World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It

First session, Geneva, 1985

REPORT TO THE SECOND SESSION OF THE CONFERENCE

(See Resolution 1)

General Secretariat
of the
International Telecommunication Union
Geneva, 1986

FIRST SESSION OF THE
WORLD ADMINISTRATIVE RADIO CONFERENCE
ON THE USE OF THE GEOSTATIONARY-SATELLITE
ORBIT AND THE PLANNING OF THE SPACE SERVICES
UTILIZING IT
Geneva, 1985

Geneva, 15 September 1985

The Chairman
of the Second Session of the
World Administrative Radio
Conference on the Use of the
Geostationary-Satellite Orbit
and on the Planning of Space
Services Utilizing It

Dear Sir,

In accordance with Nos. 226 and 228 of the International Telecommunication Convention, Nairobi, 1982 and the provisions of Resolution 1 adopted at the First Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of the Space Services Utilizing It, Geneva, 1985, I enclose the Report of the First Session for submission to the Second Session of the Conference.

Yours faithfully,

Ilija Stojanović

Dr. I. STOJANOVIĆ
Chairman

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CHAPTER 1

Introduction

1.1 The World Administrative Radio Conference (Geneva, 1979), in its Resolution 3, invited the Administrative Council to take all necessary steps to convene a world space administrative radio conference with the objective to guarantee in practice for all countries equitable access to the geostationary-satellite orbit and the frequency bands allocated to space services. It also resolved that the Conference should be held in two sessions.

1.2 The Plenipotentiary Conference (Nairobi, 1982) in its Resolution 1, stated that the agenda of the First Session should also contain the formal adoption for inclusion in the Radio Regulations, of the relevant decisions of the 1983 Regional Administrative Conference for the Planning of the Broadcasting-Satellite Service in Region 2.

1.3 In its Resolution 8, the Plenipotentiary Conference (Nairobi, 1982) instructed the Administrative Council to consider the question of feeder links with a view to including in the agenda of the First Session of the World Administrative Space Radio Conference, scheduled for 1985, the planning of the bands allocated to the fixed-satellite service and reserved exclusively for feeder links for the broadcasting-satellite service and to instruct the IFRB accordingly.

1.4 In conformity with Resolution 1 of the Plenipotentiary Conference (Nairobi, 1982), the Administrative Council, at its 38th session (1983), following consultation with the Members of the Union, adopted Resolution 895. This Resolution, as approved by a majority of the Members, decided that the First Session of this Conference should be convened in Geneva on 8 August 1985 for a duration of five and a half weeks; it also drew up an agenda for the First Session.

1.5 Consequently, the First Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of the Space Services Utilizing It was held in Geneva from 8 August to 15 September 1985.

1.6 This First Session, in conformity with the terms of reference contained in its agenda, decided:

a) to adopt the present report for submission to the second session of the Conference;

b) to establish the guidelines for the work to be carried out by the IFRB and the studies to be undertaken by the CCIR in preparation for the second session of the Conference, as contained in Chapters 3, 5, 6 and 8 of the present report;

c) to invite the Administrative Council to consider the resources and facilities required for this intersessional work, taking into account the recommended draft agenda for the Second Session of the Conference, contained in Recommendation 1 annexed to the present report;

d) to adopt also Resolutions 1 and 2 and Recommendations 1, 2 and 3 annexed to the present report; and

e) to request the Secretary-General to bring the present report to the attention of the administrations of all the Members of the Union.

In addition, having considered the relevant decisions of the Regional Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service in Region 2, the First Session decided to incorporate these decisions in the Radio Regulations, as appropriate.

CHAPTER 2

The characteristics of typical in-service networks of The fixed-satellite service

2.1 Introduction

The FSS has evolved considerably over the last 20 years and handles a wide range of traffic. It is the most heavily utilized of all the space services and probably the most highly developed. This review of the characteristics of typical in-service networks of the FSS is based on the CPM Report, Annex 3, with new material added at WARC-ORB-85.

The FSS networks currently in operation vary considerably with regard to technical parameters, operational techniques and the services provided. For example, the capacity of the radio carriers may vary from a single telephone channel (SCPC) up to several thousand channels; the corresponding bandwidths of the carriers range from about 20 kHz to 70 MHz and modulation may be analogue or digital. These systems are used to provide telephony, television, teleconferencing, data transmissions, intracompany services, communications between computers, telecommunication services for isolated regions and weather forecasting services. The services and characteristics will continue to change in the future with technical progress.

Today's satellite services are implemented in several ways, viz: by independent space networks, by consortia or by lease of space segment from operating organizations. The choice can be related to need or economic viability, although technical characteristics may be similar. Existing systems mainly use the 3 700 - 4 200 MHz, 5 925 - 6 425 MHz, 10.95 - 11.20 GHz, 11.45 - 11.70 GHz, 11.7 - 12.2 GHz and 14.0 - 14.5 GHz bands although some use is also made of the 3 400 - 3 700 MHz, 5 725 - 5 925 MHz, 7 250 - 7 750 MHz and 7 900 - 8 400 MHz bands and of other bands between 12.2 and 12.75 GHz. A beginning has been made in using certain FSS allocations above 15 GHz. Very little use is made, for the FSS, of bands which were newly allocated for the FSS at WARC-79, the so-called expansion bands, namely 4 500 - 4 800 MHz, 10.70 - 10.95 GHz and 11.20 - 11.45 GHz (for down-links) and 6 425 - 7 075 MHz and 12.75 - 13.25 GHz (for up-links).

Some FSS networks use spacecraft with multiservice, and/or multifrequency telecommunication payloads. There would appear to be a growing trend in the use of such satellites, due to the availability of larger spacecraft. This situation may introduce additional constraints to the harmonization process, especially if the orbital position of the satellite is determined by a previous plan (for example, BSS).

Another fundamental characteristic of the FSS is the wide range of service areas. In general, there are three categories of coverage: global, regional and national.

Initial exploitation of the FSS was largely for transoceanic communications and this continues to be a growing and very important use of the GSO.

International systems provide a wide range of telecommunication services. INTELSAT and INTERSPUTNIK are examples of the use of frequency bands 6/4 GHz and 14/11 GHz.

Regional systems in the FSS are operated by specific groups of countries to provide joint telecommunication services. Current systems use the frequency bands 6/4 and 14/11 GHz. The EUTELSAT regional network will soon begin operation in the 14/11-12 GHz bands for European international traffic and has already come into service to meet certain domestic and international requirements, with the lease of standby capacity. The ARABSAT regional network is already in operation in the 6/4 GHz bands.

National satellite networks are used by various countries to satisfy their national telecommunication needs. Demands for such networks are increasing in all regions. Such systems mainly use the 6/4, the 14/11-12 GHz frequency bands. However, there is at least one operational system which utilizes the 30/20 GHz FSS bands.

Apart from the technical differences, an important difference between international and national networks is that the most suitable orbit locations are usually not the same, thus minimizing conflicts in that sense. On the other hand, the technical differences often lead to difficulties in coordination despite the orbit separations that are feasible.

Another major difference between international and national networks relates to the coverage areas. The former can require wide coverages, while the latter might conform approximately to the boundaries of the country itself. This leads to some of the technical disparity between the two types of networks. In the case of domestic systems, where the coverage areas are sufficiently separated, satellites can operate in close proximity.

Feeder links to satellites of various services, such as the mobile-satellite service and the broadcasting-satellite service, may be assigned frequencies in bands allocated to the FSS.

The growing number of satellites in service gives rise to increasing difficulties to administrations trying to use orbital positions within segments of that orbit and in preferred frequency bands that are intensively used by other countries. In fact, there are certain orbital segments and frequency bands that are already congested, and this may lead to coordination processes which may be complex and costly. An analysis of information made available to the CPM by the IFRB on the number of satellites in orbit and in various stages of coordination is in Annex 1 to the present chapter.

2.2 FSS operating networks

2.2.1 FSS networks operating at 6/4 GHz

By far the most highly developed, both in technology and in utilization, the bands 5 925 - 6 425 MHz and 3 700 - 4 200 MHz are used on nearly all the commercial FSS networks in service as well as those in the planning stage.

This has led existing system operators to employ advanced techniques and design (e.g. lower side-lobe antennas, polarization isolation and shaped beams) to allow larger numbers of satellites to access the orbit in these bands.

Several of the other frequency bands allocated to the FSS in this frequency range are limited in their use by significant inter-service sharing considerations. However, in the expansion bands at 6 and 4 GHz, there is substantial bandwidth for which there are no significant sharing problems in many parts of the world and these bands are essentially unused by the FSS today. In addition, because of the proximity to the conventional 6/4 GHz bands, the technology from these bands could be transferred to the expansion bands at 6 and 4 GHz without significant cost to systems operating only in these bands.

2.2.1.1 Space stations at 6/4 GHz

The earliest FSS space stations were in international service and provided global coverage capabilities. Within ten years, domestic coverage satellites were in service while regional coverage systems are a more recent development as more countries begin to use satellite technology for domestic services or as a supplement to regional terrestrial systems.

Along with the growth in numbers of satellites, the capacity of a single satellite has been increased by frequency reuse accomplished by the use of orthogonal polarization in the same coverage area and/or spatial isolation between narrow spot beams on the same satellite serving different coverage areas. This is generally a characteristic of international networks; in some such networks six-fold frequency reuse has been obtained in this way. Domestic FSS systems, on the other hand, have utilized orthogonal polarization to achieve a two-fold frequency use.

The predominant transponder bandwidth of 6/4 GHz FSS satellites is 36 MHz, with 40 MHz spacing between transponder centre frequencies, for a total of 12 transponders on a single polarization in a single antenna beam. Use of orthogonal polarizations would therefore provide a total of 24 transponders. Bandwidths up to 80 MHz are used in some FSS networks in the 6/4 GHz bands and provide for high bit rate digital transmissions.

Transponders presently operating in the 6/4 GHz bands commonly use 5 W to 8 W travelling-wave tube amplifiers (TWTAs). Some planned satellites will carry transponder TWTAs with power up to 30 W and solid-state amplifiers with power up to 8.5 W. Table 2-1 presents some typical FSS space station parameters.

TABLE 2-1

Typical parameters of 6/4 GHz FSS space stations

Parameter	Type of coverage		
	Global	Regional	National
Satellite antenna gain (dBi)			
Transmit	17-19	21-25	28-32
Receive	17-19	21-24	30-34
e.i.r.p. (dBW)	22-24	26-31	30-39
Receiver noise temperature (K)	800-2000	800-2000	800-2000
G/T (dB(K^{-1}))	-17 to -14	-12 to -5	-3 to +5

It is common for present-day FSS space stations to have the capability to maintain station keeping within tolerances of $\pm$ 0.1° in both latitude and longitude. In some cases the North-South excursion may somewhat exceed this figure without detriment to orbit utilization. Such tolerances are often met in actual operations, particularly for domestic networks with large numbers of earth stations, for which steerable antennas are economically unattractive.

Expected satellite lifetimes have increased substantially over the past twenty years, with design lifetimes of ten years being currently most common for satellites to be launched during the mid-1980s. It should be noted, however, that the design lifetime of a space station may not be the same as its operational life at a particular orbit location. This may occur in a particular satellite network where traffic is rapidly growing and a higher capacity design is introduced before the design life of the first spacecraft is reached. In such cases the earlier launched satellite may be relocated to satisfy other traffic requirements.

2.2.1.2 Earth stations at 6/4 GHz

As the FSS space station e.i.r.p. has increased, lower-cost, smaller diameter earth-station antennas have become operationally feasible. Table 2-2 provides typical parameters of earth stations presently operating in 6/4 GHz FSS networks.

TABLE 2-2

Typical parameters of 6/4 GHz FSS earth stations

Parameter	Type of coverage		
	Global	Regional	National
Antenna size (m)	4.5-32	4.5-25	3-30
Gain (dBi)			
Transmit	47-64	47-62	43-63
Receive	43-61	43-59	40-59
Receiver noise temperature (K)	50-150	50-150	50-200
G/T (dB(K^{-1}))	23-41	23-38	17-41
Typical output power (kW)	1-12	0.3-3	0.005-1
e.i.r.p. (dBW)	46-95	46-74	45-84

Coast earth stations providing feeder links to maritime-mobile satellites have characteristics lying within the range indicated for regional networks in Table 2-2.

The largest antennas are used primarily in global coverage systems although they may also find applications in domestic networks for high capacity links. Antennas with diameters in the range 10 to 15 m are common for medium capacity routes or special service applications in global coverage systems. Smaller antennas in the 3 to 7 m range are particularly suited for services in regional and national coverage systems, as well as for receive-only applications.

2.2.2 FSS networks operating at 8/7 GHz

Several FSS networks are presently in operation in the 8/7 GHz bands and a number of new networks are expected to become operational in the near future. It should be noted that many of these systems also operate in the mobile-satellite service. It should also be noted that these networks are primarily used for official correspondence within and among a number of administrations.

Some basic factors which are common to a number of satellite systems using the 8/7 GHz bands are:

- large service areas; i.e., approaching the visible areas in size;
- Earth coverage, hemispheric coverage and re-directable narrow beam satellite antennas;
- capabilities for changing satellite antenna/transponder configurations;
- circular polarizations; no frequency reuse within a network;
- large differences in earth-station antenna sizes, the smallest are of the order of 1 to 3 m;
- relatively high maximum transmission gains (see Appendix 29 of the Radio Regulations), which coupled with high up-link satellite antenna gains, result in relatively high up-link sensitivity.

These factors are consistent with satellite networks which could operate in either or both the FSS and the MSS.

Conversely, there is no uniformity in transponder arrangements, frequency translations, satellite antenna configurations, or types of modulation, carriers, and satellite accessing.

It should also be noted that the meteorological-satellite and earth exploration-satellite services also have frequency allocations with primary status in these frequency bands; these services could have very different characteristics from those of the FSS and MSS.

2.2.3 FSS networks operating at 14/11-12 GHz

FSS systems in the 14/11-12 GHz bands have only become operational within the last 6-7 years. Over that time, significant improvements in orbit/spectrum efficiency and capacity have resulted from progress in the technologies associated with these systems.

A particular attraction of these bands, as compared to the 6/4 GHz bands, is the ability to provide high satellite e.i.r.p., permitting the use of smaller earth station antennas for many telecommunication services. This arises partly from the facility with which satellite transmitting antennas of higher gain can be provided, and partly from the fact that some of the space-to-Earth frequency allocations near 12 GHz are not generally shared with terrestrial services having primary allocation status. A sample analysis of the information on current satellites using these bands, contained in the Annex to the present chapter indicates that the median value of the gains of satellite beams is about 38 dB, with upper and lower decile values of 49 dB and 29 dB respectively. The availability of improved launch systems and improvements in satellite power technologies have facilitated this development. As a consequence, many new satellite communication services which rely upon small aperture earth station antennas are being implemented.

As the physical antenna size required for a particular D/λ is much smaller than at 6/4 GHz, the frequency reuse potential using satellite antenna spot or shaped beams is considerably enhanced and some systems under construction will utilize this technique to achieve eight-fold frequency reuse on a single satellite.

The principal disadvantage of the use of frequencies above 10 GHz is the higher RF signal attenuation and depolarization effects in areas subject to heavy rainfall. Various techniques to alleviate these problems are available and include up-link power control and adaptive depolarization cancellers.

At 14/11 GHz and higher frequency bands, the service arc restrictions are severe for networks with very large service areas and those with service areas at high latitudes, since earth stations in these bands normally require operation at higher elevation angles than 6/4 GHz in order to reduce rain attenuation and depolarization effects to acceptable levels.

Allocations, for the 12 GHz space-to-Earth frequency bands currently allocated, vary among the ITU Regions as follows:

Region 1: 12.5 to 12.75 GHz,

Region 2: 11.7 to 12.2 GHz,

Region 3: 12.2 to 12.5 GHz and 12.5 to 12.75 GHz. (Note that the use of the 12.2 to 12.5 GHz band for the FSS is governed by RR 845.)

In each Region there are primary allocations to terrestrial services, in the International Frequency Allocation Table or in footnotes to it, but the down-link power flux-density limits imposed by RR 2574 do not apply in a large number of countries, and the availability of high-gain satellite antennas facilitates the prevention of power flux-density levels in breach of RR 2574 in countries where its terms do apply. These bands are used by both national and international systems.

The 11 GHz (10.7 - 11.7 GHz) space-to-Earth frequency band is allocated on a world-wide basis and the segments 10.95 - 11.2 GHz and 11.45 - 11.7 GHz, are used by international and national systems. The remaining segments, 10.7 - 10.95 GHz and 11.2 - 11.45 GHz, represent expansion bands that are not currently used.

All of the above bands currently in use utilize the 14 - 14.5 GHz Earth-to-space bands for transmission to the satellite. An additional 500 MHz band from 12.75 - 13.25 GHz is available, but has not been used to date.

With respect to the typical parameters of systems in the 14-11/12 GHz bands, space station receiving system figure-of-merits range from approximately -3 dB/K to 9 dB/K while satellite transponder e.i.r.p.s vary from 35 to 50 dBW at the edge of coverage when spot or shaped beams are used. Earth station antenna diameters vary from about 1 metre to as large as 32 metres.

2.2.4 Frequencies above 15 GHz

Studies are in progress to define the parameters of space stations operating in the 30/20 GHz bands, and two administrations have launched experimental space stations operating in these bands. In general, the use of frequency bands around 20 GHz and 30 GHz, where 3.5 GHz of bandwidth is available, would make possible the provision of very high capacity systems using narrow spot beam antennas and high speed digital transmissions.

The research and development of 30/20 GHz bands FSS systems have been promoted in many countries, for example, the Japanese CS-1 experimental system, NASA's advanced 30/20 GHz system, ESA's OLYMPUS (formerly L-SAT) project, the ITALSAT system, the ATHOS experimental satellite project, the Federal Republic of Germany's DFS and other experimental satellite projects.

In Japan, the first operational domestic FSS system using CS-2a and 2b satellites started from the end of May 1983. The 30/20 GHz bands are used for transmitting telephone signals using TDMA and FM-TV signals between regional centres with 11.5 m diameter offset Cassegrain antennas. Small transportable 30/20 GHz band earth stations with 3 m diameter antennas are used for emergency communications and for telephone and TV signals.

Diversity earth stations may be required (in areas of high precipitation rates) in order to ensure that service availability is high. It is also expected that very broadband transponders will be used at these frequencies.

2.3 Common user systems

Various networks in the FSS are used by more than one administration on a common basis to satisfy their domestic and/or international communication services.

A particular example of such a user system is the INTELSAT system. Other examples of common user systems are INTERSPUTNIK, ARABSAT, PALAPA and EUTELSAT.

INTELSAT provides satellite communication services to all nations on a non-discriminatory basis. At the end of 1984, the space segment consisted of 15 satellites and the earth segment consisted of a total of about 850 earth station antennas, including about 300 international and nearly 550 domestic antennas in more than 160 countries, territories and dependencies. The international service provided more than 36,000 full-time voice and data circuits and over 49,000 half-channel hours of television transmissions. Allotments amounting to some 40 transponders were leased to 27 nations for domestic communications.

The most recent INTELSAT satellites use approximately 500 MHz of spectrum for up-links and down-links in both the 6/4 GHz and the 14/11 GHz FSS bands. Advanced satellite antennas with spatially-isolated and polarization-isolated beams are used to achieve four-fold reuse of the 6/4 GHz spectrum in INTELSAT V and a six-fold reuse in INTELSAT VI services (see Table 2-3). In the earth segment, some INTELSAT users have introduced TDMA-PCM-DSI, which achieves a bandwidth utilization efficiency of about 35 channels/MHz as compared to 15 channels/MHz in the FDM-FM transmission mode.

TABLE 2-3

Characteristics of INTELSAT satellites

Satellite	No. of transponders	Frequency spectrum (MHz)	Total bandwidth (MHz)	Frequency reuse	Achievable channel capacity
INTELSAT-IVA	20	5 925-6 425 3 700-4 200	800	2 x 6/4	6 000 2-way voice + 2 TV channels
INTELSAT-V[1]	27	5 925-6 425 14 000-14 500 3 700-4 200 10 950-11 200 11 450-11 700	2 137	4 x 6/4 2 x 14/11	12 000 2-way voice + 2 TV channels
INTELSAT-VA[2]	32	5 925-6 425 14 000-14 500 3 700-4 200 10 950-11 200 11 450-11 700	2 252	4 x 6/4 2 x 14/11	15 000 2-way voice + 2 TV channels
INTELSAT-VI	50	5 850-6 425 3 625-4 200 14 000-14 500 10 950-11 200 11 450-11 700	3 200	6 x 6/4 2 x 14/11	35 000 2-way voice[3] + 2 TV channels

1) INTELSAT-V F5-F9 are equipped to provide maritime communications using the frequency bands:

1 636.5 - 1 644.5 MHz; 1 535.0 - 1 542.5 MHz
6 417.5 - 6 425.0 MHz; 4 192.5 - 4 200.5 MHz

2) INTELSAT-VA F13-F15 are equipped to provide business communications using the frequency bands:

14 000 - 14 500 MHz; 12 500 - 12 750 MHz (Europe), 11 700 - 11 950 MHz (North America).

3) This assumes an increased number of digital links using SS-TDMA.

In addition, modified INTELAT-VA series of satellites under construction will use the 14/12 GHz bands for the provision of international business services directly to urban centres in many countries, while the INTELSAT-VI series satellites will be equipped to use 75 MHz of spectrum in the 6/4 GHz bands newly allocated at the WARC-79.

2.3.1 Special issues of relevance to common-user systems

2.3.1.1 Service arc considerations

The choice of orbital locations for a common-user system may be more constrained by the geographical locations of the various users of the system than would be the case for some national systems. The choice of orbital locations for a satellite system which must have the capability to connect all users in a given region is limited by the need to provide visibility, at satisfactory angles of elevation, for earth stations at the edge of the coverage area.

In the Atlantic Region for INTELSAT, for example, the location of the primary path satellite cannot be varied by more than 1.5^{o} without reducing the elevation angle of the limiting earth stations to less than 5^{o}, i.e., the minimum for satisfactory operation in the 6/4 GHz bands. In the Indian and Pacific Ocean Regions the service arc for the primary path satellite is only 3^{o} wide.

2.3.1.2 Space station coverage considerations

The size of satellite antenna beam coverage may also be affected by the geographical extent of the user administrations. The largest such beam would occur in systems providing service on a global basis. In such a case, a beam which covers all administrations served by the common-user system, whether global or regional, is particularly useful for TV distribution services, in which several widely dispersed earth stations which are not located in other coverage beams require simultaneous reception of a certain telecast. Such beams can also provide connectivity for widely distributed thin-route earth stations throughout the service area and the trend is to limit the bandwidth required for use in such beams to the minimum.

2.4 Current technology and operational characteristics in the FSS

2.4.1 Earth-station technology

The most important earth-station technologies are those associated with antenna characteristics and transmitter/receiver techniques. These factors affect the satellite network characteristics, and some of them have much to do with the efficiency of utilization of the geostationary-satellite orbit/spectrum.

2.4.1.1 Antenna characteristics

The most relevant earth-station element, amongst those mentioned above, is the antenna sub-system. Two important performance parameters of an earth-station antenna have a direct effect on orbit utilization: side-lobe and polarization characteristics.

The antennas used in most earth stations are of the axisymmetric Cassegrain type. It is known that for this type of antenna the effect of blockage and diffraction due to the sub-reflector and its supports results in increased side-lobe levels. Nevertheless, many antennas now in use have improved side-lobe performance, particularly those of D/λ greater than 150. There are also new small asymmetric type antennas that are being installed with better side-lobe performance.

2.4.1.2 Polarization characteristics

Polarization discrimination depends on the polarizer characteristics and the surface accuracy of the main and sub-reflectors, the former being the major contributor. A typical value of polarization discrimination required for current earth-station antennas is 30 dB (axial ratio of approximately 0.5 dB for circular polarization) and earth-station antennas with polarization discrimination of more than 30 dB are currently feasible. On the other hand, improvement in polarization discrimination beyond a certain threshold (approximately 30 dB), while feasible, does not result in a significant increase in capacity. This is the case, for example, for small-sized earth stations with low traffic requirements, that usually have reduced polarization isolation performance.

2.4.1.3 High power amplifiers (HPAs)

Klystrons and travelling wave tubes (TWTs) are used at the present time for earth-station high power amplifiers. Though the signal bandwidths of klystrons are about 40 MHz to 80 MHz, a band of 500 MHz can be covered by tuning the cavity in the 6, 14 or 30 GHz bands. Regarding the maximum saturated output power, klystrons of 14 kW in the 6 GHz band, 3 kW in the 14 GHz band and 500 W in the 30 GHz band have been developed. TWTs have signal bandwidths of 500 MHz in the 6, 14 and 30 GHz frequency bands respectively and do not require tuning. Regarding the maximum saturated output power, TWTs of 14 kW in the 6 GHz band, 3 kW in the 14 GHz band and 700 W in the 30 GHz band have been developed.

To reduce the level of intermodulation products produced in the HPA for multi-carrier operation, a linearizer of the pre-distortion type has been developed and used in some earth stations. By using such a linearizer, the level of intermodulation products will be reduced by more than 10 dB in the range of output back-off equal to or larger than about 6 dB.

2.4.1.4 Receiver techniques

Use of a receive chain with a low system noise temperature at an earth station is an essential requirement in a satellite communication system. The receiving system noise temperature is mostly determined by the noise contribution of the antenna and the first stage amplifier. At present, parametric amplifiers either cooled by gaseous helium or thermo-electrical devices or operating at ambient temperature are in use. Low noise amplifiers using a GaAs FET have been developed. The noise temperature achieved in the 4 GHz frequency band by these four kinds of low noise amplifiers is less than 20 K, 45 K, 80 K and 80 K respectively. The bandwidth of LNAs currently being used in the 4 GHz frequency band is 500 MHz. In the 11 GHz frequency band, parametric amplifiers with a bandwidth of 750 MHz and a noise temperature of about 90 K and an FET amplifier with a noise temperature of about 120 K are available. In the 20 GHz frequency band, parametric amplifiers with a bandwidth of 2.5 GHz and a noise temperature of about 80 K (cooled by gaseous helium), 200 K (cooled by a thermo-electrical device) and FET amplifiers with a noise temperature of about 220 K (cooled by a thermo-electrical device) or 300 K (ambient temperature) are feasible.

2.4.2 Space station technology

The most important space station technologies are those associated with antenna characteristics and transponder components. These factors affect the satellite network characteristics and also contribute to increasing the efficiency of utilization of the geostationary-satellite orbit/spectrum. In particular, satellite antenna technology provides the major technique for the provision of increased frequency reuse from a single orbit location, whether on the same satellite or on different satellites.

2.4.2.1 Antenna technology

While spot beam antennas provide for more frequency reuse of a given bandwidth, this is limited by the need for coverage and by the separation of the covered areas. Shaped beam technology offers some possibilities to enhance the application of spot beam technology for a wide variety of requirements.

Shaped beam antennas offer the potential for improved side-lobe control particularly where the coverage area itself is rather large, thus improving the possibility of frequency reuse between coverage areas closer to each other. However, it should be noted that discrimination beyond the edge of coverage is a function of satellite antenna dimensions; launch vehicle constraints may be a factor here. Some present launch vehicles can accept a solid antenna with dimensions of approximately 3.8 metres.

The orbital positions of existing satellites may have to be changed to accommodate new satellite systems. To cope with this situation, space station antennas would have to be designed accordingly. The direction of the radiation patterns would probably have to be changeable by control from the ground. In some cases it may be desirable to reshape beams in service in order to allow for a large change of location. However, the cost and operational impact of introducing such capabilities have not been sufficiently studied.

2.4.2.2 Transponder components

Since the introduction of communication satellites, there has been continuous improvement in the e.i.r.p. The higher e.i.r.p. levels translate into higher down-link C/N and correspondingly increased channel capacity, for a given size earth station. A domestic satellite concentrates its radiated power onto a single country, and generally achieves a higher e.i.r.p. than an international system with global or large area coverage, for the same size TWTA. In addition, these higher e.i.r.p. levels result from the use of higher power amplifiers in the satellites.

Solid-state devices such as field effect transistors (FETs) are generally less efficient than TWTs as power amplifiers but provide better linearity. Thus, higher capacity may be achievable for multiple access systems because of better carrier-to-intermodulation ratios.

2.4.3 Multiple-access and modulation techniques

Multiple-access and modulation techniques are interrelated, and affect the bandwidth efficiency of systems.

2.4.3.1 Multiple access

Multiple access is the technique which enables respective transmission links of a large number of earth stations to be interconnected through the same satellite. This technique is essential to exploit the unique geometric properties of wide-area visibility and multiple connectivity which are features of satellite communication systems.

Multiple-access techniques can be classified into the following two systems in respect of circuit utilization:

a) pre-assigned multiple access;

b) demand-assigned multiple access.

In the former system the channels required by earth stations are assigned permanently. In the latter system the channels are assigned to the stations only on demand and satellite channels are therefore time shared amongst users.

Moreover, multiple-access techniques can be classified into the following three systems:

- FDMA: frequency-division multiple access;
- TDMA: time-division multiple access;
- CDMA: code-division multiple access.

In FDMA, the usual practice is pre-assigned multiple access; therefore carrier frequencies are assigned exclusively to each earth station and multiple carriers of different frequencies share a common satellite repeater. Such a multiple carrier operation always results in less capacity being available as compared with the single-access mode due to the power back-off which is required to reduce the level of intermodulation products. The modulation techniques associated with FDMA can be single-sideband AM, frequency modulation or various digital modulations such as 2-PSK or 4-PSK.

In TDMA, a carrier of the same frequency is time shared by stations on the basis of non-overlapping (in time) burst transmissions through a satellite repeater. From the viewpoint of traffic, a TDMA system has greater flexibility than an FDMA system.

The CDMA system is one where signals occupy the same location in both the frequency domain and the time domain, but can be distinguished from others by appropriate signal processing. Spread spectrum multiple access (SSMA) is one example of a CDMA. SSMA makes use of a deterministic noise-like signal structure to spread the narrow-band information over a relatively wide band of frequencies. The spectrum spreading is achieved by modulating each signal by a unique code, so that a wanted signal can be demodulated by means of correlation detection in which signals having different codes will not be correlated.

2.4.3.2 Modulation techniques

For efficient utilization of the geostationary-satellite orbit/spectrum, it is desirable to adopt bandwidth-efficient modulation methods. The modulation methods widely used in current satellite communication systems are frequency modulation (FM) and phase-shift keying (PSK). Recent developments include the use of the SSB-AM in conjunction with compandors. SSB-AM provides a high-density analogue modulation alternative to digital systems. The development of highly stable, solid-state linear amplifiers for satellite transponders has given new life to this technique.

Frequency modulation is currently the predominant form of modulation in FSS networks. Typical bandwidths of individual RF carriers in use range from about 25 kHz to 36 MHz; (see Table 2-4).

TABLE 2-4

Bandwidth of typical FM RF carriers

Bandwidth	Application
25 - 45 kHz	SCPC
100 - 250 kHz	Broadcast-quality audio-programme distribution
1.25 - 36 MHz	FDM-FM, 12 to 1,800 channel telephony
17 - 36 MHz	Television, possibly with multiple audio bandwidth sub-carriers

PSK modulation uses digital signals which for voice requires analogue-to-digital conversion. The resulting digital signal is processed and coded usually into 64 kbit/s per channel. The PSK can be accomplished using any number of phase pairs to distinguish the binary state. Theoretically, 4-PSK requires the same power, but half the bandwidth per bit, as against 2-PSK for a given link performance. Higher order (greater than 4-phase) PSK systems are more susceptible to noise and, therefore, need more power than either 2- or 4-phase systems to achieve the same standard of performance. A decrease in the number of phases permits closer satellite spacing; however, the utilization of the GSO tends to be optimized when the number of phases is in the range of 4 to 8 and the orbit utilization efficiency tends to decrease as either a higher or a lower number of phases are utilized.

Typical bandwidths and applications of digital modulation (2-PSK and 4-PSK) are shown in Table 2-5.

TABLE 2-5

Bandwidth of typical digitally-modulated RF carriers

Bandwidth	Application
30 - 60 kHz	SCPC for thin-route voice applications, and 48-64 kbit/s data, with or without FEC
100 - 8 000 kHz	TDM data and/or digitized voice channels (high speed digital channels), thin-route TDMA
30 - 72 MHz	High capacity single access or TDMA systems, with or without digital speech interpolation (DSI)

Other digital modulation techniques, amplitude-shift keying (ASK), frequency-shift keying (FSK) and composite modulation techniques involving both amplitude and phase-shift keying have been studied. Of these techniques, ASK and hybrid techniques involving ASK are not suitable for TDMA because transponder non-linearities and power-efficiency effects usually constrain the modulation format to have a constant envelope. In the case of FDMA, the use of ASK and of hybrid techniques involving ASK is also restricted because of the greater sensitivity of ASK techniques to co-channel interference.

Recently, new modulation techniques such as minimal shift keying (MSK) and tamed frequency modulation (TFM), in which the envelopes of modulated carriers are constant, have been studied. Because these modulation techniques are expected to be desirable candidates for future systems, further studies are required.

The above modulation techniques are used in the RF domain. Also of importance are baseband and channel modulation techniques. In digital systems, it is possible to use 32 kbit/s modulation, and work on 16 kbit/s appears promising. A Recommendation of CCITT Study Group XVIII for 32 kbit/s ADPCM was recently approved. These techniques can yield up to four times the capacity, relative to 64 kbit/s PCM.

It is also possible to gain another factor of two to three in capacity using digital speech interpolation (DSI) in conjunction with any of the above modulation techniques.

Another common technique in use in satellite communication systems is single-channel-per-carrier (SCPC) on selected transponders for use with low-capacity earth stations. Typically, PCM (digital) or companded FM (analogue) equipment is used to modulate a single voice transmission, but delta modulated 2-PSK and 4-PSK units are also in service. SCPC systems are also in operation for medium-speed data (56 kbit/s) and audio distribution.

In satellite video transmissions FM with frame-rate energy dispersal is typical. The baseband may include multiple audio/data sub-carriers. Techniques are under development for dual television signal transmission through interframe interleaving of independent video signals. Such techniques will allow a single satellite transponder to carry two independent television transmissions with a quality comparable with today's single television transmission per transponder.

2.4.4 Some trends in system characteristics

Several other factors will have a significant impact on the changes in FSS characteristics affecting orbit utilization that can be expected in the future.

2.4.4.1 Traffic growth

FSS system characteristics are probably most affected by the growth in traffic volume carried over the system, the changing pattern of this traffic, and the introduction of new services. Initial loading may consist of a relatively few high-density links between major traffic centres. In time, additional links may be established to lower-density traffic centres and thin-route services provided to remote locations. Moreover, demand for services may be greatly stimulated by the availability of high quality communication facilities at a given location. Once earth stations are installed to provide basic services to a community, it is also relatively easy and economical to expand the range of services provided. Such additional services might include video and audio programme distribution and data transmission. Also, it is often more economical for a country initially to lease capacity in an existing, larger capacity satellite. Eventually, traffic may grow to the point where a dedicated satellite is economically justified. Where several nearby countries have been leasing capacity on a global satellite system, such a dedicated satellite system might initially take the form of a regional system, rather than individual national systems, to reduce space segment costs. It is expected that each system will have its own unique pattern of development.

2.4.4.2 Integrated services digital networks

With the rapid growth in international and national digital services, satellite systems are expected to play an increasingly important role. The CCIR is developing a Recommendation which discusses the necessary satellite performance characteristics to meet the CCITT ISDN objectives. For satellite systems which are expected to provide channels for an ISDN, these performance objectives should be taken into account.

2.4.4.3 Modulation type and transmission parameters

Changes in traffic volumes and patterns, as well as the introduction of new services and types of earth stations, can be expected to affect the types of modulation and carrier transmission parameters associated with an FSS system. These changes may result in transmissions having greater or lesser susceptibility to interference and greater or lesser potential to cause interference. For example, as traffic grows on high traffic density links, it is usually more economical to increase the RF carrier capacity by using more bandwidth-efficient modulation techniques than to utilize additional transponders. In addition, SCPC-FDMA transponder configurations are used more often as lower density, thin-route locations are added to the FSS network. However, low capacity TDMA systems are also under development where several such systems may access a transponder in an FDMA mode.

2.4.4.4 Trend to limited coverage and beam shaping

Spot beams from space stations in the FSS increase satellite G/T and e.i.r.p. and permit frequency reuse. The use of narrow antenna beams that concentrate gain over the coverage area helps to reduce earth segment costs and increase satellite capacity.

