XVII A.P.
DÜSSELDORF
21.5-1.6 1990
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XVIIth PLENARY ASSEMBLY
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INTERNATIONAL TELECOMMUNICATION UNION

REPORTS OF THE CCIR, 1990

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ANNEX TO VOLUMES X AND XI – PART 2

BROADCASTING-SATELLITE SERVICE (SOUND AND TELEVISION)

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

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BROADCASTING-SATELLITE SERVICE (SOUND AND TELEVISION)

(Study Groups 10 and 11)

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SECTION 10/11A: TERMINOLOGY

There are no Reports in this Section.

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 <u>Attenuation</u>

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.

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* 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.

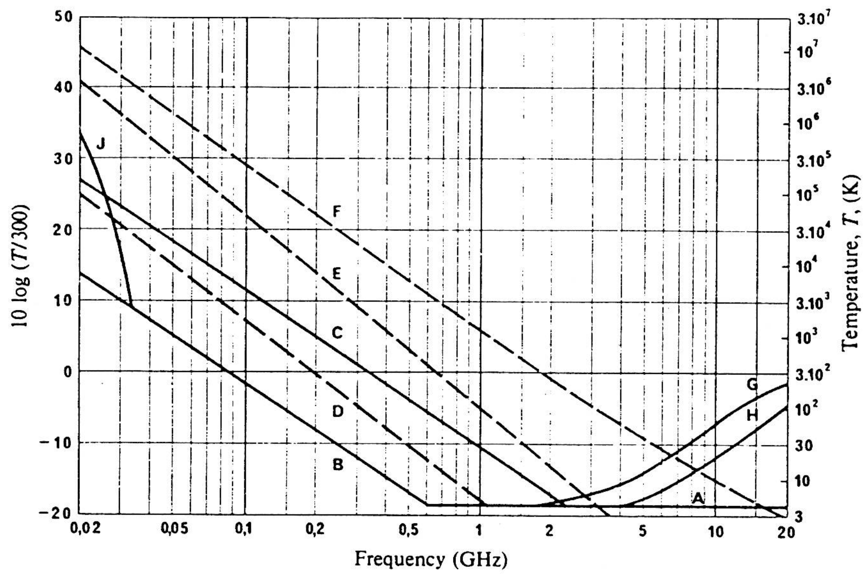

FIGURE 1 – *Noise temperature from natural and man-made sources*

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.

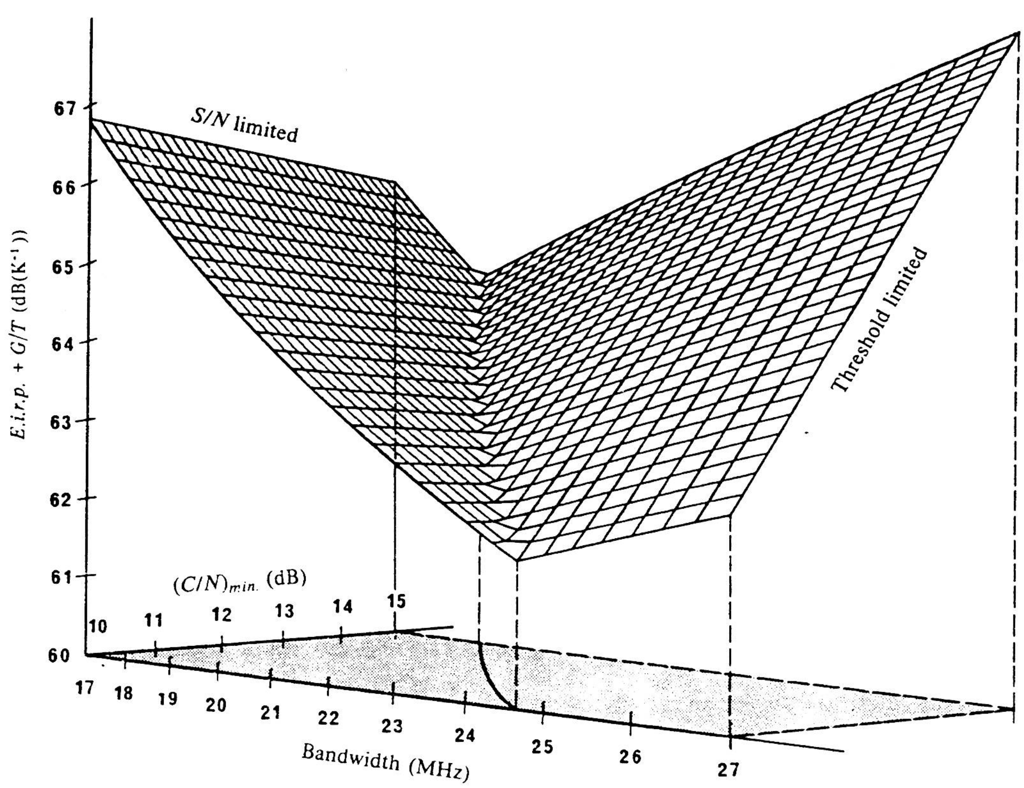

FIGURE 2 – *Parametric surface for the determination of the optimum bandwidth (minimum video S/N = 45 dB)*