SECTION 10/11B: SYSTEMS

REPORT 215-7

SYSTEMS FOR THE BROADCASTING SATELLITE SERVICE (SOUND AND TELEVISION)

(Question 2/10 and 11, Study Programme 2A/10 and 11)

(1963-1966-1970-1974-1978-1982-1986-1990)

1. Introduction

This Report describes the essential elements of broadcasting-satellite system design and their relationships. The object of the Report is to assist the system designer, frequency planner, and spacecraft and earth-station engineer in their choice of system characteristics. Such choices, as is the case in the design of systems in general, are bounded by various constraints: limitations imposed by the state of international agreement and, most important, by considerations of system economics.

Other relevant information on the systems aspects of the broadcasting-satellite service are given in the Recommendations and Reports listed below;

- Terminology
  Recommendation 566
- Television broadcasting systems
  Recommendation 650, Reports 1073 and 1074
- Sound broadcasting systems
  Report 955
- High definition television broadcasting systems
  Report 1075
- Feeder links
  Report 952
- Modulation, multiplexing and coding
  Recommendation 651, Reports 632, 953 and 954
- Transmitting and receiving antennas
  Recommendation 652, Report 810
- Earth receiving equipment
  Report 473
- Satellite technologies
  Report 808
- Interservice frequency sharing
  Report 634

2. Major system parameters

There are different ways to approach the selection of system parameters. One method is given in this section.

As a first step, decide on system input factors. That is, the desired quality for various percentages of time, the number of channels (including the number of accompanying audio programme channels) and the area of coverage on the Earth. The subject of quality of reception is discussed in greater detail in § 3.

2.1 Factors affecting choice of orbit and of orbital position in the GSO

2.1.1 General

Among the factors to be considered in the selection of preferred orbits for satellite broadcasting are coverage, number of daily broadcast hours desired and antenna characteristics.

The satellite orbit for a broadcast service must provide coverage of selected regions of the Earth the (broadcast service area) during desired viewing or listening hours, which may vary from several to twenty-four hours per day. For non-continuous broadcast periods, it is desirable to have these intervals occur at the same local time each day. Regardless of the duration of the broadcast period, it is desirable to have an orbit that does not require antenna tracking equipment for broadcast recieving installations.

2.1.2 Geostationary satellite orbit (GSO)

The geostationary satellite orbit (GSO, altitude 35786 km above the equator) has been chosen for most existing and planned broadcasting satellite systems. It permits a continuous broadcast service to areas as small as individual countries or as large as continents, up to about one-third of the surface of the Earth. The limitation imposed by the minimum usable angle of elevation can be determined from Fig. 1 of Report 206. A geostationary satellite also permits the use, if required, of a fixed receiving antenna of very high gain (and hence directivity).

2.1.3 Inclined orbits

A satellite in a sub-synchronous circular equatorial orbit can provide coverage at the same local time each day. The number of uninterrupted broadcast hours possible from such a satellite to a given area on the surface of the Earth is a function of the satellite altitude and the latitude of the receiving point. Representative visibility times are shown in Annex I (see Table XI).

Because the sub-synchronous satellites in circular orbits have a lower altitude than a geostationary satellite, a stronger signal is available for a given transmitter e.i.r.p. Such satellites may therefore have an advantage when the maximum transmitting antenna gain is limited by size restrictions and when the receiving antenna can be nearly omnidirectional.

2.1.4 Choice of orbital position in GSO

The following factors shall be considered in choosing an orbital position in the GSO:

- receiving antenna elevation angle within the broadcasting service area;
- effect of the eclipse due to the moon.

(Generally, orbital position of the broadcasting satellite is chosen about 20 to 40 degrees westward from the centre of the broadcasting service area to overcome eclipse blackout during service time.)

2.2 Frequency of operation

2.2.1 General

In selecting a frequency band for a broadcasting-satellite system, the choice obviously is constrained not only to the frequency allocations established in the Radio Regulations for the broadcasting-satellite service, but by other factors such as current or planned use of certain frequencies shared with other services within the desired area of coverage, or in areas subject to interference from the system being planned (e.g., see Report 634).

The principal propagation effects to be taken into account are attenuation, due to atmospheric gases and rain, and depolarization.

2.2.1.1 Attenuation

Atmospheric attenuation is due mainly to rain and cloud attenuation. It varies with frequency, angle of elevation and local climate. It can be closely extended from a rain attenuation model.

Measurements that have been carried out in Europe*, Japan, Malaysia, Australia, United States and France are described in Annex II. The values of attenuation not exceeded during 99% or 99.9% of the worst month are listed in Table I.

Table I. - *Worst-month attenuation observed in different locations and at frequencies from 11.6 to 30 GHz*

Location of measurements	Frequency (GHz)	Elevation angle (deg)	Attenuation (dB) not exceeded during given fraction of worst month	
			99 %	99.9 %
Europe*	11.5	20 to 45	1.1	3.3
France (Paris)	11.6 and 11.8		1.8	4.0
France (Brittany)	11.6 and 11.8		1.5	3.4
Japan (12 locations)	12	30 to 60	2.4	6.9
Malaysia (Klang)	12	corrected to 45	1.7	8.7
Australia (Darwin)	12.75	50	6	16
Australia (Sydney)	12.75	53	1	20
USA (Maryland)	11.70	29.5	<1	5.4
USA (North Carolina)	11.70	36	1	1.8
"	20	36	1.5	11.0
"	30	36	2.4	19.5

* Measurements done by the European Space Agency (ESA) in certain countries of Western Europe.

The rain attenuation model based on rain fade statistics corresponding to 1% of the worst month has been applied to both feeder-link and down-link planning for the 12 GHz broadcasting-satellite service as described in Appendices 30 (Orb 85) and 30A of the Radio Regulations. (See Report 723 for a method of estimating worst-month statistics from annual statistics.)

Further information is contained in Reports 564 and 565, and a method for calculating rain attenuation can be found in Report 563.

* Measurements done by the European Space Agency (ESA) in certain countries of Western Europe.

For any frequency f(GHz), other than 11.5 GHz, an approximate value for the atmospheric attenuation A_f may be calculated from the values for 11.5 GHz, $A_{11.5}$, by means of the following formula which is valid from 11.0 to 14.5 Ghz:

$$A_f = A_{11.5}\,[1 + 0.2\,(f - 11.5)] \quad \text{dB}$$

Measurements can be corrected with respect to elevation angle by using the cosecant law [CCIR, 1978-82a].

Little data on rain attenuation is available for tropical rain climates. More measurements are required in these areas above 11.6 GHz to provide a useful body of data.

2.2.1.2 Depolarization

In addition to their effects on attenuation, clouds and rain can cause depolarization of the signal. Statistical analysis of measured results with circular polarization in Region 1 suggests that the level of the depolarized component (relative to the level of the co-polar component after attenuation) can be expressed approximately in terms of the attenuation caused by the atmosphere, according to the following equation:

Relative level of depolarized component (for circular polarization)

$$\approx -[30 - 20 \log A] \quad \text{dB}$$

where A is the atmospheric attenuation, in decibels.

Actual measurement statistics have been analyzed in Report 564 where a more detailed equation taking into account the influence of frequency and elevation angle can be found.

A more detailed discussion of depolarization effects due to precipitation can be found in Report 814, Annex 5 of Appendix 30 (ORB-85) of Radio Regulations and Appendix 30A.

2.2.2 Effect of additive radio noise

Additive radio noise ———— is produced from both natural and man-made sources (power lines, electrical apparatus, automobile ignition systems). Figure 1 indicates typical noise levels associated with these sources, and shows that in the lower part of band 10 and in the greater part of band 9 a minimum of noise is introduced depending upon the conditions. It should be noted however that, while many measurements of impulsive noise level have been made, evaluation of these data is as yet incomplete . Therefore, the noise levels shown in Figure 1 must be considered as provisional.

At present, limited information on the subjective aspects of impulsive noise is available [Pacini *et al.*, 1971]. There is insufficient knowledge regarding the dependence of man-made noise on the angle of arrival, polarization, frequency, height of antenna, etc., to make adequate engineering analyses of the levels likely to be present at the terminals of the receiving antenna.

In addition to the noise sources indicated in Fig. 1, a significant increase in noise level can occur for short periods when the Sun is within the antenna beam, if narrow-beam receiving antennas (beamwidth less than about 5°) are used. For geostationary satellite orbits, these periods occur in the day-time for a few consecutive days in spring and autumn. The noise temperature and the angular size of the quiet solar disc is observed at 12 GHz as about 12 000 K and 0.6° of arc, respectively. Examples of solar inteference to small antennas are described in Annex III obtained by the experiments with the medium-scale broadcasting-satellite for experimental purposes, (BSE) of Japan.