Such spot beams are becoming almost universal for national coverage FSS systems. When coupled with fast roll-off side-lobe characteristics, a substantial increase in orbit utilization can be achieved. This is because the orbital separation between narrow-beam satellites serving non-overlapping coverage areas can be reduced due to the satellite antenna discrimination. With coverage areas a sufficient distance apart and/or fast enough roll-off characteristics, such satellites could be located at the same nominal orbital locations; the risk of collision is remote.

The use of spot beams covering different portions of a satellite's service area can also lead to greater orbit utilization. The spatial isolation between narrow beams permits frequency reuse at the orbital location.

In addition, advances in satellite antenna design technology permit shaping of the satellite antenna beam. Such shaping may be used to adapt the contours of the antenna beams to fit the required coverage areas more closely.

2.4.4.5 Increase in e.i.r.p. and sensitivity

There is a distinct trend towards increased satellite e.i.r.p. and decreased space-station and earth-station receiver noise temperatures. This trend tends to encourage increased transponder capacity and lower-cost earth stations.

Also, the trend towards higher e.i.r.p. satellites may also be used to advantage to improve orbit utilization by permitting an increase for each FSS system in the portion of the noise budget allocated to interference from other satellite systems.

2.4.4.6 Trend towards bandwidth limited and interference limited operation

In many systems, one satellite may be required to serve an increasing number of earth stations. The ability of a single satellite to satisfy such growing requirements may be limited by the bandwidth available. In the case of satellites using multiple spot beams for frequency reuse, available capacity may also be limited by interference levels between the various spot beams.

2.4.4.7 Expansion bands

While little use has been made of the new bands allocated by WARC-79 in the 6/4 and 14/11 GHz ranges, it can be expected that they will be of increasing value in the future as requirements continue to increase.

The propagation conditions which will be experienced in the new bands in the 6 and 4 GHz region result in the same transmission environment as the conventional 6 and 4 GHz bands. This will allow new systems using these bands to employ designs for both space station and earth stations essentially identical to current systems.

Systems using the new bands around 14/11 GHz will be essentially identical to those currently in use in the conventional bands at 14/11 GHz. The additional 500 MHz that is available for both up- and down-links can provide the same capacities as current systems since the transmission environment is the same. No significant extra cost is expected for new systems.

2.4.4.8 Higher frequency bands

FSS systems will increasingly use the higher frequency bands for a number of reasons. First, the addition of higher frequency bands to an FSS system may be more economically and technically attractive than more intensive frequency reuse techniques. Additionally, increasing orbital congestion in the lower frequency bands will also lead to use of the higher bands. In particular, the greater antenna directivities available at the higher frequencies will permit smaller satellite spacings and thus a greater number of satellites to be accommodated. Consideration of terrestrial interference may also lead to an increased use of higher frequency bands, especially if terrestrial systems are not highly developed in the higher bands. Finally, the higher frequency bands tend to have higher bandwidths available. For example a bandwidth of 3 500 MHz is available between 17 and 31 GHz.

ANNEX TO CHAPTER 2

The extent of usage of the GSO by the FSS

An example of the usage of fixed-satellite networks operating at 6/4 GHz, is illustrated in Figure 2-1 which is derived from information (December 1983) filed by administrations with the IFRB for the use of orbital locations. Some of these satellites are not now in orbit, nor are all satellites operating in the full band, e.g., some are exclusively for feeder links in the maritime mobile-satellite service (MMSS). These factors are illustrated by the breakdown of statistics accompanying the figure. In addition, Figure 2-2 displays the use of the 6/4 GHz band relative to other currently allocated FSS bands. Also, multiple entries appear at some orbit locations. This provides for contingency or replacement of one satellite series with another and reduces the number of real operational satellites carrying traffic. The total transmission capacity of these satellites depends on a large number of factors including earth-station antenna size and satellite communications payload parameters.

Figure 2-3 shows networks operating at 7 and 8 GHz which have been published in IFRB circulars. The satellite density is obviously much lower than in the 6 and 4 GHz bands.

Similarly, Figures 2-4 and 2-5 show the situation at 14/11-12 GHz and above 15 GHz.

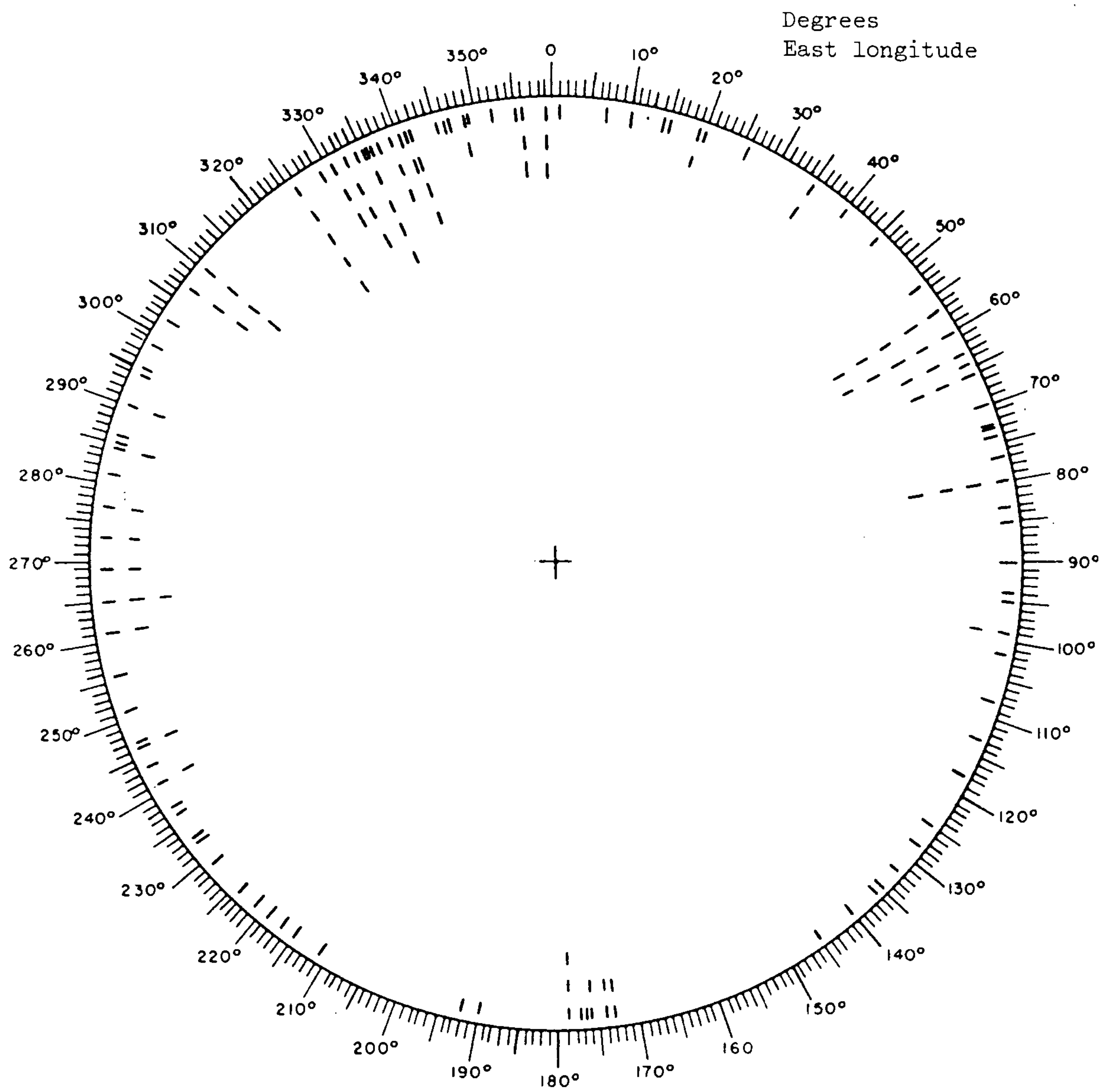

FIGURE 2-1

Orbital locations of 6/4 GHz FSS entries

(IFRB data as of December 1983)

Each dash within the circle represents one space station at a specific orbital position

Approximate distribution of networks

FSS only one band	FSS only ≥ 2 bands	Total FSS only	FSS and other services
55%	30%	85%	15%

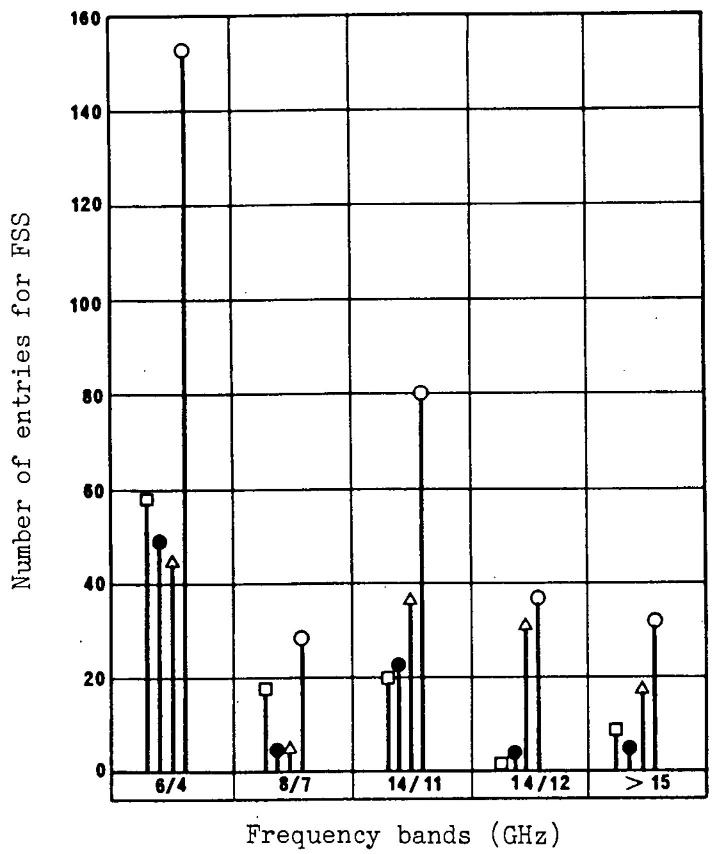

FIGURE 2-2

Tabulation of FSS entries by frequency band

(IFRB data as of December 1983)

□ registered
● presently being coordinated
△ only advance publication
○ total

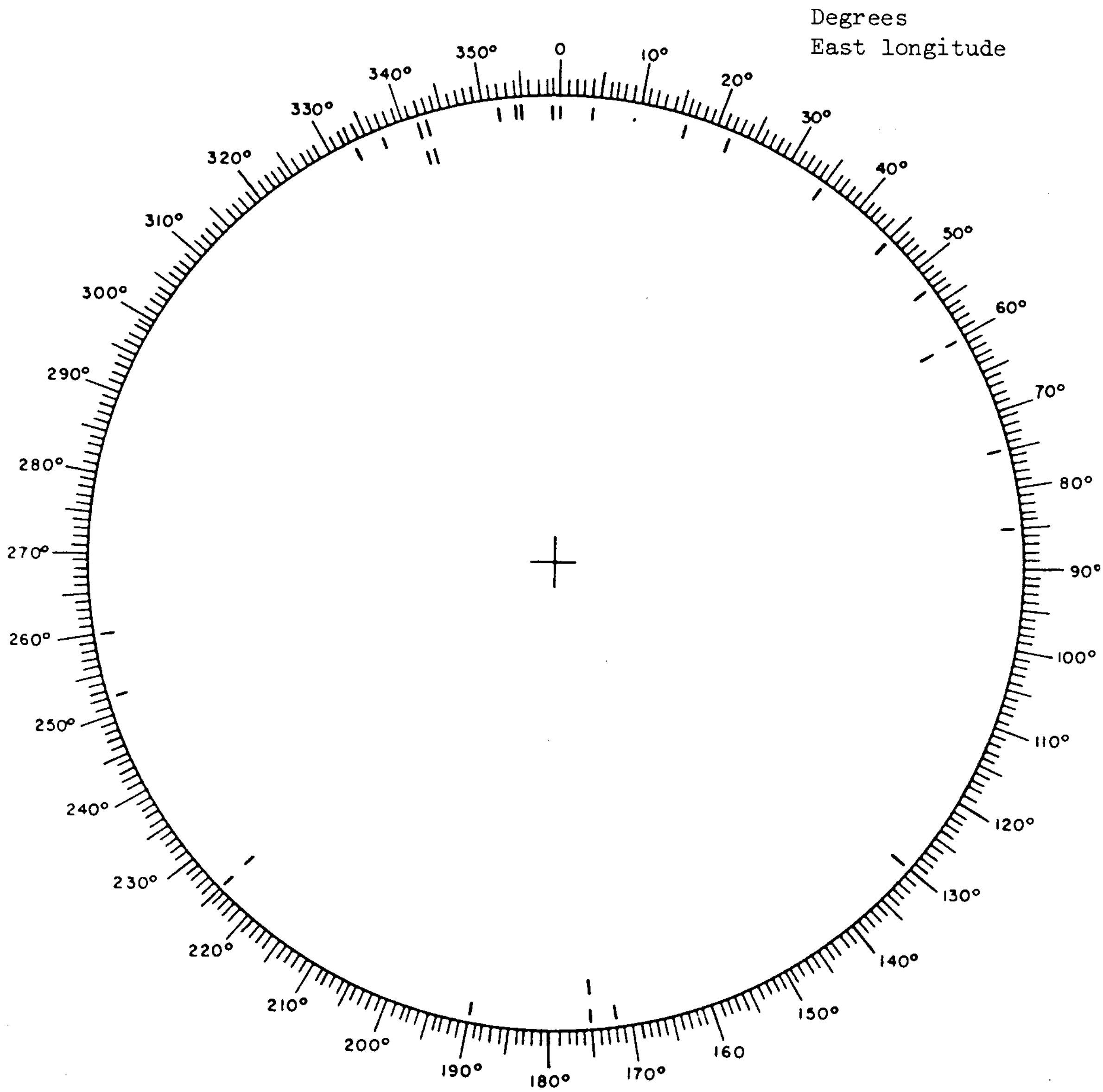

FIGURE 2-3

Orbital locations of 8/7 GHz FSS entries

Each dash within the circle represents one space station at a specific orbital position

Approximate distribution of networks

FSS only one band	FSS only ≥2 bands	Total FSS only	FSS and other services
40%	-	40%	60%

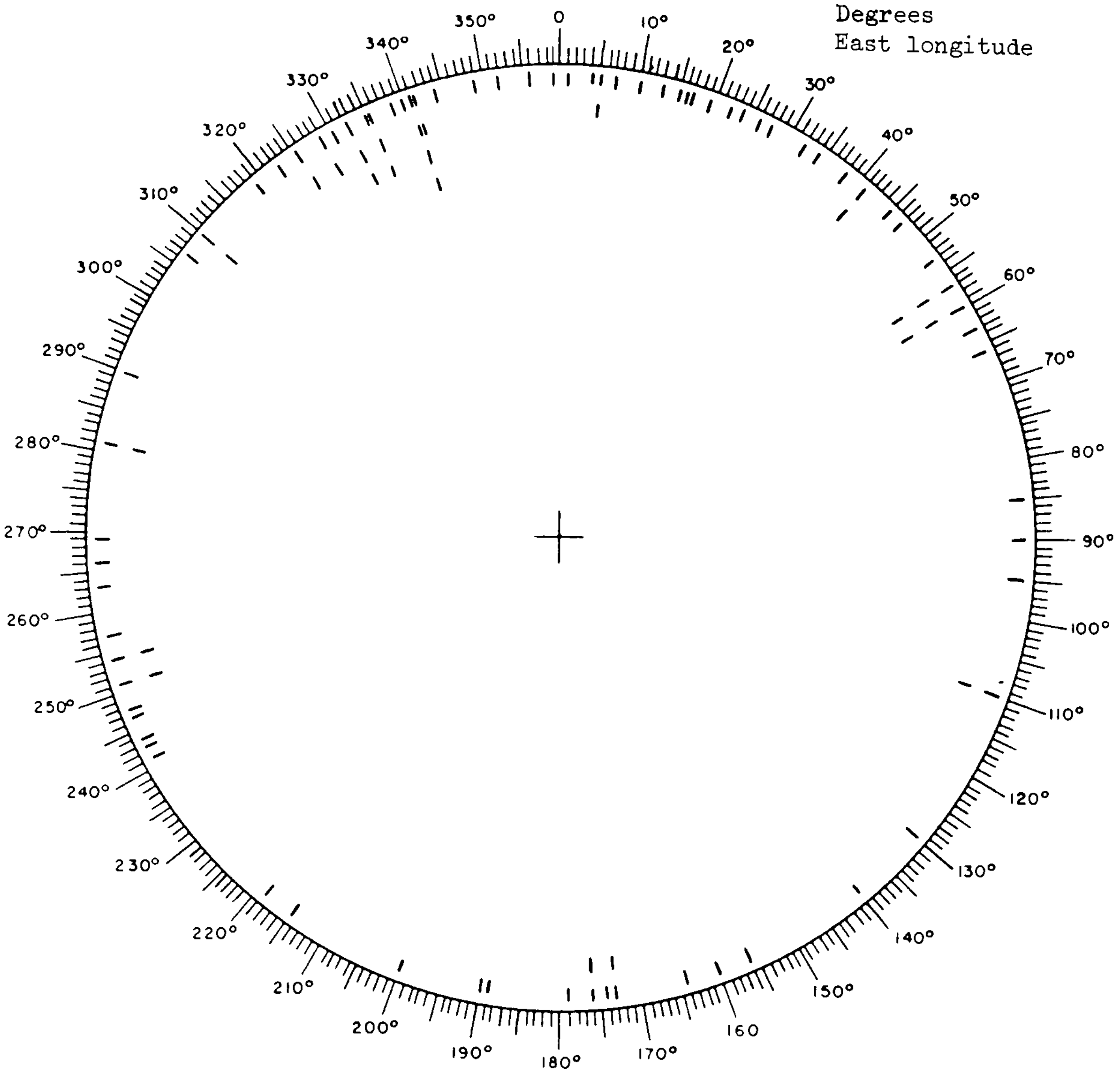

FIGURE 2-4

Orbital locations of 14/11-12 GHz FSS entries

Each dash within the circle represents one space station at a specific orbital position

Approximate distribution of networks

FSS only one band	FSS only ≥ 2 bands	Total FSS only	FSS and other services
35%	50%	85%	15%

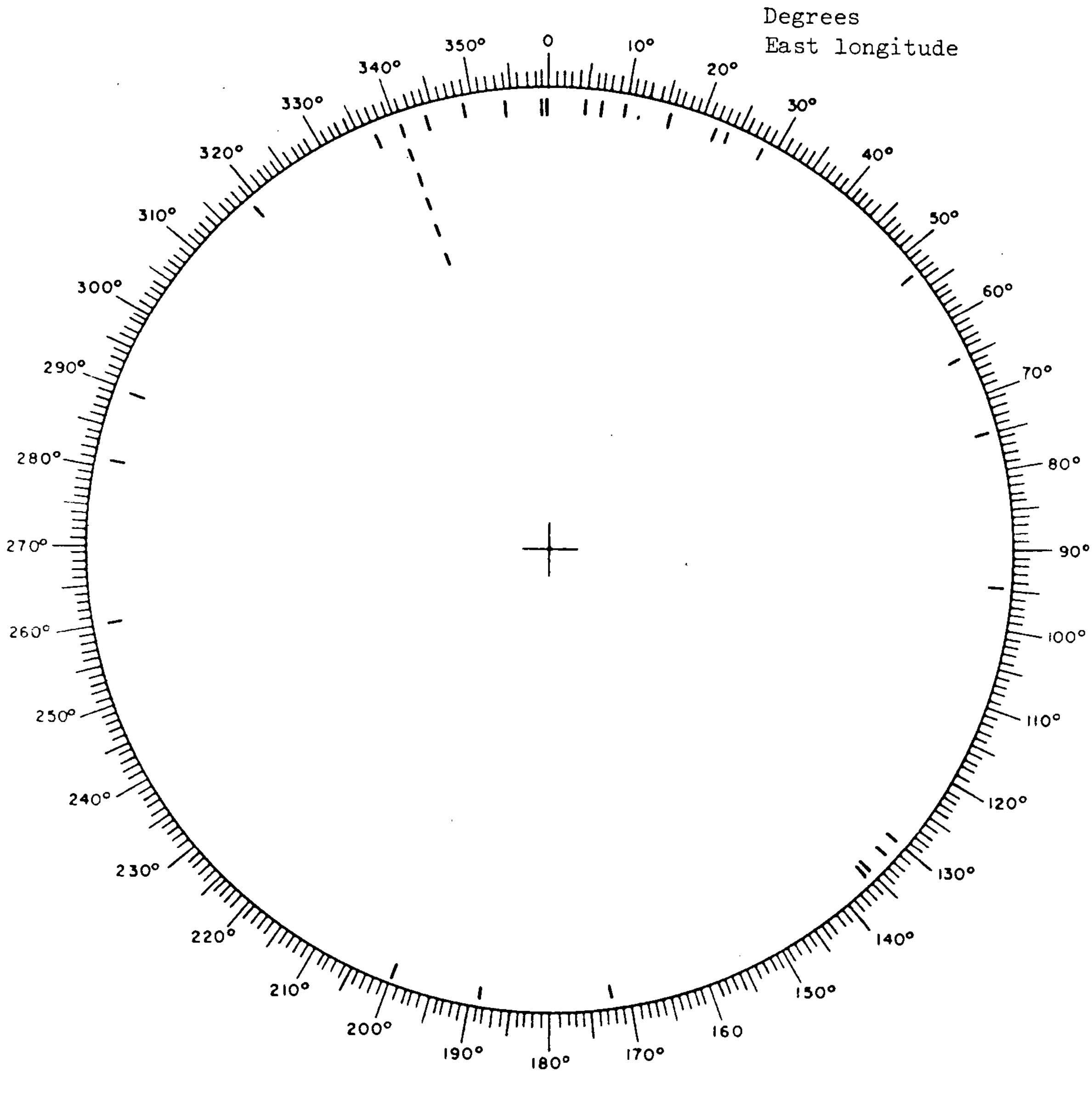

FIGURE 2-5

Orbital locations of >15 GHz FSS entries

Each dash within the circle represents one space station at a specific orbital position

Position 341°: these are feeder links in the band 17.3 - 18.1 GHz for the broadcasting-satellite service.

CHAPTER 3

Planning

3.1 Frequency bands and space services identified for planning

The planning shall concern only the FSS in the bands 6/4 GHz, 14/11-12 GHz and 20/30 GHz*.

3.2 Planning principles

3.2.1 Guarantee of access and equitability

The planning methods shall guarantee in practice for all countries equitable access to the geostationary satellite orbit and the frequency bands allocated to the space services utilizing it, taking into account the special needs of developing countries and the geographical situation of particular countries.

3.2.2 Sharing with other services

Where frequency bands allocated to one space service using the geostationary satellite orbit are also allocated to other space services and/or to terrestrial services on an equal primary basis, the planning methods must fully respect the equality of rights to operate in these bands. Therefore, the planning method and associated regulations must not impose additional constraints on terrestrial and/or space services sharing the band on an equal basis.

3.2.3 Reservation of resources

a) The planning method should consider the full orbit/spectrum resource. The possibility of setting aside portions of the resources to accommodate unforeseen requirements and requirements of future members of the Union shall be considered after all requirements are satisfied.

b) The planning approach must be consistent with the universally accepted principle that administrations or groups of administrations are not entitled to permanent priority in the use of particular frequencies and GSO positions in such a way as to foreclose access by other administrations to the GSO and frequency bands allocated to space services.

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* Note by the General Secretariat - See 3.3.1 b) and the associated foonote**.

3.2.4 The technical aspects of special geographical situations

The planning method should take into account the relevant technical aspects of the special geographical situation of particular countries.

3.2.5 Consideration of existing systems

The planning method shall take into account existing systems. If necessary, these systems may be subjected to some adjustments to allow for the accommodation of new systems. The degree of adjustment to which a system would be subjected would depend upon the stage of development of the system.

3.2.6 Provisions for multi-administration systems

a) The planning method shall take into account the requirements of administrations using multi-administration systems created by inter-governmental agreement and used collectively without affecting the rights of administrations with respect to national systems.

b) The planning method shall take account of the specific characteristics of such multi-administration systems in order to enable them to continue to meet the requirements of administrations for international services as well as, in many cases, for national services.

c) It is understood that these multi-administration systems include those having a safety-of-life aspect* and having feeder links in the FSS.

3.2.7 Flexibility

The planning method should provide means to accommodate unforeseen requirements and modification of requirements of administrations. It should also be capable of accommodating advances in technology and should not prevent the use of technologies which are well proven and widely available.

3.2.8 Different planning solutions in different circumstances

A world-wide planning solution would be the most suitable, but the possibility of having different planning methods for different regions, frequency bands or orbital arcs shall not be excluded. In this case, the planning would be done at the same World Conference.

3.2.9 Efficiency

The planning method should ensure efficient and economical use of the geostationary orbit and frequency bands allocated to space services.

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* Some national systems serve the same purpose.

3.2.10 Provisions for multi-service and multi-band networks

The planning method should be able to accommodate multi-service and/or multi-band satellite networks, without imposing undue constraints on planning.

3.2.11 Others

The administrative cost of the developing and application of the planning method must be as low as possible.

3.3 Planning method

3.3.1 The planning method shall consist of two parts:

a) an allotment Plan that shall permit each administration to satisfy requirements for national services from at least one orbital position, within a predetermined arc and predetermined band(s). The allotment Plan shall be established in the bands:

- 4 500 - 4 800 MHz and 300 MHz to be selected in the band
  6 425 - 7 075 MHz; and

- 10.70 - 10.95 GHz, 11.20 - 11.45 GHz and 12.75 - 13.25 GHz;

b) improved procedures that shall satisfy requirements in addition to those appearing in the allotment Plan. These procedures shall be applied in the bands:

- 3 700 - 4 200 MHz
  5 850 - 6 425 MHz, and

- 10.95 - 11.20 GHz,
  11.45 - 11.70 GHz,
  11.70 - 12.20 GHz in Region 2*,
  12.50 - 12.75 GHz in Regions 1 and 3*,
  14.00 - 14.50 GHz,
  18.10 - 18.30 GHz* **,
  18.30 - 20.20 GHz**,
  27.00 - 30.00 GHz**.

3.3.2 Both parts of the planning method will need to conform to the planning principles contained in section 3.2.

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* In these bands the improved procedures shall apply between networks of the FSS only.

** The CCIR is asked to study the technical characteristics of the FSS in these frequency bands and to report to the Second Session of the Conference with a view to taking a decision on the future planning of these bands by a future competent conference.

3.3.3 The planning method must preserve the rights of other services having equal primary status in the bands to which this method is to be applied. This will necessitate the adoption and application of appropriate sharing criteria.

3.3.4 The allotment Plan

3.3.4.1 Service area

The allotment Plan shall be limited to national systems providing domestic services. The procedures associated with this Plan should contain provisions permitting administrations with adjacent territories to combine all or part of their allotments with a view to ensuring a sub-regional service.

3.3.4.2 Generalized parameters

The Plan shall be prepared on the basis of generalized parameters applicable to all allotments.

*3.3.4.3 Guarantee of access

All ITU Members shall have at least one allotment in the Plan. Each allotment shall consist of:

- an orbital position in a predetermined arc;
- a minimum bandwidth within the band(s) defined in section 3.3.1 a);
- a service area (see 3.3.4.1).

In order to make the Plan more flexible, the associated procedures should make it possible to modify an orbital position within the limits of the predetermined arc and to define the conditions for such modifications.

3.3.4.4 Bandwidth

The bandwidth associated with each allotment shall be 800 MHz.

3.3.4.5 Predetermined arc

This allotment Plan refers to "a predetermined arc" as a means of increasing the flexibility of the Plan. The size and position of the arc necessitate intersessional studies.

3.3.4.6 Duration of the Plan

The allotment Plan is to be established for a period of at least ten years. The Second Session of the Conference shall decide on its exact duration. It shall form an integral part of the Radio Regulations and, as such, may be revised, if necessary, in accordance with the relevant provisions of the Convention.

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* Note - At the final readings of this paragraph at the seventeenth Plenary Meeting there was insufficient participation for a valid vote to be taken (No. 500 of the Nairobi Convention). An alternative proposition was maintained by two administrations.

The WARC-ORB(2) should adopt pertinent provisions to ensure that any allotment to satisfy national requirements shall not be deleted without the agreement of the administration(s) concerned.

3.3.4.7 Procedures associated with the Plan (see Annex 1 to the present Chapter)

The procedures associated with the Plan shall include:

- the procedures to be applied by administrations wishing to modify their allotments appearing in the Plan;
- the procedures to be applied for converting an allotment into an assignment;
- the procedures to be applied in order to ensure that new Members of the ITU obtain an allotment in the Plan.

3.3.4.8 Additional requirements

An additional requirement in the frequency bands covered by the allotment Plan may be accommodated to the extent that it will not introduce limitations to the bringing into use of an allotment in the Plan except if agreed by the administrations concerned. It shall not cause interference unacceptable to assignments in use which are in conformity with the Plan.

*3.3.4.9 Existing systems

In considering the establishment of the allotment Plan, existing systems are those:

a) which are recorded in the Master International Frequency Register;

b) for which the coordination procedure has been initiated; or

c) for which the information relating to advance publication was received by the Board before 8 August 1985.

Existing systems in the bands mentioned in section 3.3.1 a) shall be included in the Plan on an equal basis with planned allotment and may be subject to some adjustments. The degree of adjustment of which an existing system would be subjected would depend upon the stage of its development. The adjustment criteria shall be drawn up at the Second Session of the Conference.

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* Note - At the final readings of this paragraph at the seventeenth Plenary Meeting there was insufficient participation for a valid vote to be taken (No. 500 of the Nairobi Convention). An alternative proposition was maintained by two administrations.

3.3.5 Planning by improved procedures

3.3.5.1 General

The principal characteristic of this method is the convening of periodic multilateral planning meetings.

The multilateral planning meeting shall be the normal process for gaining access to the GSO/spectrum resources.

Additionally, in cases where administrations have an urgent need between multilateral planning meetings, simple matters of access or modifications could be dealt with between administrations. These cases shall be formalized at the next multilateral planning meeting.

The multilateral planning meeting approach should be a new and separate procedure to be added to the Radio Regulations.

The nature of these meetings and the status of their decisions or conclusions should be considered by the Second Session of the Conference. The meetings may be convened at fixed intervals or convened when required, and may or may not need to be covered by new provisions within the framework of the Convention.

3.3.5.2 Guarantee of access

The overall aim of these procedures shall be to guarantee in practice for all countries equitable access to the orbit/spectrum resources in the relevant bands at the same time protecting existing systems.

3.3.5.3 Guidelines

These guidelines for procedures shall combine the best features of the proposals made by administrations and the views expressed by administrations. Some of the possible features of these procedures include:

a) simplification of the advance publication procedure of Article 11;

b) consideration of periodical multilateral planning meetings;

c) "burden-sharing", including proportional burden sharing where appropriate, for possible use in assistance in ensuring access to the orbit/spectrum resources when appropriate;

d) the use of further technical measures in resolving problems of space station coordination;

e) consideration of existing systems in these bands;

f) provisions for bilateral consultations between administrations and the availability of the assistance by the IFRB.

3.3.5.4 Necessary studies

Administrations should be urged to consider the implications and possibilities of this approach in the intersessional study period, and submit proposals to the second session. Among factors relevant to such meetings which should be considered are:

- the timing;
- the status of the decisions taken;
- the financial implications;
- the scope and form of requirements and the stage at which they should be submitted;
- the participants in the meeting;
- safeguarding the interests of non-participants;
- the convening authority;
- whether bilateral agreements reached in the period between meetings should be subject to ratification at the next meeting.

3.3.5.5 Possible approach

An outline description representing a synthesis of proposals from administrations is included in Annex 2 to the present Chapter.

3.4 Technical parameters and criteria

3.4.1 Introduction

This section outlines some technical considerations related to the planning of the fixed-satellite service. The material is in support of the planning methods given in section 3.3. Several items have been identified for study in the intersessional period and the results of these studies should provide the necessary level of technical detail.

This section outlines specific technical principles in the effective use of orbit and spectrum, optimization of satellite arrangements, and inter-service sharing considerations related to planning.

3.4.2 Principles of effective use of orbit and spectrum by the fixed-satellite service

3.4.2.1 Efficiency and cost in the use of orbit and spectrum

3.4.2.1.1 The world-wide demand for fixed-satellite service facilities is growing rapidly and it is expected to continue to grow in the foreseeable future. The total capacity of the geostationary satellite orbit and of the frequency bands allocated to the fixed-satellite service (FSS) can be increased very greatly, by technical and administrative means, to meet this future demand. Many factors can contribute to this growth of available capacity; perhaps the most important are:

- the use of efficient planning procedures for regulating access to the radio spectrum for space services;
- effective harmonization of the characteristics of networks which use adjacent orbital locations, as one of the first stages of any planning method to be adopted;
- the adoption of guidelines applicable to the use of different frequency bands which will reduce the inhomogeneity of networks which interfere with one another;
- limitation of satellite antenna coverage to the required service area, accompanied by a rapid roll-off of antenna gain outside the coverage area;
- improvement in earth station antenna side-lobe suppression;
- limitation of the spectral radiation density outside the main beam of earth station antennas;
- good satellite station-keeping and satellite antenna beam pointing;
- the use of transmission techniques which enable a large amount of information per unit of bandwidth to be carried, which are relatively insensitive to interference and which produce a well-dispersed power spectrum;
- relatively high circuit interference noise within acceptable limits from other networks of the service within the overall noise budget;
- use of polarization discrimination within or between networks.

3.4.2.1.2 In general, these factors can give benefit only if all or most satellite networks operating in a frequency band support them; the burden must be shared. It is, however, of the greatest importance that any regulatory procedures that are required to achieve this burden-sharing are not so rigid as to prevent the development of the FSS to provide economically the very great diversity of user applications for which it is a good medium.

3.4.2.1.3 The technological advances considered for the establishment of satellite telecommunication systems should be aimed not only at a more effective use of the orbit and spectrum, but also at acceptable economy, especially in the Earth segment. The stringent application of these factors will tend to increase system costs, and thus may make the benefits of space radio services less available. This may be particularly true for countries in certain special geographical situations. These situations are discussed in some detail in the CPM Report, Annex 4, section 4.5 and include the following:

- special latitudes
- dispersed territories
- terrain obstruction
- precipitation and sandstorms
- geographically small countries
- countries covering large geographical areas
- elongated countries
- dispersed population centres.

It has been possible to take into account the majority of these factors in the technical considerations of this Report.

3.4.2.1.4 Thus, it is necessary to take economic factors carefully into account when deciding how, and to what degree, these factors which enhance orbit/spectrum capacity should be applied by the ITU. The following possible approaches to the optimization of the balance between the costs of individual networks and the total capacity of the orbit and spectrum have been identified:

a) Given the necessary time, the cost of efficient harmonization of satellite networks within the framework of planning as discussed in the CPM Report is likely to be small relative to the cost of building and running the networks themselves, yet the benefits of efficient harmonization will be large.

b) The technical performance criteria for equipment would not be needlessly stringent if the regulation of access to the radio spectrum in the geostationary satellite orbit were based on reasonably accurate forecasts of requirements.

c) The demand for satellite networks will vary between different frequency band pairs and, in a given frequency band pair, between different arcs of the geostationary satellite orbit. Thus, where constraints are applied to satellite network characteristics, it may be feasible to set mild constraints for some frequency bands and orbital arcs, where the demand is low, even though more stringent constraints may have to be applied where the demand is high. Intersessional study is required to determine how this might be achieved, to give relief in particular to networks of low capacity and complexity.

d) Article 29 of the Radio Regulations constrains certain network characteristics, such as accuracy of satellite station-keeping and the CCIR establishes Recommendations on key network characteristics, such as antenna performance and carrier energy dispersal. These measures have done much to increase the efficiency of the use of the geostationary satellite orbit. Much more improvement will, no doubt, be achieved by such means in the future. However, if it becomes necessary to impose new mandatory constraints on satellite networks, consideration should be given to constraining, not single characteristics, but the combined performance of groups of characteristics. In this way it would be possible to achieve the objective of limiting interference from one network to another, yet the designer of a network could conform to the constraint by whatever combination of these characteristics was most economical in the particular circumstances of the network in question.

e) When the need to recommend more stringent performance can be foreseen for one major characteristic of networks or more stringent mandatory constraints, a long period of notice should be given, to give sufficient time for the necessary equipment to be developed and manufactured. Where a large improvement in performance is foreseen to be necessary over a long period, it may be desirable to introduce the improvement in two or more stages. It would be desirable for such changes to be determined at regular intervals, perhaps at the Plenary Assemblies of the CCIR or at periodic administrative radio conferences which might be scheduled to follow the CCIR Plenary Assemblies.

f) It is essential that the introduction of more stringent mandatory constraints on networks should provide for the continued use of equipment, already in service, which has not completed its economic working life, even though it may not achieve the new standards. Similar provision may be necessary for equipment which is in an advanced stage of manufacture at the time when the new constraints are agreed.

