

RECOMMENDATION 740

TECHNICAL COORDINATION METHODS
FOR FIXED-SATELLITE NETWORKS

(Question 49/4)

(1992)

The CCIR,

considering

- a) that during the planning stage of a satellite network it is necessary to calculate levels of potential interference between planned and existing networks;
- b) that the methods to determine the need for coordination of satellite networks are given in Appendix 29 to the Radio Regulations and Recommendations 738 and 739;
- c) that once the need for coordination has been identified, it would be necessary to make a technical assessment of the potential for interference between satellite networks;
- d) that the CCIR has reviewed various approaches to the management of the geostationary-satellite orbit;
- e) that the approach used in the detailed technical coordination process is left to the administrations concerned;
- f) that if the potential interference exceeds the allowable criterion, the administrations concerned must agree on the conditions for the operation of their respective networks;
- g) that Recommendations 466, 671, 483, 523 and 735 provide permissible levels of interference between networks of the fixed-satellite service;
- h) that in certain cases there may be a need for multilateral coordination,

recommends

1. that in undertaking detailed technical coordination of fixed-satellite networks, the techniques listed below and described in Annex 1 may be used, by agreement between the administrations concerned in the absence of any other mutually agreed approach:
 - carrier power technique;
 - power density averaging bandwidth technique;
 - isolation technique,
2. that Note 1 should be considered part of this Recommendation.

Note 1 – Annexes 2, 3 and 4 contain the methods for the detailed calculations of the above techniques.

ANNEX 1

Technical coordination methods for fixed-satellite networks**1. General approach**

For the purpose of this Annex, the network seeking access to the orbit is designated A. It is assumed that ΔT calculations, based on information as required under Appendix 4 of the Radio Regulations and as published by the IFRB for registered networks (a registered network is one whose assignments have been recorded in the IFRB Master Register), for networks not yet registered but already coordinated, and for networks which are in the process of being coordinated, have established the need to coordinate with networks B, C, D, etc. which may fall in any of the above categories. All such networks have precedence over the applicant's network A.

2. Coordination process

The coordination process can, for purposes of discussion, be divided into three phases.

The first involves the inspection of the actual or planned transmissions of the involved networks and an assessment of their interaction against "standard" interference criteria.

The second phase of the process is an investigation of potential changes to the transmission plan elements (transmission characteristics, frequency plans) or orbital locations which could lead to a solution of any interference problems identified in phase 1. Generally, the applicant administration will tend to have more latitude in considering such changes to its network than the administration operating an existing system; however, phase 2 would not expect either network to consider the acceptance of serious constraints on its current or planned mode of operation, type, distribution and quality of service. This phase should, through very detailed consideration of all technical and operational parameters, be capable of resolving specific and apparently relatively severe interference situations.

The third phase, if necessary, would be consideration and negotiation of system modifications and adjustments on either or both involved networks. Such changes may affect the quality and type of service and the future growth options of either or both networks.

In dealing with the resolution of interference conditions it must be borne in mind that any specific solutions found for the two networks under consideration may generate or aggravate problems with other networks; this may be particularly significant when considering space station relocations.

3. Technical considerations

Fundamentally, there are two initial facets to the coordination process:

- agreement on acceptable interference criteria; and
- agreement on the calculations of the interference.

CCIR Recommendations may be used for interference criteria but other criteria may be used by mutual acceptance. The calculations generally involve a translation of receiver output criteria to receiver input (RF) criteria and the RF interference path parameters. Since many of the parameters amenable to modification are associated with the RF domain, it may be convenient to classify approaches to coordination in this domain, i.e. based on RF criteria.

3.1 Interference domains

A first step in the coordination process is identification of the interference domains. Each band or band segment common to both networks for each satellite beam in the two space segments must be identified. Within each such band or band segment, those portions over which the space station and earth station receiving sensitivities (G/T) and space station and earth station e.i.r.p. densities remain constant in either network are identified.

This process yields all the interference domains. Certain portions of the spectrum may appear several times because they may represent intra-satellite frequency re-use. Where up-link frequencies and down-link frequencies or satellite beams or both may be paired in a variety of ways (switching of beam connectivity in a space station), all possible operational configurations need to be considered. Further, the number of domains will usually be bounded, at least in current space stations, by the transponder arrangement in the space stations and may, in simple space stations, encompass several or all transponders. Where two space stations have single satellite antenna beams (i.e. common-coverage transmit and receive beams) and all their transponders have uniform characteristics over the common frequency band there would be only one interference domain.

