponding to the shortest percentage of time (lowest C/N value).” In this Annex, a criterion similar to the above is presented to derive an acceptable limit for the short-term interference.

The short-term performance objectives are usually stated in terms of the bit-error-rate (BER) levels or the carrier-to-noise (C/N) ratio levels that may not be degraded for a specified time period. For example, for a given C/N ratio and time percentage pairs, $((C/N)_j, p_j\%), j = 1, 2, \dots, J$, the C/N ratio may be less than $(C/N)_j$ for only $p_j\%$ of the time of any month. Similar to considering o) in Recommendation ITU-R S.1323-2, let us consider propagation effects to result in degradation of the link for at most $(1 - p_{short}/100) \times p_j\%, j = 1, 2, \dots, J$, of the time of any month where p_{short} represents the fraction of the time allowance specified in the short-term performance objective allocated to short-term interference (for example, $p_{short} = 10$). Noting that the long-term interference is limited as proposed in the previous section, the proposed criteria to limit the short-term interference and comply with the short-term performance objectives are expressed as:

- In the presence of propagation effects and the long-term interference, the C/N ratio should not be less than $(C/N)_j$ for more than $(1 - p_{short}/100) \times p_j\%, j = 1, 2, \dots, J$, (for example, $p_{short} = 10$) of the time of any month.
- In the presence of short-term interference, the C/N ratio should not be less than $(C/N)_j$ for more than $(p_{short}/100) \times p_j\%$ of the time of any month, where j corresponds to the smallest $(C/N)_j$ value.
- In the presence of propagation effects and total interference, the C/N ratio should not be less than $(C/N)_j$ for more than $p_j\%, j = 1, 2, \dots, J$, of the time of any month.

Note that in order to comply with the above conditions, the victim link should contain a sufficient link margin to satisfy condition a) and the e.i.r.p. density level of the interferer should be limited to satisfy conditions b) and c). Also note that according to condition c), the combined impact of propagation degradation and the total interference is such that C/N ratio still meets the short-term performance objective.

4.1 Expressing the C/N ratios

The C/N ratio under clear-sky conditions, considering the long-term interference component can be expressed as:

$$(C/N)_{CS} = \frac{C_{CS}}{N_{CS} + I_{long}}$$