RECOMMENDATION ITU-R M.1473[*, **]

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 video baseband performance in TV-FM analogue line-of-sight fixed service receivers

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

(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 subject to RR Nos. 5.389A and 5.389C;

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

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

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

e) that the output of such simulations is typically in the form of C/I, C/N and $C/(N + I)$ statistics into the given FS systems;

f) that the impact and acceptability of such interference in most cases may be assessed in detailed bilateral coordination by studying via computer simulation the radio frequency C/N, C/I and $C/(N + I)$ statistics as described in Recommendation ITU-R M.1319;

g) that, in some critical cases, there may be a need during detailed bilateral coordination to evaluate via computer simulation the interference impact on analogue TV-FM FS video baseband performance objectives,

recommends

1 that the methodology in Annex 1 may be used in detailed bilateral coordination between concerned parties for detailed assessment of the impact of interference from TDMA/FDMA MSS satellites in the 2 GHz MSS allocations on video baseband performance in analogue TV-FM line-of-sight FS receivers, in cases where the results obtained by the methodology described in Recommendation ITU-R M.1319 needs further refinement (see Notes 1, 2 and 3).

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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.

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.

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

Methodology to evaluate the impact of interference from TDMA/FDMA MSS systems operating in the 2 GHz range on video baseband performance in TV-FM analogue line-of-sight FS receivers

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 radio-frequency 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* baseband performance objectives for analogue FDM-FM and TV-FM FS systems provided in Recommendations ITU-R F.393 and ITU-R F.555 can be translated into equivalent radio-frequency $C/(N + I)$ requirements for an associated percentage of time, with if necessary appropriate scaling to address actual FS routes of shorter length than the reference circuits. These equivalent radio-frequency 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 radio-frequency domain. The methodology of proposed 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 analogue FS systems. This could be the case where the results of the simulation method described in Recommendation ITU-R M.1319 are not sufficiently definitive to enable conclusion of frequency coordination.

The objective of this Annex is to present methodologies to evaluate from radio-frequency C/I and C/N statistics the video baseband performance impairments more accurately for TV-FM analogue FS carriers taking into account the effects of varying frequency separations that would exist for multiple TDMA/FDMA interfering carriers, recognizing that the interference reduction factor or B factor and the protection ratio requirements of Recommendation ITU-R SF.766 indicate a strong dependence on frequency separation between the wanted and the interfering carriers.

The methodology presented in this Annex necessarily involves more sophisticated computer simulation tools than those described in Recommendation ITU-R M.1319 and is expected to require considerably more computer resources to execute.

2 Methodology for TV-FM FS systems

2.1 Reference TV-FM FS system for simulation

In the detailed coordination phase, it is expected that that actual analogue FS route parameters will be available in order to assess the impact of MSS interference. It is noted that, in the 2 GHz range, the intermediate FS stations in a FS modem section are usually equipped with IF repeaters. The demodulation to the baseband takes place only at the terminal station. Since the demodulation to baseband does not take place at the intermediate repeaters, it is only necessary to calculate the baseband interference at the last/terminal repeater in the actual FS route.

According to Recommendation ITU-R F.555, in the 2 500 km hypothetical reference circuit for the transmission of television signal, the ratio (dB), of the nominal amplitude of the luminance signal to the r.m.s. amplitude of the weighted noise measured under the conditions given in Parts B and C of ITU-T Recommendation J.61, should not fall below the following values:

- 57 dB for more than 20% of a month;
- 45 dB for more than 0.1% of a month.

The Recommendation also indicates that a S/N value of 53 dB is desirable for more than 1% of any month.

2.2 Estimation of statistics of baseband video $S/(N+I)$

2.2.1 General description

The impact of interference from MSS systems employing narrow-band modulation/access schemes into a TV-FM baseband video signal can be assessed as follows.

Using the simulation methods described in Recommendation ITU-R M.1319, at each time step in the simulation period for each FS receiver in an FS route one can estimate the C/I and C/N values, where now the C/I levels are computed due to each individual TDMA/FDMA MSS carrier within the bandwidth of the TV-FM FS receiver. In principle, one should determine the baseband noise and interference at each hop and accumulate them along the route. However, noting that the baseband noise and interference at each hop are linearly related to the respective C/N and C/I for that hop, it is equivalent to accumulate the radio frequency noise and interference along the route and to determine the baseband noise and interference at the terminal station from these overall C/N and C/I values. Thus, the overall C/N and C/I levels due to each carrier at each time step at the terminal station in the actual FS route comprising of ($n + 1$) stations, where n is the number of hops, can be assessed as below.