3.4.2.2 Multi-band and multi-service factors

3.4.2.2.1 In some satellite networks it may be technically necessary for two pairs of frequency bands to be used by the satellite. The use by maritime mobile satellites of FSS frequency bands for feeder links is a good example of this need. In the similar case of broadcasting satellites, it is also necessary to use an FSS frequency band for feeder links.

3.4.2.2.2 In other situations it may be economically advantageous or operationally desirable to use two or more pairs of frequency bands for one or more services on a satellite. For example:

- The working bandwidth of a satellite network can be increased in this way. The circuit and radio frequency channel connectivity would also be increased if cross-strapping between the frequency bands in use is provided.

- Cross-strapping between frequency bands provides added flexibility in network configuration.

- The technology and practice of combining several space services on a single satellite is attractive in certain cases and is emerging. It is particularly attractive for countries requiring several space services and for which capacity requirements in any particular service are limited. Space stations serving two or more purposes may separately require only part of the minimum payload mass and power supply that is economically viable for a satellite. By putting both space stations on a single spacecraft, the total cost of the space segment may be significantly reduced, since heavier satellites tend to cost less per unit of payload mass and power to construct, put in orbit and control.

3.4.2.2.3 Such use of several frequency bands on one satellite will, of course, have to be taken into account in coordination or planning. It may have little impact on the efficiency of use of the geostationary-satellite orbit. This may be true if only one of the pairs of frequency bands on a multiband satellite is heavily used and if,

a) the other bands on that satellite are not heavily used near that location, and

b) the satellite is not constrained to that orbital position by operational requirements or by a frequency/orbital position plan.

3.4.2.2.4 However, this practice may reduce the efficiency of orbit utilization in other situations. The minimum angular separation required in the different frequency bands to prevent inter-network interference exceeding the permissible value will probably be different, creating the possibility that full use will be made of the orbit in only one frequency band or pair of frequency bands. If different satellites were used for each pair of frequency bands or each different service, optimum orbital positions could be used for each of these satellites after coordination or planning. When a single satellite is carrying all these facilities, a compromise orbital position must be used, and this is not likely to allow optimum coordination or planning with all other networks.

3.4.2.2.5 Two strategies have been suggested for reducing the impact of this problem where it might lead to inefficient usage, namely:

- for certain multiple-band configurations, system parameters may be adjusted to minimize the overall orbit/spectrum capacity losses. This generally consists in equalizing the required separation angles in the various bands;

- it may be feasible to make room between two multi-band satellites for an additional satellite operating in only one pair of frequency bands used on the multi-band satellites. This, however, may involve adjustment of the characteristics and parameters of the satellite networks.

It is recommended that these two possible strategies should be taken into account in determining the characteristics and parameters of satellite networks using more than one pair of frequency bands. In addition, it should be noted that the techniques of harmonization method M3 may be employed to optimize the utilization of the orbit in the vicinity of a complex satellite.

3.4.2.2.6 Nevertheless, such strategies may not be generally applicable, and it is recommended that administrations should give careful consideration to the advantages and disadvantages of this practice for applications in which it is technically avoidable.

3.4.2.3 <u>Systematic use of frequency bands</u>

3.4.2.3.1 <u>Frequency band pairing</u>

3.4.2.3.1.1 The typical fixed satellite service communication link involves transmission from an earth station to a space station and retransmission from the space station to another earth station. Accordingly, the Table of Frequency Allocations allocates several frequency bands to the fixed-satellite service for either Earth-to-space or space-to-Earth use. Although these frequency bands are used in pairs, the Radio Regulations do not require a satellite to use a specific Earth-to-space band with a specific space-to-Earth band. However, it is recognized that utilization of the GSO and the frequency spectrum would be more efficient, and coordination of networks would be facilitated, if specific Earth-to-space and space-to-Earth bands were designated in pairs. It can be foreseen that difficulties will arise in implementing the principle of pairing frequency bands. In view of these difficulties, it may be doubted whether future systems should be required to conform in a rigid way to a specific list of frequency band pairings.

3.4.2.3.1.2 In existing FSS systems, there is a high degree of standardization of frequency band pairing based mainly on frequency allocations as they existed before WARC-79, on the difficulties of coordination with terrestrial services, and on the requirements of the FSS themselves. It is clearly necessary that this existing situation be respected as much as possible and that due account be taken of the requirements of satellite networks for which other pairings are operationally essential.

3.4.2.3.1.3 Additional frequency bands newly allocated to the FSS at WARC-79 are being considered for the implementation of future satellite systems. Any band pairing arrangements in these additional frequency bands will have to take account of the operational requirements of future fixed-satellite systems, the different frequency allocations in the different regions, and the sharing constraints that exist in the relevant bands. Accordingly, any specific list of frequency pairings that can be developed should be used as a guide to be followed whenever feasible, and not as a regulatory requirement.

3.4.2.3.1.4 A number of technical considerations relating to the choice of bands for pairing are to be found in section 3.4.

3.4.2.3.2 Translation frequency for narrow-band satellites

Some satellites, for example satellites of the mobile-satellite services with feeder links in FSS bands, need to use only a part of the bandwidth of the allocated FSS band. In such cases the coordination of several narrow-band satellites occupying the same part of the GSO would be facilitated if all the satellites used the same effective translation frequency between the up-link and the down-link. In addition, it is desirable to keep to a minimum the number of translation frequencies.

3.4.2.3.3 Use of multiple frequency band pairs in satellites

In some satellite networks, it may be economically and operationally advantageous to use more than one pair of frequency bands; for example, to enable the working bandwidth of the network to be increased, to enable several different functions to be performed by one satellite, or to improve network connectivity by enabling communications to be established between users with different earth segments. Cross-strapping of transponders is essential for some applications and should not be prevented by any formal scheme of band pairing.

3.4.2.3.4 Conclusions and recommendations

3.4.2.3.4.1 Additional studies should be undertaken during the intersessional period, for consideration by WARC-ORB(2), with a view to:

1) determining the potential value of frequency band pairings for the work of the Conference, and

2) providing, if necessary and if possible, a list of FSS frequency band pairings which may be used as a guide for administrations to follow, to the extent possible, when designing and implementing future satellite systems.

3.4.2.3.4.2 The following list of technical considerations should be taken into account when developing any list of frequency band pairings in studies on the frequency bands to be planned:

- the ratio of mid-band frequencies of up-link and down-link bands should preferably not be so great as to complicate antenna design, nor so small as to complicate duplexer design;

- the paired bands, which will not necessarily include the full bandwidth of frequency allocations, should in most cases have equal bandwidth, and the number of translation frequencies for the paired bands should be kept to a minimum;

- as far as possible, no frequency in one band should be a simple multiple of any frequency in its paired band;

- pairings already well established in practice should be retained;

- to the extent feasible and necessary, consideration should be given to the use of FSS allocations for feeder links, taking due account of present utilization by the FSS;

- provision must be made to continue the established practice of cross-strapping from one pair of bands to another in a multi-band satellite;

- ITU Regional variations exist in the FSS allocations for Earth-to-space and space-to-Earth use.

3.4.2.4 Homogeneity of orbit utilization

3.4.2.4.1 The most effective orbit utilization would be obtained if all satellites utilizing the GSO, particularly those illuminating the same geographical area and using the same frequency bands, had the same characteristics, i.e. if they formed a homogeneous ensemble. However, in practice, satellite systems will have differences.

3.4.2.4.2 The extent to which inhomogeneity may represent an inefficient utilization of the GSO is dependent on many factors in the design of satellite systems. It is possible for the GSO to be more effectively utilized if inhomogeneity is taken into account during satellite system design. The system parameters which should be given particular consideration are satellite and earth-station e.i.r.p.s, the service area, the transponder gain, the earth-station figure of merit (G/T), the relative immunity of the modulation method to interference, etc. Even when these basic parameters remain inhomogeneous it may be feasible to mitigate their effect on the orbital separation requirements of satellites by a careful trade-off between the e.i.r.p.s and receiver sensitivities of networks using adjacent satellites. Thus, inhomogeneity is to be reduced, where feasible. However, the complete elimination of inhomogeneity is not compatible with economic use of the FSS for the wide diversity of applications for which it is needed.

3.4.2.4.3 Studies have shown that, in principle, the impact of inhomogeneity can be reduced by segregating highly incompatible emissions by orbit sectorization or spectrum segmentation.

3.4.2.4.4 Orbit sectorization would probably permit a reduction of inhomogeneity without constraining system characteristics. However, it is likely to impose constraints on the choice of orbital locations for satellites. Such constraints may not be significant in arcs of the GSO where the demand for access is light, but severe problems might arise for networks with very large service areas or those serving high latitudes, since such networks have small service arcs. Orbit sectorization might considerably reduce the benefits which might otherwise be obtained by the use of cross-beam geometry to enhance the capacity of the orbit for spot-beam satellites. In addition, to avoid severe inhomogeneity at the interfaces between sectors, there might be a need for guard arcs, although these would significantly reduce the benefits which would arise from the reduction of inhomogeneity within the sectors.

3.4.2.4.5 On the other hand, orbit sectorization might provide other benefits, in particular where the services required within a discrete geographical area are harmonious or where there are regional differences in frequency allocations. There is a need for further study of the potential benefits and disadvantages of orbit sectorization which it would raise. This study should be undertaken during the intersessional period in order that the results may be made available to the second session of this Conference.

3.4.2.4.6 Spectrum segmentation is also likely to permit a significant reduction in inhomogeneity. This subject is discussed further in section 3.4.3.4.4.

3.4.2.4.7 Another possible approach is to apply constraints to certain system characteristics in some of the frequency bands allocated to the FSS, by the use of unified technical parameters and criteria as far as possible. The economic impact of this approach on systems could be reduced by combining it with orbit sectorization and/or spectrum segmentation.

3.4.2.5. Global coverage and short service arcs

3.4.2.5.1 Introduction

Some telecommunications satellite systems are required to cover much or the whole of the visible portion of the Earth. Such applications include major international and regional systems, and perhaps also some national systems covering dispersed or wide territories or dispersed population centres.

3.4.2.5.2 Beams covering very large areas

3.4.2.5.2.1 The use of global beams by satellites is at present a common means of providing global coverage. However, from the standpoint of efficient orbit/spectrum use, global beams do not usually constitute the most satisfactory solution because they diminish the potential for using service area separation to reduce inter-satellite spacing and introduce inhomogeneity in relation to systems using spot beams.

3.4.2.5.2.2 Furthermore, the "arc of mutual visibility", reduced by other constraints in an FSS system to the "service arc", is an absolute limitation on the choice of an orbital location if service is to be provided between any two earth stations at the extremities of the service area(s) and at a nominal minimum elevation angle of 3° at the Earth's surface (see RR 2550).

3.4.2.5.3 Application of intersatellite links

3.4.2.5.3.1 Due to sharing constraints, some portions of the GSO may not be available for satellites used to provide fixed-satellite networks in global coverage or very large coverage area systems. A possible solution is the use of direct satellite-to-satellite relays. In this manner, a satellite serving earth stations widely dispersed in longitude, and therefore having an unavoidably short service arc, can be replaced by two satellites with direct interconnections, each with a long service arc, thus introducing much greater flexibility in the choice of an orbital location. The use of intersatellite links (ISLs), among other techniques, may facilitate coordination between global or large coverage area systems and domestic or small coverage area systems to the extent that they reduce inhomogeneity through reduced coverages and higher e.i.r.p.s.

3.4.2.5.3.2 The introduction of ISLs, however, depends on technical and economic considerations and on the availability of a mature level of technology.

3.4.2.5.3.3 The technical feasibility of the use of ISLs has already been experimentally demonstrated. However, in the short to medium term, the use of ISLs to provide wide-area coverage is likely to carry a large implementation and economic penalty. As a result, the use of ISLs to reduce the need for global beams is not considered a practical option at present, and thus does not warrant specific study during the intersessional period. In the long term ISLs may become economically attractive for some applications. Thus, continued study by the CCIR of their characteristics, advantages and penalties is warranted.

3.4.2.5.4 Conclusions

3.4.2.5.4.1 It is very desirable that global beams should be used only when strictly necessary, and with their use limited, as far as practicable, to a specified portion of the allocated band, thus facilitating spectrum harmonization. Studies and experiments should be conducted with a view to developing a more efficient system to replace this type of beam in the medium or long term.

3.4.2.5.4.2 The requirements of global and other satellite systems covering large areas, which are different from those of satellite systems covering only limited areas, must be given due consideration.

3.4.2.5.4.3 In summary, it is concluded that ISLs will not offer a viable alternative to the use of global beams for at least the next 10 to 15 years for most applications. As a result, the continuing use of global beams is warranted and can be expected to continue for some considerable time, but their use should be employed to the minimum extent necessary.

3.4.2.6 <u>Reverse band working</u>

3.4.2.6.1 It is feasible to use the same frequency band for up-links to one satellite and for down-links from another satellite, given suitable off-axis antenna characteristics at both satellites, a certain minimum orbital separation between the satellites and sufficient separation between the earth stations of the two networks. When combined with forward band working, reverse band working (RBW) could provide a significant degree of resource enhancement for the FSS. One study confirms that this enhancement might indeed be obtained if means could be found to deal with interference to and from terrestrial services.

3.4.2.6.2 As a technique it is well within current technology, although its implementation would add some constraint to coordination with existing systems sharing the same frequency bands.

3.4.2.6.3 Operation of a frequency band in both directions creates additional interference paths which do not arise when bands are operated unidirectionally. Recent studies by one administration examined these new interference situations and concluded that:

a) there will be no insuperable problems of interference with terrestrial services given a minimum angle of elevation of about 40^{o}, for earth stations at edge of coverage of the satellite, given good control of antenna side-lobe characteristics of earth stations and space stations;

b) the separations required between earth stations using a pair of frequency bands in opposite directions will be no greater than are typically required between earth stations and radio-relay stations;

c) difficulties associated with the antipodal interference path may be substantially reduced by arranging beam areas and/or satellite positions for RBW satellites in such a way that beams pointed at the equator are displaced by at least one half of the 3 dB beamwidth from the earth's equatorial limb (for a 2^{o} beam based on satellite antenna characteristics in CCIR Report 558-2).

3.4.2.6.4 These restrictions would be achieved naturally in the case of regional/domestic uses, particularly in low-latitude countries where relatively high rain rates and system geometry would dictate high elevation angles. Indeed, in the situation considered in the studies referred to above, the relatively high earth station elevation angles assumed would overcome the difficulties associated with antipodal interference.

3.4.2.6.5 From the foregoing considerations, the technique of reverse band working could offer substantial spectrum/resource enhancement for the FSS if it were carefully implemented. The problems of implementation should be the subject of intersessional studies. These studies should focus primarily on national or regional systems. Consideration should be given to:

- problems that may arise from inter-Regional differences of frequency allocations;
- the possible need for coordination modes not covered in Appendix 28 and Appendix 29;
- the extent to which the introduction of RBW would increase the orbit/spectrum resources available to the FSS;
- the impact of the introduction of RBW on the freedom to locate earth stations within a service area and on the ability to reposition satellites;
- sub-division of permissible interference budgets between interference from FSS networks operating in the same frequency band mode and interference from FSS networks in the opposite mode;
- the most appropriate means of facilitating sharing between RBW satellite networks and terrestrial services;
- the most economically advantageous way of implementing RBW;
- the development of means to deal with interference to and from terrestrial services.

3.4.2.6.6 It would be valuable to confirm the outcome of these studies by experimentation. The impact of reverse band working on sharing between the FSS and terrestrial services is considered in section 5.2.6.

3.4.2.7. Polarization discrimination

3.4.2.7.1 The use of orthogonal linear or circular polarizations permits discrimination to be obtained between two emissions in the same frequency band to and from the same satellite or different satellites at the same nominal orbital location.

3.4.2.7.2 The most effective way to employ polarization discrimination is by frequency reuse in the same satellite, where the greatest control of orthogonality is close to the beam axis. An improvement in capacity per unit bandwidth close to double is obtainable in this way. Polarization orthogonality between different satellites occupying the same orbit location may also be beneficial.

3.4.2.7.3 If the polarizations of adjacent satellites are orthogonal, it may be possible to use the polarization discrimination in the side-lobes of the earth-station antennas to reduce interference between the satellite networks, and to allow satellite spacing to be reduced. The side-lobe polarization discrimination obtainable in this way will be small, but even a few decibels of discrimination would permit a significant reduction in satellite spacing. However, it would not be possible to realize this benefit in a systematic way unless and until preferred polarization characteristics have been identified. This would need to involve a choice between linear and circular polarization and, where linear polarization is adopted, a choice of the preferred planes of polarization. There is not, at present, sufficient information to allow these choices to be made.

3.4.2.7.4 It is not in general feasible to benefit from polarization discrimination, whether between co-located satellites or adjacent satellites, if either or both use dual polarization of the same type within their own network. However, under specific circumstances and combined with interleaving of carriers, some benefit may be obtained.

3.4.2.7.5 Intersessional studies should be carried out to ascertain how much benefit could be obtained:

a) from polarization discrimination between nominally co-located single-polarization satellites serving different coverage areas;

b) between adjacent satellites, perhaps serving the same coverage area, both also having single-polarization.

3.4.2.8 <u>Climate and radio propagation</u>

3.4.2.8.1 Propagation effects are extremely important for planning the use of geostationary satellites for various radio services. It has been acknowledged that propagation attenuation in heavy rainfall areas imposes additional requirements on satellite system designs in the frequency bands above 10 GHz. In addition, rainfall also affects system polarization characteristics.

3.4.2.8.2 Normally, rain attenuation may be ignored for frequencies below about 5 GHz but constitutes a very important factor in systems above 10 GHz. The P and N rainfall zones correspond broadly to the countries at low and middle latitudes, particularly those of the tropical and equatorial areas. Stations in such areas should be designed to take due account of the effects of rain attenuation at the higher frequency bands. Furthermore, stations operating at such frequencies in territories at high latitudes may also be adversely affected by rainfall, particularly when viewing satellites from low elevation angles. Sandstorms may also be an important factor in some areas, such as deserts, in the frequency bands above 10 GHz.

3.4.2.8.3 Snow, especially dry snow, is much less serious than heavy rain, but melting snow can cause significant attenuation. Also, snow on the antenna and feed system can be more serious than heavy rain.

3.4.2.9 Provision for spare satellites in orbit

Provision for spare satellites in orbit reduces greatly the risk of serious loss of availability of satellite facilities due to spacecraft failures in service. Three situations commonly arise:

a) With appropriate telecommand and telemetry design, a spare satellite can be co-located with the operational satellite. In this case, the spare satellite does not increase the requirements of the system for orbit or spectrum.

b) Where a common spare satellite is used to protect services via two or more operational satellites which are close together in orbit, co-location of the spare satellite with any one of the operational satellites would not be satisfactory. For example, with that arrangement it would not be feasible to transfer services to the spare satellite from one of the operational satellites with which it was not normally co-located without first moving the spare satellite away from its nominal location and preferably to the location of the failed satellite. This would involve a long period of loss of service, a significant expenditure of thruster fuel and the possibility of interference with other satellites during the transit period. A common spare would have to occupy a planned or coordinated orbit location of its own, permitting rapid point-over from a failed satellite to the spare. This practice clearly increases the total orbit/spectrum occupancy of the system without a corresponding increase in the traffic carried.

c) However, it is currently usual for a spare satellite to carry pre-emptible traffic when it is not carrying traffic displaced from a failed satellite. A spare satellite which is used in this way needs its own orbit assignment, which increases the total orbit/spectrum occupancy of the system, although it increases the total traffic carried as well.

3.4.2.10. Space operation functions for the FSS

3.4.2.10.1 The space operation service with its space telemetry, telecommand and tracking functions performs both crucial and routine duties for space missions. In many cases, the services performed in space operation bands are on a short-term basis (e.g. launch and positioning operations); thereafter they are routinely performed in bands other than those allocated to the space operation service (e.g. the mission bands of the satellite).

3.4.2.10.2 The station-acquisition and station-changing phases of geostationary satellites will increase in number over the next few years and their individual duration may be extended. In view of the importance of space operation during these phases, the frequency requirements must be examined with as much care as in the case of phases of normal use.

3.4.2.10.3 To reduce the risks of mutual interference between satellites already on station and satellites being manoeuvred, two solutions may be envisaged, one of them being to use frequencies selected from the bands allocated to the space operation service for the satellite being manoeuvred.

3.4.2.10.4 Another solution, which might be better from the economic standpoint and from that of optimum spectrum utilization, is to use frequencies chosen from each of the bands allocated to the FSS. The administration concerned would determine which bands should be used for space operations functions for each system.

3.4.2.10.5 The feasibility of reserving a sub-band for operational functions in launch phases and manoeuvres should be the subject of future studies in the CCIR, along with other possible solutions. These studies should take into account the current practices and the needs of world-wide tracking networks.

3.4.2.11 Sources of physical interference

3.4.2.11.1 In the geostationary-satellite orbit there is a risk of collision with active spacecraft and blockage of beams of operational satellites due to the presence of uncontrolled man-made objects. At present, the probability of such physical interference is very low, though the number of satellites is expected to increase over time. It is advisable therefore, to urge the CCIR to develop, in the intersessional period, a better understanding of this physical interference process leading to:

- an identification of the relevant factors of what is thought at present to be a theoretical problem;

- an evaluation of the risks that this phenomenon could present in the future, and

- a recommendation for a solution to the problem should the study results justify further action.

3.4.2.11.2 The second session of WARC-ORB is invited to review the progress of these CCIR studies.

3.4.3 Optimization of the arrangement of satellites and emissions of the fixed-satellite service

3.4.3.1 Visible arc and service arc

3.4.3.1.1 The arc of the geostationary-satellite orbit within which a satellite must be located if it is to perform its mission satisfactorily is determined by the "visible arc" and the "service arc" of the network. The concept of these terms is explained in the Radio Regulations, Appendices 3 and 4.

3.4.3.1.2 A satellite located anywhere within the visible arc should be visible from any of the earth stations of the network at an angle of elevation not less than 10°. (It should be noted that CCIR Report 204 contains a definition of "visible arc" which is not precisely the same as the usage of the Radio Regulations.) This visible arc will be short in certain geographical situations, and particularly if the service area is very long in the East to West direction or if it includes territory at high latitudes. For small service areas, not at high latitudes, the visible arc will be very long.

3.4.3.1.3 The service arc is the arc of the orbit within which the space station could provide the required service. Ideally the service arc may be as long as the visible arc in the initial stages of the design of a satellite network; indeed it may be larger than the visible arc if an angle of elevation of less than 10^o is acceptable at earth stations. If the climate in the service area involves heavy rain, such that performance would be severely impaired at low angles of elevation, the administration responsible for the network may determine the initial service arc so that the minimum angle of elevation at earth stations is greater than 10^o, particularly if frequency bands above 10 GHz are to be used. Some such limitation may also be appropriate if there are sand or dust storms in the service area; however, little is known at present about the effect of sand or dust in the atmosphere on slant path propagation.

3.4.3.1.4 In terrain obstruction situations, where the propagation paths between earth stations and the satellite at low angles of elevation may be blocked by mountains, it may be possible to determine the visible arc taking into account the angle of elevation of the actual horizon as seen from all of the earth stations in the network. However, this may not always be possible, since the location of some of the earth stations may not be known at the time when the characteristics of the network are initially being determined. In such a case, it may be desirable to disregard terrain obstructions when determining the visible arc, and to determine the initial service arc so that the angle of elevation at all earth stations would not restrict the possible location of earth stations unduly. In a very mountainous country a suitable value for the minimum angle of elevation might be 30^o, unless the latitude of the country was too high to allow such a figure.

3.4.3.2 <u>Permissible interference</u>

3.4.3.2.1 The regulation of interference arising from sharing between fixed-satellite networks, without degrading the performance of circuits below recommended objectives, is achieved in the following way:

- a hypothetical reference circuit (HRC) or its equivalent is defined;
- a maximum level of total degradation from all sources is determined for that circuit;
- some fraction of that level of degradation is allocated to interference from all other networks of the FSS: this is called "total permissible interference";
- some fraction of this total permissible interference is recommended to be the level of interference which a network should permit from any other network. This is called the "single-entry" value;
- frequency coordination is used to make sure that the single-entry limit is not exceeded, the relationship between the single-entry value and the total permissible interference having been chosen so that the aggregate of single entries will not exceed the total permissible interference.

3.4.3.2.2 Hypothetical reference circuits (HRCs) are defined for various types of circuits (analogue, digital, voice, TV) in the relevant CCIR Recommendations. For these HRCs specific allowances for the permissible interference levels have been established. To cite only one example, Recommendation 353-4 (MOD I) recommends that the noise power in any telephone channel in an FDM-FM system conforming to the HRC defined in Recommendation 352-4 shall not exceed 10000 pWOp for more than 20% of any month. Recommendation 466-3 (MOD I) recommends that the noise level in such a circuit due to interference from other fixed-satellite networks should not exceed 2000 pWOp under the same conditions and the maximum level of interference entering from any single network (the "single entry" value) should not exceed 600 pWOp. Exceptionally, the maximum level of permissible interference would be maintained at 1000 pWOp for networks, for which an Advance Publication of information had been made by 1978, and the corresponding single entry limit would be 400 pWOp.

3.4.3.2.3 Considerable attention continues to be given to the question of what constitutes an acceptable level of interference. The gain of earth and space-station antennas decreases with increasing angle off the direction of maximum gain. These antenna characteristics may be the only source of isolation between networks, in which case there is an inverse relationship between the interference level and the separation angles. Thus, the greater the permissible interference between two networks serving the same or adjacent areas on the Earth's surface, the smaller can be the orbital separation between the space stations of the two networks. Similarly, the greater the permissible interference between two networks whose space stations are in approximately the same orbit location and serve different areas on the Earth's surface through narrow-beam antenna, the closer can those service areas be to each other, and the greater the number of times that the frequency band can be reused in different parts of the world.

3.4.3.2.4 The total interference in a network of the FSS, or other services which make use of large numbers of satellites, is due to contributions from many other networks. The question arises of how to determine all the individual entries so that their cumulative total does not materially exceed the level that the network has been designed to be capable of accommodating. The answer depends on the method used for coordinating or planning the use of the spectrum and the orbit.

3.4.3.2.5 The Radio Regulations, Article 13, requires the characteristics of all new or modified satellite networks to be coordinated bilaterally with all other networks if the test of need to coordinate set out in the Radio Regulations, Appendix 29, gives an affirmative result. This process of bilateral coordination allows the worst-case single-entry interference level between the subject network and each of the other networks to be constrained to a pre-determined value. The ratio between the total permissible interference level and the maximum single-entry value must be chosen so that the latter is as large as it may be without permitting the aggregate of all the single entries to exceed the former under worst-case conditions.

3.4.3.2.6 Since the recommended CCIR values have a bearing on the number of satellites that can be accommodated, the CCIR undertakes studies in this area. It is for example estimated that an increase in the permissible interference level in FDM-FM networks from 2000 pWOp to 2500 pWOp would allow the separation of satellites used solely in that mode to be usefully reduced.

3.4.3.2.7 There are, however, also disadvantages:

- the extent of the loss to the system operator of control of the performance of the system is substantial;
- interference takes various forms and may lead to types of degradation not simply constrainable by a bound on channel noise power; for example, impulsive interference might develop;
- the capacity of the satellites is reduced if their characteristics remain unchanged;
- the feasibility of a large measure of frequency reuse within a satellite network, which may be in itself a very powerful method of increasing the efficiency of use of orbit spectrum, is reduced by the presence of so much external interference.

3.4.3.2.8 In order to increase the number of satellites that can share the GSO, the total permissible interference noise power in any channel of an FDM/FM satellite HRCs should be increased from 2000 pWOp to 2500 pWOp[1]. The permissible single-entry interference noise level, now 600 pWOp, might also be increased. However, study is required to better define the role of the single-entry limit in the future, when satellite networks will tend to become interference-limited and to determine the optimum value for the single-entry limit which would correspond with a total interference level of 2500 pWOp. The possible need to revise the threshold value of $\Delta T/T$ given in Appendix 29 of the Radio Regulations in consequence of any proposed increase in the single-entry limit should also be studied. It will be necessary to make provision for relieving existing networks from the impact of higher interference levels. Finally, consideration should be given to the possible need to revise permissible interference levels for digital systems and also to the compatibility of these new permissible interference for FDM-FM telephony levels with the corresponding levels for analogue FM TV recommended in CCIR Recommendation 483. These studies should be done during the intersessional period.

3.4.3.3 <u>Estimation of potential interference in the Advance Publication phase</u>

3.4.3.3.1 The interference calculations in the "Advanced Publication phase" follow Appendix 29 and are based on the data about the published satellite network as contained in Appendix 4. Due to the general nature of these data, the calculated result is not very specific, although the calculations themselves tend to be laborious if they have to be done for many networks.

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1 This figure may need further clarification according to the results of intersessional studies.

3.4.3.3.2 The calculation gives the relative increase in the equivalent noise temperature $\Delta T/T$ of the interfered with satellite network. If the $\Delta T/T$ exceeds the threshold value of 4%, then it is assumed, under the present Radio Regulations, that the permissible interference may be exceeded and the need for coordination is established.

3.4.3.3.3 In some cases administrations can assess at this stage the actual interference situation by exchanging additional data. Normally, however, this assessment will be made in the "coordination phase" when the more detailed data of Appendix 3 are available. In addition to the $\Delta T/T$ values the actual interference levels caused by the carriers of the two networks can then be calculated.

3.4.3.3.4 It is obvious that the proper values of the $\Delta T/T$ threshold and the permissible single-entry interference values in relation to the aggregate interference values, along with the calculation methods themselves are of crucial importance for the current coordination process. Experience has shown that in many cases the present threshold value of 4% for the $\Delta T/T$ criterion was too low. This has led to some unnecessary requests for coordination being initiated, posing an additional workload on administrations and the IFRB. It is also true that the calculations are very time consuming. Furthermore, some data in Appendix 4 are probably not very relevant for determining whether a request for coordination is necessary. Lastly, as already mentioned elsewhere, there may be room for the acceptance of higher interference levels.

3.4.3.3.5 Studies concerning the technical aspects of coordination procedures are necessary:

a) If the present procedures, as far as their basic philosophy is concerned, were to be maintained, then the following studies would be desirable from a technical point of view:

- possibility of a higher $\Delta T/T$ threshold value, also taking into account that in future higher interference values may have to be accepted;

- development of simpler, though still accurate interference calculation methods.

b) In recognition of the fact that the interference potential depends on the type of the respective interfering carriers, it would be conceivable to define, for coordination calculation purposes, types of carriers identified by means of a standard classification. Depending on the combinations of these standard carriers more than one $\Delta T/T$ threshold value could be established. This might permit identification of the networks affected with more precision.

It is, however, apparent that this approach would necessitate having more data available than those specified in Appendix 4. Strict reliance on a variable ΔT/T approach could cause difficulties to late changes in a transponder plan.

For this kind of approach it would be desirable, from a technical viewpoint, to study what would be the benefit of several ΔT/T thresholds and what these values should be.

3.4.3.4 Technical measures for harmonizing the arrangement of specific neighbouring satellites

3.4.3.4.1 Introduction

3.4.3.4.1.1 The purpose of the harmonization phase is to identify and resolve system interactions according to some agreed technical and operational criteria. This phase is particularly important when apparent conflicts are noted in the identification phase. During the harmonization phase, the agreed threshold for identifying potential interference among systems is applied, followed by a process of harmonizing any incompatibilities.

3.4.3.4.1.2 The following is a description of the technical measures that permit effective harmonization of interfering networks which use adjacent or nearby orbit locations. Consideration is given in section 3.4.3.5 to means of combining these various measures, which in some suitable form may also be usefully incorporated into planning procedures.

3.4.3.4.1.3 Four technical measures are listed below, sections 3.4.3.4.2 - 3.4.3.4.5; the list is not exhaustive. The preferred approach in any specific case will depend greatly upon the circumstances.

3.4.3.4.2 Flexibility in the positioning of satellites

3.4.3.4.2.1 Changes in the positions of existing satellites and in the proposed positions of new satellites can be an important way of harmonizing different satellite networks, because a relatively large change in the off-beam gain of an earth station antenna in the direction of an unwanted satellite can be produced by a small change in the angular separation of the wanted and unwanted satellites.

3.4.3.4.2.2 The service arc for a service area which is not very large may initially be long. However, as the design and manufacture of the equipment for the network progress, in step with the determination of the nominal location of the satellite, the service arc becomes shorter. Finally, when the spacecraft has been launched and the network is in service, the service arc may become quite short, perhaps only a few degrees.

3.4.3.4.2.3 There will be a few cases where the coverage requirements of a satellite will be so critical that even a small change in the satellite position would impair service to some earth stations. On the other hand, there will be many cases where the design of the satellite and the associated earth stations is such that the need to change the satellite position slightly would not present any difficulty or penalty, provided such changes were required only once or twice in the lifetime of a satellite. Flexibility of this kind could prove very useful in minimizing interference between systems in congested parts of the orbit and in implementing changes found to be desirable as a result of coordination for a new planned satellite.

3.4.3.4.2.4 It has also been shown that the length of the orbital arc that is needed for a number of satellites serving different service areas depends upon the relative positions of the various satellites. It was found that the minimum length of orbital arc that would be acceptable, for given interference conditions, varied considerably depending upon the arrangement of the satellites in the orbit. Substantial savings in orbital arc occupation could be obtained in this way. It should also be noted that it is not possible to say with certainty which geographical areas would need to be served at some time in the future from a given part of the orbit; full advantage could therefore be taken of this means of optimizing the use of the orbit only if networks were designed so that their satellites could, if necessary, be relocated within a service arc after having been put into service.

3.4.3.4.2.5 However, provision for more than quite a small amount of flexibility of orbital position may also raise substantial problems which have not been fully evaluated yet. For example:

a) the design of satellite antennas to accommodate flexibility of satellite position without loss of coverage of parts of the service area may increase the cost of the antennas. Such design may also slightly reduce the antenna gain, with some consequential impact on the communications capacity of the network and possibly an effect on the required separation between satellites; it may also lead to some expansion of coverage areas;

b) transfer of satellites from one location to another would involve the expenditure of a significant amount of fuel if such transfers were rapid or frequent;

c) substantial operational problems may arise when a working satellite is being moved, particularly if it must pass close to another working satellite whilst in transit. Service will often be interrupted for considerable periods. Non-tracking earth station antennas will have to be repointed, possibly several times if the transit arc is long or the transit rate is slow, which could be costly;

d) there may be reasons why little or no significant flexibility is feasible in the nominal location of some specific satellites. The visible arc may be very small, for example, because the service area is very large or at a high latitude or because the service area includes mountainous terrain. Alternatively, flexibility may be constrained by the requirements of another service on a multi-service satellite or by FSS use of more than one frequency band pair.

3.4.3.4.2.6 In this context, there could be benefit in encouraging administrations to take up orbital locations for new space stations which would reduce the probability of any such need to re-locate. This may require careful consideration of the probable future occupation of an orbital arc when the initial location is selected.

3.4.3.4.2.7 Studies of these matters are in progress in CCIR. Intersessional studies are needed to provide a full evaluation of the technical, operational and economic issues, to enable WARC-ORB(2) to decide what regulatory action, if any, would be appropriate. These studies should consider two situations, firstly where the relative order of satellites in orbit remains unchanged but their relative angular separation is changed, and secondly where the order is changed.

3.4.3.4.3 Adjustment of carrier parameters

When a relatively small proportion of carriers in a network suffer excessive interference, it may be feasible to reduce that interference to the recommended level without an unacceptable loss of satellite capacity by increasing the carrier power or, in digital systems, by using error correction. In cases where interference from terrestrial stations or from other satellite networks is likely to be small, an interference entry in excess of the recommended value may be accepted without exceeding total interference limits. Alternatively, it may be feasible to reduce circuit noise or bit errors arising within the wanted network from other causes, by error correction or increase of FM deviation and carrier power, so that a higher single interference entry does not cause failure to achieve the circuit performance standards. It may be feasible substantially to reduce interference entering a network at an earth-station receiver by means of an interference canceller. This latter technique, however, requires further study, especially as to its applicability to interference from multiple or broadband transmissions.

3.4.3.4.4 Spectrum segmentation to reduce spectrum overlap and inhomogeneity

3.4.3.4.4.1 When two networks are being coordinated, it may sometimes be found that the interference criteria cannot be met over the whole frequency band. If so, then it may be necessary to consider segmenting the frequency band, thereby facilitating the coordination within more homogeneous bandwidth segments. Particular attention should first be given to interference from emissions with high spectral power density, such as FM television.

