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Radiocommunication Study Group 5

DRAFT REVISION OF RECOMMENDATION ITU-R F.1107-1

Probabilistic analysis for calculating interference into the fixed service from satellites occupying the geostationary orbit

Summary of the draft revision

This revision includes removal of Annex 1 on the method of developing sharing criteria for analogue fixed service systems, its consequential changes, addition of the scope and updating of old information in the text.

DRAFT REVISION OF RECOMMENDATION ITU-R F.1107-1*

Probabilistic analysis for ~~calculating~~ assessing interference into the fixed service from satellites ~~occupying~~ using the geostationary orbit

~~(Question ITU-R 223/9)~~

(1994-2002)

Scope

This Recommendation provides methods for assessing sharing criteria for interference from satellites using the geostationary orbit into digital fixed wireless systems. Annex 1 provides the approach to calculate interference into digital systems, and provides an outline of a calculation methodology and includes examples and a software model to implement the methodology.

The ITU Radiocommunication Assembly,

considering

~~a) that the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) has allocated to a number of satellite services, operating in the geostationary orbit, spectrum that is also allocated to the fixed service (FS);~~

a~~b~~) that emissions from space stations operating in the geostationary orbit and sharing the same spectrum may produce interference in receiving stations of the fixed service (FS);

b~~c~~) that it may be impractical to coordinate between the many terrestrial stations and the many space stations, and that, therefore, sharing criteria should be established to preclude the need for detailed coordination;

c~~d~~) that in devising such sharing criteria, account needs to be taken of the operational and technical requirements of networks in the satellite service as well as of the requirements of the FS and measures available to them;

d~~e~~) that it has been determined that a probabilistic basis for developing sharing criteria results in a more efficient use of the spectrum than from criteria developed using worst case analysis;

e~~f~~) that it is difficult and burdensome to assemble sufficient statistically accurate information about real existing and planned terrestrial and satellite system stations;

f~~g~~) that computer simulations of FS and satellite services operating in the geostationary orbit can generate statistically accurate information suitable for determining sharing criteria for a wide variety of sharing scenarios,

recommends

1 that information derived from computer simulations of FS and satellite services operating from the geostationary orbit and using the same spectrum may be acceptable for developing sharing criteria;

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4~~ (WP 4-9S)~~, 6~~ (WP 6S)~~ and~~,~~ 7~~ and 8 (WP 8D)~~.

~~2 that when deriving information for developing sharing criteria the material in Annex 1 should be taken into account;~~

~~3~~**2** that when developing sharing criteria with respect to digital systems in the FS, the material in Annex ~~2~~1 to assess interference from FS into digital FS should be taken into account.

(Delete Annex 1)

~~ANNEX 1~~

~~Method of developing criteria for protecting the fixed service from emissions of space stations operating in the geostationary orbit~~

(Renumber Annex 2 and its two Appendices)

ANNEX ~~2~~1

Information for assessing the interference into digital fixed service systems from emissions of space stations operating in the geostationary orbit

1 Introduction

~~Annex 1 to this Recommendation describes a method of developing criteria for protecting mainly long-haul analogue FS systems. However, currently most FS systems employ digital modulation. Many basic elements described in Annex 1 are applicable to the method of developing criteria for protecting these FS systems.~~ This Annex presents additional information that is necessary for assessing the interference into such FS systems employing digital modulation.

The methodology provides statistics for both the interference-to-noise ratio (I/N) values of individual stations and the fractional degradation of performance (FDP) values of routes. The methodology employed for assessing the route FDP as described in Section 3 is only valid when the I/N of a receiver station of that route is not so large as to drive the receiver into a non-linear range. The user is therefore encouraged to assess the I/N per receiver statistics, as described in Section 2, before assessing the FDP statistics on a multihop basis, as described in Section 3.

This Annex applies to digital FS systems where multipath fading generally predominates and does not apply to those systems where precipitation attenuation generally predominates.

