RECOMMENDATION ITU-R M.1474*, **

Methodology to evaluate the impact of interference from time division multiple access/frequency division multiple access (TDMA/FDMA) mobile-satellite service (MSS) systems operating in the 2 GHz range on baseband performance in digital line-of-sight fixed service receivers based on statistics of radio-frequency interference

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

(2000)

The ITU Radiocommunication Assembly,

considering

a) that the frequency bands 1980-2010 MHz and 2170-2200 MHz in all Regions, 2010-2025 MHz and 2160-2170 MHz in Region 2 subject to the dates of entry into force mentioned in RR Nos. 5.389A and 5.389C are allocated to the MSS (Earth-to-space) and the FS on a co-primary basis;

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

c) that transmissions from mobile satellites and associated mobile earth stations (MESs) could cause interference to line-of-sight FS receivers operating in these bands;

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

e) that simulation usually is the only way to accurately evaluate such interference;

f) that the output of such simulations is typically in the form of C/I, C/N and $C/(N+I)$ statistics;

g) that the impact of such interference often can be assessed by studying RF statistics only;

h) that, in critical cases, there is a need to evaluate the interference impact on FS baseband performance objectives,

recommends

1 that the methodology in Annex 1 be used as guidance in detailed bilateral coordination for initial assessment of the impact of interference from TDMA/FDMA MSS satellites and associated MESs, operating in the 2 GHz MSS allocations, on baseband performance in digital line-of-sight FS receivers based on statistics of RF interference.

NOTE 1 – The methodologies in Annex 1 are considered as provisional. Administrations are invited to contribute to this Annex with a view to further developing these methodologies.

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

** Radiocommunication Study Group 8 made editorial amendments to this Recommendation in 2004 in accordance with Resolution ITU-R 44.

Annex 1

1 Introduction

Sharing between MSS and FS involves time-varying phenomena such as interference geometry, propagation conditions, etc. Simulation is usually the only way to accurately evaluate interference between MSS and FS systems. The output of such simulations is typically in the form of RF C/I, C/N and $C/(N+I)$ statistics presented usually as a cumulative distribution function.

Recommendation ITU-R M.1319 provides a methodology whereby *inter alia* BER objectives for digital FS systems can be translated into equivalent RF $C/(N+I)$ requirements for an associated percentage of time. These equivalent RF performance objectives are plotted on the cumulative distribution plots of $C/(N+I)$ in order to determine if the interference from MSS satellites is acceptable.

The method described in Recommendation ITU-R M.1319 although it requires extensive computer simulation is relatively straightforward to implement in software, since all calculations and comparisons are undertaken in the RF domain. The methodology of Recommendation ITU-R M.1319 should be used in the detailed coordination phase between administrations, when coordination is formally required and triggered in application of RR Article 9 and RR Appendix 5, in order to determine if interference is acceptable or not considered in the context of actual FS system information and the relevant ITU-R performance and availability objectives.

In some cases during the bilateral coordination phase, it may be necessary for the parties concerned to further examine the impact of MSS interference on the performance objectives of digital FS systems. This could be the case where the results of the simulation method described in Recommendation ITU-R M.1319 above are not sufficiently definitive to enable conclusion of frequency coordination.

The objective of this Annex is to present methodologies to convert RF $C/(N+I)$ statistics into baseband performance measures for digital FS carriers.

2 Conversion of $C/(N+I)$ into BER

A $C/(N+I)$ value can be converted into an equivalent symbol error ratio (SER) using the equations or curves given in Recommendation ITU-R SF.766. For example, for a M-PSK modulated carrier:

$$SER = \text{erfc}\left(\sqrt{\log_2(M)\gamma_b}\ \sin\frac{\pi}{M}\right) \tag{1}$$

where:

$\gamma_b = E_b/(N_0 + I_0) = [C/(N+I)](B/R)$ (numerical ratio)

B: noise bandwidth of the FS receiver

R: bit rate

M: number of states.

The SER can then be converted to BER assuming that $BER = SER/\log_2(M)$.

3 Other performance objectives

Other common digital FS performance objectives (besides BER) are:

– unavailability;

– errored second ratio (ESR);

– severely errored second ratio (SESR);

– background block error ratio (BBER).

Accurate assessment of these measures requires continuous monitoring of the FS system performance. In a simulation this would mean that ideally the time interval should be very small, say of the order of milliseconds. This may not be practicable in a computer program simulating interference from a non-GSO MSS system into FS receivers, due to the necessity of also modelling the longer term variations, since the run time could be prohibitive.