3.4.3.4.4.2 Carrier frequency interleaving could be one means of facilitating coordination. The extent to which closer satellite spacing and improved orbit/spectrum utilization may be achieved by interleaving the carrier frequencies of one satellite with those of a neighbouring satellite is critically dependent on the type of modulation (e.g., FM or PSK) and the multiple-access technique (e.g., single carrier or FDMA) applied to the wanted and interfering carriers. For the case of frequency-modulated FDM telephony an improvement in required carrier-to-interference ratio is obtained when interleaved carrier frequencies are used. The improvement is found to be up to about 12 dB, depending upon the modulation indices. Little reduction in satellite spacing requirements is to be obtained by interleaving digital signals. Sharing can frequently be facilitated by the use of carrier energy dispersal. However, in the case of FM TV interference into SCPC it may be necessary to trade off the dispersal bandwidth with potential loss of transponder capacity in order to optimize the separation between satellites. Carrier energy dispersal may sometimes increase interference between interleaved FDM/FM carriers.

3.4.3.4.4.3 Another very promising approach has been designated by the term "spectrum segmentation". Spectrum segmentation is based on the fact that high spectral density carriers like TV-FM and high-capacity FDM-FM cause higher interference to carriers such as SCPC and low-capacity FDM-FM, as compared to other similar types of carriers. The use of the same frequency by high-density and low-capacity carriers in two potentially interfering networks produces inhomogeneity and leads to a relatively large intersatellite spacing requirement. The GSO could be used more efficiently if frequencies of high density and low-capacity carriers could be segregated, particularly for TV-FM and SCPC carriers. Methods should be sought for applying this technique without too much loss of flexibility in the use of transponders.

3.4.3.4.4.4 Frequency band segmentation can be achieved by various means. One approach could be called macro-segmentation, where frequency bands are segmented into large blocks, typically many transponder widths wide. In contrast, micro-segmentation would be based on small blocks typically the width of a transponder or less. A further way to achieve (flexible) segmentation would be first to define the two edges of a frequency band and then place TV carriers starting from one edge of the band and SCPC carriers starting from the other edge.

3.4.3.4.4.5 At this stage it is not yet possible to envisage how spectrum segmentation should be best implemented.

3.4.3.4.4.6 One item that has to be considered are the needs of international systems with their special traffic patterns. Also assumptions about the size of future network populations might be necessary before reaching any conclusions. Future studies in this area should therefore give careful consideration to the situation in each band to determine whether rules should have mandatory force or should have more the status of recommendations, guidelines or preferences.

3.4.3.4.4.7 In principle, spectrum segmentation, if flexibly applied, is clearly desirable. However, it is recommended that intersessional studies be carried out to identify the potential benefits of spectrum segmentation and the way in which they may be best achieved.

3.4.3.4.5 Improvements in satellite and earth station antenna radiation patterns

One potentially important way of improving the efficiency of the utilization of the GSO is by improving antenna radiation patterns. Therefore, in principle, recommendations on their performance characteristics should be as stringent as necessary and practicable.

3.4.3.5. The combination of technical measures for harmonization

3.4.3.5.1 Computer programs

3.4.3.5.1.1 The main function of computer optimization is, ideally, to find the best satellite orbital positions, satellite beam shapes and frequency assignments. Several computer programs (e.g. Orbit II, CAP-N, G-SOAP, and SOUP) already exist, which individually do not yet fulfil the overall requirements. Furthermore, the basic parameters to be used in the optimization process need defining.

3.4.3.5.1.2 The assumptions made for these computational aids depend to some degree on the studies to be carried out concerning the technical measures, described in the previous paragraphs, such as beam pattern, frequency plans and spectrum segmentation.

3.4.3.5.1.3 While it is recognized that the assumption of elliptical beams may simplify the computer calculations, it should also be kept in mind that antenna beam characteristics with a fast roll-off pattern result in better orbit utilization.

3.4.3.5.2 Harmonization M3

One example of how to combine some of the technical measures mentioned in section 4 of the CPM Report is Harmonization M3. This method is based on "spectrum segmentation", "relocation of satellites" and the concept of "equitable interference" (see the CPM Report, section 4.4.9.4).

3.4.3.5.3 Equitable burden-sharing in order to achieve harmonization

3.4.3.5.3.1 As already discussed, the various elements which relate to harmonization may raise different technical and operational problems for actual implementation. These various elements can be conceived as a "burden" to be shared between existing and new networks. The concept of burden-sharing includes the "equitable interference" and "relocation" aspects of Harmonization M3, together with additional technical and operational factors.

3.4.3.5.3.2 The penalty of burden-sharing depends to a large extent on the stage of communication satellite development. The following stages could be considered, although more as a starting point for further discussion than to prejudge later decisions:

a) Initial Concept and Design. A satellite system at this stage has been sufficiently defined such that technical information is available to meet the data requirements of Appendix 4 to the Radio Regulations. This includes specifications of orbit location and frequency, and while the paper design may have been completed, implementation has not begun.

b) Implementation. Typically it may take several years to implement a satellite system. This includes construction of the satellite up to, but not including, its launch. Also during this time earth stations are designed and constructed and the system would have obtained regulatory recognition. Depending on the progress of the implementation programme there can be opportunities to make design changes to accommodate burden-sharing. Appendix 3 data on the system should be available.

c) Operation. At this stage the satellite system has been built, launched and is operating from a particular orbit location, with its associated earth segment. Many of the system features are fixed, although there may be some built-in flexibility such as beam repointing, transponder gain settings, carrier frequency planning, etc.

d) Second-generation satellite system. At the end of the useful life of a communications satellite, typically 10 years, it is likely to be replaced. At this time, there will be in place an extensive array of earth station users. Therefore, there are a number of transmission parameters which must be retained in order to preserve continued service. On the other hand, the opportunity does exist to incorporate design changes which can assist in burden-sharing. A second-generation satellite thus has some of the characteristics of each of the three previous stages.

3.4.3.5.3.3 Technical and operational burdens such as satellite relocation, interference increase, earth station antenna side-lobe performance, satellite antenna side-lobe performance and traffic planning can be defined.

3.4.3.5.3.4 It may be concluded that the potential value to the harmonization process could be better assessed if this concept of burden-sharing were studied in more detail to determine the extent of parameter adjustments (burdens) practicable over a period of time. It is therefore recommended to include the concept of equitable burden-sharing in studies during the intersessional period.

3.4.4 Criteria and parameters for planning the fixed-satellite service

3.4.4.1 Generalized parameters

3.4.4.1.1 Introduction

There have been various proposals for using generalized parameters to manage the orbit/spectrum resource. This would provide the maximum flexibility to the users with respect to meeting their requirements while, at the same time, providing for control of the interaction between networks. Specific proposals have also been made on particular sets of such parameters to accomplish this purpose.

Generalized parameters can be employed for several purposes:

a) to provide network design guidelines containing the elements necessary to produce a certain level of orbit utilization efficiency, while retaining a degree of flexibility for the network designer;

b) to establish threshold conditions to identify the need for coordination;

c) to expedite the resolution of some problems without the need for detailed examination during the coordination process.

Particular generalized parameters have been used in the past for very specific applications, for example $\Delta T/T$ for the coordination threshold. Others have been studied for the purpose of improving efficiency of orbit utilization through constraints, for example, the ABCD parameters. Still others can be, and have been, developed for particular application and include characteristic orbital spacing (COS), isolation, and variants of the ABCD parameters.

Although there are a number of possibilities, it should be noted that all derive from the same basic interference relationships among the system characteristics. In its simplest form, each interference term is composed of the ratio of the interfering and wanted carrier e.i.r.p. densities reduced by the discrimination of earth and space station antennas; the absolute e.i.r.p. levels are not material to the level of interference. To minimize the interference, the total discrimination should be maximized.

There are examples of the application of generalized parameters, although not necessarily for the purpose contemplated here. They are usually contained in CCIR Recommendations and in Articles of the Radio Regulations. The parameters generally define one or more aspects of the interference environment which results from the simultaneous use of the same frequencies by systems of the same or different services. The parameters include power flux-density (pfd), e.i.r.p. density, and terms establishing the interference susceptibility of systems.

An important aspect in considering the use of such parameters is that associated with the objectives of a) above. A given set of parameters can be improved with time to permit greater orbit utilization to meet growing demand. Such improvements can be based on a specific technology affecting only one parameter, or can be more generally based on a need to establish a better overall orbit utilization which may be essential to permit accommodation of new networks in the future. Such improvements would likely carry additional constraints.

3.4.4.1.2 Generalized parameter specifics

3.4.4.1.2.1 Parameters A, B, C and D

The study of this particular set of parameters began in 1977 by Interim Working Party 4/1 of the CCIR.

The parameters, as defined in CCIR Report 453, are as follows:

Parameter A: The maximum up-link e.i.r.p. per unit bandwidth in the direction of the geostationary-satellite orbit radiated at an angle Θ to the axis of the main beam of the earth-station antenna.

Parameter B: The up-link sensitivity, defined as the minimum interference spectral pfd at the geostationary-satellite orbit which corresponds to the recommended maximum single entry of interference in a channel.

Parameter C: The maximum spectral pfd produced at the Earth's surface by the satellite emissions.

Parameter D: The down-link sensitivity, defined as the minimum interference spectral pfd at the Earth's surface arriving at an angle Θ to the direction of the wanted signal which corresponds to the recommended maximum single entry of interference in a channel.

Efforts to define prescribed values have been unsuccessful primarily because of consequential constraints on systems and detailed study has been virtually abandoned in recent years.

A general observation on the ABCD parameters as defined in Report 453 is that they are not precise in characterizing actual interference, requiring some assumptions regarding actual individual transmission characteristics. In particular, A and C characterize the interference potential of transmissions only by the highest spectral density in a relatively narrow bandwidth, while B and D reflect only the receiving system characteristics and not the specific characteristics of individual carriers.

Parameter A is currently limited in the 6 GHz band by CCIR Recommendation 524, while parameter C is limited in various frequency bands by Article 28 of the Radio Regulations. Constrained in these ways, parameters A and B in combination will yield one value for satellite spacing while parameters C and D in combination will yield a different one unless specifically chosen to yield the same result. Both pairs are dependent upon the assumption of a particular value of $\Delta T/T$, for the up-link for A and B and for the down-link for C and D. This provides a degree of refinement not possible with the current $\Delta T/T$ concept, but requires that up- and down-link contributions to interference be known.

3.4.4.1.2.2 Variations on the ABCD approach

A particular variation of the ABCD approach involves modification to the parameters B and C to reflect their impact on the environment outside the intended coverage while maintaining A and D in the usual form. The parameters are defined as follow:

A (Θ) maximum permissible value of the power radiated by the earth station in a given frequency band, as a function of angle Θ calculated from the direction of maximum radiation;

B (β) permissible power flux-density (pfd) that may be produced at the location of the wanted satellite by interfering signals from other satellite systems arriving at angle β to the axis of the receiving antenna of the wanted satellite. This parameter characterizes the sensitivity of the satellite receiver to interference;

C (β) maximum permissible pfd produced at the Earth's surface by the satellite emission, as a function of angle β calculated from the direction of maximum radiation;

D (Θ) permissible pfd that may be produced at the Earth's surface by interfering signals from other satellite systems arriving at angle Θ to the direction of the wanted signal. This parameter characterizes the sensitivity of the earth receiving equipment to interference.

This variant appears to improve on some of the perceived shortcomings of the original ABCD set, but further study is required. The ability to establish realistic values for B and C in this variation also relies on appropriate definition of spacecraft antenna characteristics.

A second variation presented is nearly the same as the above except that B* and D* are not related to the single entry interference criterion, but to the aggregate interference level. This is aimed at the orbit congestion situation in which all systems are already at the aggregate limit or nearly so, and at this time the single entry has little meaning. This particular set would also require the definition of an appropriate bandwidth unit to be used that would likely be different from the one used with the original ABCD parameters. The parameters of this set are defined as follows:

$A_i^*(\Theta)$ The maximum up-path off-axis e.i.r.p. (for a certain bandwidth) in the direction of the geostationary orbit radiated at the angle Θ to the axis of the main beam. The formulae can be given by the following:

$$A_i^*(\Theta) = P_{ei}\, G_{ti}(\Theta)$$

$$\Theta \geqslant 1^{\circ}$$

It will be necessary to add a further factor to this formula to take the size of the service area into account. This requires further study.

B_i^* The maximum permissible power of aggregate interference (measured in the defined bandwidth) at the output of the satellite receive antenna i using the reference side-lobe pattern.

$C_i^*(\phi)$ The maximum down-path off-axis e.i.r.p. (for a certain bandwidth) in the direction of the Earth's surface radiated at the angle ϕ to the axis of the main beam. The formulae can be given by the following.

$$C_i^*(\phi) = P_{si}\, g_{ti}(\phi)$$

where ϕ is measured radially outwards from the edge of the service area.

D_i^* The maximum permissible power of aggregate interference (measured in the defined bandwidth) at the output of earth station antenna i using the reference side-lobe pattern.

Implementation in this particular situation is based on a simplified calculation of the aggregate C/I which would be used to support a planning exercise by specifying limits which take into account coverage and various reference parameters. It is also suggested that in an evolutionary environment, the values for A*, B*, C*, and D* would be those actually used by existing systems and would be used to optimize the satellite locations.

As in the general ABCD case, a number of limitations exist and the possibilities for particular constraints are present for each of the variants. For planning purposes, other series of generalized parameters could be prepared which might be more satisfactory, depending on the planning method chosen.

3.4.4.1.2.3 Isolation

Isolation between two networks may be defined as the C/I required for protection, normalized with respect to the necessary carrier-to-noise densities (C/N_o) of two transmissions. It is derived from the network parameters of a co-coverage reference condition which is used with the intent of establishing a high level of orbit utilization efficiency. An equivalent satellite spacing concept results, which provides a network with the same interference protection for its actual spacing as if it were in full conformity with the co-coverage reference condition. The efficiency which can be expected or is needed can be identified with all of the network parameters which produce this limit. The presentation is in a form which separates those elements which can be standardized easily and those which cannot.

In this regard the isolation concept is considered to yield a precise measure of actual interference between carrier pairs and can be used with knowledge of only major network design characteristics. As a result, its general use as a criterion would result in systems which are sufficiently compatible for successful coordination to be likely. In this sense, isolation also provides a realistic threshold for establishing need for coordination.

There would be a need to establish the relationship between isolation and C/I for actual coordination purposes.

3.4.4.1.2.4 Characteristic orbital spacing

The "characteristic orbital spacing" (COS) of a network is defined as the minimum spacing required between a hypothetical series of identical satellites serving a given service area, with the satellites assumed to be spaced equally across the visible arc.

The approach would be to select a value for COS which would in turn reflect the technical characteristics for all interference parameters collectively. Alternatively, various parameters such as C/I or antenna patterns could be selected and the usable COS so defined.

In use, the actual spacing would be the COS reduced by the satellite antenna discrimination that might be obtained. The reduction factor is particularly simple to derive when off-axis e.i.r.p. density of the Earth and space stations (parameters A and C of ABCD) are standardized or confined to a small range.

Another aspect is the possibility for checking the aggregate interference by adding only the actual separation angles for nominal cases.

The COS is in essence, a property of a given network. It applies whether or not in practice there is more than one satellite serving a given service area, and it is readily quantifiable, without necessitating the detailed consideration of technical parameters, traffic types used, interference standards, etc. Due to its quantifiable nature, it can be readily standardized, and used as a basis for equitably defining any sharing scheme for the spectrum/orbit resource.

3.4.4.1.3 Observations

A number of interesting possibilities have been considered and the following observations are made:

a) generalized parameters can be useful in technical management of the GSO regardless of specific planning approaches while providing some degree of flexibility;

b) they can also be useful in establishing coordination thresholds and in resolving some coordination problems. When use for this purpose is considered, particular attention would have to be paid to assessing the noise of the satellite link as a whole;

c) all the particular approaches examined would appear to produce some constraints, although these constraints are applied to the general parameters which are made up of specific parameters. Some degree of variation is then possible for each constituent parameter;

d) an area of particular concern that was identified are those parameters that may depend upon current practice in operational systems, as it is expected that they will result in a wide range of values to be accommodated;

e) it is not possible at present to establish how well any of the particular approaches identified would achieve their stated objectives and further study of each is needed in the intersessional period.

3.4.4.2 Earth station antennas

The side-lobe radiation pattern of the earth-station antenna, more particularly in the first 10° from the principal axis and in the direction of the GSO, is one of the most important factors in determining the interference between systems using geostationary satellites. A reduction in side-lobe gain levels would reduce the minimum orbital separations required between satellites and significantly increase the efficiency of utilization of the orbit.

Technical improvements are being made in the design of these antennas, reducing side-lobe gain levels. The definition by the CCIR of recommended performance objectives for new antennas should lead to further improvements. In the course of time, the cost of high performance antennas will fall and their use should become more general. Nevertheless, the cost of earth station antennas is a major element in the economics of networks which use large numbers of small-diameter antennas with low traffic density, above all in situations involving dispersed territory and dispersed centres of population. Such situations are typical of the networks of developing countries, and it is important that the opportunity remain available for antennas of well-established, mature technology with low unit cost to be used in such networks.

The following earth station antenna radiation patterns should be assumed in determining any generalized performance criteria required during the first planning period.

a) In frequency bands and orbital arcs where recognition is given to the special needs of the developing countries, the gain of the side-lobe peaks at an angle φ from the boresight direction will not exceed:

$32 - 25 \log \varphi$ (dBi) where $1^{o} < \varphi \leqslant 48^{o}$

and

-10 (dBi) where $\varphi > 48^{o}$

if the diameter of the main reflector is greater than 100 times the wavelength. For smaller antennas, performance should be related to the diameter/wavelength ratio, D/λ, such that the gain of the side-lobe peaks will not exceed:

$52 - 10 \log D/\lambda - 25 \log \varphi$ (dBi) where $\frac{100\lambda}{D}^{o} < \varphi \leqslant$ and 48^{o}

and

$10 - 10 \log D/\lambda$ (dBi) where $\varphi > 48^{o}$,

b) In other frequency bands and orbital arcs, a more stringent standard should apply within the solid angle where unwanted radiation has the most serious effect on other networks. For antennas for which D/λ exceeds 150, it should be assumed that the gain of 90% of the side-lobe peaks within 3^{o} of the geostationary-satellite orbit and for which $1^{o} < \varphi < 20^{o}$ will not exceed

$29 - 25 \log \varphi$ (dBi).

The notes on the interpretation of "90% of the side-lobe peaks" in CCIR Recommendation 580 should be applied. In other directions, the assumptions given in a) above should be applied in this case also. The performance to be assumed for antennas smaller than 150 λ needs to be determined in intersessional studies.

It is to be expected that many existing earth station antennas will not achieve the standard stated in b) above. However, it is foreseen that the generalized performance criteria to be developed for planning purposes will allow considerable flexibility in the way in which the criteria are met, permitting such antennas to remain in service. This should be verified when the criteria are under study.

From time to time, on occasions which might be related to Plenary Assemblies of the CCIR, the side-lobe gain assumptions used for determining planning criteria should be reviewed in the light of then current CCIR Recommendations and the cost of equipment. The procedures for implementing these reviews should be included within the framework of any planning method accepted.

3.4.4.3 Satellite antenna radiation characteristics and the pointing accuracy of satellite beams

An ideal satellite antenna would have the following radiation characteristics:

- the gain is uniform (or follows in a controlled way some other chosen characteristic) towards all parts of the service area, with some extension beyond the edges of the service area to allow for beam pointing errors within the constraints imposed by Article 29 of the Radio Regulations;

- this in-beam gain is maintained beyond the service area and the margin required for beam pointing errors to the extent that is necessary to provide a sufficiently wide service arc in those services where the concept of service arc is applicable;

- beyond those limits, the gain falls away rapidly with increasing angle off-axis to a low out-of-beam value and remains low in all other directions which intercept the Earth.

Satellite antennas with specially-shaped beams facilitate the suppression of spillover (transmitting) to and sensitivity (receiving) to transmissions from outside the area which the beam is intended to serve, while maintaining an effective coverage in the intended area.

The techniques of beam-shaping also provide means of controlling the distribution of gain within the beam. This feature would be of value in situations involving dispersed territory, where it may be desirable to distribute more gain to populous parts of the service area, and less gain to other parts of the service area where the extent of use will be small.

Shaped beams can be generated in reflector antennas by controlling the phase and amplitude distribution over the aperture according to the shape of the coverage area. The following two methods of doing this have been developed:

- shaping the surface of reflectors according to the contours of the beam coverage;
- controlling the amplitude and phase of the illumination patterns across the aperture, which are fed by the multiple horns, in order to match the contours of the beam coverage.

The former is simpler in its feed assembly composition. However, the shape of the pattern cannot be changed when the satellite is in orbit. The latter method, which is an application of the multi-beam antenna method, has an advantage in that beam-shaping capability is greater and it could be possible to reshape the beam by command from the ground.

Shaped-beam antennas offer the potential for improved side-lobe control particularly where the coverage area itself is rather large, thus improving the possibility of frequency reuse between coverage areas closer to each other.

However, it should be noted that discrimination beyond the edge of coverage is a function of satellite antenna dimensions; launch vehicle constraints may be a factor here. Measurements made on current shaped beam antennas show that reasonable discrimination is achieved in those directions for which specific consideration has been exercised in the design stage. The radiation patterns of shaped beam antennas and also elliptical beam antennas are currently under study in CCIR, with a view to recommending reference radiation patterns.

The advantages of frequency reuse may not be fully realized if the control of the satellite beam position is inadequate. Radio Regulations Article 29 requires that the beam pointing direction should be maintained within 10% of the half-power beamwidth, or 0.3° of the nominal direction, whichever is the greater.

It may be necessary to limit the gain of geostationary satellite antennas in the direction of other geostationary satellites, in particular when those antennas are used in frequency bands which are allocated for both up-link and down-link operation.

For networks in which elliptical beams fit the service area closely, subject to a minimum beam size related to the capability of launchers to launch solid antenna reflectors, acceptable orbit/spectrum utilization efficiency may be achieved with such antennas at less cost than with shaped beams. It should be assumed that elliptical beams will be used in such cases in the foreseeable future. However, shaped beams with good side-lobe suppression outside the coverage area will be advantageous in some circumstances, particularly when the service area is large, and their use should be encouraged.

Intersessional studies are required to determine the necessary criteria for satellite beams, including:

a) reference radiation patterns for elliptical and shaped beams;

b) an appropriate minimum required beam size, as a function of frequency;

and to study whether

c) beam pointing constraints more stringent than those in Article 29 of the Radio Regulations are desirable;

d) limits need to be applied to satellite antenna side-lobe gain in the direction of neighbouring satellites in frequency bands used in both directions of transmission.

3.4.4.4 Satellite station-keeping

Natural forces cause three main perturbations of the orbits of geostationary satellites. Relative to an earth station, the apparent effects of these perturbations are as follows:

a) there is a long-period east-west movement due to errors in the orbital period;

b) there is a daily north-south movement, having also a small east-west component, due to orbital inclination;

c) there are daily movements with an east-west component and another component involving movement towards the Earth and away from the Earth, due to ellipticity of the orbit.

Article 29 of the Radio Regulations imposes limits on east-west movements, in order to maintain efficient orbit utilization. Most satellites of the FSS in the future will be required to remain within $\pm 0.1^{\circ}$ of their nominal position in the east-west plane. Some satellites in service are already controlled to within $\pm 0.05^{\circ}$. Precise station-keeping may provide benefits to the system.

At the present time there is no regulatory constraint on satellite movement in the north-south direction but many satellites now in operation are, in practice, controlled in this direction within limits similar to the east-west tolerances. However, the cost to systems of a regulatory constraint in terms of thruster fuel could be substantial and it might, in some circumstances, require a satellite to be withdrawn from service before the expiry of its planned lifetime. It is not evident at present that there is a need for regulation in this matter but it should be kept under review.

There is also no regulatory provision for limiting the ellipticity of orbits other than the constraint on the daily east-west component of motion provided by Article 29 of the Radio Regulations. However, it is possible that the relative motion, due to orbital ellipticity, of satellites which are adjacent in orbit would impede the application of reverse band working. There has been no study on this matter in the CCIR to date. Intersessional studies would be desirable to investigate the possible need to apply regulatory constraints on orbital ellipticity in frequency bands where reverse band working is implemented.

3.4.5 Inter-service sharing criteria for FSS bands to be planned

In view of the decision of this session to select only the FSS, and the bands identified in section 3.1 of this Report, for planning at the second session, the following information is provided, both to guide the studies to be conducted during the intersessional period, and to facilitate the work of the second session.

3.4.5.1 Principles of inter-service sharing

As outlined in section 5.2 of this Report, the following principles of inter-service sharing have been developed:

a) Interference and sharing criteria are necessary to permit the equitable sharing of a band by services having primary allocations in that band. Such criteria have developed for many bands and services, and are responsible for the successful and intensive use now being made of shared bands.

b) Services, whether space or terrestrial, having primary allocations in a particular band, have equal rights with respect to the use of the spectrum. The requirements of both services must be taken into account when planning a space service, without changing their existing sharing status, regardless of the planning method or approach employed, taking into account, in specific bands, Article 8 of the Radio Regulations.

3.4.5.2 Sharing in the 6/4 GHz bands

Existing sharing criteria for the FSS in the 4 and 6 GHz bands include the pfd limits set forth in RR 2565-2568, the restrictions on the pointing of antennas in the fixed service at or near the orbit contained in RR 2502-2547, and certain other provisions of the Regulations.

These criteria, which have enabled extensive sharing between the fixed, mobile (except aeronautical mobile) and fixed-satellite services for many years, are deemed adequate to permit the continuation of sharing in the 4 and 6 GHz bands as indicated in the above-mentioned provisions of the Radio Regulations. These conclusions are valid regardless of which of the possible planning methods is employed, unless the planning method violates the principle outlined in section 3.4.5.1 by specifying nominal earth station locations.

3.4.5.3 Sharing in the 14/11-12 GHz bands

The sharing criteria for the 11 - 12 and 14 GHz bands include the pfd limits set forth in RR 2572-2576, and the restrictions on the pointing of antennas in the fixed service at or near the orbit contained in RR 2502-2547, and certain other provisions of the Regulations.

These criteria, which have enabled sharing between the fixed, mobile (except aeronautical mobile) and fixed-satellite services to develop in recent years, are deemed adequate to permit the continuation of sharing in these bands. This conclusion is valid, regardless of which of the possible planning methods is employed, unless the planning method violates the principle of section 3.4.5.1 by specifying nominal earth station locations.

3.4.5.4 Sharing with digital terrestrial systems

It should be noted that sharing criteria for bands below 15 GHz are generally derived from analogue-modulated terrestrial systems, and parameters for digital systems need to be developed.

3.4.5.5 Sharing considerations regarding planning using reverse band working

The planning of bands shared by space services operating in different directions of transmission (i.e. reverse band working) could well impose additional constraints on both services, particularly when a terrestrial fixed service is also a primary service in those bands.

It may be possible in some operational environments to increase the overall use of some FSS/FS shared bands through reverse band working (RBW), without significantly affecting terrestrial services or significantly reducing the capacity in the forward-band working, if the initial indications can be confirmed that the favourable geometry associated with the high elevation angles (above 40^{o} was proposed by one administration) significantly ameliorates the constraints outlined above. It is recommended that such studies be conducted during the intersessional period. It would, however, be necessary, in particular, when considering RBW at 4 and 6 GHz, to restrict satellite pfd and require adequate satellite antenna discrimination towards the limb of the Earth, taking into account existing terrestrial stations (whether they employ analogue or digital techniques). The limits on pfd and the required satellite antenna discrimination should also be determined during the intersessional period.

ANNEX 1 TO CHAPTER 3

Guidelines for regulatory procedures associated with the planning method

1. This section identifies the procedures to be associated with the planning method.

2. Consideration should be given during the intersessional period and at the Second Session to the possibility of reducing the number of procedures and simplifying them in order to reduce the workload of the administrations and the IFRB.

3. The procedures should foresee the possibility for administrations to seek the assistance of the IFRB at the different steps of the above procedures.

4. Guidelines for regulatory procedures for the allotment Plan

   a) A procedure for the modifications of the allotment Plan to be applied by the administrations intending to modify their allotments in the Plan or by new ITU Members which are candidates to an allotment in the Plan;

   b) a procedure for the implementation of the Plan to be applied by administrations intending to bring into use assignments in conformity with an allotment in the Plan, i.e. to convert allotments into assignments. This procedure was considered during the First Session and is described in the flowchart presented in the attached Appendix;

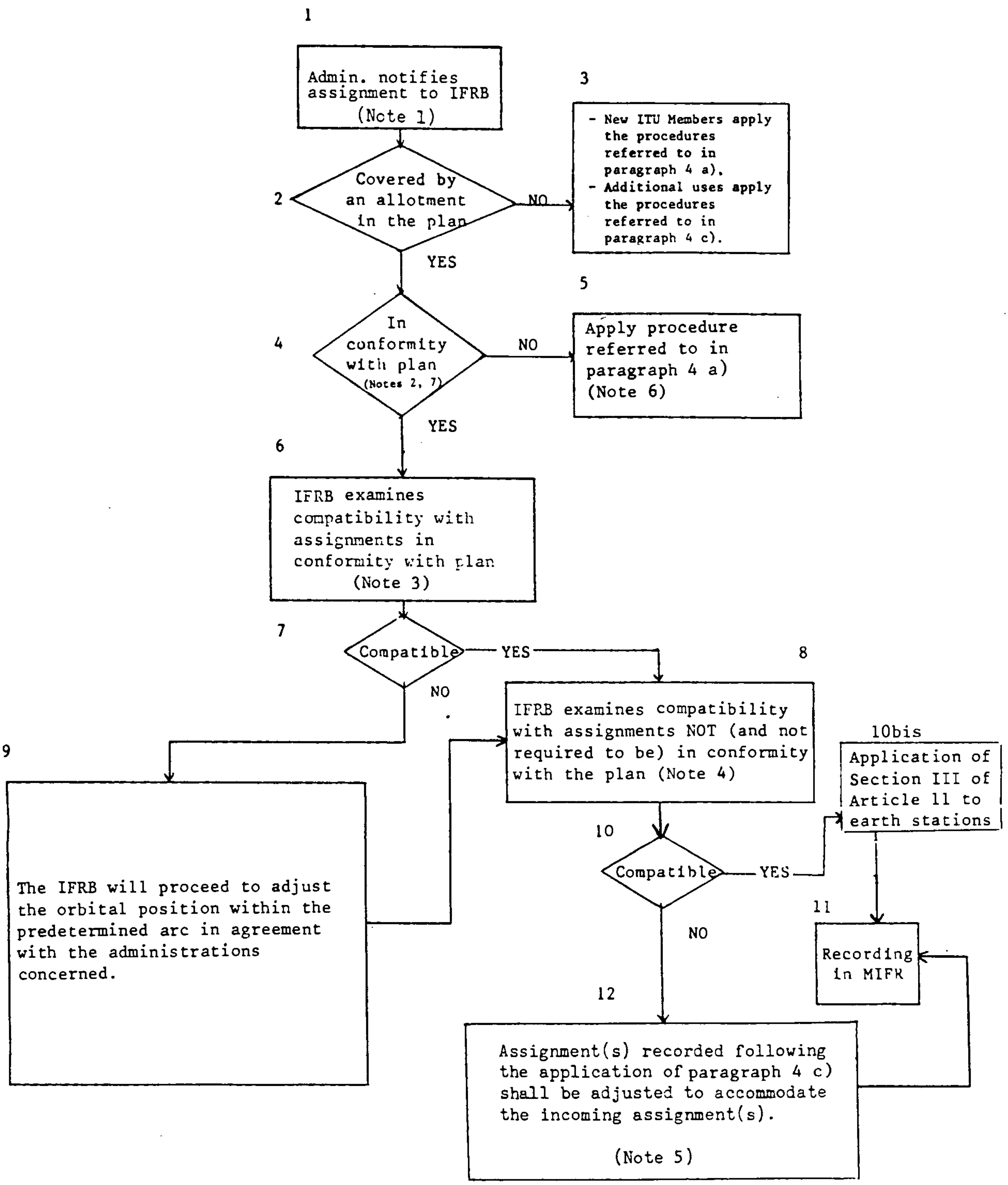
   c) a procedure applicable to additional FSS users in the bands covered by the allotment Plan.

5. Guidelines for improved procedures applicable to the parts of the planned band which are not covered by the allotment Plan

An approach and some associated regulatory procedures are described in section 3.3.5 and the attached Appendix.

APPENDIX TO ANNEX 1 TO CHAPTER 3

A possible procedure for converting an allotment into an assignment



Notes to the flowchart

Note 1 - Submission of this information shall be made within (a period to be determined by the Second Session) before the date on which the assignment is to be brought into use such that the coordination procedure can be completed.

Note 2 - It is to be noted that the Plan will probably conform to the power flux-density limits existing in the Radio Regulations, and hence give appropriate protection to terrestrial services against transmissions from space stations. The relationship between earth stations and terrestrial stations is a matter that may be treated through the present coordination procedures contained in Sections III and IV of Article 11 when an allotment is to be implemented.

Note 3 - This examination is with respect to any assignment, the characteristics of which are in accordance with the Plan and have been notified to the IFRB.

Note 4 - This examination is with respect to assignments referred to as "additional uses".

Note 5 - This implies that assignments notified in conformity with the Plan shall have preferential protection with respect to "additional assignments". The protection of "additional assignments" vis-à-vis each other shall be determined by their respective dates of receipt or if applicable, by the date of their recording in the MIFR.

Note 6 - If a group of administrations decides to combine all or part of their allotments in order to provide a sub-regional service this should be made through the procedure for modification of the Plan referred to in paragraph 4 a) so that the sub-regional use will become part of the Plan and be protected as such.

Note 7 - The Second Session should consider the manner in which the following cases should be treated:

- assignments exceeding the bandwidth recorded in the allotment;
- assignments with a service area greater than that in the Plan.

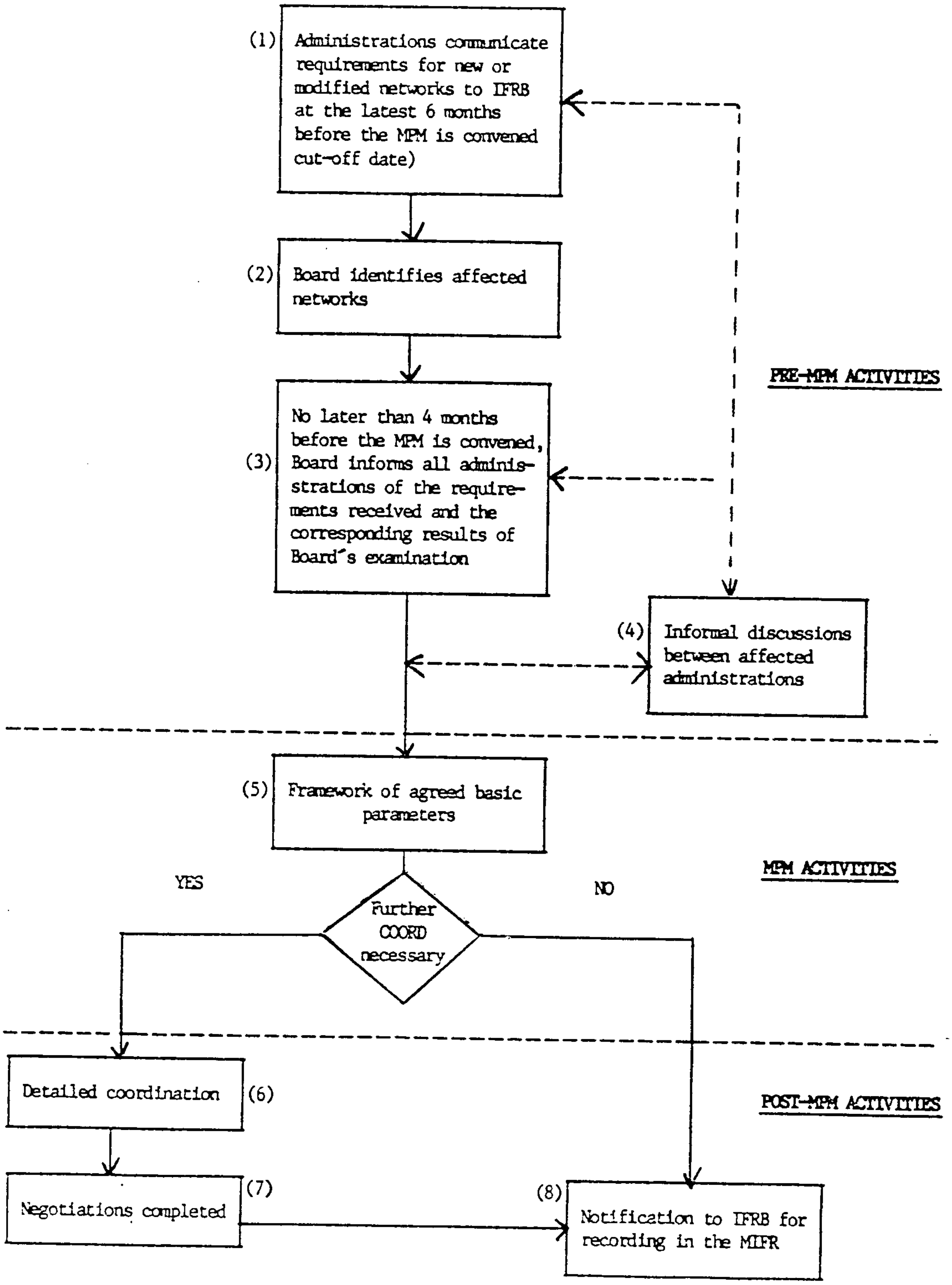
ANNEX 2 TO CHAPTER 3

Possible approach for improved procedures

This Annex describes in the form of a flowchart a method that can be applied to the planned FSS bands which are not subject to an allotment plan. This method is referred to as multilateral planning meetings (MPM).