2 Station-by-station analysis

~~In the case of analogue FS systems, the interference from geostationary satellites is evaluated in terms of channel interference noise in pW (see Appendix 1 to Annex 1). However, i~~In the case of digital point-to-point (P-P) and point-to-multipoint (P-MP) FS systems, it is appropriate to evaluate interference in terms of FDP as defined for the time varying interference from non-geostationary satellites in Annex 3 to Recommendation ITU-R F.1108. As an analogy, when there is only one FS station, FDP_{hop} due to interference entries from geostationary satellites can be defined at the input of a receiver as follows, taking into account that the interference level is almost time-invariant:

$$FDP_{hop} = \frac{I}{N_T} \qquad (~~14~~1)$$

where:

I: aggregate interference (W/MHz) from visible satellites into the FS receiver;

N_T: receiver thermal noise (W/MHz).

A methodology proposed in Appendix 2 of this Annex may be used for evaluating the *I*/*N* statistics.

When it is necessary to determine the effect of interference on digital FS receivers employing diversity, a different formula may be more appropriate for evaluating FDP_{hop} as described in Annex 4 to Recommendation ITU-R F.1108.

3 Multi-hop P-P FS systems

For digital FS systems with *n* hops operating at frequencies where multipath fading generally predominates and acknowledging that, in general, the performance objectives for multi-hop P-P FS systems are specified on a route basis, two probabilistic assessment methods may be employed. One is described in Section 2 and another is to evaluate the FDP for the route defined as the ratio of total interference power to total noise power for one direction of a route as follows:

$$FDP_{route} = \frac{\sum_{k=1}^{n}(I_k)}{n \times N_T} \qquad (~~15~~2)$$

where I_k is the aggregate interference falling into the *k*-th receiver from visible satellites.

It should be noted that equation (~~15~~2) is based on the assumptions that:

– the digital signal is regenerated at each repeater; and

– the fading has Rayleigh characteristics.

It should also be noted that, for evaluating FDP_{route} for digital FS systems employing diversity, an appropriate formula different from equation (~~15~~2) should be used. Further studies are required.

Although there are a variety of fading types, Rayleigh fading is regarded as the most severe fading encountered in line-of-sight paths and is a determining factor in the evaluation of FS system performance. The feature of Rayleigh fading is that the probability of 10 dB deeper fading, for example, becomes smaller by a factor of 1/10. Therefore, if there exists a time-invariant interference in a hop whose level is equal to the thermal noise level (*I*/*N* = 0 dB), the probability of severely errored seconds (or the probability of unavailable time) will become twice as much as that of the case where there is no interference.

The FDP concept has certain limitations, the most important assumption is that the FS receiver operation remains within a linear response range. If there is an exceptionally high level of interference so that the FS receiver operation falls into a non-linear response range, the FDP concept will not apply or will underestimate the effect of interference (see paragraph following equation (16) in Annex 3 to Recommendation ITU-R F.1108). However, as long as the FS receiver operation is maintained within a linear response range, equation (~~15~~2) is valid for multi-hop FS digital systems.

The discussion in the preceding section does not result in a conclusion that only FDP should be evaluated on a route basis. Station basis evaluation of FDP will be also useful for understanding the effects of interference.

A typical hop distance of long haul systems ~~in Appendix 1 to Annex 1~~ is assumed to be 50 km, but a shorter hop distance may be appropriate for short haul systems, depending on various factors including the operating frequency and propagation effects. For example, in the case of an operating frequency in the 1-3 GHz range, random selection between specified limits (e.g. between 10 and 30 km) may be appropriate as typical hop distances.

FS routes under survey should be selected according to the Monte Carlo simulation approach~~, as described in Appendix 1 to Annex 1 to this Recommendation~~ with the route starting point randomly selected within a user specified test box identified by latitude and longitude limits.

In performing route analysis for digital systems subject to multipath fading, it may not be necessary that each individual hop meets the *I*/*N* criterion. The overall route performance, however, must meet the fractional degradation of performance criterion. This issue is explained below.