3.2 Coordination approaches

The selection of the methods used to effect coordination is determined by agreement between the participating administrations. The characteristics of the affected networks and the potential severity of the interference will influence the choice of the approach to be used for coordination.

Interference coordination can, in practice, be achieved with a variety of techniques. Among these are:

- the comparison of the *total carrier power* characteristics of transmissions with criteria of acceptable received interfering power;
- the comparison of the *power density* characteristics of transmissions with criteria of acceptable received interfering *power density*;
- the comparison of available inter-network *isolation* (normalized inter-network coupling loss) with criteria of required *isolation* between transmissions (normalized wanted-to-unwanted carrier ratio).

For the first case, RF criteria can be expressed as I/N or C/I and for the second case as I_0/N_0 or C_0/I_0 where I is the interference power, N is the internal link noise power and C is the desired carrier power and subscript "0" indicates power/Hz averaged over a reference bandwidth. In the third case, interference criteria are expressed in terms of the required C/I between two transmissions, normalized by the carrier-to-noise density ratios C/N_0 which characterize the performance requirements of the two transmissions.

3.2.1 Carrier power technique

This technique is most applicable to the following cases:

- in frequency bands in which satellite networks are well developed and in which the satellite population is relatively high;
- for modulations which are well defined and may be of any type, e.g. SCPC, analogue, digital, FM/TV, etc.;
- in frequency bands in which this approach has been extensively used.

The mandatory information required under Appendix 4 of the Radio Regulations is not sufficient to serve as a basis for coordination under an I/N or C/I approach. It is necessary for the applicant administration to submit more detailed information on his network. Other administrations having networks with which the need to coordinate has been established must also furnish more detailed information. To effect coordination using the I/N or C/I approaches requires a full exchange of Appendix 3 data including superscript information for each carrier type, earth-station type and satellite antenna beam within all bands or band segments common to both networks; and where available, individual frequency plans. Since this information is adequate for the C/I approach, it would appear desirable to proceed on this approach, since it provides a more accurate estimate of interference.

The interference domains must first be identified. For each of these it is necessary to identify the transmission (carrier) types which are used or are planned to be used in both networks. In the absence of known frequency plans the worst interference combination of the carriers of the two networks should be assumed. In most cases, this would correspond to frequency coincidence of the carriers. Where frequency plans are known, or where only one arrangement of transmissions in the two networks within a given interference domain is possible, the interference analyses are simplified.

For each domain, interference from each transmission type of one network into each transmission type of the other is calculated for coincident frequency assignments (or, where available, for the actual or planned frequency assignments) in each direction (i.e., from network A into network B and *vice versa*). Each interfering transmission is assumed to originate at the lowest-gain antenna of a transmitting earth station (i.e., the one having the highest off-axis e.i.r.p.) which does or is expected to use it. When the interfering transmission occupies a bandwidth much less than that of the interfered-with transmission, it should be assumed that transmissions of the interfering type occupy, at appropriate intervals, the whole band occupied by the interfered-with transmission.

It is then necessary to compare the resulting calculated values of C/I with the mutually acceptable single entry values. If these calculations show that acceptable values of C/I result in all cases, then a successful coordination has been effected.

If the interference criteria are not satisfied in one or more cases, then each case must be individually considered. Where the criteria are only slightly exceeded, it may be agreed that these interference levels could be tolerated by either network. In particular, the applicant administration may decide unilaterally that interference into its network, although somewhat exceeding the criteria value(s), would be acceptable and, if there is no other area of disagreement, it could claim immediately successful coordination. Otherwise, a number of measures may need to be considered in order to meet the mutually acceptable criteria.

Annex 2 provides the method for calculating the C/I for GSO satellite networks.

3.2.2 Power density technique

This technique may be most applicable to the following cases:

- in frequency bands in which satellite networks are in the early stages of development and in which the satellite population is small;
- for modulations which have a nearly uniform power spectral density, e.g., digital modulations;
- where initial $\Delta T/T$ calculations result in values which are acceptable to each administration. This may be the case for some common domains between the networks;
- where there is a considerable degree of flexibility in one or both networks so that power density values can be modified.