The overall C/N (dB) at the terminal FS station is given by the following expression:

$$\left(\frac{C}{N}\right)_{total} = 10 \log\left[\left(\sum_i 10^{-0.1\left(\frac{C}{N}\right)_i}\right)^{-1}\right] \tag{1a}$$

The overall C/I (dB) due to each individual interfering carrier at the terminal FS station is given by the following expression:

$$\left(\frac{C}{I}\right)_{total} = 10 \log\left[\left(\sum_i 10^{-0.1\left(\frac{C}{I}\right)_i}\right)^{-1}\right] \tag{1b}$$

$$\left(\frac{C}{N + I}\right)_{total} = 10 \log\left[\left(10^{-0.1\left(\frac{C}{I}\right)_{total}} + 10^{-0.1\left(\frac{C}{N}\right)_{total}}\right)^{-1}\right] \tag{2}$$

The overall S/N (dB) at the terminal FS station due to each individual interfering carrier can be expressed as follows:

$$S/N = S/(N_{th} + I) = 10 \log\left(10^{-0.1(S/N_{th})} + 10^{-0.1(S/I)}\right) \tag{3}$$

The S/I (dB) at the terminal FS station due to each individual interfering carrier in turn can be expressed as follows:

$$S/I = C/I + B \tag{4}$$

where B is the video interference reduction factor.

In Report ITU-R SF.449 (1990), an expression for B is obtained through measurements which can be expressed as follows:

$$B = 6 + 20 \log (\Delta F) \tag{5}$$

and ΔF being the peak to peak deviation (MHz). Assuming a peak-to-peak deviation of 10 MHz the value of B can be calculated as 26 dB. The expressions for computing B factor for interference into TV-FM carriers are taken from the published literature [Wu and Chang, 1985].

The interference reduction factor can be expressed as follows:

$$B = S/N - C/I = 20 \log\left[\ 0.7\,(A_2 / A_1)/(75\,P_n)^{1/2}\ \right] \tag{6}$$

in which S/N is the ratio of nominal peak voltage of the baseband signal to the r.m.s. interference noise voltage expressed in dB, $C/I = 20 \log A_1/A_2$, A_1/A_2 is the ratio of the unmodulated carrier amplitude of the interfered signal to that of the interfering signal and P_n is the baseband weighted interference noise power. Equation (6) was used in the following analysis.

The noise P_n is obtained from the following equation:

$$P_n = \frac{2A_2^2}{75A_1^2 \Delta F^2} \sum_n \left[nf_0 \, g(nf_0) \, h(nf_0) \right]^2 |C_n| \tag{7}$$

where:

$g(nf_0)$: weighting function

$h(nf_0)$: pre-emphasis characteristic of the TV signal

ΔF: peak-to-peak deviation of the TV signal

$|C_n|$: n-th coefficient determined from the auto-correlation function of the complex envelop and the index $k = \Delta f/f_0$, with Δf being the frequency separation between the wanted and the interfering carriers and $f_0 = 0.00390625$ MHz. (The complex envelop is a function of the spectral line amplitude V_r, power P_r and frequency f_r of the unpre-emphasised periodic random TV signal, $f(t)$.)

The expression for $[S/N_{th}]$ can be expressed as follows:

$$[S/N_{th}] = 10 \log(3/2) + 20 \log (\Delta F/F_{max}) + pw + C/N \tag{8}$$

where:

ΔF: peak-to-peak frequency deviation of a signal at the input of the Tx chain

F_{max}: top video baseband frequency (MHz)

pw: combined effect of pre-emphasis and de-emphasis weighting

C/N: carrier to thermal noise ratio.

2.2.2 Specific methodology

The computation of aggregate video baseband $S/(N + I)$, due to interference noise and thermal noise power in the given TV-FM video baseband, involves the following steps:

Step 1: calculation at each time step of C at each receive FS station with multipath fading taken into account on that particular hop. Multipath fading is taken into account using a random fade depth predictor, whose output is consistent with the statistical distribution derived from Recommendation ITU-R P.530 multipath fading model.

Step 2: calculation at each time step of I at each receive FS station due to each interfering TDMA/FDMA MSS carrier from each spot beam of each visible MSS satellite, taking into account MSS satellite spot beam and receive FS antenna discrimination and MSS satellite spot beam power/traffic loading and frequency plans.