Where multipath is the dominant fade mechanism, Recommendation ITU-R P.530 relates the probability of an outage on a hop *P*(*hop outage*) to the link thermal fade margin (TFM):

$$P(hop\ outage) = K \cdot d^{3.6} \cdot f^{0.89} \cdot (1 + |h_r - h_e|/d)^{-1.4} \cdot 10^{-TFM/10}$$

where:

K: geoclimatic factor

d: link length (km)

f: frequency (GHz)

h_r and h_e: transmit and receive antenna heights (metres above sea level or another common reference)

TFM: thermal fade margin on a hop (dB)

$$TFM = 10 \log\left(\frac{C}{N_T}\right) - CNC$$

where:

$10 \log\left(\frac{C}{N_T}\right)$: unfaded carrier-to-noise ratio (*C*/*N*) (dB)

CNC: value of *C*/*N* at which the performance criterion is just met (dB).

Setting

$$K \cdot d^{3.6} \cdot f^{0.89} \cdot (1 + |h_r - h_e|/d)^{-1.4} \cdot 10^{-CNC/10} = \gamma$$

Then:

$$P(hop\ outage) = \gamma \cdot N_T/C$$

Thus

$$P(hop\ outage\ before\ satellite\ interference) = \gamma \cdot N_T/C$$

$$P(hop\ outage\ after\ aggregate\ satellite\ interference) = \gamma \cdot (N_T + I)/C$$

where C, N_T and I are in consistent power units.

If it is assumed that:

– each hop is designed to have a similar nominal probability of outage before satellite interference; and

– hop fades are independent and sufficiently rare that the outage probabilities may be added,

then the net nominal probability of outage for the route is:

$$P(route\ outage) = \Sigma\ (P(hop\ outage))_{number\ of\ hops\ in\ route}$$

Thus, the fractional increase in the probability of a route outage due to a degraded fade margin on each hop within the route is simply:

FDP(*route outage*)

$$= \frac{P(route\ outage\ with\ interference) - P(route\ outage\ without\ interference)}{P(route\ outage\ without\ interference)}$$

$$= \frac{\sum\ (\gamma \cdot (N_T + I)/C) - \sum\ (\gamma \cdot N_T / C)}{\sum\ (\gamma \cdot N_T / C)}$$

$$= \frac{\sum\ I}{\sum\ N_T}$$

i.e. the route FDP is the total route interference power divided by the total route noise power:

$$= \frac{\sum\ I}{n \cdot N_T} \qquad \text{as a power ratio}$$

$$= 100\ \frac{\sum\ I}{n \cdot N_T} \qquad \%$$

Thus the FDP approach for the assessment of the impact of interference on a FS route and the usage of percentages (rather than dB) is appropriate.

In P-MP systems, most links are single hop therefore equation (~~14~~1) would apply. In P-P systems, multihop deployments are typical, therefore equation (~~15~~2) will apply.

4 P-MP FS systems

(No change)

5 Test area

(No change)

6 Satellite constellation

(No change)

7 Pfd mask

(No change)

8 FS parameters

(No change)

9 Other considerations

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9.3 Slightly inclined orbits

Satellite service to near omnidirectional antennas permits the satellite operators to take advantage of the fuel savings afforded by relaxed North-South station keeping and allows the satellites to employ slightly inclined orbits. This causes the interference arrival angles to terrestrial networks to vary on a daily basis, in effect extending the orbital arc below the static radio horizon for part of the time and increasing the arrival angle (and hence the pfd) of interference of satellites above the horizon for another part of the time. A simple mechanism for evaluating this effect is to modify, for calculation purposes, the latitude of the FS station: nominal station latitude, nominal station latitude plus maximum orbit inclination, and nominal station latitude less maximum orbit inclination can be determined~~ (see also Recommendation ITU-R SF.1008 on this subject)~~.

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10 Output results

(No change)

APPENDIX 1 TO ANNEX ~~2~~1

Software model for probabilistic interference assessment on a multi-hop P-P basis

(No change)

APPENDIX 2 TO ANNEX ~~2~~1

Derivation of $I/N_{aggregate}$ for individual FS receivers

(No change)