For these reasons it is proposed that the above performance measures be evaluated based on an averaging approach, i.e. BER is assumed to be constant between time samples. Furthermore it is assumed that the bit errors are uniformly spread over time. Such an approach will generally give conservative estimates, since the bit errors will be spread across a maximum number of blocks (for definition of a block see § 3.2); a greater variation in the clustering of bit errors would result in fewer blocks being affected (assuming that the total number of bit errors is given). The following sections describe methods that can be used for this evaluation.

3.1 Unavailability

Recommendation ITU-R F.557 defines unavailability for digital FS links:

"The period of unavailable time begins at the onset of ten consecutive severely errored second (SES) events, in at least one direction of transmission. These ten seconds are considered to be unavailable time. For the definition of SES refer to related ITU-T Recommendations G.821 and G.826.

A new period of available time begins at the onset of ten consecutive non-SES events for both directions of transmission. These ten seconds are considered to be available time. For the definition of SES refer to related ITU-T Recommendations G.821 and G.826."

Since it is assumed that the only available information is the probability density function of $C/(N+I)$, a simplified approach has to be used here. The unavailability will therefore be estimated as the percentage of time that the BER exceeds, 1×10^{-3}. The unavailable time T_U (s) is then:

$$T_U = N_s \sum_{i=a}^{x} pdf_i \tag{2}$$

where:

N_s: total simulation time in (s)

pdf_i: calculated probability density function of $C/(N+I)$

a: smallest $C/(N+I)$ value represented in the distribution

x: $C/(N+I)$ value corresponding to BER $= 1 \times 10^{-3}$.

The unavailability in per cent is thus $100\ T_U / N_s$.

3.2 Errored seconds

ITU-T Recommendation G.826 defines an errored second (ES) as “a one-second period with one or more errored blocks or at least one defect.” An errored block is defined as a block with one or more bits in error. Only available time should be considered in the calculation of ESR:

$$ESR = \frac{ES}{N_s - T_U} \tag{3}$$

where ES is the number of errored seconds during available time.

The number of errored seconds during available time can be calculated as:

$$ES = N_s \sum_{i=x}^{b} pdf_i \ \min\left[1, BlockE_s(i)\right] \tag{4}$$

where:

b: highest $C/(N+I)$ value represented in the distribution.

$BlockE_s(i)$: average number of block errors per second for $C/(N+I) = i$.

Note that if the average number of block errors per second is greater than 1, all seconds with $C/(N+I) = i$ are considered to be errored

$$BlockE_s(i) = N_{Blocks/s} \ \min\left[1, BE_{Block}(i)\right] \tag{5}$$

where:

$N_{Blocks/s}$: number of blocks per second

$BE_{Block}(i)$: average number of bit errors per block for $C/(N+I) = i$. Similarly to above, if the average number of bit errors in a block is greater than 1, all blocks for $C/(N+I) = i$ are considered to be errored

$$BE_{Block}(i) = BER_i \cdot N_{B/block} \tag{6}$$

where:

BER_i: BER corresponding to $C/(N+I) = i$

$N_{B/block}$: number of bits per block.

3.3 SESs

ITU-T Recommendation G.826 defines an SES as “a one-second period which contains ≥30% errored blocks or at least one defect.” In the following, the concept of defect has been ignored. Only available time should be considered in the calculation of SESR.

$$SESR = \frac{SES}{N_s - T_U} \tag{7}$$

where:

SES: number of SESs during available time:

$$SES = N_s \sum_{i=x}^{b} pdf_i \cdot CHECK1_i \tag{8}$$

where:

$CHECK1_i = 1$ if $BlockE_s(i) > 0.3\ N_{Blocks/s}$, else $CHECK1_i = 0$.

3.4 Background block error (BBE)

ITU-T Recommendation G.826 defines a BBE as “an errored block not occurring as part of an SES”.

$$BBER = \frac{BBE}{N_s - T_U} \quad (9)$$

where:

BBE: number of block errors occurring during available time:

$$BBE = N_s \cdot N_{Block/s} \sum_{i=x}^{b} pdf_i \min\left[1, BE_{Block}(i)\right] CHECK2_i \quad (10)$$

where:

$CHECK2_i = 1$ if $BlockE_s(i) < 0.3\ N_{Blocks/s}$, else $CHECK2_i = 0$.

4 Conclusion

This Annex has presented equations that can be used to derive estimates of the impact of interference on baseband performance for digital FS systems based on RF $C/(N + I)$ statistics. The methods are based on an averaging approach, which will give conservative estimates, since the bit errors will be spread across a maximum number of blocks; a greater variation in the clustering of bit errors would result in fewer blocks being affected (assuming that the total number of bit errors is given).

The methods given in this Annex should be used only in critical cases, when examination of the RF interference statistics does not provide sufficiently definite results to enable conclusion of the frequency coordination.