Step 3: calculation at each time step of C/I due to each interfering TDMA/FDMA MSS carrier from each spot beam of each visible MSS satellite and C/N at each receive FS station.

Step 4: calculation at each time step aggregate C/N and C/I at the terminal FS receive station using equations (1a) and (1b) respectively.

Step 5: calculation at each time step, at the terminal FS receive station, of baseband interference reduction factor or B factor at various frequency offset intervals with equations (6) and (7) based on per carrier C/I estimates taking into account the allocated bandwidth of the interfering TDMA narrow-band MSS carrier. A look-up table can be used for B factor values for various frequency offsets.

Step 6: calculation at each time step, at the terminal FS receive station, of baseband S/N_{th} based on C/N estimates using the applicable C/N to S/N translation for the given FDM-FM FS system (equation (8)).

Step 7: calculation at each time step, at the terminal FS receive station, of aggregate $S/(N + I)$ for the baseband video TV-FM signal due to interference from each of multiple TDMA/FDMA MSS interfering carriers and thermal noise.

Step 8: the above steps are repeated for each time step over a statistically valid period commensurate with a full or equivalent orbital cycle period of the MSS satellite constellation and a representative period for multipath fading behaviour.

Step 9: finally the probability distribution of total $S/(N + I)$ is computed and plotted. This can then be compared with the objectives of Recommendation ITU-R F.555, appropriately apportioned.

3 An example

An example application of the above method is given in Appendix 1.

References

WU Z.-Y. and CHANG S.-Y. [1985] The Interference Theory of TV and System Compatibility. Proc. of International Conference on Communications, IEEE.

Appendix 1
to Annex 1

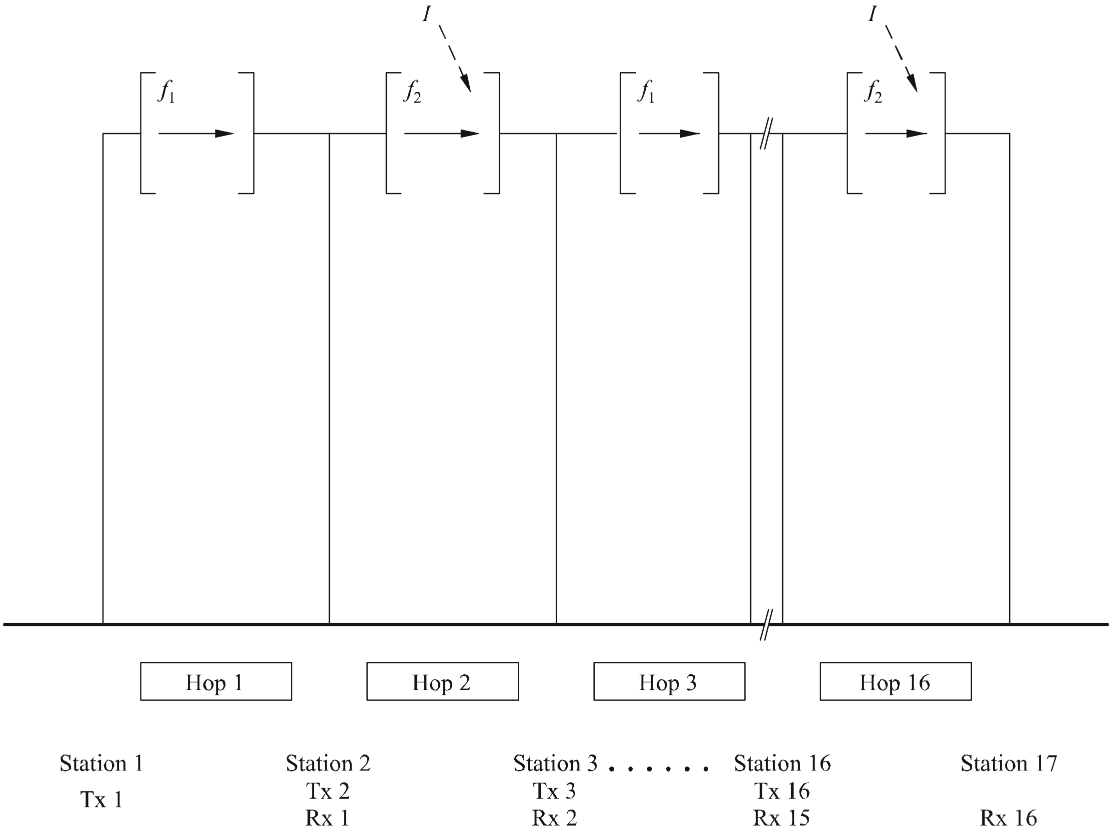
Example application of methodology for the computation of baseband interference from LEO-F system into 16-hop TV-FM radio-relay system

1 Introduction

In this Appendix, the methodology explained in Annex 1 is applied to compute the baseband interference from the LEO-F system into an example 16-hop TV-FM radio-relay system (see Fig. 1).