FLOWCHART

(see explanatory remarks on following pages)



Explanatory notes

Box 1

1. The data to be sent to the IFRB should enable the identification of affected networks. Furthermore, the data should be at least sufficient to enable the MPM to establish a list of basic elements guaranteeing the access. These basic elements should be decided upon by the Second Session. In any case, the list should include the orbital position, frequency bands, coverage area and service area.

2. The requirements for new or modified networks which are submitted six months prior to the MPM will be eligible for consideration at the MPM concerned. The MPM will decide how to deal with requirements received at a later date.

3. Only requirements relating to networks planned to be put into use within five years from the "date of its first accommodation" will be considered at the MPM. However, administrations may submit their requirements at an earlier date.

Box 2

The Board should identify the affected networks by using Appendix 29 as possibly improved.

Box 3

In preparing for the MPM, administrations should study the data published by the Board with a view to determining possible solutions to accommodate new networks.

Box 4

1. Administrations may at this stage initiate informal discussions with a view to speeding up the work at the MPM.

2. An administration may report the results of its discussions to the MPM.

3. The possibility of the IFRB providing assistance to administrations should be considered.

MPM activities

1. The MPM shall carry out its activities on the basis of the provisions agreed to at the Second Session. Some of the guidelines for these provisions are given below.

2. The MPM should be convened at regular intervals of not less than two years and not more than four years.

3. Another possibility could be that the MPM be normally convened every two years; extension of this period may be envisaged in certain circumstances, but the maximum period between two MPMs shall be four years.

4. Participation in the MPM should be open to every administration. Appropriate secretariat assistance should be provided by the ITU.

5. The administrations having submitted requirements shall be present. In the event that they are not present, their requirements will not be considered.

6. All administrations with existing systems should be present, particularly those which the IFRB has identified as being affected.

7. Notifying administrations/multi-administration networks shall ensure that decisions can be taken with regard to those networks.

8. A mechanism should be developed to enable the MPM to make decisions in the event that a notifying administration, having a system which may be affected, is not present at the MPM.

9. The technical bases for the activities of the MPM should be in conformity with the agreed planning principles and should permit the use of the most recent agreed performance and inteference criteria.

10. The costs of the MPMs should come from the budget for conferences in the usual fashion.

11. To cover the situation where the accommodation of a new system is not possible without affecting networks which are already afforded protection, the MPM should have a mechanism for establishing burden-sharing criteria, and therefore this mechanism should be adopted at the Second Session.

Box 5

The results of the MPM will be published by the IFRB as soon as possible after the MPM. This report shall contain a list of the new or modified networks agreed upon at the MPM. For each network it should at least contain:

- a framework of the basic elements such as orbital position, frequency bands, coverage and areas;

- general information on the interference conditions;

- any special agreements reached.

The resulting framework of basic elements will be protected.

Box 6

In some instances, negotiations with regard to the detailed coordination may be completed during an MPM.

Box 7

In this part of the procedure there are two possibilities. The normal situation is when the negotiations are completed without changes to the agreed basic elements. In this case, an administration may proceed with the notification to the IFRB. In some special cases, the negotiations may lead to modifications in the agreed basic elements. When these changes do not affect other networks over the limits agreed to at the MPM, the administration may proceed with the notification. The framework of agreed basic elements is correspondingly updated. If other networks are affected beyond the limits agreed upon at the MPM, the modified requirements shall be submitted to the following MPM.

Box 8

In the event that a notified network is not put into use within six months from the planned date of putting into use, the IFRB shall delete the entry from the MIFR and no longer take it into consideration when identifying affected networks (c.f. Box 2). Extension of this period is restricted to cases of "force majeur". In those cases, the next MPM shall decide on the prolongation to be granted.

CHAPTER 4

Guidelines for regulatory procedures for space services and frequency bands not identified for planning

Introduction

The guidelines relating to the regulatory procedures applicable to the space services and frequency bands which have not been identified by this Conference for planning are set out in seven sections as follows:

Section I: Guidelines concerning Sections I and II of Article 11

Section II: Guidelines concerning Article 13

Section III: Guidelines concerning Article 14

Section IV: Guidelines concerning Resolution 4 of WARC-79 and other Resolutions relating to space services

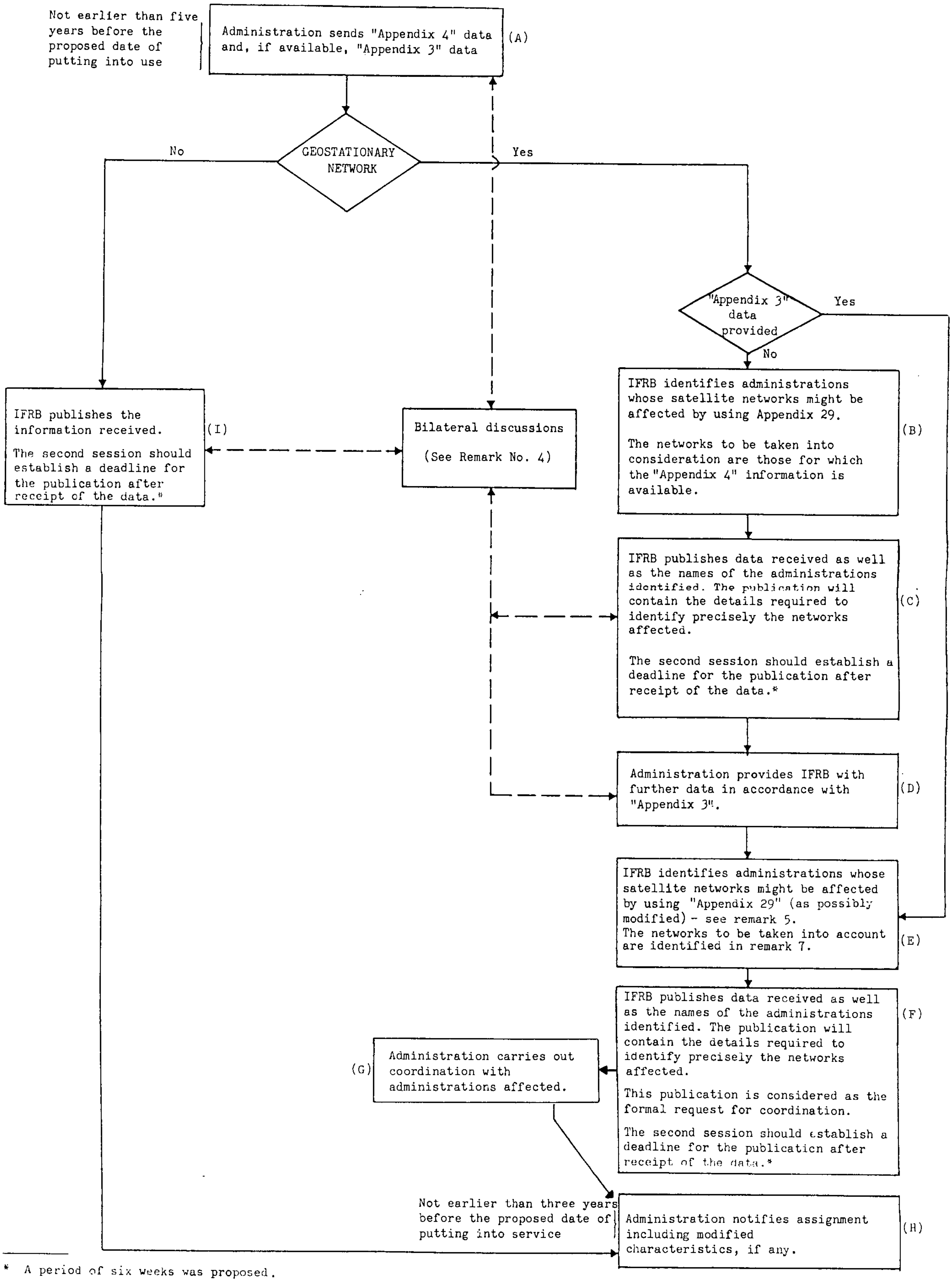
Section V: Simplified Handbooks

Section VI: IFRB Technical Standards and Rules of Procedure

Section VII: Technical parameters and criteria

4.1 Section I: Guidelines concerning Sections I and II of Article 11

4.1.1 The First Session of the Conference recommends that the Second Session should revise Sections I and II of Article 11 of the Radio Regulations in accordance with the following flowchart and associated remarks.



* A period of six weeks was proposed.

Remarks relating to the flowchart

1. Appendices 3 and 4 are merged in order to avoid duplication of information. The first section of the merged appendix contains the information required for advance publication (referred to as "Appendix 4" data); the second section contains the information required to carry out detailed and precise calculations (referred to as "Appendix 3" data). The use of the merged Appendix in application of Article 14 should also be considered.

2. The coordination procedure between satellite networks should be carried out on the basis of a satellite network and not on an assignment-by-assignment basis.

The coordination of an earth station with a space station will only be required when its characteristics exceed those taken into account in the coordination procedure (i.e. when application of "Appendix 29" shows coordination to be necessary).

3. Only one special section is published per satellite network. It will be updated, if necessary, as the definition of the characteristics becomes more precise.

4. Bilateral discussions at the advance publication stage are presently covered by RR 1047 to RR 1053. These provisions do not specify which existing and planned assignments should be taken into account; the Second Session should consider these provisions and modify them if so decided. The Second Session is also requested to provide for the assistance the IFRB may give in the framework of the advance publication (RR 1054).

5. An "improved Appendix 29" (to be used in box (E)) might permit more precise identification of the networks affected, and so reduce the number of cases in which coordination is required.

6. When an administration communicates "Appendix 4" and "Appendix 3" data at the same time, they may be published at the same time: the "Appendix 4" data are then considered as the advance publication and the "Appendix 3" data as the request for coordination.

7. The satellite networks to be taken into account in box (E) are:

- any satellite network for which at least one assignment is recorded in the Master Register;

- any satellite network, the detailed characteristics of which ("Appendix 3" data) have been received by the IFRB. However, when this information is received by the Board at the same time as the "Appendix 4" information, or less than six months after the date of the advance publication, the satellite network will be taken into account only at the expiry of this period of six months.

8. The Second Session of the Conference shall consider retaining the principle contained in RR 1080 when reviewing Article 11.

Note - The Second Session of the Conference should consider how to deal with any modification to the characteristics communicated under the advance publication or the coordination procedures.

4.1.2 The First Session of the Conference noted that a change of orbit location may lead to a situation where a given satellite may be afforded protection in more than one orbit location, thus causing difficulties for other administrations in the planning, coordination and notification of their space systems. It is therefore recommended that the Second Session of this Conference should study the problem and make an appropriate decision on the matter, which may also concern Article 13.

4.1.3 The First Session of the Conference noted that in some instances different networks with overlapping time frames may be notified in a single orbit location by the same administration. This situation could lead to excessive coordination difficulties and inefficient use of the orbit/spectrum resource. The Second Session should therefore consider this problem and take an appropriate decision on this matter.

4.2 Section II: Guidelines concerning Article 13

4.2.1 During discussion at the First Session of the Conference, concern was expressed over the Board's views on the difficulty of notification and registration of data at the network level, as proposed by one administration as opposed to the assignment level as at present.

It was agreed that the First Session should request the Board to prepare a report supplementing its Report to the WARC-ORB(1) on Notification of Frequency Assignments to Stations in the Space Radiocommunication Services and to distribute this new report to all administrations not later than six months before the Second Session. The Second Session should consider this matter further.

4.2.2 It is recommended that the provisions of RR 1503 should be clarified to state expressly that examination of a notice shall include verification that the notified date of putting the assignment into use falls within the permitted period of time following the date of receipt by the IFRB of the information for advance publication.

4.2.3 Resolution 2 concerning the application of Section VI of Article 13 was adopted; it relates to improvement of the accuracy of the records held by the IFRB and the information provided to administrations.

4.2.4 The First Session of the Conference, having noted the difficulties experienced by some administrations in the application of RR 1550, recommends that that provision should be modified to enable an extension of up to 18 months to be granted (instead of the present four months), and in exceptional circumstances to permit the IFRB to provide a further extension, taking into account Resolution 2 of WARC-79, the justification provided by the administration, and any limit on the extension which may be imposed by the Second Session of this Conference.

4.3 Section III: Guidelines concerning Article 14*

4.3.1 Factors which need to be taken into account

4.3.1.1 The procedures of Article 14 must be applied to assignments of radiocommunication services where a footnote of the Table of Frequency Allocations requires the application of that Article.

4.3.1.2 It has been noted that the precise interpretation of certain footnotes which refer to Article 14 is ambiguous or unclear. The Report of the IFRB annexed to IFRB Circular-letter No. 600 of 10 December 1984 was considered and, in accordance with the explanation given by the Board, it was noted that when Article 14 is successfully applied to footnotes where the only condition is the application of that Article, the assignments concerned in that service would have primary status. In this regard the assignments to stations of a space service under RR 747 and RR 750 are considered as primary on successful completion of the procedure, except however that the space-to-space assignments would operate on a non-interference basis (RR 435) only in relation to other space services.

4.3.1.3 It was noted that, as in the case of other assignments, the Board accepts notifications under RR 342 of assignments which are subject to application of the Article 14 procedure at any stage of the application of that procedure.

4.3.1.4 It was noted that administrations in their bilateral relationships may accord a status other than that prescribed in a footnote requiring application of Article 14, provided that the services of other administrations are not thereby affected.

4.3.1.5 In developing the guidelines given in section 4.3.2 below, the question of the application of the Article 14 procedure to the broadcasting-satellite service was not addressed.

4.3.2 Guidelines

The following guidelines are recommended for consideration by the Second Session and for any intersessional work which may be scheduled.

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* It was noted that there may be consequential matters relevant to Articles 11 and 13 arising from the decisions of the Second Session concerning Article 14.

4.3.2.1 The provisions of Article 14 as they relate to assignments to stations in space services should be reviewed and modified in such a way that they are applicable to a satellite network instead of individual assignments: therefore, the data requirements should be reviewed and specified accordingly.

4.3.2.2 The relevance of Article 14 to assignments for reception should be considered and clarified.

4.3.2.3 The procedure should include a means by which "affected administrations" are identified. During the intersessional period, administrations should review the technical standards adopted by the IFRB and, if necessary, propose alternative standards for consideration.

4.3.2.4 The procedure to be applied in unresolved cases of disagreement should be included in the Radio Regulations. Objections to agreement under Article 14 must be based on valid technical grounds which demonstrate non-compatibility. It is noted that, in the application of the Article 14 procedure, the Board has applied this principle (see section 4.3.2.4 of the IFRB Report referred to in section 4.3.1.2 above). The Second Session should consider the matter of technical information to be supplied in such cases.

4.3.2.5 The meaning of the term "planned assignment" (RR 1617 and RR 1618) should be considered. It is suggested that assignments on which an objection has been based would normally be expected to be brought into use within a reasonable period (perhaps 5 years). It was concluded that such assignments should be notified to the IFRB in accordance with RR 1214 or RR 1488, as appropriate, in order to ensure that the objection raised on the basis of these assignments continues to be valid. If a specific period is to be adopted for bringing into use the "planned assignments" referred to in RR 1617, a corresponding time limit for the initiation of the Article 14 coordination procedure for space services should be considered by the Second Session of the Conference for incorporation in RR 1610.

4.3.2.6 The question of modification to a network which has successfully completed the Article 14 procedure should be considered. The Second Session might decide that if, in the case of a transmitting station the modification results in a reduction of potential interference, and if, in the case of a receiving station, the administration accepts the probability of increased interference to its assignment, then Article 14 need not be reapplied in respect of the modified network.

4.3.2.7 The Second Session should consider the matter of priority of dates (see section 4.3.2.3.1 of the IFRB Report referred to in section 4.3.1.2 above). The Radio Regulations should specify that an assignment which has successfully completed the Article 14 procedure is to be taken into account by an administration applying the procedure at a later date for an assignment which would achieve the same status after successful completion.

4.4 Section IV: Guidelines concerning Resolution 4 of WARC-79 and other Resolutions relating to space services

4.4.1 Noting that section 3.9 of the IFRB Report referred to in section 4.3.1.2 above indicates that experience to date is not sufficient to permit the provisions of Resolution 4 to be fully assessed, and that notification of assignments with a long period of validity may put at a disadvantage assignments notified with a shorter period, it was concluded that this question merits further consideration by the Second Session, which should take the necessary action.

4.4.2 Other Resolutions relating to space services are drawn to the attention of this session of the Conference in section 3.2 of the IFRB Report referred to in section 4.3.1.2 above. It is suggested that the Second Session of the Conference should consider these as appropriate.

4.5 Section V: Simplified Handbooks

The First Session of the Conference concluded that it would be preferable to consider the matter of simplified Handbooks at WARC-ORB(2) after administrations have had time to consider the usefulness of the IFRB Handbook on Regulatory Procedures. It would also be necessary to update the Handbook in the light of changes made to the Radio Regulations as a result of the Final Acts of WARC-ORB(2). In the meantime documents prepared by the Board for its seminars may be circulated to administrations as a simplified description of the regulatory procedures.

4.6 Section VI: IFRB Technical Standards and Rules of Procedure

It was noted that the Technical Standards and Rules of Procedure of the IFRB developed in accordance with RR 1001 and distributed in accordance with RR 1001.1 are important to administrations. The First Session of the Conference concluded that these should be fully developed; up-to-date copies should be distributed as early as practicable, in particular those elements which may concern administrations involved in bilateral or multilateral discussions. Distribution of the Board's "Notes to Heads of Departments" to all administrations might be considered in the interim.

4.7 Section VII: Technical parameters and criteria

4.7.1 General technical considerations

Section 3.4 discusses a variety of technical parameters and criteria related to the efficient use of the geostationary-satellite orbit. Many of these considerations are also relevant to bands and services not identified for planning in section 3.1 of this report; that information has not been reproduced in this chapter.

In addition, section 3.4.3.3 of Chapter 3, for example, addresses possible modification to the Appendix 29 procedures and criteria. Such considerations may also have benefits in unplanned bands. Likewise, studies related to Appendices 3, 4 and 28, as discussed in Chapter 3, may be useful in improvement of the inter-service coordination and sharing procedures for unplanned frequency bands.

4.7.2 Sharing considerations in unplanned bands

This Session did not consider it necessary to address problems of inter-service sharing in unplanned frequency bands, other than those considerations relating to the technical criteria to be used in the application of Article 14 procedures. The latter discussions are given in Chapter 5 of this report.

CHAPTER 5

Inter-service sharing considerations

5.1 Introduction

In the CPM Report, Chapters 8 and 10, all of Annex 5 and section 6.1.3.4 of Annex 6 treat sharing principles, performance requirements, interference criteria and the available criteria for sharing between services.

That material and the associated conclusions set forth in the CPM Report are endorsed for the information and guidance they offer, particularly with regard to the bands and services to be planned, planning principles and criteria.

5.2 Principles and conclusions

5.2.1 Among the principles and conclusions of particular importance in the CPM Report are those discussed below. Where there are additional views on inter-service sharing situations, based on information included in the Report of the IFRB to this session, and on contributions of administrations, they have been included.

5.2.2 Interference and sharing criteria are necessary to permit the equitable sharing of a band by services having primary allocations in that band. Such criteria have been developed for many bands and services, and are responsible for the successful and intensive use now being made of shared bands.

5.2.3 Services, whether space or terrestrial, having primary allocations in a particular band, have equal rights with respect to the use of the spectrum. The requirements of both services must be taken into account when planning a space service, without changing their existing sharing status, regardless of the planning method or approach employed, taking into account, in specific bands, Article 8 of the Radio Regulations.

5.2.4 In order for the development of terrestrial services in shared bands to continue, as a corollary or consequence of the principle set forth immediately above, earth station locations should not be included in the planning of bands shared on a primary basis with terrestrial services.

5.2.5 Techniques that may be necessary or desirable to facilitate sharing also bring about more efficient use of the spectrum by all services.

5.2.6 The planning of bands shared by space services operating in different directions of transmission (i.e. reverse band working) could well impose additional constraints on both services, particularly when a terrestrial fixed service is also a primary service in those bands.

It may be possible in some operational environments to increase the overall use of some FSS/FS shared bands through reverse band working (RBW), without significantly affecting terrestrial services or significantly reducing the capacity in the forward-band working, if the initial indications can be confirmed that the favourable geometry associated with the high elevation angles (above 40° was proposed by one administration) significantly ameliorates the constraints outlined above. It is recommended that such studies be conducted during the intersessional period. It would, however, be necessary, in particular when considering RBW at 4 and 6 GHz, to restrict satellite pfd and require adequate satellite antenna discrimination towards the limb of the Earth, taking into account existing terrestrial stations (whether they employ analogue or digital techniques). The limits on pfd and the required satellite antenna discrimination should also be determined during the intersessional period.

5.2.7 Further study may be needed for a number of combinations of services, listed below, which may share a band or bands. Certain of these sharing situations are more likely to occur, and more problematic than others. In view of the limited time and resources available during the intersessional period, attention should focus on those situations identified in Chapter 8 for the Second Session.

a) BSS/FSS at 2.5 GHz;

b) BSS/FSS at 12 GHz - inter-Regional;

c) FSS/EESS (passive) at 18.6 - 18.8 GHz;

d) FSS/MetSS at around 7/8 GHz and at 18 GHz;

e) ISS/BSS at 22.5 - 23 GHz;

f) FSS/FS in bidirectional bands;

g) MSS/FS at 1.6/1.5 GHz;

h) BSS/FS at 22.5 - 23 GHz;

i) FSS/EESS at 8 GHz.

5.2.8 Interference limits and sharing criteria must permit a continuation of at least the same level of sharing between services in a particular band. However, certain planning methods could adversely affect the ability of these sharing criteria to ensure the same level of sharing.

5.2.9 By Recommendation 66, WARC-79 recommended that the CCIR study (as a matter of urgency) the question of spurious emissions from space stations. It is important that intersessional studies provide the Second Session of the Conference with information to be able to take appropriate action at that time.

5.2.10 The CCIR can provide a knowledgeable and efficient forum for the development of new criteria and the examination of existing ones; however, special arrangements may be necessary to enable the CCIR to provide the information required within the limited available time.

5.2.11 In situations where interference and sharing criteria had not been incorporated in the Radio Regulations, the IFRB, acting in accordance with the Regulations, developed and applied such criteria to Article 14 procedures to space services on a provisional basis. These sharing criteria should be reviewed during the intersessional period, and appropriate recommendations should be made to the Second Session of WARC-ORB.

There are several services and bands in which sharing could take place under current footnote allocations, employing the provisions of Article 14, which are not included in Table I of Appendix 28. These instances are summarized in Table 5-1 below, which also gives the number of such cases that have been received by the IFRB during the period 1 January 1982 to 31 July 1985.

Furthermore, the first three columns of Table II of Appendix 28 do not contain values of certain interference parameters and criteria (p_o%, n, J(dB), $M_o(p_o)$, W, B or $P_r(p)$). Other columns should be added to Table II of Appendix 28 for the bands and services marked in Table 5-2 with a plus sign (+).

5.2.12 With regard to Appendix 29, it should be noted that the value of 4% increase in equivalent satellite link noise temperature which triggers the requirement for coordination between space systems was adopted some years ago for the FSS, on the basis of the sharing situations that could arise at that time, and assuming the FSS technical characteristics then envisaged.

This threshold of 4% may not be appropriate for space services other than the FSS, and may even need revising for application to the FSS (many, or even most, FSS systems whose equivalent satellite link noise temperature is increased by 4% may still not experience unacceptable interference). This matter should be studied by the CCIR during the intersessional period and the results made available to the Second Session.

5.2.13 The sharing situations which are the subject of many such communications to the IFRB as shown in Tables 5-1 and 5-2 would appear to be in greatest need of having sharing criteria studied by the CCIR during the intersessional period, for consideration by the Second Session, but other bands may have equal or greater need, because of the narrower bandwidth available or the technical characteristics of systems likely to be employed.

The IFRB is invited to identify early in the intersessional period, those services which, in its opinion, are in greatest need of formally adopted sharing criteria, or of review and revision of existing criteria.

5.2.14 It should be borne in mind during the intersessional period, when considering changes to the technical provisions of coordination (such as those set forth in Appendix 28), that Resolution 703 offers those administrations wishing to amend these provisions within their particular geographic area a possible means to do so, without imposing these amendments on other administrations, and without causing unacceptable interference to any administration.

TABLE 5-1

Services and frequency bands subject to the procedure of Article 14 and not included in Table I of Appendix 28 (between 1 and 40 GHz)

Frequency bands	RR footnote	Services concerned	Status of services (through footnote)	Direction of links	Number of cases received by the IFRB during the period 1.1.82 to 31.7.85
1 610 - 1 626.5 MHz	732	Radionavigation-satellite	Not mentioned	Not mentioned	
1 610 - 1 626.5 MHz	733	Aeronautical mobile-satellite (R)	Primary	Not mentioned	3
1 750 - 1 850 MHz	745	Space operation	Not mentioned	Up-link	5 (for this and the next row)
1 750 - 1 850 MHz	745	Space research	Not mentioned	Up-link	
1 770 - 1 790 MHz	746	Meteorological-satellite	Primary	Not mentioned	
2 025 - 2 110 MHz***	747	Space research	Not mentioned	Up-link	
2 025 - 2 110 MHz***	747	Space operation	Not mentioned	Up-link	54 (for the three 2 025 - 2 110 MHz rows)
2 025 - 2 110 MHz***	747	Earth exploration-satellite	Not mentioned	Up-link	
2 110 - 2 120 MHz	748/749	Space research	Not mentioned	Up-link	5 (for this and the next row)
2 110 - 2 120 MHz	749	Space operation	Not mentioned	Up-link	
2 655 - 2 690 MHz**	761	Fixed-satellite	Primary	Up-link, down-link	2
5 000 - 5 250 MHz	797	Fixed-satellite	Not mentioned	Not mentioned	
5 000 - 5 250 MHz	797	Intersatellite	Not mentioned	Intersatellite	
7 125 - 7 155 MHz	810	Space operation	Not mentioned	Up-link	
7 145 - 7 235 MHz**	811	Space research	Not mentioned	Up-link	
7 900 - 8 025 MHz	812	Mobile-satellite	Not mentioned	Up-link	8
13.25 - 13.4 GHz	852	Space research	Secondary*	Up-link	
15.4 - 15.7 GHz	797	Fixed-satellite	Not mentioned	Not mentioned	
15.4 - 15.7 GHz	797	Intersatellite	Not mentioned	Intersatellite	
37 - 39 GHz	899	Fixed-satellite	Not mentioned	Up-link	

* Because of its secondary status, this Session does not propose inclusion of the space research service in this band in Table I of Appendix 28.

** These frequency bands are actually covered by Table I of Appendix 28 but are subject to Article 14.

*** These three frequency bands for inter-satellite links are included in Table 5-2.

TABLE 5-2

Services and frequency bands subject to Article 14 procedure not included in Section IV of Article 28 (between 1 and 40 GHz)

Frequency bands	RR footnote	Services concerned	Status of services (through footnote)	Direction of links	Number of cases received by the IFRB during the period 1.1.82 to 31.7.85
1 610 - 1 626.5 MHz+	732	Radionavigation-satellite	Not mentioned	Not mentioned	
1 610 - 1 626.5 MHz+	733	Aeronautical mobile-satellite (R)	Not mentioned	Not mentioned	3
1 770 - 1 790 MHz	746	Meteorological-satellite	Primary	Not mentioned	
2 025 - 2 110 MHz*[3]	747	Space research	Not mentioned	Intersatellite	
2 025 - 2 110 MHz*[3]	747	Space operation	Not mentioned	Intersatellite	
2 025 - 2 110 MHz*[3]	747	Earth exploration-satellite	Not mentioned	Intersatellite	
2 200 - 2 290 MHz*+	750	Space research	Not mentioned	Down-link and intersatellite	
2 200 - 2 290 MHz+*	750	Space operation	Not mentioned	Down-link and intersatellite	62
2 200 - 2 290 MHz+*	750	Earth-exploration satellite	Not mentioned	Down-link and intersatellite	
2 500 - 2 535 MHz+	754	Mobile-satellite	Not mentioned	Down-link	
5 000 - 5 250 MHz+	797	Fixed-satellite	Not mentioned	Not mentioned	
5 000 - 5 250 MHz+	797	Intersatellite	Not mentioned	Intersatellite	
8 025 - 8 400 MHz*	815	Earth exploration-satellite	Primary	Down-link	4
11.7 - 12.7 GHz+	839	Broadcasting-satellite	Primary	Down-link	34
11.7 - 12.7 GHz	839	Fixed-satellite	Primary	Down-link	
22.5 - 23 GHz+	877	Broadcasting-satellite	Primary	Down-link	
31.8 - 33.8 GHz	892	Fixed-satellite	Not mentioned	Down-link	

Note 1 - In bands marked with an asterisk (*) Table references specify that the service concerned is subject to power flux-density limits under Article 28, Section IV.

Note 2 - Bands and services marked with a plus sign (+) are not included in Table II of Appendix 28.

Note 3 - These three frequency bands for up-links are included in Table 5-1.

CHAPTER 6

Feeder links for the 12 Ghz broadcasting-satellite service in Regions 1 and 3

6.1 Frequency bands for which the frequency plan should be established for feeder links

6.1.1 Introduction

Agenda item 3.1 of WARC-ORB-85 requests the present Session of the Conference to select from among the frequency bands listed in resolves 1 of Resolution 101 of WARC-79 those bands for which frequency plans should be established for feeder links.

6.1.2 Recapitulation of available frequency bands for planning

The following frequency bands are available for planning the broadcasting satellite feeder links (see Resolution 101).

Region 1	Region 3
10.7 - 11.7 GHz	
14.5 - 14.8 GHz limited to countries outside Europe and for Malta	14.5 - 14.8 GHz
17.3 - 18.1 GHz	17.3 - 18.1 GHz

6.1.3 Conclusions

6.1.3.1 With reference to agenda item 3.1, it was decided to select the frequency bands 17.3 - 18.1 GHz and 14.5 - 14.8 GHz (for countries outside Europe and for Malta) for the feeder-link assignment Plan.

6.1.3.2 It was decided not to use the frequency band 10.7 - 11.7 GHz for the feeder-link assignment Plan.

6.1.3.3 It was also decided to include recommendations in the report of the First Session with a view to:

- advising administrations in preparing their requirements;
- giving guidelines to the Second Session of the Conference for the elaboration of the Plan.

6.1.3.4 These recommendations are as follows:

6.1.3.4.1 In formulating their requirements, administrations are urged to use the band 17.3 - 18.1 GHz as far as possible, in the light of the following factors:

6.1.3.4.1.1 The 14.5 - 14.8 GHz band which has a width of 300 MHz would probably be inadequate to provide feeder links for all the channels in Appendix 30 (ORB-85).

6.1.3.4.1.2 From the point of view of economy it would be disadvantageous for a given country to have some of its feeder links in one band and the rest in another. This may be irrelevant if an administration wishes to set up only some of its feeder links.

6.1.3.4.1.3 Exclusive use of the band 17.3 - 18.1 GHz for feeder links leaves more scope for the fixed and mobile services sharing the band 14.5 - 14.8 GHz on a primary basis with the FSS. It would be advantageous to concentrate all feeder links (or as many as possible) in one band. This is only possible in the band 17.3 - 18.1 GHz, which was also selected by Region 2 in the RARC-SAT-R2 Plan.

6.1.3.4.1.4 Recent estimates supplied by one administration show that on average the feeder-link carrier-to-noise ratio for the band 14.5 -14.8 GHz is 1.5 dB higher than for systems in the band 17.3 - 18.1 GHz, because of athmospheric propagation conditions.

6.1.3.4.2 For planning, the Second Session of the Conference should follow the following guidelines:

6.1.3.4.2.1 For countries requesting to use the band 17.3 - 18.1 GHz and countries not expressing any choice of frequencies, planning should start by using only the band 17.3 - 18.1 GHz in Region 1 and 17.3 - 17.8 GHz in Region 3.

The band 17.8 - 18.1 GHz may be used in Region 3 if the band 17.3 - 17.8 GHz should prove insufficient and in order to provide additional planning flexibility.

6.1.3.4.2.2 The band 14.5 - 14.8 GHz should be planned for Region 3 and Region 1 (for countries outside Europe and for Malta) countries which specifically request to use it.

6.1.3.4.2.3 In the band 14.5 - 14.8 GHz, the number of channels per beam should be restricted to a number less than in the down-link Plan whenever necessary because of the limited bandwidth.

6.1.3.4.2.4 Account should be taken of the protection of the fixed and mobile services sharing the bands, particularly in regions where the band 14.5 - 14.8 GHz is used most intensively.

6.2 Planning method, technical parameters and criteria

6.2.1 Selection of centre frequencies for planning the broadcasting-satellite feeder-link channels in Regions 1 and 3 in frequency bands 14.5 - 14.8 GHz and 17.3 - 18.1 GHz

The planning for both feeder link bands shall use the general characteristics of the BSS R1,3* Plan, and as far as possible linear translation and one translation frequency for a set of transponders serving the channels assigned to the same beam and administration.

6.2.1.1 General characteristics of the BSS R1,3 Plan

	Region 1	Region 3	
Maximum allocated frequency band	11.7 - 12.5	11.7 - 12.2	GHz
Maximum available bandwidth	800	500	MHz
Necessary bandwidth of a channel	27	27	MHz
Channel separation	19.18	19.18	MHz
Number of channels	40	24	
Centre frequency of the lowest channel	11 727.48	11 727.48	MHz
Centre frequency of the highest channel	12 475.50	12 168.62	MHz
Lower guard band	13.98	13.98	MHz
Upper guard band	11.00	17.88	MHz

6.2.1.2 Centre frequencies for planning the broadcasting-satellite feeder links in the band 17.3 - 18.1 GHz

6.2.1.2.1 As the maximum available bandwidth of 800 MHz is the same for Region 1 BSS Plan and for the feeder-link band 17.3 - 18.1 GHz a translation frequency of 5 600 MHz can be used for a single frequency subtractive mixing. In Region 3 the same translation frequency of 5 600 MHz appears to be the optimum for single frequency subtractive mixing also in the case of the feeder-link band 17.3 - 17.8 GHz. This will produce a linear translation of all channels and preserve the same guard bands. This kind of conversion will produce down-link channels free from any spurious mixing products which might arise from combination of harmonic frequencies up to at least the 10th order of any spectral line within the feeder-link channels and up to 10th order harmonics of the translation frequency.

* Wherever the expression BSS R1,3 occurs, it refers to the broadcasting-satellite service in Regions 1 and 3.

6.2.1.2.2 In the case when a translation frequency other than 5 600 MHz is desirable for a single conversion mixing, then the ratio of the translation frequency to any frequency within the necessary bandwidth of a feeder-link channel must not be equal to 3/10 or 1/3.

6.2.1.2.3 Table 6-1 indicates the correspondence between the channel numbers, the frequencies assigned in the BSS R1, 3 Plan, and the frequencies assigned to the feeder links, for the translation frequency of 5 600 MHz.

6.2.1.3 Centre frequencies for planning the broadcasting-satellite feeder links in the band 14.5 - 14.8 GHz

6.2.1.3.1 As the maximum available bandwidth for the feeder-link band 14.5 - 14.8 GHz is only 300 MHz as against 800 and 500 MHz in the down-link Plan for Regions 1 and 3, respectively, several translation frequencies must be considered to allow any channel in the Plan to be used. Consequently, a particular feeder-link channel must be assigned to several BSS Plan channels simultaneously.