2.3 Required margin

The choice of frequency and the desired quality for various percentages of time dictate an operating margin (see Report 811) which depends both on the attenuation statistics applicable to the broadcasting service area and on the values of carrier-to-noise power ratio corresponding to the signal quality objectives and the modulation parameters of the signal and the receiver.

In the case of frequency modulation it is necessary to keep the carrier-to-noise ratio above the threshold for as high as possible a percentage of time (usually 99.9%) and also to achieve a given signal-to-noise ratio objective for a specific percentage of time (usually 99%). Thus it is necessary to choose a margin above threshold such that both requirements are met simultaneously. This margin should include the atmospheric loss and other terms not specifically included in the power budget. Provision should be made in the required value for *G/T* for atmospheric effects on system temperature.

Table I gives examples of the margins for atmospheric loss for the European broadcasting area, part of the USA, Australia, Japan and Malaysia.

Note. - In the case of the operational Japanese broadcasting-satellite BS-2a, the time statistics of carrier-to-noise ratio exceeding 14 dB for 99% of the time and exceeding 10 dB for 99.95% of the time for a period of seven months including the worst months of June and July for rain attenuation, were obtained. The results are shown in Table II.

Table II – *Time statistics of received C/N ratio measured over the period of 12 May-24 December, 1984*

C/N ratio (dB)	14.0	12.0	10.0	8.0
Time percentage exceeded above *C/N* ratio (%)	99.0	99.9	99.95	99.98

Frequency:	11.996 GHz
Receiving antenna:	75 cm in diameter (gain: 37.6 dB)
Receiver noise figure:	3.0 dB
Effect of feeder link on down-link *C/N* ratio:	0.2 dB
Accumulated rainfall during the period:	710 mm
Measurement site:	Tokyo (rain climatic zone M)

The report of JIWP 10-11/3 [CCIR, 1986-90a] pointed out a need of studying alternative criteria for determining appropriate margins for high definition television (HDTV) signals which may require higher carrier-to-noise ratios than conventional television signals and may operate in frequency bands where attenuation margins are higher than in the 12 GHz bands.

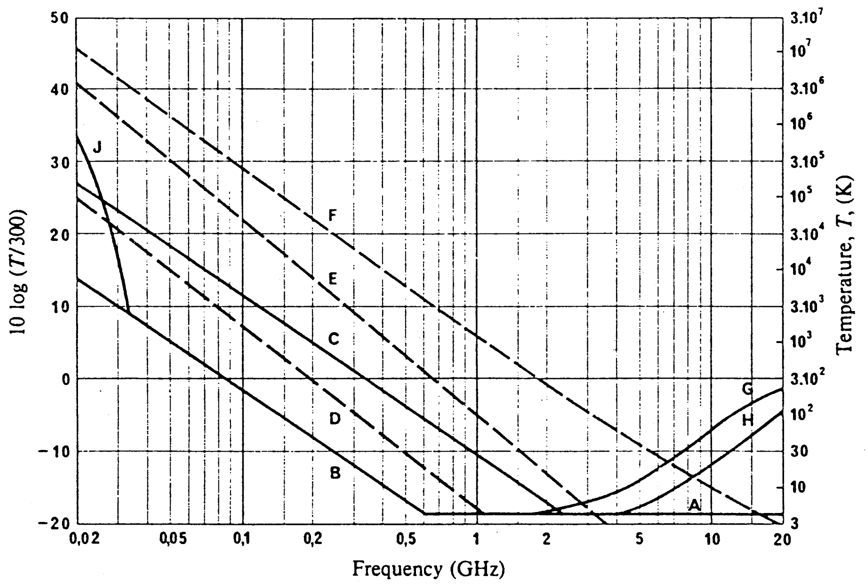

FIGURE 1 – *Noise temperature from natural and man-made sources*

Note. – This graph should be extended to 100 GHz and curves G and H should be projected according to the best available data, so as to include performance predictions for the 40 and 80 GHz broadcasting-satellite service allocations. It is realized that curve E is in conflict with Fig. 1 of Report 258 for frequencies up to 250 MHz. Therefore, curve E and, as a result, curve F, should be treated with caution. Administrations and the appropriate CCIR Study Groups are requested to study and submit data.

Curves A: Cosmic noise background (Report 205).

B: Minimum cosmic noise (Report 205).

C: Maximum cosmic noise (Report 205).

D: Typical man-made noise in "rural" area (omnidirectional receiving antenna (Report 670, Fig. 3).

E: Typical man-made noise in "urban" area (omnidirectional receiving antenna) (Report 670, Fig. 3).

F: "Urban" noise, adjusted for a directional antenna orientated at angles of elevation greater than 45: noise discrimination equal to one half the gain of the antenna (in dB) is assumed with a gain of 8 dB at 20 MHz and 25 dB at 2500 MHz.

G: Typical noise due to rainfall and atmospheric absorption for 0.1% of the time: temperate latitudes: angle of elevation 30°.

H: Typical noise due to rainfall and atmospheric absorption for 1% of the time: temperate latitudes: angle of elevation 30°.

J : Night-time atmospheric noise (Report 322).

2.4 Modulation and required bandwidth

The transmission of radio signals by satellite normally use a modulation method that involves a power-bandwidth trade-off. Satellites to date have generally been power rather than bandwidth limited and have, therefore, usually used FM. AM, while having a significantly narrower bandwidth, requires so much more power that it has not been competitive. FM also has the advantage of being a constant envelope signal and is, therefore, not as sensitive to transponder amplitude non-linearities.

Report 632 discusses details of the modulation methods used for satellite systems including a comparison of FM with digital modulation techniques.

2.4.1 *Television broadcasting using frequency modulation*

The required RF bandwidth, b, for video combined with an audio FM sub-carrier is approximated by the following equation:

$$b = D_{b(p-p)} + 2f_b$$

where $D_{b(p-p)}$ is the peak-to-peak deviation of the carrier by the composite baseband signal and f_b is the composite baseband bandwidth.

System performance for video baseband signals only is discussed in § 3.2. Artificial energy dispersal, a technique useful to facilitate sharing with other services whose signal energy is confined to bandwidths much smaller than those required for FM analogue transmission (as is the case for the BSS) would increase the bandwidth occupied by the signal from the satellite. (A requirement to employ artificial energy dispersal of 600 kHz on all transmissions serving Regions 1 and 3 is incorporated in the Radio Regulations, Appendix 30. Energy dispersal is also required in some circumstances on transmissions serving Region 2.) Other details are discussed in §2.4.4and are given in Report 631.

In the 12 GHz band, laboratory tests have shown that for frequency-modulation transmission of a 625-line colour television signal accompanied with sound transmitted by a frequency-modulation sub-carrier, a good compromise was obtained between the transmitter bandwidth and the quality of the signal for a radio-frequency bandwidth of about 25 MHz.

Some tests carried out in Japan ———— have shown that in the transmission of frequency-modulated television signals accompanied by sound signals in a single channel, using a multiplexed frequency-modulation sub-carrier at 4.5 MHz, satisfactory results can be obtained with a bandwidth of 23 MHz. Moreover, advantage can be taken of over-deviation to transmit six supplementary sound signals of medium quality, by means of a second subcarrier using frequency modulation and time-division-multiplexing by pulses.

The bandwidth occupied by a signal from a broadcasting satellite must be increased to accommodate one or more sound channels. Typically this increase is a quite small percentage of the bandwidth required for the video alone. The radio-frequency channel width of the satellite transmitter must also be larger than the occupied bandwidth to account for both transmitter frequency instability and to keep adjacent channel interference to acceptably small values.

The increase in bandwidth to accommodate both sound channels and guard bands is of the order of 10% of the radio-frequency bandwidth, *b*.

Further details on the signal characteristics, bandwidth requirements and system performance for the baseband signals being considered for future satellite broadcasting systems are given in Report 1075.

2.4.2 *Sound broadcasting*

For sound broadcasting, both FM and digital modulation are considered.

Modulation methods and required bandwidth are indicated in Report 955 and Report 1228. —— The systems described in Report 955 are intended for use in bands 7 and 9 for portable, mobile and fixed radio receivers. The systems described in Report 1228 — are intended for the broadcasting-satellite service in the 12 GHz band, generally for fixed reception.

