

RECOMMENDATION ITU-R S.1002

ORBIT MANAGEMENT TECHNIQUES FOR THE FIXED-SATELLITE SERVICE

(Question ITU-R 49/4 (1990))*

(1993)

The ITU Radiocommunication Assembly,

considering

- a) that there is a need to manage portions of the geostationary-satellite orbit (GSO) in order to achieve an efficient utilization of both the GSO and the radio spectrum;
- b) that it is advantageous to develop one or more sets of generalized parameters which could be used to adequately describe fixed-satellite networks in order to facilitate the orbit management process;
- c) that the generalized parameters can be modelled accurately by one or more computer programs to aid in the management of the orbit;
- d) that there are currently computer programs which can assist in the management and use of the orbit,

recommends

- 1. that to assist in orbit management of a portion of the GSO, generalized parameters may be used as described in Annex 1;
- 2. that efficient computer algorithms which optimize the use of the orbit, as given in Annex 2 may be used.

ANNEX 1

**Generalized satellite network parameters
for orbit management**

1. Introduction

Studies have been made to quantify the benefits of introducing an optimization process for identifying orbital positions for new networks through example exercises.

The results of exercises indicate that, if the positions for new networks had been selected at random and non-optimized positions had been selected, a significant advantage would have been forgone by comparison with a selection made using the optimization process. Moreover, particularly with a large number of existing networks, the optimization process can result in savings of time and effort in inter-system coordination activity.

The orbit management process therefore consists of identifying a set of generalized parameters and developing efficient computer algorithms and implementation methodologies.

2. Method based on A, B, C and D parameters

2.1 Network parameters A, B, C and D

The A, B, C, D generalized parameters specify the interference-producing capability (variables A and C) and the interference sensitivity (variables B and D) of a satellite network.

* Former CCIR Question 49/4.

Since many different combinations of implementation parameters (such as antenna characteristics and transmitter powers) can result in a similar set of parametric values, it can be applied irrespective of the modulation characteristics and specific frequency used.

The generalized parameters selected by the World Administrative Radio Conference on the use of the Geostationary-Satellite Orbit and on the Planning of Space Services Utilizing It (Geneva, 1988) (WARC ORB-88) for the allotment plan are the *A*, *B*, *C*, *D* parameters based on power density averaged over the signal bandwidth. The purpose of this set is to generalize not only the standard parameters used, but also the type of traffic assumed in the allotment plan. Under this concept, the required input powers into the standard earth station and the particular space station antennas are first determined during the planning process. These are then converted into power density (P_1 and P_2 (dB(W/Hz))) by dividing by the bandwidth of the signal type, which is in turn used to compute and record the plan's generalized, *A*, *B*, *C* and *D* parameters.

The equations shown below describe the *A*, *B*, *C*, *D* generalized parameters where:

A : uplink off-axis e.i.r.p. density averaged over the necessary bandwidth of the modulated carrier

B : uplink off-axis receiver sensitivity* to interfering e.i.r.p. density averaged over the necessary bandwidth of the modulated carrier

C : downlink off-axis e.i.r.p. density averaged over the necessary bandwidth of the modulated carrier

D : downlink off-axis receiver sensitivity* to interfering e.i.r.p. density averaged over the necessary bandwidth of the modulated carrier

$$A = p_1 \cdot g_1(\varphi)$$

$$B = \frac{1}{p_1 \cdot g_1 \cdot \Delta g_2(\psi)}$$

$$C = \frac{p_3 \cdot g_3}{\Delta g_3(\psi)}$$

$$D = \frac{g_4(\varphi)}{p_3 \cdot g_3 \cdot g_4}$$

where:

p_1 : power density, averaged over the necessary bandwidth of the modulated carrier, fed into the transmitting earth station antenna (W/Hz)

g_1 : maximum gain of the earth station transmitting antenna (numerical power ratio)

$g_1(\varphi)$: earth station transmitting antenna radiation pattern (numerical power ratio)

g_2 : maximum gain of the space station receiving antenna

$g_2(\psi)$: gain in the space station receiving antenna in the direction of the earth station (numerical power ratio)

$\Delta g_2(\psi) = g_2 / g_2(\psi)$: discrimination of the space station receiving antenna (numerical power ratio)

p_3 : power density, averaged over the necessary bandwidth of the modulated carrier, fed into the space station transmitting antenna (W/Hz)

g_3 : maximum space station transmitting antenna gain (numerical power ratio)

$g_3(\psi)$: space station transmitting antenna gain in the direction of the earth station

* Note that here the meaning is susceptibility to interference rather than the precise technical definition of sensitivity

$\Delta g_3(\psi) = g_3 / g_3(\psi)$: discrimination of the space station transmitting antenna (numerical power ratio)

g_4 : maximum gain of the earth station receiving antenna (numerical power ratio)

$g_4(\phi)$: earth station receiving antenna radiation pattern (numerical power ratio)

'(prime) : denotes parameters for the interfering network.