FIGURE 1

Layout of 16-hop TV-FM radio-relay system



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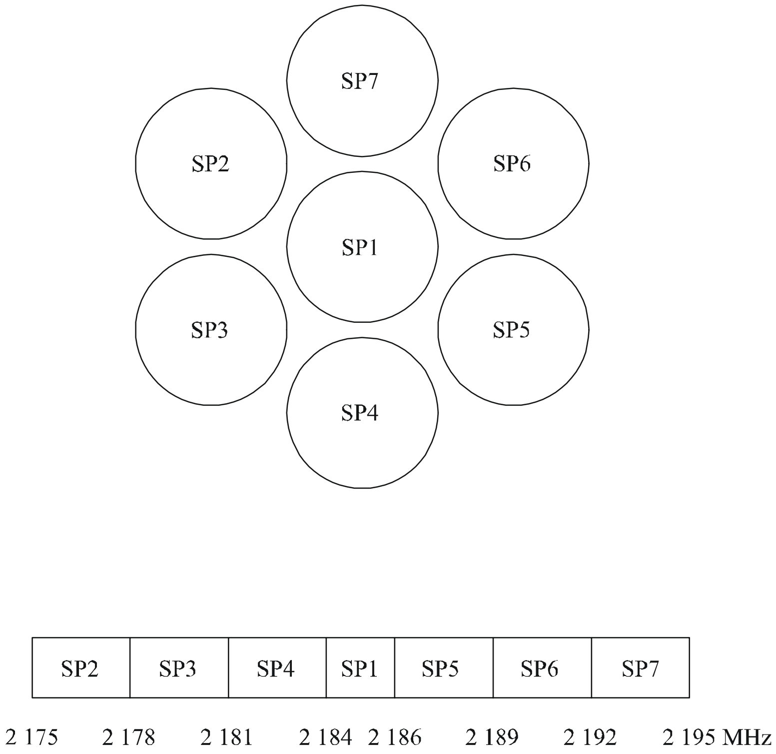
2 Frequency plans of LEO-F and TV-FM radio-relay system

A seven-cell frequency re-use pattern has been considered. Six spot beams (SP2, SP3, SP4, SP5, SP6 and SP7) each of 3 MHz bandwidth and 1 spot beam (SP1) of 2 MHz bandwidth is assumed. The frequency span of 2 175-2 195 MHz is assumed for the simulation of TV-FM system (see Fig. 2). The centre frequency of the TV-FM system is assumed as 2 185 MHz with a bandwidth of 20 MHz.

FIGURE 2

Frequency plan of LEO-F spot beams and 20 MHz TV-FM FS systems



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3 Transmission parameters of TV-FM systems

Recommendation ITU-R F.1245 is used for the off-axis gain pattern of the FS antenna. The parameters of the TV-FM system are given in Table 1. The hypothetical station particulars and the transmission frequencies of the FS system assumed in the simulation are given in Table 2.

TABLE 1

Parameters of TV-FM system

Parameter	625-line PAL TV-FM system
RF bandwidth (MHz)	20
Top video baseband frequency (MHz)	5.00
Peak-to-peak frequency deviation (MHz)	10.00
Combined effect of pre-emphasis and de-emphasis weighting (dB)	15
LOS receiver antenna (3.7 m diameter) gain (dBi)	35
Feeder multiplexer loss (dB)	5
Maximum Tx output power level (dBW)	10
Nominal receiver input power level (dBW)	–68
Receiver noise figure(1) (dB)	10

(1) While this example calculation used a noise figure of 10 dB, a more appropriate representative value for noise figure in this frequency range would be 8 dB.