2.4.3 Frequency deviation and pre-emphasis

Planning of the broadcasting-satellite service has been based on the use of pre-emphasis characteristics given in Recommendation 405. However this does not preclude the use of other pre-emphasis characteristics, provided that the use of such characteristics does not cause greater interference (Radio Regulations, Appendix 30 (ORB-85) (Annex 5, § 3.1.3)). ———— [D'Amato and Stroppiana, 1979] illustrate the results of an investigation carried out in order to optimize the pre-emphasis characteristic. All the factors affecting the signal quality (threshold noise visibility, spurious amplitude modulation, distortions, sound-on-video and video-into-sound crosstalk) have been taken into consideration. The experimental data support the use of the current CCIR recommended pre-emphasis characteristic for broadcasting satellites.

The pre-emphasis specifications for the signal formats recommended for use with future broadcasting satellite systems are given in a Special Publication of the CCIR [CCIR, 1988].

[CCIR, 1974-78a] considers a technique for improving the video signal-to-noise ratio on an FM satellite link by optimizing the frequency deviation and the pre-emphasis characteristic simultaneously. Further studies are required to establish the applicability of this technique to the broadcasting-satellite service.

2.4.4 Energy dispersal in feeder and down links

Energy dispersal is used in connection with FM-TV transmissions via FSS satellites in order to reduce interference to other systems which share the same frequency bands. In the case of broadcasting-satellite transmissions, energy dispersal may be required on the down link in order to protect terrestrial radio-relay links while, on the feeder link, it may be required in order to protect transmissions to fixed-service satellites at neighbouring orbit locations, sharing the same frequency bands (e.g. 14 to 14.5 GHz). (*Note.* – The 11, 14.5 to 14.8 and 17 GHz bands (Earth-to-space) are limited to feeder links for the BSS. Worldwide plans for feeder-link assignments in the 14 and 17 GHz bands were developed at RARC-83 and WARC-ORB 88, and are given in Appendix 30A of the Radio Regulations.)

In principle, the required energy dispersal bandwidth is different in the two directions of transmission, typically being greater on the feeder link. On the other hand, it is desirable to use the smallest possible dispersal bandwidth on the down link so that the cost of removing the dispersal signal in home television receivers can be minimized. Similarly, dispersal at the television line frequency may be most effective in the feeder link for protecting fixed-satellite transmissions, while a television frame frequency dispersal signal may be less expensive to remove on the down link. If such a conflict arises between the requirements for the feeder and down links, consideration should be given to energy-dispersal modulation conversion in the broadcasting satellite as one possible means of improving orbit conservation. Further study is required on the need for and practicability of this technique.

In practice, the amounts of energy dispersal to be used in connection with the assignments in the 12 GHz down-link Plans and the 14 and 17 GHz feeder-link Plans are given in Appendices 30 (ORB 85) and 30A respectively.

2.4.5 Preservation of d.c. component in frequency modulators

In order to obtain the maximum utilization of the available bandwidth by either monochrome or colour signals, the centre frequency of the carrier modulated by a video signal should be preserved (e.g. by preservation of the d.c. component in the frequency modulator), especially in satellite circuits which operate under constraints of power and bandwidth.

The centre frequency can be constrained to correspond to the mid-point of a pre-emphasized peak white video signal [AuBC, 1983].

If the centre frequency is not preserved, then not only could system performance be impaired, but signals could be radiated outside the assigned channel bandwidth during periods of rapid changes in luminance, thus creating the possibility of interference to second adjacent channels. More restrictive filters, with all their limitations, would then be required at the output of the modulator to suppress these out-of-band signal components.

In the case of transmissions employing multiplexed analogue components (MAC), the pre-emphasis characteristic likely to be employed will attenuate low video frequencies only slightly. Therefore it is even more important for such systems to preserve the centre frequency corresponding to the central value of the video signal [CCIR, 1988].

2.5 *Satellite e.i.r.p. and earth receiver figure of merit (G/T)*

2.5.1 *Optimizing satellite e.i.r.p. and earth receiver figure of merit*

In any satellite communication system there are usually trade-offs to be made between satellite and ground terminal cost and complexity, therefore one of the key trade-offs involves the e.i.r.p. of the satellite as a function of the figure of merit (G/T) of the ground terminals. With all other system parameters unchanged, e.i.r.p. and G/T can be varied as long as their sum remains constant. Figure 2 shows graphically the sum of *e.i.r.p.* and figure of merit, in the case of 12 GHz systems with a minimum S/N of 45 dB, for various bandwidths and minimum C/N ratios. No losses other than the free space loss are included. Analogous results can be obtained in the case of other frequency bands or other minimum S/N ratios.

The available satellite e.i.r.p. per channel for a given satellite transmitter output power depends on the transmitting antenna gain corresponding to the required coverage area. High e.i.r.p. satellite designed to provide several television channels to large geographical service areas are currently difficult to implement because of the high primary power required.

Other system options available for decreasing the required e.i.r.p. are to use modulation methods which require less power, or to obtain sufficient video compression so that digital modulation techniques become power effective (see Report 631).

Determining the effects of increasing the antenna size of receiving earth stations is fairly straightforward, since gain as a function of size is well known and antenna cost data are available. Practicality (mounting, wind loading, etc.), particularly for home (individual) use, must also be considered. Further information is given in §3 of Report 473.

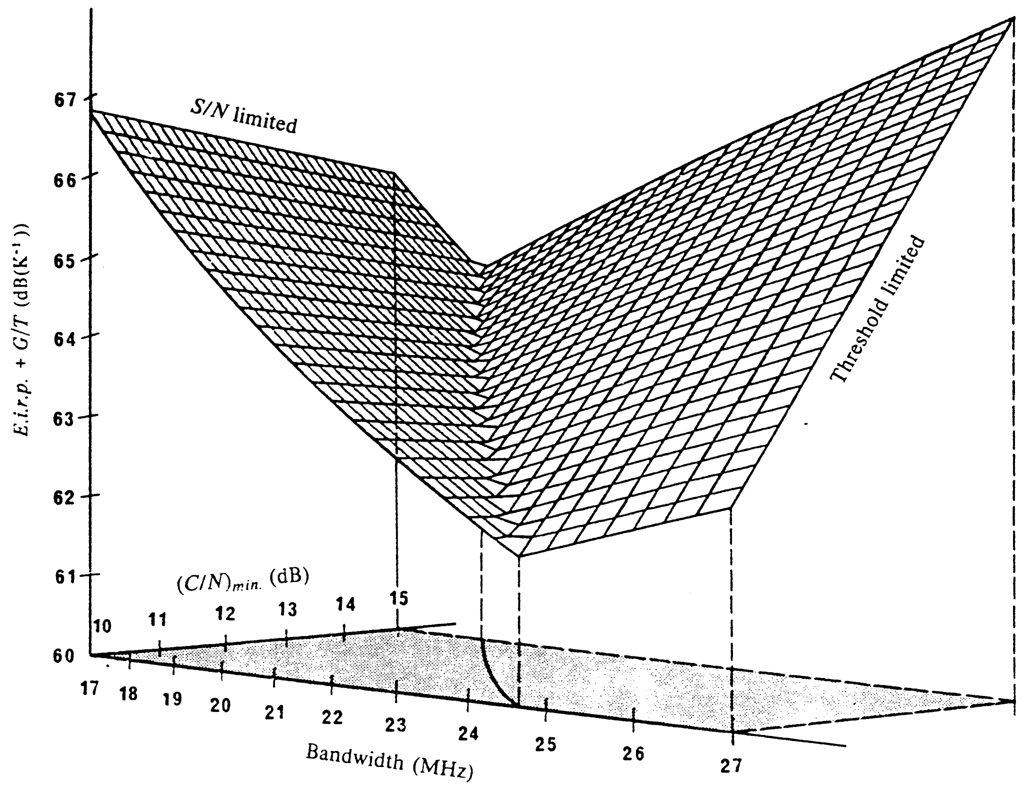

FIGURE 2 – *Parametric surface for the determination of the optimum bandwidth (minimum video S/N = 45 dB)*

2.5.2 *System calculation formulae*

The relationship between satellite e.i.r.p. and earth-station figure of merit is:

$$C/N_d = e.i.r.p. - L_{FS} + G/T - 10 \log kB - L_A - L_R \qquad \text{or}$$

$$e.i.r.p. = C/T + L_{FS} + L_A + L_R - G/T \qquad \text{dB}$$

where:

C/N_d: minimum acceptable carrier-to-noise ratio (dB);

C/T: carrier-to-noise temperature ratio of the space-to-Earth path, (dBW(K^{-1}));

e.i.r.p.: equivalent isotropically radiated power from the satellite towards a point on the edge of the required service area (dBW);

k: 10 log Boltzmann's constant (dB(WK^{-1} Hz^{-1}));

L_{FS}: free space path loss on the space-to-Earth path (dB)

$= 20 \log 4\pi R/\lambda$ (where R is the distance and λ is the wavelength measured in the same units);

L_A: path loss due to clear air absorption (dB);

L_R: fade level due to rain (dB);

G/T: minimum, degraded value of the receiver figure of merit (dB(K^{-1}));

B: noise bandwidth of an individual channel (Hz).