In this approach, the initial assessment of interference may be made using the Appendix 3 data for each of the interference domains. This assessment can identify the particular domains in which potential interference is most severe and also whether up-link or down-link interference is most dominant. Each party could use the I_0/N_0 values acceptable to him based on his carrier modulation types.

It is possible that these calculations could result in mutually acceptable values of I_0/N_0 , in which case a successful coordination would have been effected. If the I_0/N_0 values are not acceptable, then several other steps may be taken. If up-link interference is the dominant source, changes in the up-link power densities and transmission gains may be made to reduce the mutual interference. Additionally, rearrangement of accesses by band segments may be made i.e., a modification of interference domains, so that a greater degree of homogeneity exists between the two networks, thus reducing the mutual interference.

The average power density in a transponder can be used to determine a minimum practical satellite spacing which may be an effective measure of achievable satellite spacing in the coordination process. Since power of a transponder is limited, the power density averaged over the transponder bandwidth is also limited. Using this average power density, a satellite spacing can be determined for a given interference criteria, taking into account expected inhomogeneities in traffic in detailed coordination between the networks. This satellite spacing can be used in the coordination process as a basis for determining achievable satellite spacings. If power densities higher than this average power density exist in a portion of the bandwidth of the transponder, then power densities lower than the average must also exist in other portions of the transponder bandwidth; a condition which can be used in a coordination process.

It may also be appropriate to use reference or averaging bandwidths consistent with the carriers employed instead of the 4 kHz and 1 MHz reference bandwidths of the Radio Regulations. These will generally result in lower values of I_0/N_0 , and can facilitate the coordination process, particularly where narrow-band carriers in one satellite operate opposite wideband carriers in another satellite. In this case, a satellite spacing based upon narrow-band carrier interference criteria may be used to obtain an acceptable interference criteria for the wideband carriers, thus avoiding detailed carrier frequency planning. Interference to narrow-band carriers from wideband carriers will be relatively uniform if the wideband carrier power density is relatively uniform.

The techniques enumerated above have formed a basis for the development of a power density-averaging bandwidth method of determining interference between satellite networks. The method is based on providing a sufficient number of power density-averaging bandwidth data points so that the interference in any bandwidth of interest may be reasonably approximated using the methods described in Appendix 29 of the Radio Regulations. This method may also be used in determining the need to coordinate. The details of this method are described in Annex 3.

Where wideband carriers exhibit higher power densities in small portions of a transponder (analogue FM-TV or high density, low index FDM-FM), minimum satellite spacing may be achieved by the narrow-band carriers avoiding the high power density regions. In this situation, better spectrum utilization may be achieved if triangular function energy dispersal is not used on wideband carriers. However, there may be other factors which would justify the use of some minimal energy dispersal, e.g. consideration of existing systems and protection of terrestrial radio systems.

The C_0/I_0 approach to coordination is essentially an extension of the I_0/N_0 approach. In this approach, an additional parameter, the minimum power density in each network is identified. It may be determined that mutually acceptable C_0/I_0 values are achievable even though acceptable I_0/N_0 values were not achievable. This approach allows consideration of power compensation in transponders i.e., higher powers could be assigned transmissions subject to greater interference and less power to those with little interference, thus eliminating or moderating individual interference severity. Power compensation would be an operational measure. This C_0/I_0 approach needs further study and clarification.

3.2.3 *Isolation techniques*

The conventional and link isolation concepts discussed in Annex 4 offer another coordination method which does not involve the use of transmitted powers, power densities and noise powers.

3.2.3.1 *Conventional isolation method*

Under the conventional isolation approach a comparison is made between the available inter-network isolation - a measure of the electromagnetic coupling between two networks - and the isolation required between two interfering transmissions.

The required isolation is a fairly precise measure of the interference "incompatibility" between two transmissions, larger required isolation values indicating greater incompatibility. It is expressed in terms of the permissible wanted-to-unwanted carrier power ratio between two transmissions and their respective performance requirements (in the form of the required total link carrier-to-noise density ratio, C/N_0 , for each transmission).

To apply the isolation concept, one identifies the isolation domains and determines in each domain the available isolation. An isolation domain is characterized by any two networks' earth and space station antenna radiation characteristics, their receiving system noise temperatures and their link transmission gains.

In each domain, the interfering combinations of carriers are identified. From tables or graphs the required isolation between any two specific carriers is obtained and compared with the isolation available in the appropriate domain. A combination of carriers whose required isolation exceeds the available isolation in the pertinent domain requires that these carriers be coordinated with each other.