6.2.1.3.2 For the feeder-link band 14.5 - 14.8 GHz, 14 channels and two appropriate guard bands should be assumed.

6.2.1.3.3 Selection of translation frequencies for this purpose and for this band is a complex task due to two domains within the possible range of translation frequencies which would create spurious mixing products within certain channels. Therefore, it is necessary to optimize the translation frequencies. Ratios of translation frequency to any frequency within the necessary bandwidth of a feeder-link channel to be avoided are 1/6 and 2/11.

6.2.1.3.4 The following parameters shall be used for planning feeder links in the frequency band 14.5 - 14.8 GHz:

Necessary bandwidth of a channel	27 MHz
Channel separation	19.18 MHz
Number of channels	14
Centre frequency of the lowest channel (1)	14 525.30 MHz
Centre frequency of the highest channel (14)	14 774.64 MHz
Lower guard band	11.80 MHz
Upper guard band	11.86 MHz

Translation frequencies:

a)	for BSS channels 1 to 14	2 797.82 MHz
b)	for BSS channels 15 to 28	2 529.30 MHz
c)	for BSS channels 29 to 40	2 260.78 MHz

6.2.1.3.5 Table 6-2 indicates the correspondence between the channel numbers, the frequencies assigned to the feeder links and the frequencies assigned in the BSS R1, 3 Plan, for the three translation frequencies.

6.2.1.4 Recommendations:

i) Recognizing the reduced channel capacity of the 14.5 - 14.8 GHz band, administrations should note that if more than three channels are requested there may be difficulties in meeting all requirements. More than three channels in this band assigned to a single beam of one administration may add to the complexity of the satellite.

ii) When certain channel families pertaining to a given beam and administration are split between two translation frequencies, then the translation frequency which provides the greater number of channels would be preferable.

iii) There may be further complexity in a choice of channels if there is a requirement for a combination of 14 GHz and 17 GHz feeder links to a single satellite.

Such cases should be treated on an individual basis during the development of the Plan at the Second Session.

6.2.2 Technical characteristics for feeder-link planning

6.2.2.1 Overall performance

Assuming that there is no transponder output back-off, a 0.5 dB noise contribution of the feeder link to the overall link requires that:

$$(C/N)_u = (C/N)_{(overall)} + 10 \text{ dB}$$

For down-links, the WARC-BS-77 has adopted a figure of C/N equal to 14.5 dB for 99% of the worst month at the edge of the service area. The up-link C/N required is 24 dB for 99% of the worst month, to produce an overall C/N performance of 14 dB.

Where there are difficulties in planning feeder links, account should be taken of the protection ratio margin available on the space-to-Earth link in the WARC-BS-77 Plan so as to retain values of 30 dB for the co-channel protection ratio and 14 dB for the adjacent channel protection ratio at the earth-station receiver input.

6.2.2.2 Carrier-to-noise ratio

The minimum $(C/N)_u$ required for planning of the feeder links in Regions 1 and 3 is 24 dB. It may be desirable for some administrations to achieve a significantly higher value of C/N, but the use of any value higher than 24 dB should not prevent the interference conditions from being met in the Plan.

TABLE 6-1

Table showing correspondence between channel numbers and assigned frequencies in the BSS R1,3 Plan and for the associated feeder links using the translation frequency of 5 600 MHz

Channel No.	Plan assignm. (MHz)	Feeder assignm. (MHz)	Channel No	Plan assignm. (MHz)	Feeder assignm. (MHz)
1	11 727.48	17 327.48	21	12 111.08	17 711.08
2	11 746.66	17 346.66	22	12 130.26	17 730.26
3	11 765.84	17 365.84	23	12 149.44	17 749.44
4	11 785.02	17 385.02	24	12 168.62	17 768.62
5	11 804.20	17 404.20	25	12 187.80	17 787.80
6	11 823.38	17 423.38	26	12 206.98	17 806.98
7	11 842.56	17 442.56	27	12 226.16	17 826.16
8	11 861.74	17 461.74	28	12 245.34	17 845.34
9	11 880.92	17 480.92	29	12 264.52	17 864.52
10	11 900.10	17 500.10	30	12 283.70	17 883.70
11	11 919.28	17 519.28	31	12 302.88	17 902.88
12	11 938.46	17 538.46	32	12 322.06	17 922.06
13	11 957.64	17 557.64	33	12 341.24	17 941.24
14	11 976.82	17 576.82	34	12 360.42	17 960.42
15	11 996.00	17 596.00	35	12 379.60	17 979.60
16	12 015.18	17 615.18	36	12 398.78	17 998.78
17	12 034.36	17 634.36	37	12 417.96	18 017.96
18	12 053.54	17 653.54	38	12 437.14	18 037.14
19	12 072.72	17 672.72	39	12 456.32	18 056.32
20	12 091.90	17 691.90	40	12 475.50	18 075.50

TABLE 6-2

Table showing correspondence between channel numbers and assigned frequencies for the feeder links in the frequency band 14.5 - 14.8 GHz and the relationship to the BSS R1,3 Plan assignments

Feeder-link assignments		Translation frequencies (MHz)					
		2 797.82		2 529.30		2 260.78	
		BSS R1,3 plan assignments					
Ch. No.	Frequency (MHz)	Ch. No.	Frequency (MHz)	Ch. No.	Frequency (MHz)	Ch. No.	Frequency (MHz)
1	14 525.30	1	11 727.48	15	11 996.00	29	12 264.52
2	14 544.48	2	11 746.66	16	12 015.18	30	12 283.70
3	14 563.66	3	11 765.84	17	12 034.36	31	12 302.88
4	14 582.84	4	11 785.02	18	12 053.54	32	12 322.06
5	14 602.02	5	11 804.20	19	12 072.72	33	12 341.24
6	14 621.20	6	11 823.38	20	12 091.90	34	12 360.42
7	14 640.38	7	11 842.56	21	12 111.08	35	12 379.60
8	14 659.56	8	11 861.74	22	12 130.26	36	12 398.78
9	14 678.74	9	11 880.92	23	12 149.44	37	12 417.96
10	14 697.92	10	11 900.10	24	12 168.62	38	12 437.14
11	14 717.10	11	11 919.28	25	12 187.80	39	12 456.32
12	14 736.28	12	11 938.46	26	12 206.98	40	12 475.50
13	14 755.46	13	11 957.64	27	12 226.16	--	---------
14	14 774.64	14	11 976.82	28	12 245.34	--	---------

6.2.2.3 Co-channel carrier-to-interference protection ratio

The protection ratio to be planned for co-channel interference is 40 dB.

6.2.2.4 Adjacent channel carrier-to-interference protection ratio

Tests carried out recently by one administration showed that the adjacent channel protection ratio in feeder links for just perceptible interference could be reduced to 19 dB, when signals are passed through a 12 GHz TWT amplifier operating at saturation with an AM-PM conversion factor of 2°/dB and then received through an SAW filter with 27 MHz bandwidth before the demodulator.

These tests were carried out using a TWT amplifier with a low value of AM-PM conversion. It is believed that the effects of adjacent channel interference will be intensified by AM-PM conversion by the same mechanism as that reported for the intensification of noise. An additional margin of 2 dB above the 19 dB measured in laboratory tests is therefore recommended. It is recommended that an adjacent channel protection ratio of 21 dB be used in feeder-link planning.

Some administrations proposed that planning should use a value of 24 dB, but where this cannot be applied a value of 21 dB should be used.

6.2.2.5 Feeder link e.i.r.p.

A uniform value of e.i.r.p. for each band should be used for initial planning. For the band 17.3 - 18.1 GHz this should be 84 dBW and 82 dBW for the band 14.5 to 14.8 GHz.

These are initial values to be used in developing the Plan. They will be adjusted, if necessary, during the Plan development on a case-by-case basis to ensure that the minimum carrier-to-noise and carrier-to-interference criteria specified in the Plan are met for the feeder-link systems of all administrations. Adjustments will also be made, if required to accommodate the requirements of particular administrations.

Some administrations consider that these initial planning values may not meet their requirements.

6.2.2.6 Transmitting antenna

6.2.2.6.1 Antenna diameter

For a given value of on-axis e.i.r.p. and a given relative antenna pattern, the off-axis e.i.r.p. depends on the diameter of the antenna. The larger the diameter of the antenna, the smaller is the off-axis e.i.r.p which is a potential source of interference between adjacent orbital positions.

Hence for planning of feeder links it is necessary to define a reference antenna diameter. For the band 17.3 - 18.1 GHz the value adopted is 5 m and 6 m for the band 14.5 to 14.8 GHz.

Smaller antennas of, for example, 2.5 m diameter, can also be used provided that there is no degradation of the interference situation. In practice, this means that the e.i.r.p. might need to be reduced or the antenna diagram improved so that there is no increase in the off-axis radiation power, and hence no unacceptable interference to the adjacent orbital position or to other services.

6.2.2.6.2 On-axis gain

The on-axis gain for the 5 m antenna at 17.3 - 18.1 GHz and for the 6 m antenna at 14.5 to 14.8 GHz is taken as 57 dBi.

6.2.2.7 Off-axis e.i.r.p

The following is based on a transmitting antenna side-lobe reference pattern which follows the characteristics of 32-25 log φ.

6.2.2.7.1 Co-polar off-axis e.i.r.p.

The co-polar e.i.r.p. of the earth station for off-axis beam angles $\varphi \geqslant 1^\circ$* must not be more than:

$E - 25 - 25 \log \varphi$ (dBW) for $1^\circ \leqslant \varphi \leqslant 48^\circ$

$E - 67$ (dBW) for $\varphi > 48^\circ$

where

E (dBW) is the earth station on-axis e.i.r.p.

* Section 6.2.2.21.9 deals with co-polar e.i.r.p. of the earth station for off-axis beam angles $0^\circ < \varphi < 1^\circ$ which may be useful to resolve incompatibilities in planning feeder links.

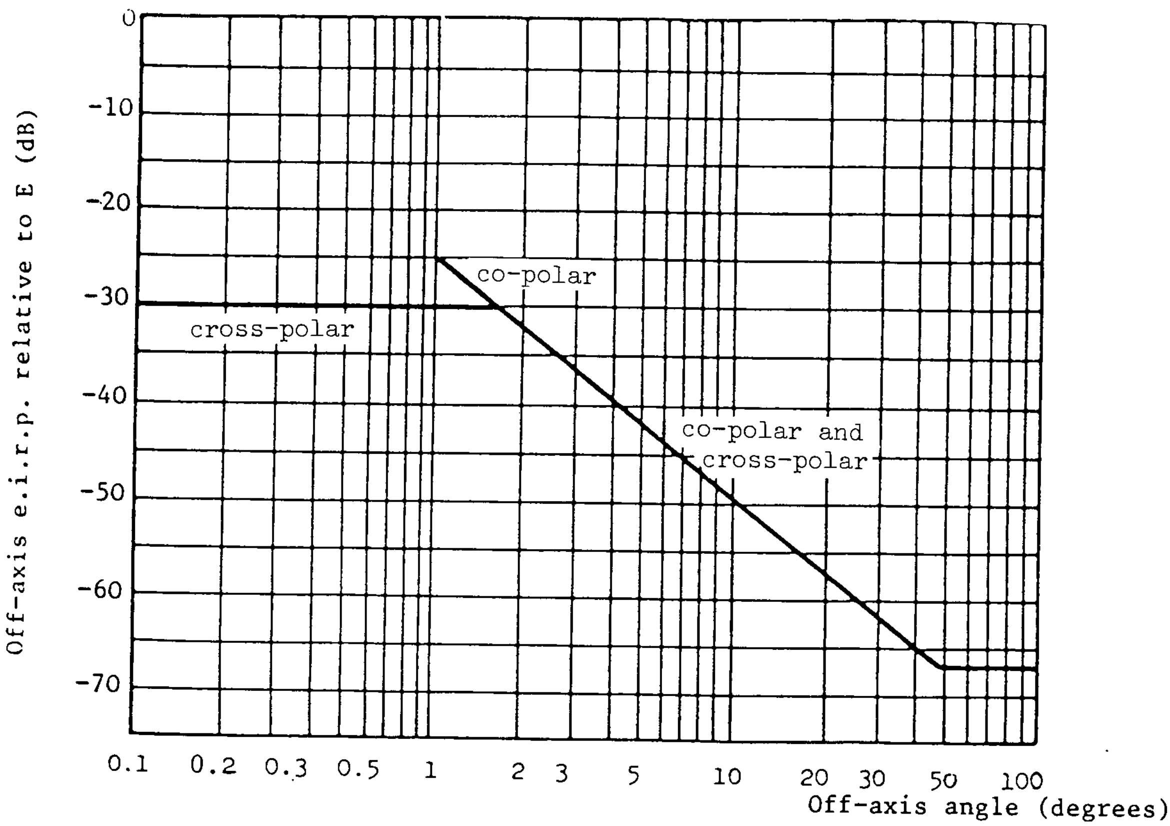

FIGURE 6-1

Earth station off-axis e.i.r.p.

Note - For $0^{o} < \varphi < 1^{o}$ refer to section 6.2.2.21.9.

In circumstances where independent planning of orbit positions is adversely affected, the off-axis co-polar e.i.r.p. of the earth station should be based on an antenna pattern of 29 - 25 log φ (dBi) for values of off-axis angle, φ , in the regions of the adjacent and next-but-one adjacent orbital positions in the plane of the geostationary orbit.

6.2.2.7.2 Cross-polar off-axis e.i.r.p.

The cross-polar e.i.r.p. of the earth station must not be more than:

E - 30 (dBW) for $0^{o} \leq \varphi \leq 48^{o}$

E - 25 - 25 log φ (dBW) for $1.6^{o} < \varphi \leq 48^{o}$

E - 67 (dBW) for $\varphi > 48^{o}$

where

E (dBW) is the earth station on-axis e.i.r.p.

In circumstances where insufficient cross-polar isolation is achieved, the cross-polar off-axis e.i.r.p. of the earth station should be based on an antenna pattern of 24 - 25 log φ (dBi) for $0.76^{\circ} \leqslant \varphi \leqslant 22.9^{\circ}$ and -10 (dBi) for $\varphi > 22.9^{\circ}$.

6.2.2.8 Earth station antenna mispointing loss

An allowance of 1 dB should be made for the loss in gain due to earth station antenna mispointing.

6.2.2.9 Satellite receiving antenna

If a common transmit/receive antenna is used, the cross-polar gain, beamwidth, pointing accuracy and radiation pattern would be dependent upon the down-link antenna characteristics.

Where separate antennas are used for transmit and receive the parameters of the receiving antenna are given in the following subsections. Separate receiving antennas offer greater flexibility in terms of independence of the feeder-link frequency, polarization and service area.

6.2.2.9.1 Cross-section of receiving antenna beam

Initial planning is to be based on beams of elliptical or circular cross-section. If the cross section of the receiving antenna beam is elliptical, the effective beamwidth φ_0 is a function of the angle of rotation between the plane containing the satellite and the major axis of the beam cross-section and the plane in which the beamwidth is required.

The relationship between the maximum gain of an antenna and the half-power beamwidth can be derived from the expression:

$$G_m = 27843/ab$$

or

$$G_m(dB) = 44.44 - 10 \log a - 10 \log b$$

where

a and b are the angles (in degrees) subtended at the satellite by the major and minor axes of the elliptical cross-section of the beam.

A minimum value of 0.6° for the half-power beamwidth is adopted for planning, except where an administration requests a lower value for its own beams.

6.2.2.9.2 <u>Co-polar reference pattern</u>

The co-polar reference pattern is given by the formula:

Co-polar relative gain (dB) (see Figure 6-2, curve A)

$G = -12\left(\frac{\varphi}{\varphi_o}\right)^2$ for $0 \leqslant \frac{\varphi}{\varphi_o} \leqslant 1.30$

$G = -17.5 - 25 \log\left(\frac{\varphi}{\varphi_o}\right)$ for $\frac{\varphi}{\varphi_o} > 1.30$

After intersection with curve C: as curve C

(curve C equals minus the on-axis gain).

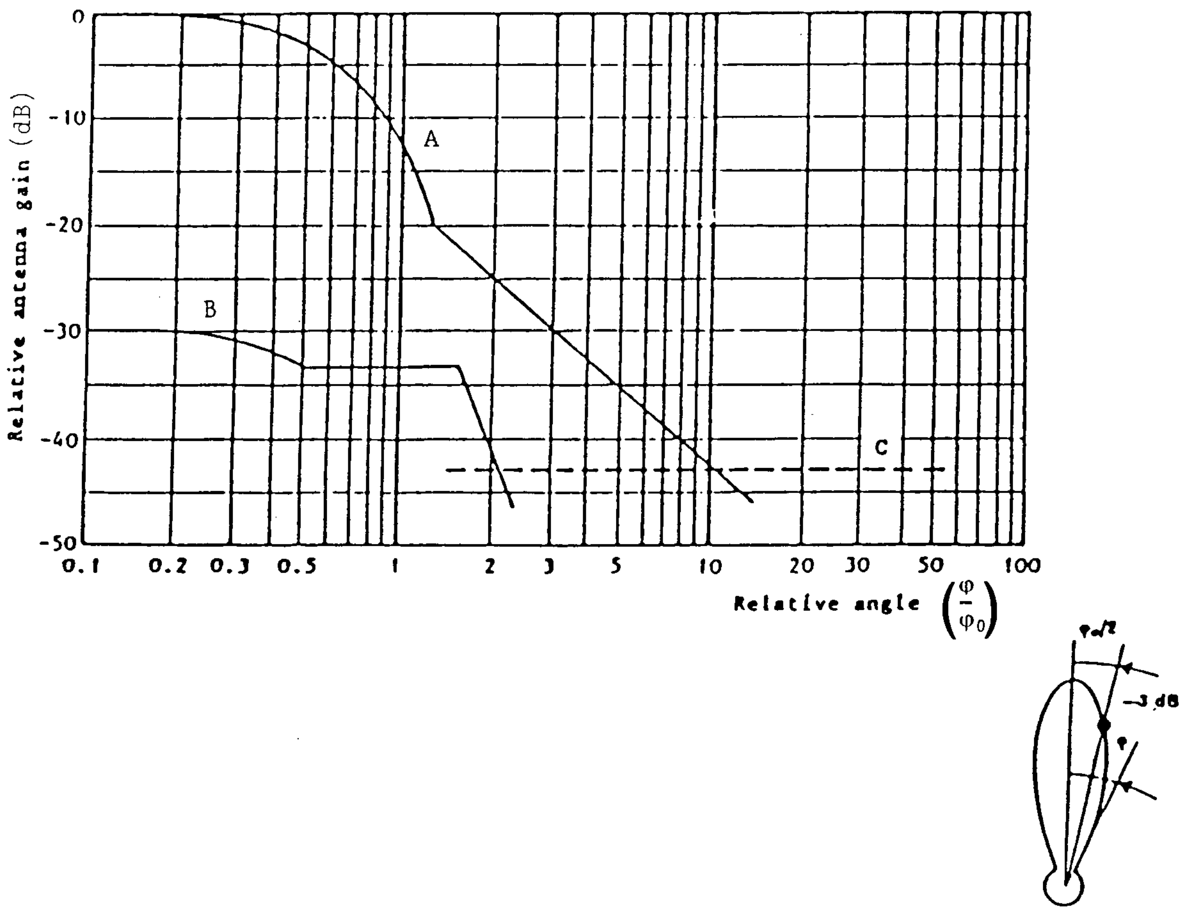

FIGURE 6-2

Satellite receive antenna reference pattern

Curve A - co-polar component (6.2.2.9.2)

Curve B - cross-polar component (6.2.2.9.3)

Curve C - minus the on-axis gain (Curve C in this figure illustrates the particular case of an antenna with an on-axis gain of 43 dBi).

6.2.2.9.3 Cross-polar reference pattern

The cross-polar reference pattern is given by the formula:

Cross-polar relative gain (dB) (see Figure 6-2, curve B)

$$G = -30 - 12\left(\frac{\varphi}{\varphi_0}\right)^2 \text{ for } 0 \leq \frac{\varphi}{\varphi_0} \leq 0.5$$

$$G = -33 \text{ for } 0.5 < \frac{\varphi}{\varphi_0} \leq 1.67$$

$$G = -\left\{40 + 40 \log\left(\frac{\varphi}{\varphi_0} - 1\right)\right\} \text{ for } \frac{\varphi}{\varphi_0} > 1.67$$

After intersection with curve C: as curve C

(curve C equals minus the on-axis gain).

6.2.2.10 Satellite receiving antenna pointing accuracy

The deviation of the receiving antenna beam from its nominal pointing direction should not exceed 0.2° in any direction. Moreover, the angular rotation of the receiving beam about its axis should not exceed ±1°; this latter limit is not necessary for beams of circular cross-section using circular polarization.

Should only one antenna be used for transmission and reception, the pointing accuracy of the receiving antenna is governed by, but not necessarily equal to, that of the transmitting antenna. Where two separate reflectors are used for transmission and reception, the transmitting antenna may be steered by using an automatic pointing mechanism, operating by detection of a terrestrial radio-frequency beacon. With this precise antenna pointing system, the receiving beam with slave control from the transmitting antenna may be stabilized to within 0.2°.

6.2.2.11 Satellite receiving system noise temperature

Planning should be based on a satellite receiving system noise temperature of 1800 K.

6.2.2.12 Type of polarization

Circular polarization is assumed in planning. Linear polarization may be used at a given orbit position subject to the agreement of all administrations concerned.

6.2.2.13 Sense of polarization

In the case of uniform frequency translation the sense of polarization of feeder links should be:

either

all opposite to their corresponding down-links,

or

all the same as that of their corresponding down-links
for each orbit position.

In the case of a non-uniform frequency translation plan, it is necessary to maintain a uniform polarization/frequency arrangement at each orbit position.

The choice of the sense of circular polarization when common transmit/receive antennas are used is influenced by the technology.

For simple elliptical beams, the opposite sense of polarization on the Earth-space and space-Earth links permits the use of a simple and economical orthomode transducer to provide isolation between the transmit and receive signals.

For shaped beams employing multiple horns, the same sense of polarization permits the use of simple and economical satellite antenna configurations avoiding the complexity of a separate orthomode transducer for each feed horn in the case of the opposite sense. Isolation between transmit and receive signals is provided by filters.

It is necessary to have one choice of polarization within one orbit position. However, provided there is no interaction between feeder links to two adjacent orbital positions it does not appear to be essential to make the same choice for all orbital positions.

6.2.2.14 Automatic gain control

The plan should not take account of automatic gain control on board satellites. Up to 15 dB of automatic gain control is permitted, subject to no increase in interference to other satellite systems.

6.2.2.15 Power control

The plan should not take account of power control. Power control is permitted only to the extent that interference to other satellites does not increase by more than 0.5 dB[1] relative to that calculated in the feeder-link plan.

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1 Note - This margin has to be shared between power control effects and depolarization compensation effects, when both are involved (see section 6.2.2.19).

Guidelines should be developed for the use of power control on the basis of the following information:

The allowable increase of earth-transmitter power applicable to earth-transmitting stations, without impairing the interference ratios in clear weather, takes into account the geographical locations of the earth stations and the feeder-link coverage areas.

Accordingly, Figure 6-3 and Table 6-3 summarize examples of probable combinations of increase of transmitting power and rain attenuation for various values of cross-polarization discrimination and elevation angle.

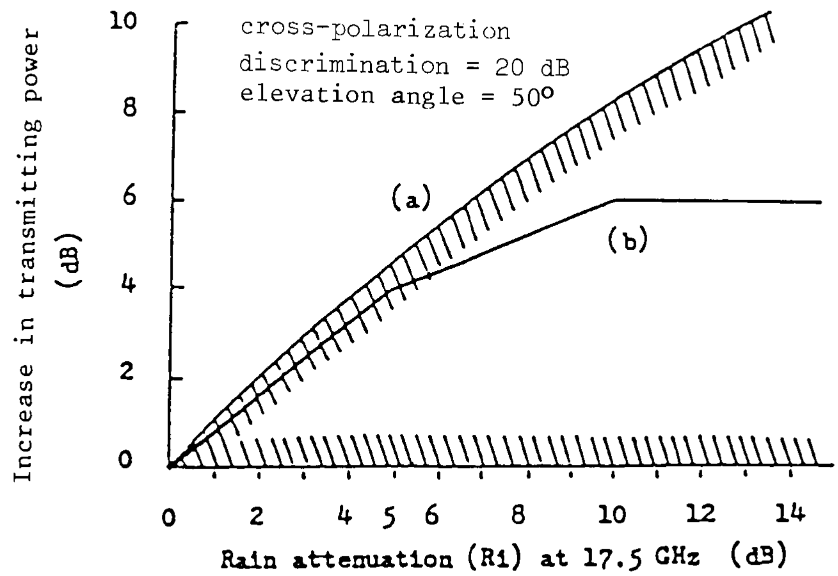

FIGURE 6-3

Possible increase in transmitting power for power control

Curve (a): upper limit for power control
Curve (b): an example of power control given in Table 6-3

TABLE 6-3

Possible increase of earth station transmitting power for power control for various values of cross-polarization discrimination and satellite elevation angle

Cross polarization discrimination (dB)	Satellite elevation angle (degrees)	Increase of earth station transmitting power (dB)	
		For rain attenuation 0 dB to 5 dB	For rain attenuation 5 dB and more
10 to 15	0 to 10	0	0
	10 to 30	0 to 4	4 to 7
	30 to 50	0 to 4	4 to 8
	50 to 60	0 to 5	5 to 9
	60 to 90	0 to 5	5 to 10
15 to 20	0 to 10	0	0
	10 to 30	0 to 2	2 to 4
	30 to 40	0 to 3	3 to 4
	40 to 50	0 to 3	3 to 6
	50 to 60	0 to 4	4 to 8
	60 to 90	0 to 5	5 to 9
20 to 25*	0 to 30	0	0
	30 to 40	0 to 2	2
	40 to 50	0 to 3	3 to 4
	50 to 60*	0 to 4	4 to 6*
	60 to 90	0 to 5	5 to 8
25 to 30**	0 to 40	0	0
	40 to 50	0 to 2	2
	50 to 60	0 to 3	3
	60 to 90	0 to 5	5

* This case is illustrated by Curve (b) in Figure 6-3.

** These cases are identical to those given in Table I, Part II of the Final Acts of RARC-SAT-83.

6.2.2.16 Earth station location

Planning should meet the requirements of administrations, but for feeder-link earth stations located outside the down-link service area it may be necessary to employ methods of resolving incompatibilities in planning described in section 6.2.2.21.

6.2.2.17 Propagation

The propagation model for feeder links is based on the value of rain attenuation exceeded for one per cent of the worst month.

6.2.2.17.1 Attenuation

For calculation, the following data are needed:

$R_{0.01}$: point rainfall rate for the location exceeded for 0.01% of an average year (mm/h)

h_o: The height above mean sea level of the earth station (km)

θ: the elevation angle (degrees)

f: frequency (GHz)

ζ: latitude of earth station (degrees)

Mean frequencies will be used for calculations for the two bands, i.e. 17.7 GHz and 14.65 GHz.

Step 1 - The mean zero-degree isotherm height h_F is:

$$h_F = 5.1 - 2.15 \log \left(1 + 10^{\frac{(/\zeta/ - 27)}{25}}\right) \quad \text{(km)}$$

Step 2 - The rain height h_R is:

$$h_R = C . h_F$$

where:

$C = 0.6$ for $0° \leqslant /\zeta/ < 20°$

$C = 0.6 + 0.02\ (/\zeta/ - 20)$ for $20° \leqslant /\zeta/ < 40°$

$C = 1$ for $/\zeta/ \geqslant 40°$

Step 3 - The slant-path length, L_s, below the rain height is:

$$L_s = \frac{2\,(h_R - h_o)}{\left(\sin^2\theta + 2\,\frac{(h_R - h_o)}{R_e}\right)^{1/2} + \sin\theta} \quad \text{(km)}$$

where:

R_e is the effective radius of the Earth (8,500 km)

Step 4 - The horizontal projection, L_G, of the slant-path is:

$L_G = L_s \cos\theta$ (km)

Step 5 - The rain path reduction factor $r_{0.01}$, for 0.01% of the time is:

$$r_{0.01} = \frac{90}{90 + 4\,L_G}$$

Step 6 - The specific attenuation, γ_R, is determined from:

$\gamma_R = k\,(R_{0.01})^{\alpha}$ (dB/km)

where:

$R_{0.01}$ is given in Table 6-4, frequency dependent coefficients k and α in Table 6-5 and rain climatic zones in Figures 6-4 and 6-5, respectively.

TABLE 6-4

Rainfall intensity (R) for the rain climatic zones (exceeded for 0.01% of an average year)

Rain-climatic zone	A	B	C	D	E	F	G	H	J	K	L	M	N	P
Rainfall intensity (mm/h)	8	12	15	19	22	28	30	32	35	42	60	63	95	145

TABLE 6-5

Frequency dependent coefficients

Frequency (GHz)	k	α
14.65	0.0327	1.149
17.7	0.0531	1.110

Frequency dependent coefficients are calculated using the following formulas and Table 6-6.

$$k = [k_H + k_V + (k_H - k_V) \cos^2 \theta \cos 2\tau]/2$$

$$\alpha = [k_H\alpha_H + k_V\alpha_V + (k_H\alpha_H - k_V\alpha_V) \cos^2 \theta \cos 2\tau]/2k$$

where θ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal ($\tau = 45°$ for circular polarization).

The formulas for k and α are general. In the case of circular polarization, the third terms in both equations are equal to zero, so that for circular polarization the formulas for k and α may be written:

$$k = (k_H + k_V)/2$$

$$\alpha = (k_H\alpha_H + k_V\alpha_V)/2k$$

TABLE 6-6

Regression coefficients for estimating specific attenuation

Frequency (GHz)	k_H	k_V	α_H	α_V
12	0.0188	0.0168	1.217	1.200
15	0.0367	0.0335	1.154	1.128
20	0.0751	0.0691	1.099	1.065

Step 7 - The attenuation exceeded for 1% of the worst month is:

$$A_{1\%} = 0.223 \gamma_R L_s r_{0.01} \text{ (dB)}$$

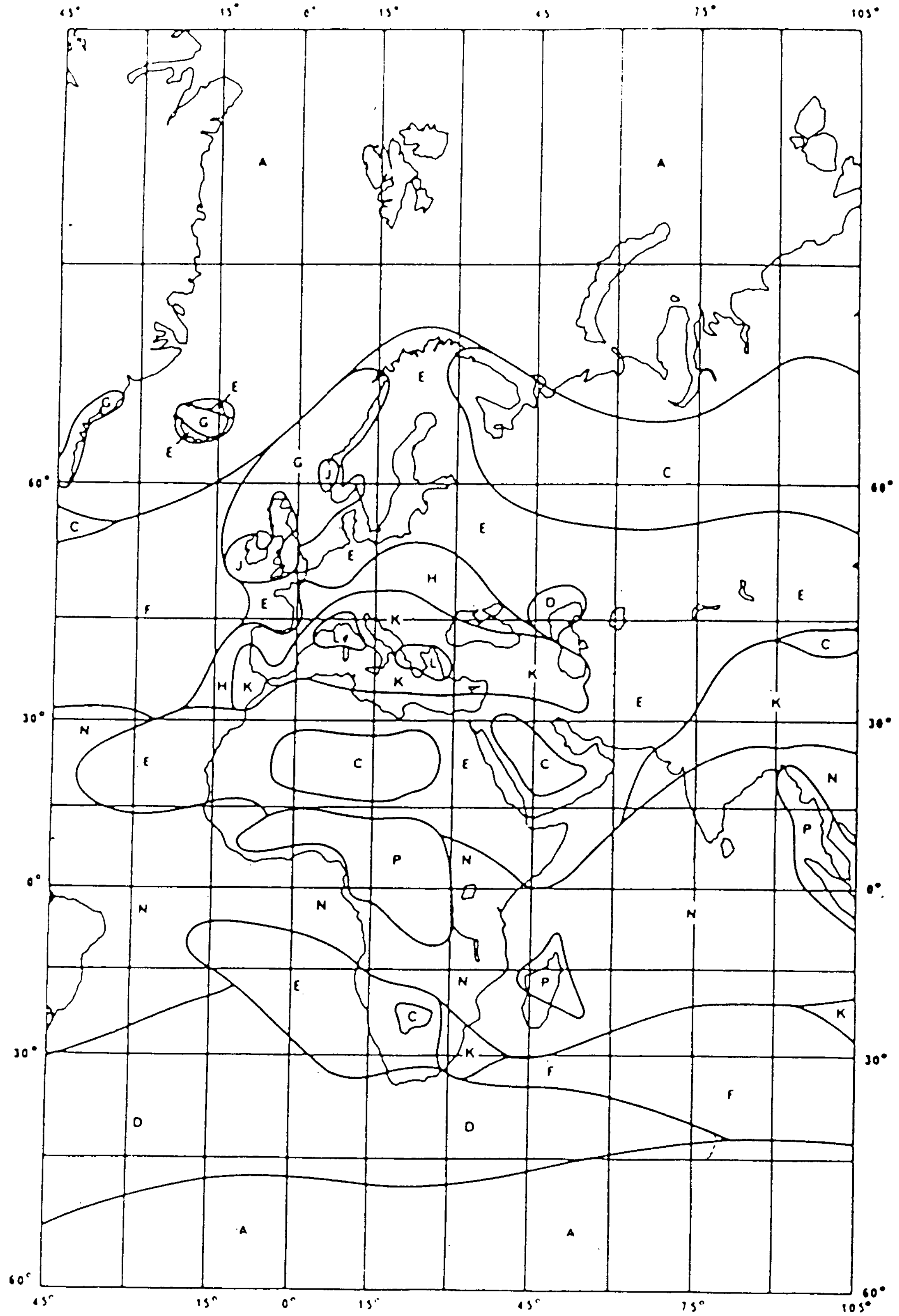

FIGURE 6-4

Rain climatic zones (45°W - 105°E)

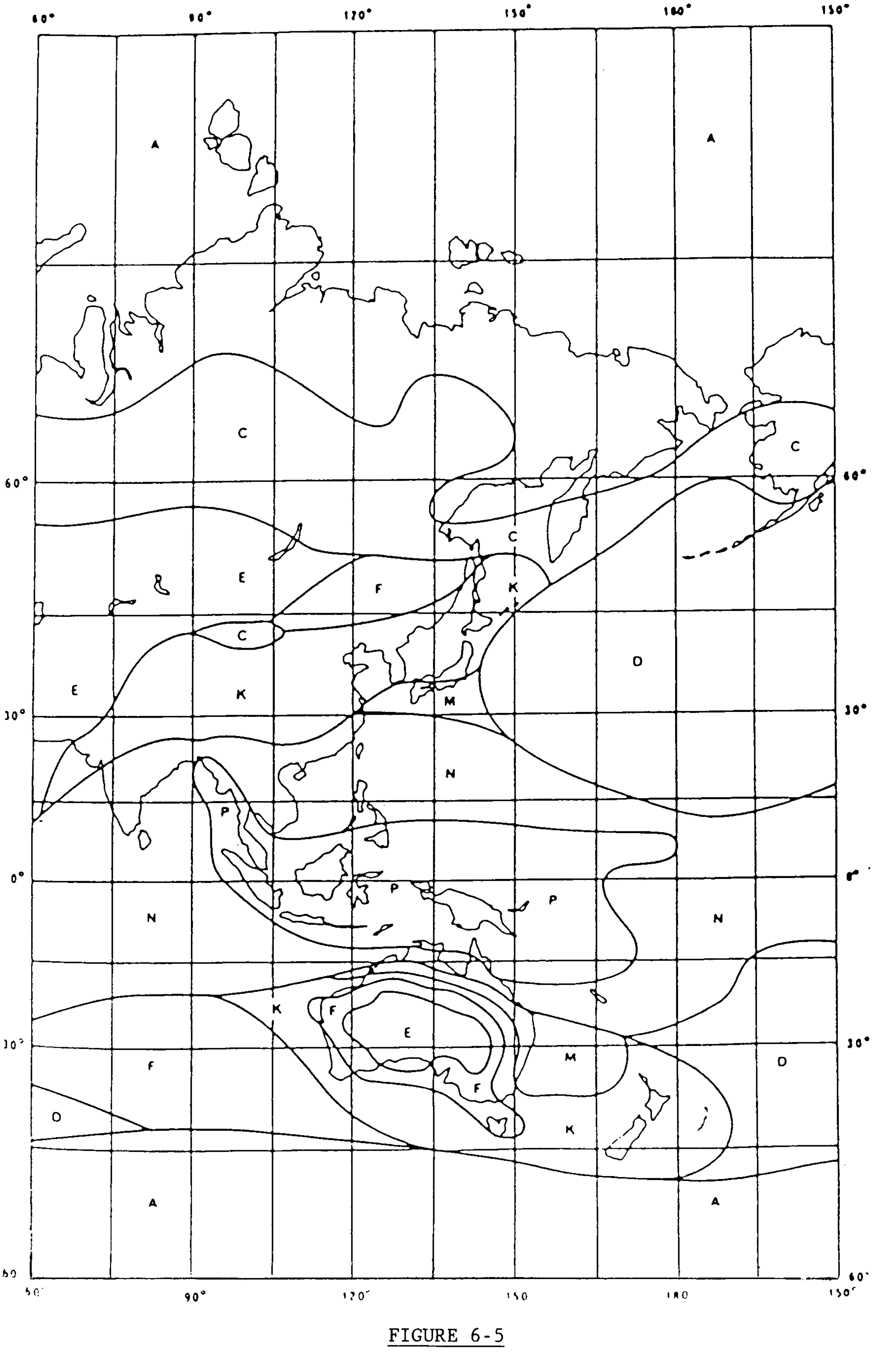

FIGURE 6-5

Rain climatic zones (60°E - 150°W)

6.2.2.17.2 Depolarization

Rain and ice can cause depolarization of radio frequency signals. The level of the co-polar component relative to the depolarized component is given by the cross-polarization discrimination (XPD) ratio. For the feeder link, the XPD ratio, in dB, not exceeded for 1% of the worst month, is given by:

$$XPD = 30 \log f - 40 \log (\cos \theta) - V \log A_p \text{ (dB) for } 5^\circ \leq \theta \leq 60^\circ$$

where

$V = 20$ for 14.5 - 14.8 GHz

and

$V = 23$ for 17.3 - 18.1 GHz

where

A_p: co-polar rain attenuation exceeded for 1% of the worst month,

f: frequency (GHz),

θ: elevation angle (degrees).