The required satellite e.i.r.p. can be converted into required satellite transmitter output power, P_S, if the satellite antenna gain, G_T is known:

$$P_S = e.i.r.p. - G_T \qquad \text{dB}$$

The half-power beamwidth θ_0 can be determined once satellite antenna gain is specified:

$$\theta_0 = \sqrt{27\,843/G_T} = 225(\lambda/\pi D)$$

where G_T is the antenna gain expressed as a ratio and D is the diameter of the antenna expressed in the same units as λ, the wavelength. An antenna aperture efficiency of 55% has been assumed.

Determination of exact coverage area on the ground is complicated because of the difficulty of determining the intersection of the satellite antenna beam with the spherical surface of the earth. For beams directed near the sub-satellite point, a 1.5° beam produces a coverage area with a diameter of about 1000 km. The same beam directed towards higher latitudes, or towards areas far removed in longitude from the sub-satellite point will cover a much larger area on the surface of the Earth [Ostrander, 1967; Sollfrey, 1966].

The following relationship exists between the magnitudes of field strength and power flux-density.

The straightforward conversion between the unit of field strength, E, (dB(μV/m)) and power flux-density Φ, (dB(W/m^2)) is:

$$\Phi = E - 145.8$$

There are several additional useful relationships:

- the noise power in a 1 MHz bandwidth is −144.0 dBW at a noise temperature of 290 K,
- 1 μV e.m.f. in a 75 Ω source corresponds to an available power of −144.8 dBW,
- 1 μV e.m.f. in a 50 Ω source corresponds to an available power of −143.0 dBW.

The relation between the e.i.r.p. of a geostationary satellite and the power flux-density at the surface of the Earth is:

$$\text{power-flux density} = \text{e.i.r.p.} - \text{spreading loss} + B - W - X$$

where:

power-flux density	is in dB(W/m^2) in the reference bandwidth B
e.i.r.p.	is in dBW
B (reference bandwidth) (See Note 1)	is in dBHz
W (actual signal bandwidth)	is in dBHz ($W > B$)

X is a factor, in dB, which takes into account the uniformity of the signal spectrum over its bandwidth W. X ranges from 0 dB when the signal spectrum is flat, to ($B - W$) dB when the signal bandwidth $W \leq B$.

For the point on the Earth at latitude $\varphi°$ and relative longitude (sub-satellite point = 0°) $\lambda°$ and with $\cos \Delta = \cos \lambda \cos \varphi$, we obtain the following relationship:

Angle Δ (degrees)	spreading loss, dB(m^2) (See Note 2)
0 (sub-satellite point)	162.1
80	163.4

For an angle of elevation ε, with $\tan \varepsilon = (\cos \Delta - 0.1513)/\sin \Delta$, we obtain the following relationship:

Angle ε (degrees)	spreading loss, dB(m^2) (See Note 2)
0	163.4
90	162.1

Note 1. – The reference bandwidth has various values. For space research, it is 1 Hz; for the fixed-satellite service it can be 4 kHz, or 1 MHz, depending on the characteristics of the terrestrial service with which a band is shared. When the emission of a satellite is not uniformly distributed over its necessary bandwidth, the limit on power flux-density is usually construed to apply to the "worst" reference bandwidth.

Note 2. – The e.i.r.p. (dBW) minus the spreading loss in dB(m^2) is equal to the power flux-density (dB(W/m^2)), atmospheric loss not included.

The foregoing formulae are typical of those used in connection with the planning of broadcasting satellite and feeder link frequency assignments in the 12 and 14/17 GHz bands respectively.

3. Quality of reception

3.1 *General considerations*

The quality of the television image on the receiving screen depends on the signal-to-noise ratio, the level and nature of any interference and on the various distortions occurring in the transmission chain (studio, terrestrial link, feeder link, satellite transmitter, signal path, receiver). Various methods of making subjective assessments of the quality of television pictures and the parameters involved are given in Report 405. **The recommended method for assessing the quality of television pictures is given in Recommendation 500.**

It seems to be important to determine the overall performance of the entire system and then define appropriate specifications of components, such as satellite repeaters and home receivers, in the form of target values. Table III of this Report shows typical major parameters of components used in the satellite broadcasting system, and it mainly deals with the least preferable quality determined at the edge of the service area for planning purposes. As satellite broadcasting is capable of delivering a high quality TV signal comparable to that of the studio to the general public, it is practicable to set a higher quality standard.

TABLE III — *Parameter values*

Component of the chain	Parameter				
	Differential phase (degrees)	Differential gain (%)	Chrominance/ luminance gain inequality (%)	Chrominance/ luminance delay inequality (ns)	Signal-to-noise ratio (weighted) (dB)
Studio	± 5(1)	± 5(1)	± 5(1)	± 10	48
Terrestrial circuit	± 5(1)	±10(1)	±10(1)	± 50	56(2)
Satellite system	± 5(1)	±10(1)	±10(1)	± 50	
Domestic receiver	±10(5)	±15(5)	(3)	±100	46(4)

(1) Statistical variable and not exceeded at least for 80% of any month.

(2) Exceeded at least for 80% of any month.

(3) It is assumed that the receiver distortion is equalized by manual chroma control.

(4) This assumes an unweighted signal-to-noise ratio of 33 dB, and a noise-weighting factor (including effect of pre-emphasis) of 13 dB. The minimum performance would be achieved at the edge of the service area in the least favourable case, for 99% of the time.

(5) Studies have shown that these tolerances can be achieved in practice with simple filters without correction circuits in the receiver, when the frequency deviation is about 14 MHz/V and the —3 dB bandwidth is 27 MHz. As a first approximation, these values may be considered as constant with time.

The television signal transmission standard for the hypothetical reference circuit (2500 km) shown in Recommendation 567 may be considered as a reference. Target performance for the part of the satellite broadcasting chain which is to replace the terrestrial broadcasting chain is shown by example in Table IV.In practice, the appropriate overall target performance should be established by giving consideration to its achievability for each component and by individually investigating the distribution ratio so that the total required cost is minimized. Report 405, Annex II indicates that there is a possibility of another law of addition to find overall impairment distribution between different items. Account may also be taken of the above consideration. Further study on this matter is invited.

The signal-to-noise ratio is a very important parameter in calculating television systems and planning transmission networks and for this reason attention is focused on this particular parameter. In selecting the required value of the signal-to-noise ratio, account must in many cases also be taken of other television signal distortions. In television, the signal-to-noise ratio at video frequencies is defined as the ratio, expressed in decibels, of the nominal peak-to-peak amplitude of the picture-luminance signal to the r.m.s. value of the noise in the working video frequency band (Recommendation 567).

The quality of service provided by a broadcasting-satellite system (which will be substantially uniform over the whole service area) should be higher than that recommended for the edge of a terrestrial broadcasting service area (in which the quality is very much better at the centre than at the edge). Two grades of reception quality (primary and secondary) are defined in Recommendation 566.

The objectives to be aimed at for reception quality for community reception should be good, to meet the special requirements of educational programmes in television transmission and should certainly not be lower than those considered appropriate to a terrestrial broadcasting system intended for individual viewing.

The subjective effect of noise depends upon the spectral distribution of the noise energy within the video-frequency band. When measuring noise power, it is common practice to use weighting networks which take account of this fact, with the result that the weighted noise power at video frequencies is lower than the total noise power by a factor depending on the spectral distribution. For most television systems, the available weighting networks are designed so that, for various spectral distributions of the noise, the measurements more closely represent the subjective impression on monochrome pictures than do unweighted noise measurements; for colour television, the subjective effect needs special consideration.

TABLE IV – *Example of the major television transmission characteristic allocations for a composite video system*

Item	Overall characteristics	Allocation to the receiving equipment (1)	Distribution factor	Law of addition (4)
Continuous random noise ratio ($dB_{p-p/r.m.s.}$) (2)	53	48/54 (3)	0.9	2
Periodic noise ratio:				
Power supply hum ($dB_{p-p/p-p}$)	35	–/41	0.5	2
Single frenquency ($dB_{p-p/p-p}$) (more than 1 kHz)	55	–/58	0.5	2
Differential gain (%)	10	10/6	0.5	1.5
Differential phase (deg.)	5	5/3	0.5	1.5
Short time overshoot (%)	15	–/8	0.5	no law
Steady-state characteristics:				
Gain/frequency (dB) (500 kHz – 4.2 MHz)	± 1	± 1.0/± 0.6	0.5	1.5
Delay/frequency (ns) (500 kHz – 4.2 MHz)	± 100	–/± 60	0.5	1.5

(1) Values shown are: minimum standard/target performance.
Minimum standard means that this is a minimum acceptable standard anywhere within the service area.
Target performance means that this is an objective for good quality achievable within the service area.