Thus, the equation for the ratio of the wanted power density to unwanted power density (as defined above), is given by:

$$(C/I)_{den} = \left[\frac{p'_1 g'_1(\phi) g_2(\psi')}{p_1 g_1 g_2} + \frac{p'_3 g'_3(\psi) g_4(\phi')}{p_3 g_3 g_4} \right]^{-1}$$

reducing simply to:

$$(C/I)_{den} = [A' * B + C' * D]^{-1}$$

where $(C/I)_{den}$ is the protection ratio normalized by the ratio of the wanted and unwanted bandwidths. With this method, this ratio would be used to determine the orbit separation matrix of the networks for synthesizing the plan.

When a network is proposed, its A , B , C , D parameters would be calculated using the actual system parameters and power densities averaged over the signal bandwidth. These power densities would be the power into the antenna divided by the bandwidth of the actual signal proposed. According to Appendix 30B of the Radio Regulations, no coordination would be required if:

- the calculated values of A and C are less than or equal to the relevant reference set, and
- the proposed frequency assignments are ordered in such a way that the upper 60% of each allotment band is used for high density carriers (i.e. those for which the ratio of power spectral density peak in the worst 4 kHz band to the average power spectral density over the necessary bandwidth of the modulated carrier is greater than 5 dB), and the lower 40% for low density carriers.

An example based on a review of some current systems and traffic types indicates that a large number of present carriers would be able to be implemented without coordination. Table 1 gives the required C/I ratios calculated for the INTELSAT "regular FDM-FM" carriers, based upon a transponder loading of carrier separation of 1.33 times the occupied bandwidth, and an acceptable interference of 800 pW0p. Table 2 gives the required $(C/I)_{den}$, calculated from Table 1 by multiplying the entries by a factor of b'/b , where b and b' are the bandwidths of the wanted and unwanted signals respectively.

It can be seen from Table 2 that a $(C/I)_{den}$ criterion of 30 dB for establishing orbital positions for various service areas, would permit a large number of combinations of FDM-FM signals to coexist in different networks. Those that are not covered are lower modulation index signals, with peak-to-average power ratios greater than 5 dB. This is demonstrated in Table 3.

For interference into digital signals with bandwidths wider than those of the interferer, multiple interfering carriers within the passband of the wanted digital signal should be assumed. A C/I of 30 dB and an I/N of 6% would yield a C/N of 18 dB, which would provide a BER better than 1×10^{-7} . Thus, a $(C/I)_{den}$ of 30 dB would very likely be suitable for digital signals.

TABLE 1

C/I ratio for INTELSAT FDM-FM signals

Interference wanted	12	24	60	60	132	132	132	252	252	432	432	432	792	Modulation index	Bandwidth (MHz)	C/N (dB)
12	26.6	25.2	24.9	22.7	22.0	20.7	20.1	20.2	18.1	18.5	17.4	16.7	14.1	2.65	1.1	13.4
24	26.5	25.7	25.6	23.9	24.0	22.1	21.6	21.6	19.6	20.0	18.9	18.2	15.7	2.55	2.0	12.7
60	34.3	33.9	33.8	32.5	32.6	30.9	30.4	30.5	28.6	29.0	27.9	27.2	24.7	1.17	2.2	21.1
60	27.9	26.6	26.6	25.7	25.8	24.5	24.1	24.1	22.5	22.8	21.8	21.1	18.7	2.17	4.0	12.7
132	36.2	33.7	33.7	33.4	33.4	32.5	32.2	32.2	30.8	31.1	30.2	29.5	27.1	0.96	4.4	20.7
132	31.8	28.9	28.9	28.0	28.0	27.4	27.1	27.1	25.9	26.2	25.4	24.8	22.5	1.61	6.7	14.4
132	32.2	29.2	29.2	28.1	28.1	27.5	27.2	27.3	26.1	26.4	25.6	25.1	22.9	1.85	7.5	12.7
252	37.8	34.6	34.6	32.4	32.4	32.2	32.1	32.1	31.3	31.5	30.9	30.5	28.4	0.96	8.5	19.4
252	33.7	30.7	30.7	27.9	27.9	27.3	27.2	27.2	26.6	26.7	26.3	25.9	24.1	1.55	12.4	13.6
432	41.5	38.5	38.5	34.6	34.6	33.7	33.8	33.7	33.6	33.7	33.4	33.2	31.7	0.82	13.0	21.2
432	39.3	36.3	36.3	33.0	33.0	31.6	31.4	31.4	31.1	31.2	31.0	30.7	29.4	1.07	15.7	18.2
432	37.8	34.7	34.7	31.7	31.7	30.0	29.6	29.6	29.4	29.5	29.2	29.0	27.7	1.27	18.0	16.1
792	40.6	37.5	37.5	34.5	34.5	32.8	31.4	31.4	30.1	30.1	29.8	29.8	29.2	1.24	32.4	16.5