The difference between required and available isolation is a quantitative measure of the severity of the incompatibility; its magnitude is a useful guide for the steps to be taken to bring compatibility about.

3.2.3.2 *Link isolation method*

In this method, the available link isolation is also compared with the required carrier isolation to determine the need for coordination. When the value of available link isolation is less than the required carrier isolation, detailed coordination would be necessary.

Under this approach, the available link isolation is determined on the basis of information concerning the input and output back-offs of the transponder, the satellite e.i.r.p. and saturation flux density together with the major link design parameters. It is not necessary to resort to detailed carrier parameters as needed for the conventional isolation method.

The required carrier isolations are expressed in terms of the applicable single entry wanted-to-unwanted carrier power ratios between two transmissions and their respective down-link carrier-to-noise density ratios.

4. **Multilateral coordination**

Although the coordination process is typically performed on a bilateral basis, coordination can also be performed on a multilateral basis. This could be the most expeditious means for achieving coordination when satellite networks of more than two administrations are affected. The general methods and techniques described in this Recommendation which may be employed during coordination are applicable to both bilateral and multilateral processes. Several more specific concepts and methods have been developed.

ANNEX 2

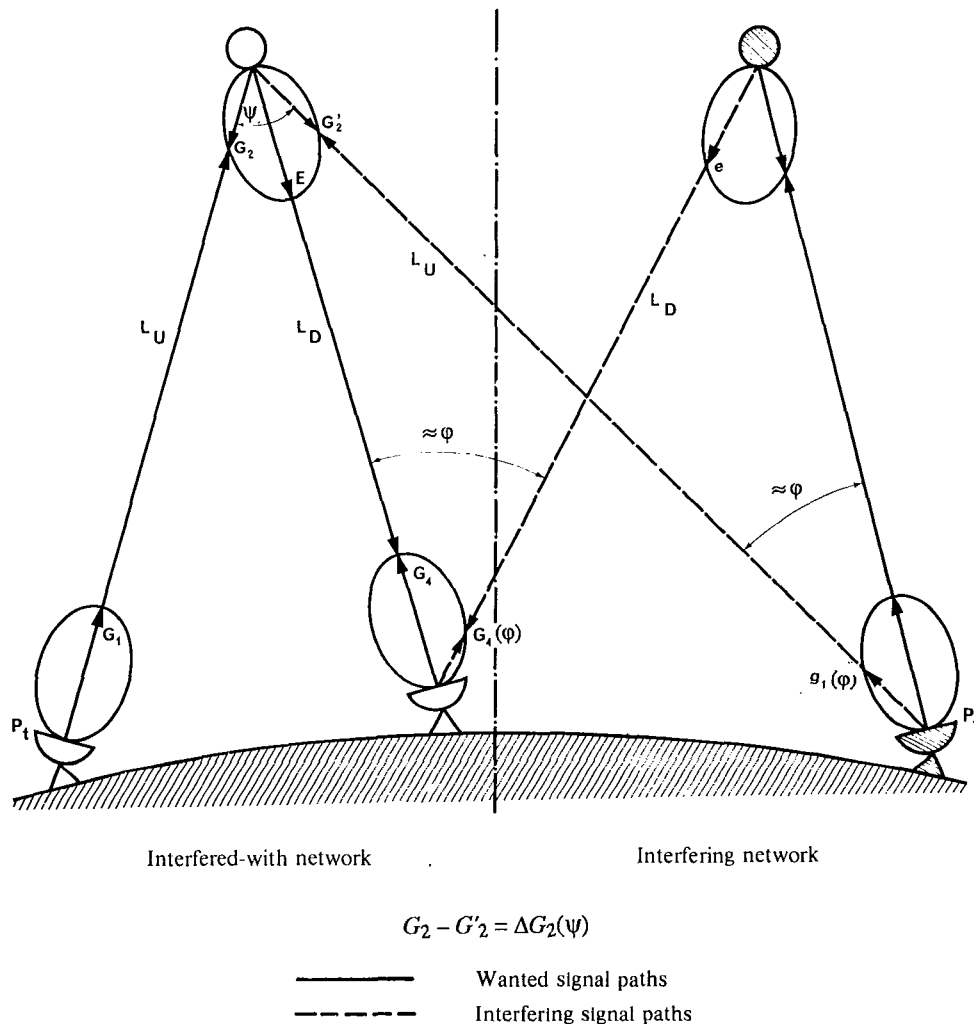
Method of calculating carrier-to-interference ratios in fixed-satellite service networks