(2) Signal-to-random noise ratio includes all sources of random noise not only from the front end but also from the IF stage and video amplifiers.

(3) The WARC-BS-77 indicated 14 dB C/N for 99% of the worst month at the edge of the service area. This figure indicates an expected value for 50% of the time in the main part of the service area.

(4) Overall performance D_t can be calculated by using sub-system performance D_i and law of addition p as follows:

$$D_t = \left[\sum_{i=1}^{n} (D_i)^p\right]^{1/p}$$

3.2.1 *Video transmission*

A method of calculation of signal-to-noise ratio after demodulation for frequency modulation television signals is given by

$$S/N = C/N + 10\log\{3(D_{p-p}/f_v)^2\} + 10\log(b/2f_v) + k_w \qquad \text{(dB)}$$

where:

- S/N: ratio of peak-to-peak luminance amplitude to weighted r.m.s. noise (dB)
- C/N: pre-detection carrier-to-noise ratio in the radio-frequency bandwidth (dB)
- D_{p-p}: peak-to-peak deviation by video signal (including synchronization pulses)
- f_v: highest video frequency; (e.g. 4.2 MHz in the case of System M)
- b: radio-frequency bandwidth (usually taken as $D_{p-p} + 2f_v$)
- k_w: combined de-emphasis and weighting improvement factor in frequency modulation systems (dB) (see Table V).

For example, in Table VI, the video signal-to-noise ratio is evaluated using the equation given above, assuming a C/N of 14 dB, and a frequency deviation due to video of 12 MHz peak-to-peak (see Appendix 30 of the Radio Regulations), where the highest video frequency for the system in use, f_v, is taken from Report 624 and the combined de-emphasis and weighting improvement factor, k_w, is taken from Table V.

TABLE V – *Video-frequency noise weighting-network reduction factor for monochrome television*

System	Weighting (dB)		Weighting including de-emphasis, k_w (dB)
	White noise	Triangular noise	Triangular noise
B, C, E, F, G, H and M (Japan)	8.5	16.3	16.3
D, K, L	9.3	17.8	18.1
I	6.5	12.3	12.9
M (Canada, USA) (1)	6.8	10.2	13.8

(1) Weighting factors for 525-lines System M (Canada, USA) are based on Recommendation 567. (Values according to Report 637).

Note – When using pre-emphasis according to Recommendation 405, the combined effect of weighting and de-emphasis for triangular noise is approximately the same as that of weighting alone. More details are given in Report 637.

Examples of the applicable video noise weighting reduction factor are given in Table V. For further details, see Report 637.

TABLE VI - *Typical video signal-to-noise ratios*

System	f_v (MHz)	k_w (dB)	S/N (dB)
M	4.2	13.8	45.5
B and G	5.0	16.3	46.1
D, K and L	6.0	18.1	45.9
I	5.5	12.9	41.7

3.2.2 *Audio transmission*

The unweighted signal-to-noise ratio of accompanying audio channels, which consist of FM sub-carriers located above the video baseband, is determined by the following equation:

$$S/N_a = 10 \log \left[\frac{3}{4} \left(\frac{b}{f_a}\right) \left(\frac{D_s}{f_s}\right)^2 \left(\frac{D_a}{f_a}\right)^2\right] + \left(\frac{C}{N}\right) + k_a$$

where:

S/N_a: audio channel r.m.s. signal to r.m.s. noise ratio (dB);

D_s: peak deviation of the main carrier by the sub-carrier (MHz);

D_a: peak deviation of the sub-carrier by the audio (MHz);

f_s: frequency of the sub-carrier (MHz);

f_a: highest audio frequency (MHz);

C/N: pre-detection carrier-to-noise ratio (dB);

k_a: combined improvement factor due to pre- and de-emphasis for the audio channel (dB). (See CMTT Report 496, Table II, for improvement factors corresponding to various audio channel baseband bandwidths);

b: pre-detection RF bandwidth (MHz) defined by the equation in §2.4.1.

The audio signal-to-noise ratio (after demodulation) is evaluated in Table VII using the equation given above, assuming the same C/N of 14 dB and frequency deviation by the composite baseband signal which is approximated to be the deviation due to the video signal, of 12 MHz peak-to-peak.

The following system values are applied:

- Peak deviation of the subcarrier by the audio (D_a) at the subcarrier frequency (f_s) : 15 kHz
- Combined improvement factor (k_a) due to pre- and de-emphasis for the predetection RF bandwidth (b) as defined in §3.2.1, but using composite baseband parameters.[1] : 9 dB
- Peak deviation (D_s) due to a sound sub-carrier amplitude equal to about 30% of the total peak-to-peak deviation of the carrier[2] : 1.8 MHz

Examples of the audio signal-to-noise ratio value which can be expected are given in Table VII.

TABLE VII - *Typical audio signal-to-noise ratios*

System	D_a (MHz)	f_s (MHz)	b (MHz)	S/N (dB)
M	0.025	4.5	21	49.7
B and G	0.050	5.5	23	54.4
D, K and L	0.050	6.5	25	53.3
I	0.050	6.0	24	53.8

[1] See Report 496, Table II, white noise conditions.

[2] See Report 632.

3.2.3 *Combined video and audio*

Other combined video and audio modulation schemes, such as video with multiple audio FM sub-carriers or with digital audio modulation are described in Reports 632, 1073 and 1074. Additionally, Report 632 gives subjective results of picture and sound quality as a function of carrier-to-noise ratio.

3.3 *Influence of standards for television*

To provide a television broadcasting-satellite service, the following may be considered:

– to take into account the specific needs of the broadcasting-satellite service as given in Recommendation 650 and Report 1073;

– to match exactly the existing standards as employed for terrestrial broadcasting in the geographic area of interest;

– to provide a receiving device to convert the satellite signal into one usable by a standard receiver;

– to provide a receiver designed specifically for the broadcasting-satellite service.

3.4 *Influence of the feeder link*

The overall carrier-to-noise ratio is related to the feeder-link carrier-to-noise ratio and the down-link carrier-to-noise ratio by a relationship which must include the two following factors [CCIR, 1978-82b]:

– the transfer characteristic of the satellite transponder,

– the statistics of rain attenuation on the feeder links and down links.

For example, to limit an impairment of the carrier-to-noise ratio, C/N, of the down link to 0.5 dB, owing to the presence of the feeder link in case of simultaneous fading due to rain attenuation on both links, a C/N of 24 dB is required in the feeder link. Both values, 14.5 dB and 24 dB, are calculated for 99% of the most unfavourable month at all points within the service area.

Where small fixed or transportable feeder-link terminals are to be employed, it may be desirable to make $(C/N)_u$ somewhat smaller in order to keep the power and cost of the feeder-links within reasonable bounds and to reduce the interference of the feeder-link transmissions into nearby terrestrial microwave links. Further details of this partitioning of link noise contributions are given in Report 952.

Feeder links, including their importance in planning, are considered in detail in Reports 561 and 952.

4. System examples

The tables in this section give, purely as illustrative examples, the parameters of broadcasting-satellite systems, using a geostationary satellite of a type that might be possible in the future. It will be observed that some of the examples call for transmitter powers greater than those likely to be practicable for many years. Furthermore, these examples do not take into consideration frequency sharing with other services. However, the parameters of these examples might be modified to correspond to other possibilities which demand less satellite power.

Note. – Examples given are for the bands allocated by the World Administrative Radio Conference, Geneva, 1979. Attention is drawn to the fact that different assumptions are made in the various examples, particularly regarding the reception quality, the receiving installation (noise factor, antenna size) and the area served as determined by the transmitting antenna beamwidth. For this reason, caution must be exercised when comparing the transmitter powers, etc., indicated in the tables.

The way in which the values given in the tables for the transmitter power in the satellite may be modified, if adjustment is made to any of the assumed parameters, is summarized below:

- assuming the use of a transmitting antenna beam of circular cross section, halving the beamwidth will permit a reduction of power by 6 dB. Doubling the beamwidth will require 6 dB more power.
- an increase in the signal-to-noise ratio, made in order to achieve better quality, will require a corresponding increase (in decibels) in the transmitter power. Similarly a decrease will permit an equivalent decrease in the power, but with frequency modulation, the deviation and radio-frequency bandwidth have to be lowered, if the region of the threshold of the discriminator is approached;
- an increase in the factor of merit of the receiving system will lead to a reduction (by an equal amount in decibels) of the transmitter power required and vice versa.