TABLE 2

 $(C/I)_{den}$ ratio for INTELSAT FDM-FM signals

Interference wanted	12	24	60	60	132	132	132	252	252	432	432	432	792	Modulation index	Bandwidth (MHz)
12	26.6	27.8	27.5	28.3	28.8	28.5	28.4	29.1	28.6	29.2	28.9	28.8	28.8	2.65	1.1
24	23.9	25.7	26.0	26.9	27.4	27.4	27.3	27.9	27.5	28.1	27.8	27.7	27.8	2.55	2
60	31.3	33.5	33.8	35.1	35.6	35.7	35.7	36.4	36.1	36.7	36.4	36.3	36.4	1.17	2.2
60	22.3	23.6	24.0	25.7	26.2	26.7	26.8	27.4	27.4	27.9	27.7	27.6	27.8	2.17	4
132	30.2	30.3	30.7	33.0	33.4	34.3	34.5	35.0	35.3	35.8	35.7	35.6	35.8	0.96	4.4
132	23.9	23.6	24.1	25.8	26.2	27.4	27.6	28.1	28.6	29.1	29.1	29.1	29.3	1.61	6.7
132	23.9	23.5	23.9	25.3	25.8	27.0	27.2	27.8	28.3	28.8	28.8	28.9	29.3	1.85	7.5
252	28.9	28.3	28.7	29.1	29.5	31.2	31.6	32.1	32.9	33.3	33.6	33.8	34.2	0.96	8.5
252	23.2	22.8	23.2	23.0	23.4	24.6	25.0	25.7	26.6	26.9	27.3	27.5	20.3	1.55	12.4
432	30.8	30.4	30.8	29.5	29.9	30.8	31.4	31.9	33.4	33.7	34.2	34.6	35.7	0.82	13
432	27.8	27.4	27.8	27.1	27.5	27.9	28.2	28.7	30.1	30.4	31.0	29.6	30.8	1.07	15.7
432	25.7	25.2	25.6	25.2	25.6	25.7	25.8	26.3	27.8	28.1	28.6	29.0	30.3	1.27	18
792	25.9	25.4	25.8	25.4	25.8	26.0	25.0	25.6	25.9	26.1	26.7	27.2	29.2	1.24	32.4

For interference of FDM-FM into digital signals with bandwidths much narrower than the interferer, then:

$$C/I = C/P_k = (C/P_{av}) (P_{av}/P_k) \\ = (C/I)_{den} (1/k_p)$$

where k_p is the peak-to-average ratio of the interferer within the occupied bandwidth, B_o . P_k and P_{av} are the peak and average power spectral densities respectively of the interferer, and are given by:

P_k : power in the worst 4 kHz band/4 kHz (W/Hz)

P_{av} : total carrier power/the occupied bandwidth, B_o (W/Hz).

TABLE 3

Peak/average density ratios for INTELSAT FDM-FM carriers

No. of channels	Occupied bandwidth B_o (MHz)	C/P_k (dB/4 kHz)	P_k/P_{av} (dB)
12	1.1	20.0	4.95
24	2.0	22.3	4.69
60	2.2	22.4	5.10
60	4.0	25.3	4.70
132	4.4	24.2	6.21
132	6.75	27.5	4.77
132	7.5	28.0	4.73
252	8.5	27.0	6.26
252	12.4	30.0	4.91
432	13.0	27.6	7.52
432	15.7	30.8	5.15
432	18.0	31.5	5.03
792	32.4	34.1	4.98

$$\frac{P_k}{P_{av}} = \frac{P_k}{C} \frac{C}{P_{av}} = \frac{P_k}{C} \frac{B_o}{4 \text{ kHz}}, \text{ or}$$

$$\frac{P_k}{P_{av}} = 10 \log (B_o / 4000) - 10 \log (C/P_k) \quad (\text{dB})$$

Note 1 – Signals with $P_k/P_{av} \leq 5.0$ are signals usable without coordination.

In the case of interference from TV-FM, however, even with energy dispersal, it is unlikely that narrow-band carriers can be co-channel with the carrier of the TV-FM signal because during energy dispersal of, say ± 1 MHz, the spectral power within the dispersion band is very high.

The requirement to coordinate with TV signals can be avoided if the TV carrier frequencies were pre-specified. With an energy dispersal bandwidth of say 2 MHz, SCPC and other narrow-band carriers can avoid the TV energy dispersion band. This concept of “micro-segmentation” is discussed in Recommendation ITU-R S.742*.

2.2 Possible modifications to the parameters of FSS systems in the Plan adopted by WARC ORB-88

Further information needs to be given in addition to the above in connection with the use of the generalized parameters A , B , C , D in the fixed-satellite service (FSS) Plan adopted by WARC ORB-88.

All the generalized parameters are functions of an off-axis angle, ϕ for earth stations and ψ for space stations. The angles ϕ and ψ may take on values starting from zero. The generalized parameters B and D relate to the system's sensitivity to interference (the higher the values of the parameters, the greater the sensitivity), but do not directly determine the permissible radiated power of the interfering signal until the permissible signal-to-interference ratio C/I is indicated. In the FSS Plan the values of A , B , C , D relate to each individual system, whereas the value

* Former CCIR Recommendation 742.