1. **Method**

The interference geometry between two satellite networks is shown in Figs. 1a and 1b. The minimum topocentric (as seen from a point on the Earth) satellite spacing angles should take into account the nominal geocentric satellite spacing angle, the satellite position uncertainties (longitude of the orbit nodes and orbit inclinations) and the geographical locations of the earth stations. The use of the geocentric angular spacing, ϕ , instead of the topocentric satellite spacing angle, is simpler for the computation and its use is justified by the fact that the two angles are nearly equal. Also, the topocentric spacing angle is always greater than the geocentric spacing angle and hence the calculations based on geocentric spacing angles are conservative.

FIGURE 1a

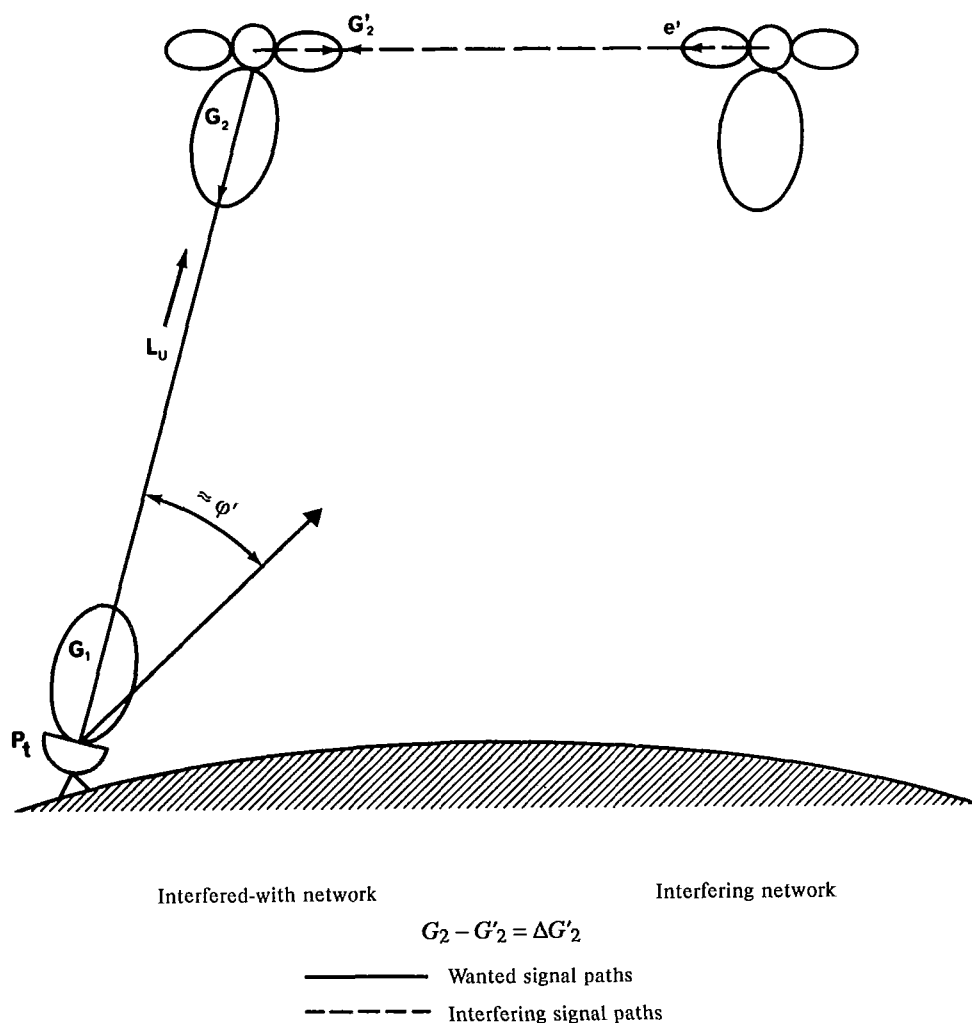
Interference geometry between two satellite networks, Case I – up link of wanted network sharing frequencies with up link of interfering network



Radiocommunication satellites require frequency assignments in two frequency bands, one for the up link and the other for the down link. It is current practice for frequency bands to be associated in pairs, one band being used for up links and the other for down links. Case I below, is concerned with the possibility of interference between two networks which have been assigned frequency bands in this way; thus interference from an up link enters the wanted up link and interference from a down link enters the wanted down link. However, some networks may use a pair of frequency bands in the reverse sense, the up-link band for one network being the same as the down-link band for the network using an adjacent satellite; in these circumstances interference from an up link enters the wanted down link and interference from a down link enters the wanted up link. This is Case II.