Thus the examples, modified as desired, can serve to indicate the conditions that would be required to enable the public to receive broadcast programmes whose technical quality would be comparable at all times with that of the services provided in the conventional way by a network of terrestrial transmitters.

These examples derive the field strength required for certain stated receiver characteristics. Other assumptions can be made which deal with colour television systems which will result in different required field strengths, and different requirements for satellite e.i.r.p. The object of all of these examples is to establish a reasonable range of satellite power output requirements for a broadcasting-satellite service.

4.1 *Television broadcasting*

Tables VIIIa and VIIIb present examples of community reception and individual reception television systems, respectively, with different frequencies.

Television broadcasting standards for satellite broadcasting are described in Recommendation 650 and Report 1073, and descriptions about multiplexed analogue component techniques are given in Report 1074.

4.2 *Sound broadcasting*

Table IX presents ——— alternative examples of parameters for providing a number of sound channels each suitable for monophonic services for individual reception at 12 GHz. Stereophonic broadcasts can be made using two (or more) such channels (see Report 632). Some sound channels could also be associated with television programmes, additional to the sound channel transmitted as proposed in §4.1.

In Germany (Federal Republic of) a digital satellite radio system (DSR) designed for the emission of 16 stereophonic digitally encoded sound programme channels has been in operation since 1989. The use of other systems is under consideration. The detailed descriptions of these systems are given in Reports 955 and 1228.

Report 955 presents the results of studies of satellite sound broadcasting systems operating in other bands for individual reception.

4.3 *High definition television*

Descriptions of HDTV systems and examples of link parameters for HDTV signals using broadcasting satellites in various frequency bands are given in Report 1075.

TABLE VIIIa - *Examples of community reception television system parameters*

Parameter	1	2	3	4	5	6	Remarks
1. System							
Frequency of carrier (GHz)	0.7	2.6	12	12.5	22.75	42	Note 7
Approximate equivalent rectangular bandwidth (MHz)	19	20	27	24	40	40	Note 1
Carrier-to-noise ratio before demodulation (dB)	16	15	16	14	11	11	Note 1
Additional noise of feeder link (dB)	0.5	0.5	0.5	0.5	0.5	0.5	
Required C/N (dB)	16.5	15.5	16.5	14.5	11.5	11.5	
2. Receiving installation							
Figure of merit, G/T ($dB(K^{-1})$)	-4.4	5.9	16.5	14.7	11.6	11.5	Note 2
System noise temperature(K)	750	750	500	500	1100	1500	
Antenna diameter (m)	3.4	3	1.8	1.4	0.8	0.5	
Required PFD at the edge of beam area ($dB(W/m^2)$)	-116.5	-116.2	-111.3	-111.6	-104.1	-98.7	Note 6
3. Propagation							
Spreading loss (dB)	162.4	162.4	162.4	162.4	162.4	162.4	Note 3
Additional attenuation for propagation (dB)	0	0	0	0	2.0	2.0	Note 4
Rain attenuation for 99% of the worst month (dB)	0	0	1.0	1.0	4.0	8.0	Note 4
Required e.i.r.p. from satellite at edge of beam area (dBW)	45.9	46.2	52.1	51.8	64.3	73.7	
4. Satellite transmitter							
Antenna beamwidth (deg.) at -3 dB points	1.4	1.4	1.4	1.4	1.4	1.4	Note 5
Antenna diameter (m)	23.0	6.2	1.3	1.3	0.7	0.4	Note 5
Antenna gain (dBi)	38.5	38.5	38.5	38.5	38.5	38.5	Note 5
Loss in feeders, filters, joints, etc. (dB)	1.0	1.0	1.0	1.0	1.0	1.0	
Required satellite transmitter power (dBW)	8.3	8.6	14.6	14.3	26.8	36.2	
(W)	6.8	7.3	29	27	480	4200	

TABLE VIIIb - *Examples of individual reception television system parameters*

Parameter	7	8	9	10	11	Remarks
1. System						
Frequency of carrier (GHz)	0.7	12	12.5	22.75	42	
Approximate equivalent rectangular bandwidth (MHz)	19	27	24	40	40	Note 1
Carrier to noise ratio before demodulation (dB)	16	14	14	11	11	Note 1
Additional noise of feeder link (dB)	0.5	0.5	0.5	0.5	0.5	
Required C/N (dB)	16.5	14.5	14.5	11.5	11.5	
2. Receiving installation						
Figure of merit, G/T ($dB(K^{-1})$)	-14.0	6.0	10.0	7.5	9.5	Note 2
System noise temperature(K)	-	1100	750	1100	1500	
Antenna diameter (m)	-	0.8	1.0	0.5	0.4	
Required PFD at the edge of beam area ($dB(W/m^2)$)	-107.0	-102.8	-106.9	-100.0	-96.7	Note 6
3. Propagation						
Spreading loss (dB)	162.4	162.4	162.4	162.4	162.4	Note 3
Additional attenuation for propagation (dB)	0	0	0	2	2	Note 4
Rain attenuation for 99% of the worst month (dB)	0	1	1	4	8	Note 4
Required e.i.r.p. from satellite at edge of beam area (dBW)	55.4	60.6	56.5	68.4	75.7	
4. Satellite transmitter						
Antenna beamwidth (deg.) at -3 dB points	1.0	1.0	1.0	1.0	1.0	Note 5
Antenna diameter (m)	32.0	1.8	1.8	1.0	0.5	Note 5
Antenna gain at the edge of service area (dBi)	41.4	41.4	41.4	41.4	41.4	Note 5
Loss in feeders, filters, joints, etc. (dB)	1.0	2.0	2.0	3.0	3.0	
Required satellite transmitter power (dBW)	15.0	21.2	17.1	30.0	37.3	
(W)	32	130	50	1000	5400	

Notes to Tables VIIIa and VIIIb:

(1) Required bandwidth and carrier-to-noise ratio depend on the modulation method and signal quality.

(2) Values are "usable figure of merit" according to the definition given in Annex I of Report 473-4. 55% efficiency and 1 dB pointing error are assumed for calculation of antenna gain, which is usually better than the indicated value, especially below the 12.5 GHz band because of the improvement of the receiver noise temperature and antenna efficiency.

(3) Satellite elevation angle is assumed as 40°.

(4) Rain attenuation should be corrected by using the appropriate value for each climate zone.

(5) Antenna beamwidth should be adjusted to the size of service area. Antenna diameter and gain will be changed accordingly.

(6) The PFD values given here are based on calculations intended to satisfy the required C/N for the satellite broadcasting system and will be required for 99% of the worst month.

(7) The carrier frequency shown in Columns 5 and 10 (22.75 GHz) is an example of the mid frequency of the band allocated to the broadcasting-satellite service in Regions 2 and 3.

5. Other applications to existing and new services

It is agreed as a basic premise that the introduction of these transmissions within a television channel must not create additional interference to other systems nor require additional protection over that required for the standard application of the broadcasting-satellite service, e.g. television transmission.

5.1 *Broadcasting of data in a frequency-modulated television channel*

It is now possible to envisage the use of certain television signal lines for broadcasting data in the broadcasting-satellite service.

The introduction of these new signals should not alter the characteristics of the television channel, the interference levels or the criteria for sharing with other services, as defined by the WARC-BS-77.

A study carried out in France showed the possibility of using this new broadcasting service within the satellite broadcasting channel. —————————— This service uses a system of digital modulation made up in the baseband of an NRZ binary signal frequency limited to the video band. The bit rate is about 6 Mbit/s. The 6.5 MHz sound sub-carrier of the television signal may or may not be superimposed on this signal.

5.2 *Interactive connection*

New and innovative applications of the broadcasting-satellite service in the community reception mode were investigated in the United States and Canada using the Applications Technology Satellite-6 (ATS-6) [IEEE, 1975] and the Communications Technology Satellite (CTS-Hermes). Examples of such applications include distribution of educational, medical, informational and other specialized material, for example, to schools, hospitals and community centres. A more detailed discussion of these applications including examples of particular applications are given in [CCIR, 1974-78b]. Many of these applications are considered to fall within the definition of community reception (Radio Regulations, No. 124).

A number of the applications also had associated with the broadcasting satellite transmission, a return communication connection – for example, to permit students in a classroom to interact with the remote instructor. In some cases this return or "interactive" link utilized satellite transmission. It is expected that the majority of such interactive links will consist of one or more sound channels.