TABLE 2

Hypothetical station and carrier frequency details for TV-FM system

Station (STN)	Latitude	Longitude	Hop length (km)	Tx frequency (MHz)	Rx frequency (MHz)
STN 1	26.30° N	127.12° E	49.4	2 166	
STN 2	26.58° N	126.74° E	49.4	2 185	2 166
STN 3	26.86° N	126.35° E	49.3	2 166	2 185
STN 4	27.14° N	125.97° E	49.4	2 185	2 166
STN 5	27.42° N	125.58° E	49.4	2 166	2 185
STN 6	27.70° N	125.19° E	49.4	2 185	2 166
STN 7	27.98° N	124.81° E	49.3	2 166	2 185
STN 8	28.26° N	124.43° E	49.4	2 185	2 166
STN 9	28.54° N	124.04° E	49.4	2 166	2 185
STN 10	28.82° N	123.66° E	49.3	2 185	2 166
STN 11	29.10° N	123.27° E	49.4	2 166	2 185
STN 12	29.38° N	122.89° E	49.4	2 185	2 166
STN 13	29.66° N	122.50° E	49.3	2 166	2 185
STN 14	29.94° N	122.12° E	49.3	2 185	2 166
STN 15	30.22° N	121.73° E	49.3	2 166	2 185
STN 16	30.50° N	121.35° E	49.3	2 185	2 166
STN 17	30.78° N	120.96° E	49.3		2 185

4 LEO-F system parameters

The spot beam, with an e.i.r.p. of 32.2 dBW, a 3 dB beamwidth of 3.4° and an off-axis pattern of $-12\ (\theta/\theta_0)^2$ (dB) is assumed for simulation purposes. The other parameters of the LEO-F system are summarized in Table 3.

TABLE 3

LEO-F parameters

a) Constellation details

Number of satellites	10
Altitude (km)	10 355
Number of planes	2
Orbital inclination (degrees)	45
Number of satellites per plane	5
Inter-plane phasing (degrees)	0
Intra-plane phasing (degrees)	72

b) Frequency bands (service links)

Earth-to-space (MHz)	1 980-2 010
Space-to-Earth (MHz)	2 170-2 200

c) Satellites beam/carrier traffic

Number of spot beams	163
Carrier type	TDMA/FDMA
Carrier symbol rate (ksymbol/s)	18
Carrier allocated bandwidth (kHz)	25
Beam e.i.r.p./carrier (dBW)	32.2
Number voice slots/TDMA burst	6
Maximum satellite capacity	4 500 voice channels
Maximum traffic load per beam	3 MHz/2 MHz

5 Fading distribution

Recommendation ITU-R P.530 is used to assess the fading distribution for various fractions of time. The typical fading distribution for the location in China with 30.78° N latitude and 129.96° E longitude for various fractions of time is given in Fig. 3.

6 *B* factor values

The *B* factor values at different frequency offsets obtained by implementing equations (6) and (7) for TV-FM are given in Fig. 4.