For values of θ greater than 60°, use $\theta = 60°$ in the above equation.

6.2.2.18 Amplitude-modulation to phase-modulation conversion

The degradation caused by AM to PM conversion should be taken into account when calculating the carrier-to-noise ratio of the feeder link. A value of 2.0 dB should be allowed.

6.2.2.19 Depolarization compensation

Depolarization compensation is not taken into account in planning. It is permitted only to the extent that interference to other satellite systems does not increase by more than 0.5[1] dB relative to that calculated in the feeder-link Plan.

6.2.2.20 Site diversity

The use of site diversity is not taken into account in planning. It is permitted and is considered to be an effective technique for maintaining high carrier-to-noise ratio and carrier-to-interference ratio during periods of moderate to severe rain attenuation.

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1 Note - This margin has to be shared between power control effects and depolarization compensation effects, when both are involved (see § 6.2.2.15).

6.2.2.21 Methods of resolving incompatibilities in planning feeder links during the Second Session of the Conference

Use of a common set of technical parameters for all feeder links in planning is desirable but preliminary studies by a number of administrations have indicated that there may be a difficulty in obtaining the required carrier-to-interference ratios on a small number of feeder links, particularly when certain administrations have special requirements to be met.

In order to overcome this difficulty, a degree of flexibility in the values of planning parameters used is proposed. Employment of one or more of the following techniques may be used, where necessary, in the planning process to attain the target values for interference protection.

6.2.2.21.1 Adjustments of the maximum level of e.i.r.p. of potential interfering feeder links or feeder links subject to excessive interference, provided that adequate carrier-to-noise and carrier-to-interference ratios on the adjusted feeder links are maintained.

6.2.2.21.2 Where independent planning of orbit positions is adversely affected, the off-axis co- and cross-polar side-lobe reference patterns of the earth station transmitting antenna may be limited to $29 - 25 \log \varphi$ (dBi), for values of off-axis angle, φ , in the regions of the adjacent and next-but-one adjacent orbital positions in the plane of the geostationary-satellite orbit.

6.2.2.21.3 Where insufficient cross-polar isolation is achieved, the off-axis cross/polar side-lobe reference pattern of the earth station transmitting antenna may be limited to $24 - 25 \log \varphi$ (dBi) for $0.76^{\circ} \leqslant \varphi \leqslant 22.9^{\circ}$ and -10 (dBi) for $\varphi > 22.9^{\circ}$.

6.2.2.21.4 Adjustment of the feeder-link channel assigments, retaining the same translation frequency for all assignments associated with a given down-link beam.

6.2.2.21.5 Modifying the satellite receiving antenna beam pattern shape, size, and/or side-lobe response (for example, a multiple beam or shaped beam antenna).

6.2.2.21.6 Off-setting the beam-pointing direction of the satellite receiving antenna subject to maintaining the target carrier-to-noise ratio.

6.2.2.21.7 Improving the beam-pointing accuracy of the satellite receiving antenna to 0.1°.

6.2.2.21.8 Setting an upper limit of 10 dB to the rain attenuation margin included in the feeder-link power budget.

6.2.2.21.9 Separating satellite orbit positions by $\pm 0.2^{\circ}$ from the nominal position and specifying the off-axis e.i.r.p. of the relevant earth station in the range 0° to 1° off-axis beam angles.

For such cases, where E(dBW) is the earth station on-axis e.i.r.p., the off-axis e.i.r.p. of the earth station transmitting antenna for angles $0^{\circ} < \varphi < 1^{\circ}$ should not be greater than:

E (dBW) for $0^{\circ} < \varphi \leqslant 0.1^{\circ}$

E - 21 - 20 log φ (dBW) for $0.1^{\circ} < \varphi \leqslant 0.32^{\circ}$

E - 5.7 - 53.2 φ^2 (dBW) for $0.32^{\circ} < \varphi \leqslant 0.44^{\circ}$

E - 25 - 25 log φ (dBW) for $0.44^{\circ} < \varphi < 1^{\circ}$

6.2.2.22 Summary table of initial technical parameters for feeder-link planning in Regions 1 and 3 (Frequency bands 17.3 - 18.1 GHz and 14.5 - 14.8 GHz)

TABLE 6-7

	Parameter	Value	Section
1.	Carrier-to-noise ratio	24 dB	6.2.2.2
2.	Co-channel carrier-to-interference protection ratio	40 dB	6.2.2.3
3.	Adjacent channel carrier-to-interference protection ratio	21 dB 24 dB	6.2.2.4
4.	Feeder link e.i.r.p. initial planning value	17.3 - 18.1 GHz - 84 dBW 14.5 - 14.8 GHz - 82 dBW	6.2.2.5
5.	Transmitting antenna	———	6.2.2.6
a)	Diameter	17.3 - 18.1 GHz - 5 m 14.5 - 14.8 GHz - 6 m	6.2.2.6.1
b)	On-axis gain	57 dBi	6.2.2.6.2
6.	Off-axis e.i.r.p.	———	6.2.2.7
a)	Co-polar off-axis e.i.r.p.	E-25-25 log φ (dBW) for $1^\circ \leqslant \varphi \leqslant 48^\circ$, E-67(dBW) for $\varphi > 48^\circ$	6.2.2.7.1 and Figure 6-1
b)	Cross-polar off-axis e.i.r.p.	E-30(dBW) for $0^\circ \leqslant \varphi \leqslant 1.6^\circ$, E-25-25 log φ (dBW) for $1.6^\circ < \varphi \leqslant 48^\circ$, E-67(dBW) for $\varphi > 48^\circ$	6.2.2.7.2 and Figure 6-1
7.	Earth station antenna mispointing loss	1 dB	6.2.2.8

	Parameter	Value	Section
8.	Satellite receiving antenna	———	6.2.2.9
a)	Cross section of beam	elliptical or circular	6.2.2.9.1
b)	Co-polar reference pattern	relative gain (dB) $-12 \left(\frac{\varphi}{\varphi_o}\right)^2$ for $0 \leq \frac{\varphi}{\varphi_o} \leq 1.30$ $-17.5 - 25 \log \left(\frac{\varphi}{\varphi_o}\right)$ for $\frac{\varphi}{\varphi_o} > 1.30$ After intersection with curve C: as curve C. Curve C equals minus the on-axis gain	6.2.2.9.2 and Figure 6-2 curves A and C
c)	Cross-polar reference pattern	relative gain (dB) $-30 - 12 \left(\frac{\varphi}{\varphi_o}\right)^2$ for $0 \leq \frac{\varphi}{\varphi_o} \leq 0.5$ -33 for $0.5 < \frac{\varphi}{\varphi_o} \leq 1.67$ $-\left(40 + 40 \log \left\lvert \frac{\varphi}{\varphi_o} - 1 \right\rvert\right)$ for $\frac{\varphi}{\varphi_o} > 1.67$ After intersection with curve C: as curve C. Curve C equals minus the on-axis gain	6.2.2.9.3 and Figure 6-2 curves B and C
9.	Satellite receiving antenna pointing accuracy	0.2^o	6.2.2.10
10.	Satellite receiving system noise temperature	1800 K	6.2.2.11

	Parameter	Value	Section
11.	Type of polarization	Circular	6.2.2.12
12.	Sense of polarization	____	6.2.2.13
13.	Automatic gain control	Not taken into account	6.2.2.14
14.	Power control	Not taken into account	6.2.2.15
15.	Earth station location	____	6.2.2.16
16.	Propagation	____	6.2.2.17
17.	Carrier to noise degradation due to AM-to-PM conversion	2.0 dB	6.2.2.18
18.	Depolarization compensation	Not taken into account	6.2.2.19
19.	Site diversity	Not taken into account	6.2.2.20

6.3 Sharing criteria between feeder links and other services (space and terrestrial) which need to be developed during the intersessional period

6.3.1 Introduction

Chapter 10 of the Report of the Conference Preparatory Meeting (CPM) of the CCIR discusses the sharing criteria required between feeder links and other services having primary allocations on an equal basis. Further relevant material is contained in Chapter 8 of the CPM Report and additional detail in Annex 5, section 5.4, Annex 6 and Annex 8.

The relevant sections of the CPM Report call for additional studies on many aspects of sharing. The following text deals with those aspects directly relevant to intersessional studies, for the frequency bands in which frequency plans for feeder links are to be developed. The criteria to be established are those necessary for inclusion in the Radio Regulations.

6.3.2 Frequency bands

For planning in Regions 1 and 3, sharing criteria are required for feeder links in the following frequency bands and sharing with the services indicated below. (It should be kept in mind that, in this context, feeder links are to be implemented in the fixed-satellite service.)

6.3.2.1 Frequency band 14.5 - 14.8 GHz

FIXED
MOBILE

6.3.2.2 Frequency band 17.7 - 18.1 GHz

FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE

6.3.3 Interference modes

The modes of interference which can occur are the following:

Mode a) Transmitting feeder-link earth station interfering with receiving terrestrial station (fixed or mobile);

Mode b) Transmitting terrestrial station (fixed or mobile) interfering with receiving feeder-link space station;

Mode c) Transmitting space station in the fixed-satellite service interfering with receiving feeder-link space station (for the 17.7 - 18.1 GHz band);

Mode d) Transmitting feeder-link earth station interfering with receiving earth station (for the 17.7 - 18.1 GHz band).

6.3.4 Sharing criteria available under various provisions of the Radio Regulations

6.3.4.1 Mode a) is covered for both frequency bands in question by Appendix 28 (Table 1). Note (5) in Table 1 states:

> "The parameters associated with these columns are for feeder links to broadcasting satellites and are provisional pending further study by the CCIR: see Resolution 101.".

For the time being, no parameters other than those in Table 1 are available. Moreover, it should be noted that sharing criteria for bands below 15 GHz are generally restricted to analogue-modulated terrestrial systems so that parameters for digital systems need to be developed. Intersessional studies should review the values associated with these parameters.

It is noted that Appendix 28 does not cover the case of aeronautical mobile receiving stations. Since these stations receive their assignments under the Radio Regulations, intersessional studies may be needed to provide the necessary sharing criteria and an appropriate method to be applied.

In addition there is a need for intersessional studies to take account of the occasionally simultaneous nature of relatively constant long-term interference to receiving terrestrial stations from the fixed-satellite service space transmitters and the short-term interference due to anomalous propagation from feeder-link earth stations at the limit of the coordination area determined by Appendix 28. It could be expected that there will be relatively few feeder-link earth stations on any particular frequency.

6.3.4.2 Mode b) is covered in Article 27 by RR 2503, RR 2505, RR 2508 and RR 2510 for the frequency band 14.5 - 14.8 GHz with Footnote 2510.2, which states:

> "The application of the limits in this frequency band is provisional (see Resolution 101).";

and also by RR 2505, RR 2508 and RR 2511 for the frequency band 17.7 - 18.1 GHz with Footnote 2511.2 referring to Footnote 2510.1, which states:

> "The equality of right to operate when a band of frequencies is allocated in different Regions to different services of the same category is established in No. 346. Therefore any limits concerning inter-Regional interference which may appear in CCIR Recommendations should, as far as practicable, be observed by administrations.".

It is, however, relevant to recall the view of the Report of the CPM on the need for pointing and/or e.i.r.p. restrictions. Chapter 12, section 12.6, responded to Recommendation 4 (COM6/4) of RARC-SAT-R2 as follows:

"Recommendation 4 (COM6/4) requests the CCIR to study the need for limits on e.i.r.p. in the direction of the GSO to be imposed on FS transmitters in the 17.3 - 17.8 GHz band to protect BSS feeder links. Report 952 (MOD I) discusses this matter for the 17.7 - 18.1 GHz band, and concludes that with the present e.i.r.p. limit of 55 dBW in Article 27, interference situations will be rare. Further, draft new Report AB/4-9 indicates that under worst-case conditions an FS digital radio-relay transmission around 18 GHz, interfering with a feeder-link receiver, will cause a maximum degradation of 0.12 dB to the nominal received broadcasting-satellite carrier-to-noise ratio (C/N) in the Region 2 Plan. This assumes a feeder-link e.i.r.p. of 86 dBW but does not take into account other factors that may further reduce the effect of terrestrial interference, such as feeder-link receive antenna discrimination and power spectral density reductions due to differences in channel bandwidths. Since the effect of terrestrial interference is considered negligible, and the additional factors may further reduce the interference, it is concluded that it is unnecessary to have restrictions as to the direction of maximum radiation for terrestrial transmitters.".

It is clear that the additional factors, which might collectively contribute 10 dB or more in additional discrimination, could alternatively be seen as permitting the use of lower feeder-link e.i.r.p. values than 86 dBW without the effect of terrestrial interference causing more than the 0.12 dB degradation which is considered to be negligible.

However, intersessional studies should be able to confirm that these conclusions regarding the fixed services are also applicable to the aeronautical mobile service.

6.3.4.3 Mode c)

There are two situations in this mode where interference might result:

- when satellites are separated by a small orbital arc,

- when satellites are at nearly antipodal positions.

Appendix 29 contains a procedure, applicable for both situations, for deciding whether coordination is required.

Intersessional studies are needed to determine the appropriate threshold value to trigger coordination, whether it would be preferable to express it in terms of $\Delta T/T$ (as in Appendix 29) or carrier-to-interference ratio (C/I), and whether it is desirable to establish common inter-Regional criteria for all three Regions.

In the fixed-satellite service, the threshold of broadcasting-satellite service feeder links for intra- and interregional interference might be expected to retain the value of 4% in Appendix 29. However, a more stringent value might more correctly reflect the appropriate C/I ratio required for BSS feeder links.

On the other hand, the threshold value of $\Delta T/T$ adopted in the provisions of RARC BC/SAT-R2 was in fact 10% for intersatellite geocentric angular separations less than 10° or greater than 150°. However, coordination is not required in the latter case if the free-space power flux-density of the transmitting space station in the fixed-satellite service does not exceed a value of -123 dB(W/m^2/24 MHz) on the Earth's surface at the limb of the Earth at the equator.

6.3.4.4 Mode d) concerns the frequency band 17.7 - 18.1 GHz which is allocated for bidirectional use, i.e. by the BSS feeder links in the Earth-to-space direction and by the FSS down-links in the space-to-Earth direction; this mode is not covered by any provisions of the Radio Regulations; however, RARC BC/SAT-R2 did develop an approach based on the use of Appendix 28 to deal with this mode. This approach was further developed by the CPM and is described in Annex 8 to its Report. Intersessional studies may help to confirm the efficacy of the method.

Note should also be made of the possibility of the occasionally simultaneous nature of the short-term interference due to anomalous propagation from feeder-link earth stations at the limit of their coordination area, and of terrestrial fixed service transmitters at the limit of their coordination area, together with the relatively constant interference from the space stations of the fixed-satellite service. Intersessional studies on the cumulative effect of the three categories of potential interference, taking account of the time distribution of the terrestrially propagated interference, appear necessary.

It could be expected that there will be relatively few feeder-link earth stations transmitting on any particular frequency simultaneously.

6.3.5 Comment on the implications for coordination distances of specifying nominal feeder-link earth station locations

6.3.5.1 In the context of developing BSS feeder-link plans in Regions 1 and 3, the possibility of specifying nominal BSS feeder-link earth station sites has been suggested in order to facilitate coordination with other services sharing a frequency allocation in which BSS feeder-link plans are being developed.

6.3.5.2 If nominal sites were to be specified, a powerful means of reducing coordination distances by such techniques as natural topographical, or artificial shielding would appear to be cast aside. The extent of the additional isolation achievable at an earth station, perhaps 30 dB, depends upon detailed knowledge of the earth station site and its surroundings - knowledge that can only reliably be obtained when sites are actually being surveyed during the site selection process.

6.3.5.3 Assuming that shielding is to be employed as a means of reducing the coordination areas of Appendix 28 to the extent practicable, there is a need for intersessional studies to review the provisional nature of the site shielding values for horizon elevation angles greater than the value of 5° as indicated in the footnote to equation 7(a) of section 3.2.2 and Figure 1 of Appendix 28.

CHAPTER 7

Satellite sound broadcasting systems for individual reception by portable and automobile receivers

7.1 Introduction

The use of satellites is one of the possible solutions for nation-wide sound broadcasting. However, current frequency allocations do not provide for the particular needs of satellite sound broadcasting serving portable receivers and receivers in automobiles. The selection of the appropriate frequency band has been the subject of various studies and experiments whose results are described in CCIR Report 955 (MOD I).

The interest of administrations, in the subject of satellite sound broadcasting at the WARC-79, resulted in Resolution 505 which resolved:

"1. that administrations shall be encouraged to carry out experiments with a broadcasting-satellite service (sound) within the band 0.5 - 2 GHz, in appropriately placed narrow sub-bands, subject to agreement of administrations concerned. One area where such a sub-band may be placed is the band 1 429 - 1 525 MHz;

2. that the CCIR shall continue and expedite studies relating to the technical characteristics of a satellite sound broadcasting system for individual reception by portable and automobile receivers, the feasibility of sharing with terrestrial services, and the appropriate sharing criteria;

3. that the next world administrative radio conference dealing with space radiocommunication services in general or with a specific space radiocommunication service shall be authorized to consider the results of various studies and to take appropriate decisions regarding the allocation of a suitable frequency band;

4. that the aforementioned conference shall also develop appropriate procedures for protection, and if necessary re-accommodation in other bands, of assignments to stations of terrestrial services which may be affected.".

Consequently, the Administrative Council, in Resolution 895, decided that in order to meet the objectives of Resolution 505 of the WARC-79, WARC-ORB-85 was to consider the question in the light of experience gained by administrations and the results of studies in the CCIR and make appropriate Recommendations for the attention of the WARC-ORB(2).

This chapter reviews the progress of the work invited by Resolution 505 (resolves 1 and 2). Technical characteristics of example systems are given. Conclusions are drawn and areas for further study are defined. Recommendations are made for the attention of WARC-ORB(2), in accord with agenda item 4 and based upon the information available at the time of WARC-ORB-85.

7.2 Results of studies and analysis

The CCIR in response to Resolution 505 of the WARC-79 has produced Report 955 concerning satellite sound broadcasting with portable receivers and receivers in automobiles. Several administrations and recognized private operating agencies have conducted experiments and undertaken studies to assess system feasibility within the 0.5 - 2.0 GHz band.

The annex to the present chapter gives technical information regarding sound broadcasting satellite systems, which have been analysed and studied. The following sections give the general characteristics of systems studied and discuss the major considerations pertinent to an allocation decision.

7.2.1 System description

A broadcasting-satellite service (sound) (BSS (sound)) could provide for three types of reception: portable receivers, mobile receivers such as automobile radios and permanently-installed receivers. Such a service implies elevation and frequency-dependent link budgets. Both aspects are discussed in the annex to the present chapter.

Two models have been studied. The first model uses frequency modulation (FM) with parameters compatible with terrestrial FM-broadcasting and provides monophonic reception in the case of portable and mobile receivers or stereophonic reception in the case of permanent installations where obstructions can be minimized and larger antennas can be used. The second model uses digital modulation and can provide a wider range of facilities independent of the type of reception.

Service quality and availability objectives are developed in the annex to the present chapter, section 2.2. Service availability has been assumed for 90% of locations. This service availability will depend on fading due to obstructions and multipath effects. Low latitudes could be served with rather moderate transmit power levels while higher latitudes would require higher levels. In both system models, it is considered that Cases A and B discussed in the annex to the present chapter, section 2.3 would provide satisfactory reception under all except very severe conditions.

The FM and digital models have been chosen as representative of possible methods of providing services. The selection of FM for a lower service quality does not necessarily imply that an FM system cannot provide a service quality equivalent to that from a digital system, since many other technical factors need to be taken into account.

A comparison of link budgets indicates that the digital model would require about twice the satellite transmit power of the FM model. The resulting technical requirements can be satisfied for some examples as given in the annex to the present chapter, with satellite and receiver technology available now or in the near future.

7.2.2 Cost considerations

The attention of administrations is drawn to the technical factors having a bearing on costs involved in the implementation of a satellite sound broadcasting system. Examples of space-segment cost estimates can be found in the annex to the present chapter. Technical and economic studies in one country have been reported since the CPM 1984 and have indicated that a satellite system could be several times more expensive than an equivalent terrestrial system. In other cases, particularly in mountainous areas, the satellite system could be less expensive, as indicated in a study by another administration based upon the cost of terrestrial television systems. The relative cost depends on the geographical location of the service area, the shape and size of the territory, the number of programmes, technological solutions chosen and other factors. Further studies by the CCIR into those technical factors which have a bearing on costs, are required.

7.2.3 Frequency, bandwidth and frequency sharing considerations

Three elements of importance in making an allocation decision are the appropriate frequency for operation, the bandwidth required and the possibilities of frequency sharing.

7.2.3.1 Operating frequencies

Studies examined by WARC-ORB-85 have used frequencies in the range 0.5 - 2.0 GHz. An increase in operating frequencies would require a corresponding increase in the satellite transmit power levels which in turn would increase with latitude. A decrease in operating frequency would require an increase in the satellite antenna diameter and would put ground receivers in an environment of higher man-made noise.

7.2.3.2 Bandwidth

The bandwidth required for a UHF satellite sound broadcasting service depends on the modulation method and on the extent of coverage overlap. As discussed in the CPM Report, studies performed for almost the whole of Africa and Europe, and in Region 2, arrive at a required bandwidth of 9 to 11 MHz for providing one national sound broadcast programme per country when this is transmitted by frequency modulation. Digital modulation tends to require a somewhat larger bandwidth. The study for Region 2 countries concluded that some 13 MHz are needed for one monophonic programme per country. These results are believed to be representative for national services.

7.2.3.3 Frequency sharing considerations

Primary users of the 0.5 - 2.0 GHz band include broadcasting, mobile and fixed services. Additionally there are substantial allocations for the aeronautical radionavigation and radiolocation services.

Sharing studies have been conducted for frequency modulation and digital modulation techniques. Frequency modulation allows very limited energy dispersal while digital modulation techniques offer a significant energy dispersal advantage. However, even the most optimistic studies for the latter modulation demonstrate that the obtainable power flux-density levels are still too high to allow frequency sharing with the broadcasting, fixed or mobile services within the service area and in large areas around it.

It can be concluded that frequency sharing will not be possible in a systematic manner. This suggests that, taking into account the existing criteria, the development of national sound broadcasting-satellite services in the frequency range 0.5 - 2.0 GHz will only be possible through the allocation of an appropriate frequency band on an exclusive basis.

7.2.4 Conclusions

The studies conducted by the CCIR on the BSS (sound) in the range 0.5 - 2.0 GHz indicate that this service is feasible from the technical point of view but, due to sharing difficulties, the implementation of such a service will not be possible unless an appropriate frequency band is allocated for it on an exclusive basis. These studies performed by the CCIR and the experiments and studies undertaken by administrations have shown that accommodation of the satellite sound broadcasting service in the frequency range 0.5 - 2.0 GHz would cause considerable difficulties.

It is necessary to investigate further the sharing possibilities between BSS (sound) and other services. Further work is also required to fully define practical system parameters that would more readily permit the implementation of such a service. The following study areas have been identified.

7.2.4.1 Quality of service

The quality of service impacts upon overall system characteristics and sharing with other services. Different administrations may desire different quality levels. It is suggested that at least medium and high quality systems be studied, with high quality possibly being attained by the use of permanently installed receivers.

7.2.4.2 Frequency of operation

A number of administrations indicated that they would be unable to accommodate the BSS (sound) in the band 0.5 - 2.0 GHz on an exclusive allocation basis. However, two administrations indicated that they may be able to accommodate, on a national basis, BSS (sound) in this band on an exclusive basis. Additional study is desirable to identify possible frequencies where the BSS (sound) might be implemented within the band 0.5 - 2.0 GHz, using the technical parameters identified for further study. In addition, studies are requested for frequencies outside but near the 0.5 - 2.0 GHz range where the possibilities for sharing or other accommodations may be greater.

7.2.4.3 Modulation type

Changes in modulation format may reduce the power required for BSS (sound) transmitters and may enhance the possibilities for sharing with other services. In this respect the technical characteristics of practicable digital systems need further determination.

7.2.4.4 Bandwidth required

The change in modulation type or the use of other digital systems may alter the bandwidth required from the values given in the example systems discussed in this report.

7.2.4.5 Receivers

Signal processing techniques, the possible use of existing receivers, and the possible development of similar receiver designs were identified as areas of study.

7.2.4.6 Antenna design

To improve sharing possibilities, it is necessary to study spacecraft antennas with improved side-lobes and multiple spot beams, and the gain and directivity characteristics of ground receiving antennas.

7.2.4.7 Feeder links

Technical characteristics of required feeder links need to be identified.

7.2.4.8 Appropriate sharing criteria (including those applicable to geographical separation)

Sharing criteria are needed to determine possibilities for sharing with all services using frequency bands in which the BSS (sound) might operate. In particular, studies need to be directed towards sharing on a geographical basis, that is, among and within regions or among groups of administrations.

7.2.4.9 Cost considerations

The results of several studies were available to determine space segment costs, total BSS (sound) system costs and, in comparison, the costs of coverage by terrestrial sound broadcast systems. Additional study is needed to identify more precisely these costs for practicable systems.

7.2.4.10 Ability of present and future technology to comply with RR 2674

This area must also be studied.

7.2.4.11 Multiple user satellite

Investigation is required into the technical implications of use of the same satellite by more than one administration to satisfy their individual requirements.

7.3 Recommendations[1]

After considering sound broadcasting by satellites in the light of experience gained by administrations and the results of studies in the CCIR, WARC-ORB-85 recommends:

a) that administrations shall continue to carry out studies on the following subjects: quality of service, frequency of operation (within, as well as outside but near 0.5 - 2.0 GHz), modulation type, bandwidth required, receivers, antenna design, feeder links, appropriate sharing criteria (including those applicable to geographical separation), cost considerations, the ability of present and future technology to comply with RR 2674 and multiple user satellites. In so doing they should take into account the information given in section 7.2.4 and the annex to the present chapter and the need to comply with RR 2674;

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[1] See also Recommendation 2.

b) that the Second Session of this Conference should consider the results of the various up-to-date studies and in reviewing the situation prevailing at that time take appropriate decisions concerning the various aspects of this system as outlined in Resolution 505 of the WARC-79.

Furthermore, WARC-ORB-85 requests the Administrative Council to consider Recommendation 2 when preparing the agenda of the Second Session of this Conference;

WARC-ORB-85 also invites the CCIR to undertake studies without additional expenditure as indicated in a) above in order to define the practical system parameters for satellite sound broadcasting.

ANNEX TO CHAPTER 7

Technical and operational information relating to satellite sound broadcasting systems for individual reception by portable and automobile receivers

1. Introduction

Satellites can provide a nation-wide sound broadcasting service, although at present there is no frequency allocation for such a service. It is technically possible to provide a service to portable receivers, receivers in automobiles and permanently-installed receivers. The minimum quality at the edge of the service area could be either grade 3 or grade 4 on the 5 point CCIR quality scale depending on the type of modulation adopted.

In response to Resolution 505 of the WARC-79, the CCIR has produced Report 955 concerning satellite sound broadcasting with portable receivers and receivers in automobiles using the UHF band, while administrations and agencies have undertaken further studies. This Annex is based upon Report 955 and these additional studies.

2. System description

2.1 System models

Two system models have been studied. The first one uses frequency modulation with parameters compatible with terrestrial FM broadcasting. The second model assumes digital modulation. The models provide for three types of reception; portable receivers, mobile receivers such as automobile radios and permanently-installed receivers.

The FM model would enable monophonic reception in the case of portable and mobile receivers using small antennas with limited directivity, and stereophonic reception in the case of permanent installations where obstructions can be minimized and larger antennas can be used.

In the case of digital modulation, the model has been based on monophony. Stereophony would require a second channel or a doubling of the bit rate, but stereophonic reception would then be possible in all the reception conditions covered by the service. A digital system has also a large flexibility to accommodate different types of facilities.

The models have assumed an operating frequency in the vicinity of 1 000 MHz and geostationary satellites with large antennas (e.g., 8-20 m diameter).

2.2 Quality objective and service availability

The availability of the service is taken as 90% of the locations in the case of portable and mobile reception.

In the case of the FM model, the quality objective at the edge of the coverage area is taken as a subjective quality corresponding to grade 3 on the 5 point CCIR quality scale. This corresponds to a weighted S/N ratio of 40 dB. As a second condition to be met, the C/N ratio needs to be kept above the FM threshold (10 dB). The interference protection ratios should be high enough to ensure that system noise is the factor controlling the system availability.

In the case of the digital model, the quality objective at the edge of the coverage area is equivalent to a subjective quality of grade 4 on the 5 point CCIR quality scale. This will correspond to an allowed bit error-ratio depending on the level of protection against errors, and to a required carrier-to-noise ratio depending on the channel coding used. In this case, interference is considered as additive noise and the protection ratios are set such that the noise contribution from the co-channel interference is 1 dB and each adjacent channel contributes 0.5 dB.

2.3 Link margin

Four values of link margin have been assumed in Table 7-1. These are estimates of the allowances required in the various cases listed below.

Case A: In this case a margin of 6 dB is used. This should give a C/N ratio of at least 10 dB for 90% of receiving points in a rural area, and for an elevation angle to the satellite exceeding 70°, corresponding to a service in low-latitude areas. Mobile reception on roads in these circumstances should be satisfactory, except when close to tall obstructions that would be obvious to the listener.

Case B: The 15 dB margin covers the case of reception in an urban area, for 20° elevation angle to the satellite (high-latitude country) and to a service quality corresponding to the minimum stated quality at 90% of sites.

Case C: The 25 dB margin covers the case of reception in urban areas where 90% of areas are served in such a way that the quality of 90% of receiving points within the area corresponds to the minimum stated quality objective.

Case D: As for Case C but with 95% of areas having 90% of points where the minimum stated quality objective is met.

A satisfactory system could be achieved without requiring a high margin that would ensure satisfactory coverage in extremely severe conditions. In any event reception will be impossible in extreme cases such as motor vehicles travelling through tunnels or through certain parts of city centres. Therefore, on the basis of simulated trials, it is considered that at 1 000 MHz a margin of 15 dB (Case B) is sufficiently large to ensure satisfactory reception in the case of a motor vehicle passing through a city (90% coverage). This applies to high latitude receiving areas. This Case B is assumed in Table 7-2. At 1 000 MHz, a margin of 6 dB (Case A) is sufficiently large for mobile reception on roads, in low latitudes and in rural areas. Some other factors relating to signal propagation such as choice of polarization and signal attenuation in buildings are considered in Report 565-2.

2.4 Modulation

Two modulation techniques are considered for this service. The first uses frequency modulation with parameters compatible with terrestrial FM broadcasting to allow reception using conventional FM receivers with an additional frequency conversion. The same carrier deviation and the same pre-emphasis are assumed as well as the same stereophonic multiplex. Preliminary analyses tend to show that for the system quality objectives given in section 2.2 of this annex, these modulation parameters are close to optimum in terms of minimizing the required satellite power and optimizing spectrum usage.

The second modulation technique assumes a digital source coding similar to the standard suggested in Report 953 for a near-instantaneous companded 15 kHz high-quality monophonic sound channel. Error protection is provided on the range code and error concealment on samples resulting in a total bit rate of 338 kbit/s. A channel coding in the family of the 4-PSK with differential demodulation (e.g., DMSK, 2-4 PSK, TFM ...) was assumed with the following characteristics in mind: spectrum efficient coding, ruggedness against channel non-linearity and demodulator simplicity for low-cost implementation with minimum margin with respect to the theoretical performance. The minimum level of signal quality (Q = 4) is found to be achievable at a bit error-ratio of 10^{-3} with a channel bandwidth equivalent to the bit rate and with a C/N ratio of 9 dB including the implementation margin (see Annex I of Report 632-2 (MOD I)).

2.5 Link budget

Table 7-1 gives a reference budget for the FM system as presented in Report 955 in which the range of link margins described earlier has been assumed to allow for various sources of degradation, while other parameters have been fixed.

TABLE 7-1

Link budgets for sound broadcasting satellite systems in the UHF band

System parameters	Standard of service			
	A	B	C	D
Type of modulation	FM			
Type of polarization	circular			
Carrier deviation (kHz)	± 75			
Noise bandwidth (kHz)	250			
Carrier-to-noise ratio (dB)	10			
Coupling loss (dB)	1			
Receiver antenna gain (dBi)	3			
Receiver system noise temperature (K)	2 000			
Carrier frequency (MHz)	1 000			
Link margin (dB)	6	15	25	33
Line-of-sight p.f.d. at edge of beam (-3 dB), (dB(W/m^2))	-106.4	-97.4	-87.4	-79.4
Equivalent field strength (dB(μV/m))	39.4	48.4	58.4	66.4
Maximum spreading loss (dB/m^2)	163	163	163	163
E.i.r.p. on axis (dBW)	59.6	68.6	78.6	86.6
Satellite antenna gain (D = 20 m) for 1° beamwidth (dBi)	43.9	43.9	43.9	43.9
Antenna input power (dBW)	15.7	24.7	34.7	42.7
Antenna input power (W)	37	295	2 951	18 621

Table 7-2 gives two link budgets, one for each type of modulation. The values used in these budgets are based on results of more recent studies. Both examples use the link margin given in Case B described in section 2.3 of this annex. The two link budgets are based on the same parameters except for the modulation parameters and those directly related to it, such that this table can be used in a direct comparison between the FM and the digital systems.

Most of the available data on the link margin have been determined for frequencies near 1 000 MHz. For a constant receiver antenna gain, the required power flux-density and hence e.i.r.p. would vary in proportion to the square of the frequency in order to maintain the same signal level in the receiver under line-of-sight conditions; for example, at 1.5 GHz the required power would be 3.5 dB greater.

In addition, the frequency also affects to some extent the link margin needed for a specific service quality. When increasing in frequency from 1 000 MHz to 1.5 GHz, the link margin for coverage of urban areas may increase from 15 to 18 dB for 20° elevation. A decrease in frequency would have the reverse effect.

Such systems are feasible in a frequency band in the vicinity of 1 000 MHz. The lower and upper frequency limits are dictated by the following considerations:

- for the lower limit (around 500 MHz):
  - the man-made noise increases proportionally with decreasing frequency;
  - the diameter of the satellite transmit antenna increases proportionally with decreasing frequency;
- for the upper limit (around 2 GHz):
  - the effective area of the receive antenna which is necessary for such a system diminishes with increasing frequency; this entails an increase in satellite transmit power.

The technical requirements resulting from the link calculations of Tables 7-1 and 7-2 for Cases A and B can be satisfied with satellite and receiver technology available now and in the near future.