TABLE IX. - *Examples of system parameters for sound broadcasting for individual reception*

Parameter	1	2	3	4	5	6	Remarks
1. <u>System</u>			Note 6	Note 6			
Frequency of carrier (GHz)	12	12	12	12	12	12	
Type of modulation	FM	FM/FM	4-PSK	4-PSK	4-PSK	4-PSK	
Sound frequency bandwidth (kHz)	15	15	15	20	15	15	
Sampling frequency (kHz)			32	48		32	
Number of sound channels	1	12	48	24	96	32	Note 1
Coding law			14/10 NIC	linear 16bit	ADM Note 7	16/14 float. point	
Transmission bit rate (Mbit/s)			24.6	24.6		20.48	
Approximate equivalent rectangular bandwidth (MHz)	0.18	22	27	27			
Carrier to noise ratio before demodulation (dB)	19	14	15.1 Note 2	15.1 Note 2		Note 3 82 (C/No)	
Additional noise of feeder link (dB)	0.5	0.5					
Required C/N (dB)	19.5	14.5	15.6	15.6			
2. <u>Receiving installation</u>						Note 8	
Figure of merit (dB(K^{-1}))	4	4	12.0			3.0	
Required PFD at the edge of beam area (dB(W/m^2))	-118	-103	-110.3			-103	
Received C/N (dB)			16.4				Note 4
C/No (dB)						85	Note 5
3. <u>Propagation</u>							
Spreading loss (dB)	162.4	162.4	162.4			162.4	
Additional attenuation for propagation (dB)	0.5	0.5	0.2			0.5	
Rain attenuation for 99% of the worst month (dB)	1.5	1.5	2.0			2.0	
4. <u>Satellite transmitter</u>							
Antenna beamwidth (deg.)	1.4	1				1.6x0.7	
Antenna gain (dB)	38	41	37			40.9	
Loss in feeders, etc. (dB)	1	1	2.5			2	
Transmitter power (dBW)	10	23	20			23.6	
(W)	10	200	100			230	
E.i.r.p. from satellite at edge of beam area (dBW)	47	63	54.5			62.5	

NIC: Near Instantaneous Companding.

(1) Monophonic channels.

(2) *C/N* for Nyquist bandwidth required to obtain BER of 10^{-7} (before error correction).

(3) For a BER of 10^{-3} (before error correction) corresponding to an excellent sound quality.

(4) *C/N* obtainable with a receiver having Nyquist bandwidth. Difference between required *C/N* and received *C/N* may be assigned as a margin in receiver design. In the case of 27 MHz bandwidth necessary for the reception of television signal, *C/N* will be about 14 dB with parameters given in this table.

(5) The margin between received and required C/N_0 may be used to further reduce the antenna size.

(6) These are possible system parameter variants based on the sound channel transmission used in the system described in § 2.3 of Report 1073. This system also specifies parameters in the first column of this table which conform to Recommendation 651.

(7) Equivalent to use of adaptive delta modulation (ADM) coding described in Report 953.

(8) Corresponding to a 40 cm dish for sound-only reception.

5.3 *Conditional access broadcasting*

A new application of the broadcasting-satellite service is the distribution of selective-access television programmes. This has led the French Administration to study a baseband scrambling technique which meets this requirement [CCIR, 1978-82c].

If the signal subject to scrambling is to remain in conformity with the characteristics of the 625-line standard, the scrambling system selected must retain the line structure of the television picture. The vertical components of the picture must therefore be destroyed so that even if absolute secrecy is not ensured the picture is sufficiently complex to discourage any attempt at deciphering.

This is achieved by introducing transformations in each television line following a pseudo-random sequence moving at the line pulse rate and initiated by each field.

The target receiver(s) is selected by means of keys (known as "service keys") comprising words of 18 bits which determine the pseudo-random sequence.

The equipment which has been under study for some years has been developed into integrated systems for use on analogue (CCD) or digital circuits which permit effective scrambling of the picture.

5.4 *Integrated service digital broadcasting*

Developments of digital technology in the field of broadcasting permit digital information to be transmitted either exclusively or in association with the main signal. A broadcasting-satellite channel is an appropriate medium for this purpose. Its high transmission quality and capacity is suitable for integrated use of various kinds of information to keep high flexibility and efficiency. It is necessary to take into account not only possible compatibility among all broadcasting media but also between other communication services and packaged media.

Study Programme 2N/10-11 decides to study the determination of the technical composition of services and specification of the technical parameters for ISDB so as to permit highly flexible and efficient operation using a broadcasting satellite television channel and to faciliate the design of cost effective systems. (See Report 1227).

6. Additional functions for broadcasting and spacecraft operations

6.1 *Narrow-band cueing channels*

In an operational system using transportable feeder-link stations, a need may be identified for independent SCPC type cueing channels transmitted using the same satellite transponder as the related television signal. A minimum of two of these narrow-band SCPC channels would seem to be necessary for cueing and talk-back. Since the antennas of the feeder-link stations are likely to be larger, these SCPC channels would be transmitted at lower power in order to limit the in-band intermodulation. The transmission of these cueing channels needs to be further studied as to the possibility of accommodating them within the Plans and the possible impact on the quality of transmission.

6.2 *Spacecraft service functions*

The Radio Regulations, No. 25, states that the accommodation of spacecraft service functions (TTC) will normally be provided within the service in which the space station is operated. For the broadcasting-satellite service this means within the satellite broadcast down-link and corresponding feeder-link bands, including the possibility of using the guard bands. The service functions to be provided are summarized in Table X.

TABLE X – *Basic spacecraft service functions*

Function	Notes
Earth-to-space:	
– telecommand	Non-continuous low data rate transmission
– ranging	Non-continuous tone or code ranging
– satellite antenna tracking	Continuous RF-sensing, on CW or swept carrier (e.g. residual carrier of telecommand signal) *
Space-to-Earth:	
– telemetry	Continuous low data rate transmission
– ranging	Non-continuous tone or code ranging
– earth station antenna tracking	Continuous, on residual telemetry carrier or swept carrier

* **Measurements made on the TDF-1 satellite have shown that a boresight error circle of 0.01 degree radius can be achieved in the pointing of the transmitting antenna through RF sensing of a ground beacon [CCIR, 1986-90b].**

While it may be desirable to use part of the broadcast frequency assignments for TTC services exclusively, it may not be feasible to do so from the operational and technology viewpoint. This implies that for certain phases during the lifetime of any broadcasting satellite, different frequency bands may have to be used.

The assignment of specific spacecraft service channels within the broadcast down-link and feeder-link frequency bands will have to be performed in close consultation with the broadcast channel frequency and polarization assignments to ensure compatibility with technological constraints and system operation constraints. Moreover, such assignments will have to be compatible with the broadcast transmissions and must not cause non-permissible interference into other services which share these frequency bands. These considerations suggest that appropriate sharing criteria may have to be developed. More detailed information on the accommodation of spacecraft service functions within the guardbands of the broadcasting-satellite service is contained in Report 1076.

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[1978-82]: **a.** 10-11S/117 (Japan); **b.** 10-11S/175 (Canada); **c.** 11/265 (France)

[1986-90]: **a.** 10-11S/8 (JIWP 10-11/3); **b.** 10-11S/139 (France)

ANNEX I

VISIBILITY TIME FOR THE SATELLITE

A satellite with a period of 12 hours, in an elliptical orbit having a plane inclined at about 63° to the equatorial plane and an apogee of 40 000 km well north of the equator, can provide a larger area of coverage in the northern hemisphere than a geostationary satellite. The use of several satellites in such orbits can provide an uninterrupted service. The times of visibility of one satellite are given in TABLE XII for a particular latitude (60° N) of the receiving point, and a particular minimum angle of elevation (20°). In theory, because of the non-spherical shape of the Earth, an inclination of the orbit of 63.4° would ensure that the major axis does not drift in the plane of the orbit, and, therefore, that successive apogees will occur at the same terrestrial latitude.

TABLE XI - *Visibility times for satellites in stationary and sub-synchronous circular equatorial (non-retrograde) orbits*

Approximate period (h)	Altitude (km)	Passes per day over a given point	Approximate periods of visibility above the horizon per pass (h)			
			At equator	At ± 15° lat.	At ± 30° lat.	At ± 45° lat.
24(1)	35 786	Stationary	Continuous	Continuous	Continuous	Continuous
12	20 240(2)	1	10.1	10.0	9.9	9.3
8	13 940(2)	2	4.8	4.7	4.6	4.2
6	10 390(2)	3	3.0	2.9	2.8	2.5
3	4 190(2)	7	1.0	1.0	0.9	0.6

(1) Exactly: 23 h 56 min 4 s.
(2) Approximate values.