FIGURE 3

Fade depth as a function of time

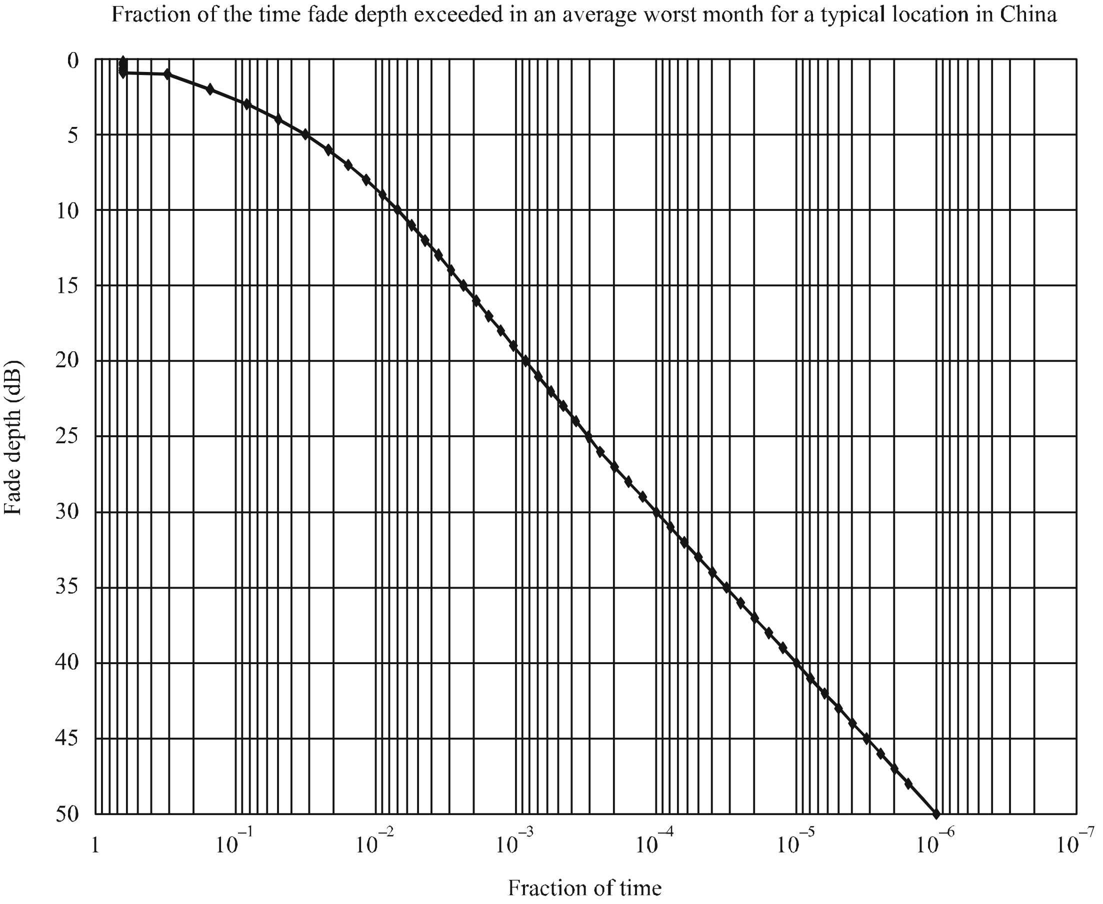

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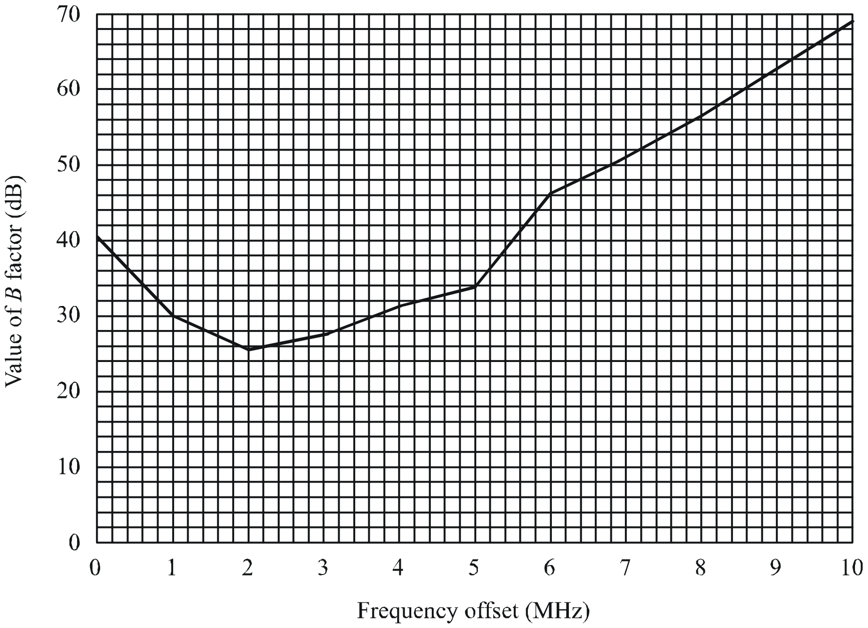
FIGURE 4

Values of *B* factor for 20 MHz TV-FM system



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7 Simulation results

The simulation was performed for the worst-case azimuth angles with a time step of 50 s. The total duration of the simulation was 20 days. The distribution of *S*/*N*, *S*/*I* and *S*/(*N* + *I*) for various fractions of time are plotted in Fig. 5 in the case of TV-FM system. The *S*/(*N* + *I*) values are then compared with the Recommendation ITU-R F.555 objectives. It can be seen that the *S*/*N* and *S*/(*N* + *I*) values are very close to each other. *S*/*I* values are higher compared to *S*/*N* values for all fractions of time. The long-term objective is met whereas the short-term objective is just met. This is due to the low values of *S*/*N* itself at certain time instants. The *S*/*I* values are much higher compared to the criterion points. The overall performance of the TV-FM link is basically determined by the *S*/*N* design characteristics.

FIGURE 5

***S*/*I*, *S*/*N* and *S*/(*N* + *I*) distribution for a 16-hop 20 MHz TV-FM system**