FIGURE 1b

Interference geometry between two satellite networks, Case II – up link of wanted network sharing frequencies with down link of interfering network



1.1 Case I

The following propagation conditions are assumed to apply to the up-link and down-link wanted-to-interfering carrier ratios:

- due to propagation effects and local precipitation both the wanted and the interfering signals which are transmitted by earth stations situated at different points on the Earth's surface will fluctuate. Unless the e.i.r.p.s of the earth stations are adjusted so that the levels received by the satellites are always the same, a margin should be introduced in calculating the mean interference value to the up-link equation;
- the ratio of the wanted signal level to the interference level on the down link does not vary with time. Any interference strong enough to have an appreciable effect would be caused by other satellites close to those of the wanted network so that the discrimination due to the directivity of the earth-station antenna is insufficient to separate the wanted from the interfering signals. Hence the wanted and interfering signals will be attenuated to the same degree when propagation conditions vary, since they will travel through the same disturbed areas. Consequently, fluctuations caused in the received wanted signal will have no significant effect on the level of interference produced in the baseband and, therefore, a down-link margin may usually be neglected.

The computation procedure requires solution of the two equations:

$$(C/I)_U = P_t + G_1 - \Delta L_U - M_U - p_t - g_1(\varphi) + \Delta G_2 + Y_U \quad \text{dB} \quad (1)$$

and

$$(C/I)_D = E + G_4 - \Delta L_D - e - G_4(\varphi) + Y_D \quad \text{dB} \quad (2)$$

where:

- $(C/I)_{U,D}$: up- and down-link wanted-to-interfering carrier ratios (dB)
- P_t, p_t : transmit powers of wanted and interfering carriers delivered to the associated earth-station antenna (dBW)
- G_1, G_4 : transmit and receive antenna gains of one or more wanted earth stations (dB)
- ΔL_U : path loss differential in the up link to the wanted satellite from the two earth stations,
 $\Delta L = L_{\text{wanted}} - L_{\text{interfering}} \quad (\text{dB})$
- ΔL_D : path loss differential in the down link to the wanted earth station from the two satellites, ΔL as above (dB)
- M_U : up-link margin in the wanted network (dB)
- $g_1(\varphi)$: antenna gain component at the unwanted earth station towards the wanted satellite (dB)
- φ : geocentric minimum angular satellite spacing at the interfering earth station
- ΔG_2 : differential in receive antenna gains at the wanted satellite toward the two earth stations,
 $\Delta G_2 = G_{2 \text{ wanted}} - G_{2 \text{ interfering}} \quad (\text{dB})$
- Y_U : minimum polarization discrimination between interfering up-link carrier and wanted satellite receive antenna (dB)
- Y_D : minimum polarization discrimination between interfering down-link carrier and wanted earth-station receive antenna (dB)
- E, e : e.i.r.p. of the wanted and interfering carriers in the direction of the wanted earth station (dBW)
- $G_4(\varphi)$: antenna gain component at the wanted earth station toward the interfering satellite (dB).

Notes on some of the factors in the above equations:

- Powers and antenna gains associated with the wanted network are in capitals, those associated with the interfering network use lower case letters. Suffixes associated with the various antenna gains follow the signal path, viz: 1 = earth-station transmit, 2 = satellite receive, 3 = satellite transmit, 4 = earth-station receive.
- The antenna gains $g_1(\varphi)$ and $G_4(\varphi)$ should, if possible, be computed using measured earth-station antenna patterns. However, for preliminary calculations, the generalized earth-station antenna radiation pattern given in Recommendation 465 may be applied.
- For very precise calculations the topocentric angles may be used in the expressions for g_1 and G_4 .
- The terms ΔG_2 , E and e should, if possible, be computed using measured satellite antenna patterns. Variations of path geometry with time may affect these terms; however, these variations are likely to be small and may usually be neglected.
- In the absence of information on satellite antenna polarization, the factors Y_U and Y_D must be set at 0 dB. The subject of polarization discrimination is discussed in CCIR Volume IV.