In the example of TABLE XII, the minor axis of the orbital ellipse is assumed to be parallel to the equatorial plane. The maximum period of visibility from a given point on the Earth at latitude 60° (10.6 hours) is then obtained when the apogee is at the same longitude as the point.

TABLE XII — *Visibility times of a satellite in a typical elliptical orbit inclined at about 63.4°*

Approximate period (h)	Approximate apogee (km)	Approximate perigee (km)	Approximate periods of visibility per pass (h) over a reception point at 60° latitude, with an angle of elevation of the receiving antenna greater than 20°	
			Maximum	Minimum
12	40 000	500	10.6	4.5

ANNEX II

MEASUREMENTS OF ATMOSPHERIC ATTENUATION AND DEPOLARIZATION AT FREQUENCIES OF INTEREST TO THE BROADCASTING-SATELLITE SERVICE

Extensive measurements of sky noise temperature at 11.5 GHz covering the European region, have been carried out by the European Space Agency for a number of years. Atmospheric attenuation was expected to vary with the angle of elevation and with the local climate. However, in the European region and for the range of angles of elevation, (from 20° to 45°) covered by the experiment, these dependencies are so small that they need not be taken into account when compared with the random year-to-year variations in attenuation values. The values of the worst-month attenuation obtained from the measurements are listed in Table XIII. For system planning, it is proposed to use the median values, corresponding to the worst month in an average year.

TABLE XIII — *Worst-month attenuation at 11.5 GHz (Europe)*

Time fraction (%)	Attenuation not exceeded during worst months (dB)		
	90% value	median value	10% value
20	0.3	0.4	0.6
5	0.4	0.6	0.9
1	0.9	1.1	1.4
0.3	1.2	1.8	2.4
0.1	1.5	3.3	6.0
0.03	3.1	7.3	11.0

For Region 3, measurements of atmospheric attenuation in the 12 GHz band have been carried out using the broadcasting satellite for experimental purposes (BSE) in Japan and using a radiometer in Malaysia, which are situated respectively in the moderate and tropical climate areas in Asia. The results are summarized in Table XIV. While the data presented should be regarded as provisional, they may be considered useful until more precise data become available.

TABLE XIV – *Worst month attenuation observed at 12 GHz in Japan and Malaysia*

Location of measurement	Period	Attenuation not exceeded during the worst month (dB)	
		99% of the worst month in an average year	99.9% of the worst month in an average year
12 locations in Japan	August 1978 to December 1979	2.4	6.9
Klang in Malaysia	October 1970 to November 1972	1.7	8.7

The values in Japan in Table XIV are medians of the data in the worst months for 12 to 14 months in 12 locations, which have been distributed all over Japan, angles of elevations ranging from about 30° to 60°. Measurements in Malaysia were corrected with respect to an elevation angle of 45° by using the cosecant law [CCIR, 1978-82a].

Measurements of rain attenuation at 11.7 GHz were carried out at Greenbelt, Maryland and Rosman, North Carolina in the United States by the NASA/Goddard Space Flight Centre by monitoring the beacon on the Communications Technology Satellite (CTS). Measurements commenced at Greenbelt, Maryland in June 1976 and were completed in the fall of 1979. The elevation angles to CTS from Greenbelt and Rosman are 29.5 and 36 degrees respectively.

Measurements of rain attenuation at 20 GHz and 30 GHz were also carried out at Rosman using the ATS-6 satellite [Ippolito, 1975].

Table XV summarizes the results of these measurements for the two worst months of the measurement period.

TABLE XV — *Rain attenuation observed at 11.7 GHz (CTS) and 20 and 30 GHz (ATS-6) in Maryland and North Carolina, USA*

Location	Frequency (GHz)	Month	One-minute mean attenuation (dB), not exceeded during month for given percentage of the time		
			99%	99.9%	99.99%
Greenbelt (Maryland)	11.7	June, 1976	<1	1.6	9.2
		August, 1976	<1	5.4	15.6
Rosman (North Carolina)	11.7	July, 1976	1	1.8	8.3
	20	July, 1974	1.5	11.0	>20
	30	July, 1974	2.4	19.5	>35

In 1978-1980 attenuation and cross-polarization measurements were carried out by CNES-TDF (France) in Brittany (11 700 hours) and near Paris (3500 hours) receiving 11.8 GHz circularly polarized and 11.6 GHz linearly polarized beacon signals respectively from the OTS satellite [CCIR, 1978-82b]. Attenuation values not exceeded for 99% and 99.9% of the worst month were 1.8 and 4 dB respectively for Paris and 1.5 and 3 dB respectively for Brittany. Polarization isolation of the circularly polarized beacon was only above 20 dB for 99.9% of the worst month and 99.99% of the entire measurement period, and was never less than 30 dB for the linearly polarized beacon.

Also, depolarization measurements were taken with the CTS satellite launched in 1976 in the 12 GHz region, using both circular and vertical polarization. Actual measurements statistics from this programme have been analyzed in Report 564.

REFERENCE

IPPOLITO, L. J. [November, 1975] ATS-6 millimeter wave propagation experiments at 20 and 30 GHz. *IEEE Trans. Aerospace Electron. Systems*, Vol. AES-11, **6**, 1067-1083.

CCIR Documents

[1978-82]: **a.** 10-11S/117 (Japan); **b.** 10-11S/13 (France)

ANNEX III

EXAMPLES OF SOLAR INTERFERENCE TO A SATELLITE BROADCASTING SYSTEM AS MEASURED DURING THE BSE EXPERIMENT

Figure 3 shows the degradation of carrier-to-noise ratio due to solar interference to the receiving system with a 1.6 m antenna and frequency of 12 GHz, bandwidth of 27 MHz, receiver noise of 650 K and antenna efficiency of 55%.

Maximum degradation due to solar interference is 6.7 dB and the longest time of degradation exceeding 1 dB is 8.4 min. Accumulated time of degradation is 32.8 min. through one period of interference.

For antennas of other sizes, maximum degradation, maximum duration of degradation and accumulated degradation time are as shown in Table XVI.

TABLE XVI

Antenna diameter (m)	Maximum degradation (dB)	Maximum duration (min)	Cumulative duration (min)
1.0	3	9.8	53.3
2.5	7	5.8	17.5
4.5	8	4.0	8.6

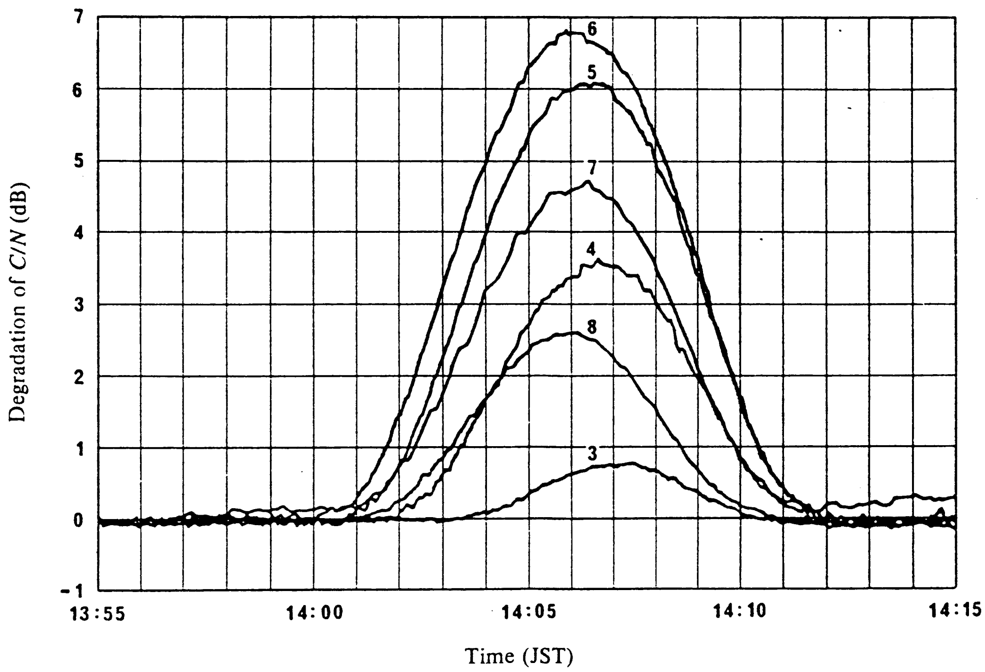

FIGURE 3 – *An example of solar interference to a receiving system with an antenna of 1.6 m diameter, measured in BSE experiment, during one solar interference period*

(Numbers adjacent to curves refer to the dates in March, 1980 on which the measurements were taken)