TABLE 7-2

Link budget examples for satellite sound broadcasting

System parameters	Analogue system	Digital system
Type of modulation	FM	4-PSK family
Primary reception mode	monophonic (1)	monophonic (2)
Carrier deviation (kHz) (or bit rate (kbit/s))	± 75	(338)
Noise bandwidth (kHz)	250	338
Carrier-to-noise ratio (C/N) (dB) (3)	10	11
Signal-to-noise ratio (S/N_W) (dB) (4)	40	(Q = 4)
Coupling loss (dB)	1	1
Receiver antenna gain (dBi) (5)	3	3
Receiver system noise temperature (K) (6)	600	600
Carrier frequency (MHz)	1 000	1 000
Link margin (dB) (7)	15	15
Line-of-sight p.f.d. at edge of beam ($dB(W/m^2)$)	-102.4	-100.1
Equivalent field strength at edge of beam (dB(μV/m))	43.4	45.7
Maximum beam-centre p.f.d. per 4 kHz (no energy dispersal) ($dB(W/m^2/4\ kHz)$)	-99.4	-117.1
Maximum spreading loss ($\varepsilon = 17^o$) (dB/m^2)	163	163
Difference in antenna gain between centre and edge of coverage (dB)	3	3
E.i.r.p. on axis (dBW)	63.6	65.9
Satellite antenna gain (D = 20 m) for 1^o beamwidth (dBi)	43.9	43.9
Antenna input power (dBW)	19.7	22.0
Antenna input power (W)	93	158

(1) System modulation and bandwidth parameters are based on stereophonic transmission, but primary mode of reception in automobiles and portable receivers is monophonic.

(2) Monophonic transmission and reception assumed for the digital system. Stereophonic reception would only be possible by using 2 channels, or alternatively transmitting at twice the bit rate.

(3) The C/N objective for FM systems corresponds to the FM threshold. The C/N objective for the digital system includes 1 dB equivalent additive noise from co-channel interference and 0.5 dB from each one of the 2 adjacent channels.

(4) Value to be exceeded for 90% of locations at the edge of the coverage area. The noise performance for the digital system is given in terms of subjective quality (4 = good).

(5) Assumes slotted dipole configuration with 120^o beamwidth.

(6) Assuming man-made noise in urban areas, (section 7 of Report 258-4), and improved receiver noise figure (NF = 3 dB).

(7) Margin corresponds to 90% of locations along mixed route in urban environment in high latitude countries (Case B, Report 955).

2.6 Space-segment cost estimates

Space-station costs may be estimated using historical data which show a close correlation between cost and in-orbit space-station mass. For a space-station mass of approximately 1 000 kg, total in-orbit costs are of the order of $ 60,000 - $ 80,000 per kg i.e. $ 60 million to $ 80 million per space station (1978 US dollars). This cost includes design, development, manufacturing, launch, launch insurance and a pro rata share of the launch risk (not all launches are successful).

Launch costs alone using the shuttle are expected to be of the order of $ 15,000 - $ 19,000 per kg depending on the mass of the space station.

For space stations of the 2 400 kg class, the total cost of 2 in-orbit space stations (one operational and the second a spare) plus one-half of an on-ground spare is estimated to be of the order of $ 360 million.

From the results of the study by an administration in Region 2 given in Annex III of Report 955, a 2 400 kg space station would be required to provide 5 channels of sound broadcasting to a rural area encompassed by a 1.5° beamwidth antenna at an operating frequency of 1 GHz. The on-axis e.i.r.p. would be 67.2 dBW per channel.

For space stations of the 600 kg class, the space segment investment cost would be about $ 90 million. For this class of space station, a single sound broadcasting channel could be provided in a rural area encompassed by a 1.2° beamwidth antenna at an operating frequency of 1 GHz.

3. Bandwidth requirements

The bandwidth required for a broadcasting-satellite service (sound) in the UHF band depends on the modulation method and on the extent of coverage overlap.

Based on the parameters with appropriate modification used for the planning of the broadcasting-satellite services in the 12 GHz band in Region 1, one can conclude from a study carried out by regional organizations covering almost the whole of Africa and Europe that approximately 60 channels with a spacing of 150 kHz and thus a total bandwidth of about 9 MHz is necessary to provide one national sound broadcasting programme per country. This study assumed frequency modulation and is valid for monophonic as well as stereophonic reception. The latter will, however, only be achievable with permanently-installed receivers. The higher protection ratio needed for the higher quality stereophonic FM reception is obtained through:

- the line-of-sight reception of permanently-installed receivers requiring little fade margin; and

- the radiation characteristics of the high-gain receiving antenna which makes it possible to discriminate between the wanted and interfering satellites if the latter are in different orbit positions.

The study conducted by an administration in Region 2 for that region based on the RARC SAT-R2 service areas concludes that frequency reuse will not be possible and consequently 10.8 MHz are needed for national coverages. A different coverage approach with a higher degree of overlap results in a bandwidth increase.

Digital modulation methods tend to require larger transmission bandwidths per channel, which, however, are partly balanced by the lower sensitivity to interference. A study made for Region 2 countries indicates a bandwidth requirement of some 13 MHz for one monophonic programme per Region 2 country. Stereophonic transmissions would consequently require 26 MHz.

The frequency of the carrier within the 500 - 2 000 MHz band affects the level of frequency reuse and hence affects the amount of spectrum required to provide one programme per service area. A lowering of the operating frequency will increase the minimum beamwidth for a given maximum antenna size. The angular distance before the frequency can be reused will consequently increase thus increasing the spectrum requirement until a point where frequency reuse becomes impossible. From that point onward, the spectrum requirement stays constant. In a study for Region 2, it was found that the spectrum requirement decreased by 25% going from 1 GHz to 2 GHz whereas a smaller increase, between 0% and 12%, was found going from 1 000 MHz to 500 MHz.

4. Frequency sharing considerations

Inter-service sharing possibilities depend on the permissible level of interference to existing services. The frequency table in the range 500 MHz to 2 000 MHz provides allocations for numerous radiocommunication services, including broadcasting, fixed and mobile services, and major allocations (in terms of bandwidth) for aeronautical, radionavigation and radiolocation services. Applicable sharing criteria are only available for the broadcasting, fixed and mobile services.

Sharing studies have been performed for frequency-modulation and digital-modulation techniques. Frequency modulation allows very limited energy dispersal while digital modulation offers a significant energy dispersal advantage.

Sharing with the broadcasting service demands a certain power flux level not to be exceeded. Consequently, energy dispersal is of no relevance and frequency modulation would produce the lowest receive power flux level. Applying the data of Tables 7-1 and 7-2 leads to a minimum required suppression of the co-polar component of the satellite transmitting antenna of the order of 30 dB.

Sharing with the fixed and mobile services requires that a certain spectral power flux-density should not be exceeded. Consequently, energy dispersal is essential and sharing can therefore only be envisaged if the digital modulation is employed for the BSS (sound). Still, the required minimum suppression of the co-polar component of the satellite transmit antenna is again of the order of 30 dB or more; the precise figure depending on the frequency and on whether low or high latitude countries are to be served.

A study on sharing with fixed services in the 1 429 MHz to 1 525 MHz band has been made by CCIR Study Group 9 in Report 941. This Report, based on the assumption of FM transmissions, is rather pessimistic on the acceptability of satellite sound broadcasting in the 1 500 MHz band.

There are no specific data available for the radiation performances of large satellite transmitting antennas in the UHF band. Figure 6 of Annex 8 to Appendix 30 (ORB-85) of the Radio Regulations may however serve as a rather stringent but achievable antenna characteristic. To obtain the required 30 dB side-lobe suppression, the angular separation, expressed in satellite coordinates, between service areas for which frequency sharing is envisaged, must exceed $\varphi/\varphi_o = 1.6$ where φ_o is the 3 dB beamwidth of the satellite transmitting antenna. The resulting geographical separation amounts to some 2 000 km for a 2^o transmitting beam. For a suppression higher than 30 dB, the angular separation exceeds $\varphi/\varphi_o = 4$. The corresponding geographical separation is 5 000 km or more for a 2^o beamwidth.

Detailed calculations have shown that sharing would not be possible except between widely separated areas by taking advantage of the off-axis radiation characteristics of the narrow-beam satellite transmit antenna.

The frequency of the carrier will affect inter-service sharing in that, as indicated in section 2.5 of this annex, the required level of p.f.d. for acceptable reception quality will increase with increasing frequency and conversely decrease with decreasing in frequency.

CHAPTER 8

Preparatory work for the Second Session

8.1. Intersessional activities relating to the planning of the feeder links for the broadcasting-satellite service (BSS) in Regions 1 and 3

8.1.1 Introduction

In order to facilitate the task of planning the feeder links for 12 GHz BSS to be carried out at the Second Session of the WARC-ORB Conference, a programme of intersessional activities is required.

It was noted that the existing computer software, developed by the Board to carry out the Region 2 BSS planning, may be of use for the planning of feeder links for BSS in Regions 1 and 3.

8.1.2. Submission of requirements

A requirement is defined as the need to provide a feeder link assignment from a specific location/area(s) on the Earth to a specified orbital position.

8.1.2.1 In requesting a feeder link assignment an administration shall provide the following information:

a) country symbol and IFRB serial number (beam identification) of the corresponding BSS down-link assignment shown in column 1 of Article 11 of Appendix 30(ORB-85);

b) frequency band preferred for each requirement;

An administration shall indicate either a preference for either 14.5 - 14.8 GHz or 17.3 - 18.1 GHz, or that it has no preference.

c) service area for the feeder links;

The service area can be defined as the geographical area(s) on the surface of the Earth within the feeder link beam area(s) within which the administration responsible for the service wishes to locate transmitting earth stations for the purpose of providing feeder links to broadcasting-satellite space stations.

Each geographical area of the service area for the purpose of feeder link planning shall be defined using:

i) not less than six points and not more than ten defined by geographical coordinates; or

ii) geographical coordinates of the boresight, major and minor axes of the elliptical cross section of the satellite receiver antenna beam and the orientation of the ellipse.

d) test points;

An administration shall provide the preferred test points (maximum 20) within the service area to be used for the calculations. This information shall be in the form of:

i) geographical coordinates;

ii) average height above mean sea level;

iii) rain climatic zone.

e) sense of polarization (for circular polarization);

Either the same as or the opposite to the sense of polarization of the corresponding down-link (see section 6.2.2.13).

f) feeder-link channel number;

The channel number of the feeder link, if the administration wishes to specify a different number to that derived from linear frequency translation (see sections 6.2.1.2 and 6.2.1.3).

g) special requirements;

- linear polarization;

Note 1 - More than one requirement (for feeder links) to a single down-link assignment will be regarded as a special requirement.

8.1.2.2 The Board shall prepare the appropriate form to be used by administrations in submitting their requirements.

8.1.2.3 For those administrations that do not submit requirements, the IFRB will include in its report appropriate feeder link entries based on the characteristics of the down-link assignments as they appear in Appendix 30(ORB-85) and use them in the planning exercises.

8.1.3. Computer software

The First Session noted that the Board had developed computer software to analyze both the feeder links and down-links of the Region 2 BSS Plan and that this software could be modified. The Board shall prepare the appropriate software to enable the second session to analyze the feeder-link Plan and provide an overall analysis of both the feeder links and the down-links. This software must be adapted to perform both the intersessional planning exercises and the planning at the second session.

Information provided in accordance with section 8.1.2.1 and supplemented with that in accordance with section 8.1.2.3 will be the basis for the compilation of the "requirements file" and technical parameters for feeder-link planning (see section 6.2) will form the basis for the "parameter file" for the computer program.

The program should provide the frequency assignments and the total co-channel and adjacent channel carrier-to-interference ratios and the total equivalent protection margin, for a given feeder-link channel, from all test points. Furthermore, the program should provide overall system equivalent protection margin at down-link test points.

It should also provide up-link C/N from all test points to enable the administrations to assess whether the e.i.r.p. value is suitable to meet their requirement or is too low or too high (see section 6.2.2.5).

For the calculation of carrier-to-noise ratios two calculations shall be made to permit assessment under both worst case and normal conditions. For normal conditions the wanted carrier power shall be calculated using free space propagation. For worst case conditions the wanted carrier power shall be calculated using 99% worst month propagation. In both cases the interfering carrier power shall be calculated using free space propagation. The system protection margins and their calculation are described in the Annex to this Chapter.

8.1.4. Proposal for software for single orbit position analysis for feeder link planning in Regions 1 and 3

8.1.4.1 The technical parameters for planning feeder links to WARC-BS-77 assignments have been designed to ensure, as far as possible, individual orbital position planning.

During the Second Session, anomalies in the initial planning will need to be resolved mainly by agreement between administrations sharing orbital locations. The software available to the IFRB for BSS planning requires modification. It is a comprehensive overall planning tool which can take several hours of computer time for each analysis and may not, therefore, be entirely suitable for use by administrations or small groups of administrations during the second session to resolve individual orbit anomalies. The comprehensive software will, however, be necessary for overall orbit analysis.

8.1.4.2 It is proposed that software for single orbital position analysis be developed during the intersessional period. Administrations should be invited to assist the IFRB by providing suitable software and/or programming assistance.

8.1.4.3 The software should be designed taking into account the following suggestions.

The software should:

8.1.4.3.1 if possible, be prepared by the adaptation of existing software. One administration has advised that it has software that may be suitable subject to modification;

8.1.4.3.2 be in one of the higher level languages that is suitable for operation on different hardware systems;

8.1.4.3.3 be capable of operation on small computing systems, and if possible adaptable for use on the microprocessor hardware currently used by the IFRB;

8.1.4.3.4 provide for single orbital position analysis of:

- C/N and C/I (single entry and total) for each orbital position and for each of the feeder links to that position,
- C/N and C/I (single entry and total) for each WARC-BS-77 assignment system for the overall performance;

8.1.4.3.5 be capable of using data from the IFRB mainframe databank by means of floppy disc or other magnetic media;

8.1.4.3.6 be designed to process data and variables as determined for planning by the First Session of the Conference.

8.1.5. <u>Planning exercises</u>

8.1.5.1 <u>Description of the exercises</u>

Using the information given in sections 8.1.2 and 8.1.3 and Table 8-1, the IFRB shall carry out the following planning exercises acccording to the time-table as set out in section 8.1.5.2.

8.1.5.1.1 <u>Initial planning exercises</u>

The first planning exercise will be carried out for the 17.3 - 18.1 GHz band on the basis of linear frequency translation for all requirements. This exercise will be done separately for adjacent channel protection ratios of 21 dB and 24 dB (see section 6.2.2.4).

The second planning exercise is to be based on using the 14.5 - 14.8 GHz band for those requirements for which administrations had indicated a preference for that band, taking into account any specific channels requested by administrations for their assignments.

The third planning exercise is to be based on using the 17.3 - 18.1 GHz band to satisfy the requirements of those administrations who had indicated a preference for that band, or for those who had indicated no preference for any particular band, taking into account any specific channels requested by administrations for their assignments.

8.1.5.1.2 Subsequent planning exercises

These planning exercises are identical to those indicated in section 8.1.5.1.1. However, they are based on adjusted requirements.

8.1.5.2 Timetable

The Board shall request, 20 months before the Second Session, that administrations submit their requirements to the Board no later than 14 months before the Second Session. The Board will prepare a consolidated list of requirements and execute the initial planning exercises as described in section 8.1.5.1.1.

Both the consolidated list and the results of the initial planning exercises will be submitted to the administrations at least 9 months before the Second Session.

At least 4 months before the Second Session, those administrations which so wish may submit adjustments to their requirements to the IFRB.

The Board will then execute the subsequent planning exercises as described in section 8.1.5.1.2 and present the results to the Second Session of the Conference.

This timetable is shown below:

20 months	14 months	9 months	4 months	2nd session
Submission of Requirements	Initial planning exercises	Submission of adjusted requirements	Subsequent planning exercises	

TABLE 8-1

Table of technical parameters for the feeder-link planning exercises for Regions 1 and 3

(Frequency bands 17.3 - 18.1 GHz and 14.5 - 14.8 GHz)

Item	Parameter	Value
1.*	Carrier-to-noise ratio	24 dB
2.	Co-channel carrier-to-interference protection ratio	40 dB
3.	Adjacent channel carrier-to-interference protection ratio	21 dB, 24 dB (See section 8.1.5)
4.	Feeder link e.i.r.p. initial planning value	17.3 - 18.1 GHz : 84 dBW 14.5 - 14.8 GHz : 82 dBW
5.	Transmitting antenna	
a)	Diameter	17.3 - 18.1 GHz : 5 m 14.5 - 14.8 GHz : 6 m
b)	On-axis gain	57 dBi
6.	Off-axis e.i.r.p.	
a)	Co-polar off-axis e.i.r.p.	E-25-25 log φ (dBW) for $1^{\circ} \leqslant \varphi \leqslant 48^{\circ}$, E-67(dBW) for $\varphi > 48^{\circ}$
b)	Cross-polar off-axis e.i.r.p.	E-30(dBW) for $0^{\circ} \leqslant \varphi \leqslant 1.6^{\circ}$, E-25-25 log φ (dBW) for $1.6^{\circ} < \varphi \leqslant 48^{\circ}$, E-67(dBW) for $\varphi > 48^{\circ}$
7.	Earth station mispointing loss	1 dB

* This value is a target value and not a fixed value for computation.

TABLE 8-1 (continued)

Item	Parameter	Value
8.	Satellite receiving antenna	
a)	Cross section of beam	elliptical or circular
b)	Co-polar reference pattern	relative gain (dB) $-12 \left(\frac{\varphi}{\varphi_0}\right)^2$ for $0 \leq \frac{\varphi}{\varphi_0} \leq 1.30$ $-17.5 - 25 \log \left(\frac{\varphi}{\varphi_0}\right)$ for $\frac{\varphi}{\varphi_0} > 1.30$ After intersection with curve C: as curve C. (Curve C is minus on-axis gain)
c)	Cross-polar reference pattern	relative gain (dB) $-30 - 12 \left(\frac{\varphi}{\varphi_0}\right)^2$ for $0 \leq \frac{\varphi}{\varphi_0} \leq 0.5$ -33 for $0.5 < \frac{\varphi}{\varphi_0} \leq 1.67$ $-\left(40 + 40 \log \left\| \frac{\varphi}{\varphi_0} - 1 \right\|\right)$ for $\frac{\varphi}{\varphi_0} > 1.67$ After intersection with curve C: as curve C. (Curve C is minus on-axis gain)
9.	Satellite receiving antenna pointing accuracy	0.2°
10.	Satellite receiving system noise temperature	1 800 K

TABLE 8-1 (end)

Item	Parameter	Value
11.	Type of polarization	Circular
12.	Sense of polarization	(Opposite to corresponding down-link)**
13.	Propagation	See section 6.2.2.17
14.	Carrier-to-noise ratio degradation due to AM-to-PM conversion	2.0 dB

** For planning during the Second Session either the same or opposite may be adopted for each orbital position.

8.2 Other intersessional activities

8.2.1 Preparation of the software required for the planning method

It is necessary for the IFRB within the resources made available to it to develop a software package for the preparation of the allotment Plan and to carry out appropriate planning exercises.

8.2.2 Criteria to be used for the preparation of a planning exercise for an allotment Plan

8.2.2.1 Service area (3.3.4.1)

The planning exercise for an allotment Plan shall provide for each country or geographical area one coverage with one or more beams as described by administrations in their submissions to the IFRB.

8.2.2.2 Standardized parameters (3.3.4.2)

The technical parameters will be established by the IFRB after full consultation with administrations as outlined in paragraph 8.2.4, taking account of the technical considerations given in section 3.4, and the Recommendations and conclusions of the CCIR available in time.

8.2.2.3 Guarantee of access (3.3.4.3)

The planning exercise for an allotment Plan will contain one allotment per country or geographical area or the minimum number of allotments that will permit one coverage irrespective of the existing networks that would be taken into account during the planning exercise.

The planning exercise should cover the frequency bands 6/4 GHz and 14/11-12 GHz or both as stated in administrations' requirements.

8.2.2.4 Bandwidth (3.3.4.4)

The planning exercise should attempt to provide the maximum bandwidth to each allotment. If this is not possible an identical bandwidth should be provided to each allotment.

8.2.2.5 Predetermined arc (3.3.4.5)

The planning exercise shall examine the possibility of establishing orbital arcs associated with the orbital position in order to provide both compatibility between allotments in the Plan and allowing for implementation of sub-regional systems.

8.2.3 Scope of the planning exercise(s)

It is desirable that two planning exercises should be undertaken with a view to enable administrations possibly to adjust their requirements between these two exercises.

8.2.4 Interactions between the administrations and the IFRB during the intersessional period

8.2.4.1 While carrying out the intersessional work, there should be provision for the IFRB to make regular reports on the activities being undertaken for the intersessional programme, and to the extent possible and appropriate, to take into account the comments received from administrations.

8.2.4.2 In particular, the following measures should be included in the intersessional programme of work being carried out by the IFRB:

a) to prepare periodical progress reports on the intersessional work, including future activities, and send them all to administrations in accordance with paragraph 8.2.4.3;

b) to invite administrations to send their comments on the reports to the IFRB;

c) to convene periodic meetings to which all administrations are invited for the purpose of explaining its work and receiving comments from administrations.

8.2.4.3 The IFRB should convene meetings at the appropriate time to carry out the following:

meeting for the IFRB to describe the computer programs to be developed, and a schedule of the work to be done prior to the Second Session;

review the progress of the work and to discuss in detail the computer programs to be developed;

review the progress of the work and to discuss initial tests of the computer programs to determine their suitability for the Conference;

final review of the intersessional programme.

In so doing, account should be taken of technical expertise and computer software that may be available from administrations.

The dates of each of these meetings will be communicated to administrations in advance.

ANNEX TO CHAPTER 8

Methods of calculation of protection margins

1. Equivalent feeder-link protection margin

The equivalent feeder-link protection margin, M_{up}, is given in dB by the formula:

$$M_{up} = -10 \log (10^{-M_1'/10} + 10^{-M_2'/10} + 10^{-M_3'/10}) \text{ (dB)}$$

where M_1' is the value in dB of the protection margin for the same channel. This is defined in the following expression where the powers are evaluated at the satellite receiver input:

$$\frac{\text{wanted power}}{\text{sum of the co-channel interfering powers}} \text{ (dB)} - \text{co-channel protection ratio (dB)}$$

M_2' and M_3' are the values in dB of the upper and lower adjacent channel protection margins respectively.

The definition of the adjacent-channel protection margin is similar to that for the co-channel case except that the adjacent-channel protection ratio and the sum of the interfering powers due to transmissions in the adjacent channel are considered.

2. Overall equivalent protection margin

The overall equivalent protection margin for the complete BSS feeder and down-link (M) is given by:

$$M = -10 \log (10^{-M_1/10} + 10^{-M_2/10} + 10^{-M_3/10}) \text{ (dB)}$$

where M_1 is the overall co-channel protection margin and M_2 and M_3 the overall upper and lower adjacent channel protection margins respectively.

These margins are given by:

$$M_1 = (C/I)_{1 \text{ overall}} - 30 \text{ (dB)}$$

$$M_2 = (C/I)_{2 \text{ overall}} - 14 \text{ (dB)}$$

$$M_3 = (C/I)_{3 \text{ overall}} - 14 \text{ (dB)}$$

where the overall carrier-to-interference ratio $(C/I)_{i \text{ overall}}$, for i-th interference category is given by:

$$(C/I)_{overall} = -10 \log \left\{ 10^{-\left(\frac{C}{I}\right)_u/10} + 10^{-\left(\frac{C}{I}\right)_d/10} \right\} \text{ (dB)}$$

where:

$\left(\frac{C}{I}\right)_u$ is the feeder-link carrier-to-interference ratio (dB) referred to the satellite receiver input

and

$\left(\frac{C}{I}\right)_d$ is the down-link carrier to interference ratio (dB) referred to the earth station receiver input.

RESOLUTION NO. 1

Report of the First Session

The World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It, (First Session - Geneva, 1985),

considering

the mandate entrusted to it by Resolution 895 of the Administrative Council;

resolves

to approve the Report of this Session of the Conference;

instructs

1. the Chairman of this Session of the Conference to transmit under his signature the Report of the First Session to the Second Session of the Conference;

2. the Secretary-General to transmit this Report to all Members of the Union and to the organizations which have participated in the First Session of the Conference.

RESOLUTION NO. 2

Improvement of the Accuracy of the Master Register, the International Frequency List, List VIIIA, and the Information Provided to Administrations

The World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It (First Session, Geneva, 1985),

considering

a) that accurate and up-to-date information is required to enable the Second Session of this Conference to carry out its work effectively;

b) the importance to administrations of an accurate and up-to-date record in the Master Register, the International Frequency List and List VIIIA;

c) that certain difficulties have been encountered by the IFRB in implementing the provisions of RR 1569;

resolves

1. that the IFRB shall apply the relevant provisions of Section VI of Article 13 in full;

2. that administrations be urged to implement the provisions of RR 1573 within the time limit prescribed therein;

3. that administrations be urged to cooperate fully in application of the provisions of RR 1570 and RR 1574;

requests the IFRB

to prepare a report on the application of this Resolution and to submit it together with any suggestions it may deem to be appropriate to the Second Session of this Conference.

RECOMMENDATION NO. 1

Draft Agenda for the Second Session of the Conference

The World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It, (First Session - Geneva, 1985),

considering

a) Resolution 1 of the Plenipotentiary Conference, Nairobi, 1982, relating to future conferences of the Union;

b) that Resolution 3 of the World Administrative Radio Conference, Geneva, 1979, invited the Administrative Council to take the necessary steps to convene a World Administrative Radio Conference consisting of two sessions relating to the use of the geostationary-satellite orbit and the planning of the space services utilizing it;

c) that Resolution 895 of the Administrative Council, 1983, includes in the agenda of the First Session the recommendation of a draft agenda for the Second Session of the Conference for consideration by the Administrative Council;

d) the Final Acts of the First Session of the Conference and the Final Acts of the Regional Administrative Conference for the Planning of the Broadcasting-Satellite Service in Region 2, Geneva, 1983;

e) that the Second Session will need to consider:

1. proposals from administrations;
2. the report of the First Session;
3. preparatory work carried out in the intersessional period;
4. the relevant reports from the IFRB and the CCIR;
5. the requirements for the allotment Plan submitted by administrations;

recognizing

that some of the bands are allocated on a shared basis with equal rights to more than one space service and that most of them are also allocated with equal rights to terrestrial services, and that these rights must be taken into account;

<u>recommends the Administrative Council</u>

1. to consider the following draft agenda for the Second Session of the Conference, which shall take due account of the radiocommunication services not specifically addressed therein:

1.1 to establish the allotment Plan and the associated regulatory procedures, based on <u>considering</u> e), for the fixed-satellite service in the bands:

- 4 500 - 4 800 MHz and 300 MHz to be selected in the band 6 425 - 7 075 MHz; and

- 10.70 - 10.95 GHz, 11.20 - 11.45 GHz and 12.75 - 13.25 GHz,

according to the principles and methods established at the First Session;

1.2 to establish the improved regulatory procedures, on the basis of <u>considering</u> e) 1 to 4, for the fixed-satellite service in the bands;

- 3 700 - 4 200 MHz
  5 850 - 6 425 MHz

- 10.95 - 11.20 GHz
  11.45 - 11.70 GHz
  11.70 - 12.20 GHz in Region 2[1]
  12.50 - 12.75 GHz in Regions 1 and 3[1]
  14.00 - 14.50 GHz

- 18.10 - 18.30 GHz[1,2]
  18.30 - 20.20 GHz[2]
  27.00 - 30.00 GHz[2]

according to the principles and methods established at the First Session;

1.3 to adopt appropriate technical standards, parameters and criteria, pertaining to the fixed-satellite service in the frequeny bands specified in items 1.1 and 1.2;

2. to review and revise, as necessary, the regulatory procedures and appropriate technical standards, parameters and criteria pertaining to space services and frequency bands not to be subject to planning;

3. to review and revise, as necessary, the definitions relating to space services;

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1 In these bands the improved procedures shall apply between networks of the FSS only.

2 The CCIR is asked to study the technical characteristics of the fixed-satellite service in these bands and to report to the Second Session of the Conference with a view to taking a decision on the future planning of these bands by a future competent conference.

4. to establish the provisions and associated Plan for feeder links, in the bands 14.5 - 14.8 GHz (for countries outside Europe and for Malta) and 17.3 - 18.1 GHz, to stations in the broadcasting-satellite service in Regions 1 and 3 operating in accordance with Appendix 30 (ORB-85) to the Radio Regulations, on the basis of the relevant material identified in considering e), and to incorporate these decisions in the Radio Regulations, revising the Radio Regulations, as well as related Resolutions and Recommendations, only for these purposes as necessary;

5. to consider, subject to the adoption of a suitable feeder-link assignment Plan for Region 1, the amendment of the relevant articles of the Radio Regulations and associated Resolutions and Recommendations, if it is appropriate, to permit the use of the band 10.7 - 11.7 GHz (Earth-to-space) in Region 1 for all modes of fixed-satellite service operation, taking into account the frequency bands identified for planning in items 1.1 and 1.2 above;

6. in accordance with Recommendation 2 of the First Session, to consider the results of the various up-to-date studies and, in reviewing the situation prevailing at that time, take appropriate decisions concerning the various aspects of satellite sound-broadcasting systems as outlined in Resolution 505 of WARC-79;

7. to review the possibility of the long-term applicability of Resolution 2 (SAT-R2), and to take a definitive decision on this matter;

8. in accordance with Recommendation 3 of the First Session of the Conference, and without prejudice to the present BSS allocation in the 22.5 - 23 GHz band in Regions 2 and 3, to consider the question of a suitable frequency band for the broadcasting-satellite service, preferably on a world-wide basis, to accommodate HDTV, including possible action as appropriate on the necessary changes to Article 8 at a later competent conference;

9. to make such consequential amendments in the Radio Regulations as may be necessitated by the decisions of the Second Session of the Conference;

10. to consider, revise as necessary, and take other appropriate action upon the relevant Resolutions and Recommendations;

11. to evaluate the financial impact of its decisions upon the budget of the Union in accordance with No. 627 and other pertinent provisions of the Nairobi Convention.

RECOMMENDATION NO. 2

Satellite Sound Broadcasting Systems for Individual Reception by Portable and Automobile Receivers

The World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of the Space Services Utilizing It (First Session, Geneva, 1985),

considering

a) that the World Administrative Radio Conference, Geneva 1979 (WARC-79), adopted Resolution 505;

b) that satellite sound broadcasting is technically feasible;

c) that several administrations made proposals to WARC-79 concerning frequency band allocations for the broadcasting-satellite service (sound) in the range 0.5 - 2 GHz;

d) that, at the CPM (1984), the CCIR indicated that further work would be needed to define the system parameters;

e) that studies of the CCIR and the experiments and studies undertaken by administrations have shown that accommodation of the satellite sound broadcasting service in the frequency range 0.5 - 2 GHz would cause considerable sharing difficulties, and that the implementation of such a service will not be possible in the range 0.5 - 2 GHz unless an appropriate frequency band is allocated for it on an exclusive basis;

f) that at the First Session of this Conference studies were not far enough advanced to make a Recommendation for any long-term solution;

g) that a number of administrations have expressed the view at the present Session that there is a future need for a broadcasting-satellite service (sound);

is of the opinion

a) that in the existing situation it is not possible to allocate in the range 0.5 - 2 GHz an exclusive band to the broadcasting-satellite service (sound) on a world-wide basis;

b) that an allocation to the broadcasting-satellite service (sound) can possibly only be found in the longer term;

recognizing

that it is competent only for the frequencies in the band between 0.5 and 2 GHz;

recommends

1. that administrations shall be invited to continue studies on the following subjects: quality of service, frequency of operation (within, and also outside but near, the range 0.5 - 2 GHz), modulation type, bandwidth required, receivers, antenna design, feeder links, appropriate sharing criteria (including those applicable to geographical separation), cost considerations, the ability of present and future technology to comply with RR 2674, and multiple user satellites; in so doing they should take into account the information given in Chapter 7.3 and the associated annex of the Report of the First Session and the need to comply with RR 2674;

2. that the Second Session of this Conference should consider the results of the various up-to-date studies and in reviewing the situation prevailing at that time take appropriate decisions concerning the various aspects of this system as outlined in Resolution 505;

invites the Administrative Council

to consider this Recommendation in the preparation of the agenda for the Second Session of the Conference which is envisaged for 1988;

invites the CCIR

to undertake studies without additional expenditure as indicated in recommends 1 in order to define the practical system parameters for satellite sound broadcasting.

RECOMMENDATION NO. 3

High definition television (HDTV)
in the broadcasting-satellite service

The World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It, (First Session, Geneva, 1985),

recognizing

that this matter is not explicitly included in its agenda;

having noted

the proposals submitted by several administrations relating to this matter;

considering

a) that the development of techniques for high definition television broadcasting is rapidly progressing;

b) that the frequency bands presently allocated to the broadcasting-satellite service do not, as presently planned, provide a world-wide allocation suitable for the implementation of a unique world-wide standard for high definition television transmission via satellites;

c) that the band 22.5 - 23 GHz has already been allocated to the broadcasting-satellite service only in Regions 2 and 3, and is authorized subject to agreement obtained under the procedure set forth in Article 14 of the Radio Regulations;

d) that due account should be taken of other radiocommunication services appearing in Article 8 of the Radio Regulations;

e) that a world-wide frequency allocation to the broadcasting-satellite service suitable for HDTV transmissions would be desirable;

f) that the CCIR has already carried out a number of studies concerning the broadcasting of HDTV signals (see Report of the CPM, 1984, Chapter 3.2.3 and Annexes 3.2.3.2 and 4.6.2.5.3) and the difficulties of sharing with terrestrial services (Chapter 8.4 of the CPM Report);

<u>recommends that the Administrative Council</u>

without prejudice to the present BSS allocation in the 22.5 - 23 GHz band in Regions 2 and 3, place on the agenda of the Second Session of the Conference consideration of the question of a suitable frequency band for the broadcasting-satellite service, preferably on a world-wide basis, to accommodate HDTV, including possible action as appropriate on the necessary changes to Article 8 at a subsequent competent conference;

<u>invites the CCIR</u>

to include in its report to the Second Session of the Conference the results of its studies relevant to the following matters:

- the development of technical parameters for HDTV transmissions by satellite;

- which frequency bands would be possible and appropriate from the point of view of propagation; and

- inter- and intra-service sharing aspects.

LIST OF ITU MEMBER COUNTRIES WHICH PARTICIPATED IN THE FIRST SESSION

(in the alphabetical order of the French version of the country names)

Algeria (People's Democratic Republic of)
Germany (Federal Republic of)
Angola (People's Republic of)
Saudi Arabia (Kingdom of)
Argentine Republic
Australia
Austria
Bahrain (State of)
Belgium
Byelorussian Soviet Socialist Republic
Bolivia (Republic of)
Brazil (Federative Republic of)
Brunei Darussalam
Bulgaria (People's Republic of)
Burkina Faso
Cameroon (Republic of)
Canada
Chile
China (People's Republic of)
Vatican City State
Colombia (Republic of)
Congo (People's Republic of the)
Korea (Republic of)
Costa Rica
Ivory Coast (Republic of the)
Cuba
Denmark
Djibouti (Republic of)
Egypt (Arab Republic of)
United Arab Emirates
Ecuador
Spain
United States of America
Ethiopia
Finland
France
Gabonese Republic
Ghana
Greece
Guatemala (Republic of)
Guinea (Republic of)
Honduras (Republic of)
Hungarian People's Republic
India (Republic of)
Indonesia (Republic of)
Iran (Islamic Republic of)
Iraq (Republic of)
Ireland
Israel (State of)
Italy
Jamaica
Japan
Jordan (Hashemite Kingdom of)
Kenya (Republic of)
Kuwait (State of)

Lebanon
Liberia (Republic of)
Libya (Socialist People´s Libyan Arab Jamahiriya)
Luxembourg
Madagascar (Democratic Republic of)
Malaysia
Malawi
Mali (Republic of)
Malta (Republic of)
Morocco (Kingdom of)
Mexico
Monaco
Mongolian People´s Republic
Nicaragua
Nigeria (Federal Republic of)
Norway
New Zealand
Oman (Sultanate of)
Pakistan (Islamic Republic of)
Panama (Republic of)
Papua New Guinea
Paraguay (Republic of)
Netherlands (Kingdom of the)
Peru
Philippines (Republic of the)
Poland (People´s Republic of)
Portugal
Qatar (State of)
Syrian Arab Republic
German Democratic Republic
Democratic People´s Republic of Korea
Ukrainian Soviet Socialist Republic
Romania (Socialist Republic of)
United Kingdom of Great Britain and Northern Ireland
Rwandese Republic
San Marino (Republic of)
Senegal (Republic of)
Singapore (Republic of)
Somali Democratic Republic
Sri Lanka (Democratic Socialist Republic of)
Sweden
Switzerland (Confederation of)
Suriname (Republic of)
Tanzania (United Republic of)
Chad (Republic of)
Czechoslovak Socialist Republic
Thailand
Togolese Republic
Tonga (Kingdom of)
Trinidad and Tobago
Tunisia
Turkey
Union of Soviet Socialist Republics
Uruguay (Eastern Republic of)
Venezuela (Republic of)
Yemen (People´s Democratic Republic of)
Yugoslavia (Socialist Federal Republic of)