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PART I

Recommendations G.211 to G.544

LINE TRANSMISSION

INTERNATIONAL ANALOGUE CARRIER SYSTEMS

MONTAGE: PAGE 2 = PAGE BLANCHE

SECTION 2

GENERAL CHARACTERISTICS COMMON TO ALL

ANALOGUE CARRIER-TRANSMISSION SYSTEMS

2.1 Definitions and general considerations

Recommendation G.211

MAKE-UP OF A CARRIER LINK

(amended at Geneva, 1964; further amended)

In the international telephone network, provision must be made for the interconnection of various sorts of carrier-transmission systems using symmetric cable pairs, open-wire lines, coaxial cable pairs or radio-relay links. It is thus desirable for the carrier equipment used in these various systems, and which is not confined to a particular sort of line, to meet general CCITT recommendations.

Basically, these equipments comprise translating equipments and through-connection filters.

1 Translating equipments

These equipments are classified below according to the procedure used to make up the large-capacity systems from the basic supergroup.

Two procedures are in use:

Procedure 1: the mastergroup and supermastergroup procedure;

Procedure 2: the 15-supergroup assembly procedure; their use is described in the Recommendations concerning the various line systems.

For international links, procedure 2 can be used above 4 MHz only by agreement between the Administrations concerned, including the agreement of the Administration(s) of the transit country or countries, if any.

In the Recommendations, the names of the equipments defined above are also used for equipments which translate a basic group, supergroup or mastergroup or a basic (No. 1) 15-supergroup assembly into the line-frequency band and vice versa.

The translating equipments used in procedure 1 are:

— channel-translating equipment, for translating the audio-frequency band into the basic group and vice versa (see Recommendations G.232, G.234 [1] and G.235);

— group-translating equipment for translating five basic groups into the basic supergroup and vice versa;

— supergroup-translating equipment for translating five basic supergroups into the basic mastergroup and vice versa;

— mastergroup-translating equipment for translating three basic mastergroups into the basic supermastergroup and vice versa;

— supermastergroup-translating equipment for translating the basic supermastergroup into the line-frequency band and vice versa.

Note — Figure 1/G.211, *a)* and *b)* recapitulates the basic frequency bands used in procedure 1; the through-connection possibilities described in Recommendation G.242 are provided for in these bands.

Figure 1/G.211, p.

The translating equipments used in procedure 2 are:

— channel-translating equipment and group-translating equipment, as defined for procedure 1;

— supergroup-translating equipment for translating 15 basic supergroups into the basic assembly No. 1 of 15 basic supergroups and vice versa;

— 15-supergroup assembly equipment for translating basic assembly No. 1 of 15 supergroups into the frequency band of the 15-supergroup assembly No. 3 and vice versa;

— supermastergroup-translating equipment for translating 15-supergroup assembly No. 3 into the line-frequency band and vice versa.

Note 1 — Figure 1/G.211, *a)* and *c)* gives a recapitulation of the basic frequency bands used in procedure 2 in which the through-connection facilities described in Recommendation G.242 are provided.

Note 2 — The frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 | 36 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 | 88 kHz). The equipments which are used for translating into the line-frequency band and vice versa may therefore be the same.

For this reason, these equipments carry the same name of ‘‘supermastergroup-translating equipment’’.

2 Through-connection filters

Through-group, supergroup, etc., filters and direct through-connection filters (see Recommendation G.242).

The equipment listed under the preceding sentence and § 1 above can be interconnected for setting up long groups, supergroups, etc., over several carrier systems. An example of such a link is shown in Figure 2/G.211 together with the expressions defined below that are recommended for describing the various parts of a circuit on such a group or supergroup, etc.

Figure 3/G.211 refers to definitions 3.2 to 3.11 below.

Those of the following definitions that concern ‘‘links’’ or ‘‘sections’’ apply, unless otherwise stated, to the combination of both directions of transmission. A distinction between the two directions of transmission may, however, be necessary in the case of unidirectional, multiple-designation ‘‘links’’ or ‘‘sections’’ set up over multiple-destination telecommunication satellite systems.

Figure 2/G.211, p.

3 Definitions

3.1 line link (using symmetric pairs, coaxial pairs, etc.)

F: liaison en ligne (à paires symétriques, à paires coaxiales, etc.)

S: enlace en línea (de pares simétricos, de pares coaxiales, etc.)

A transmission path, however provided, together with all the associated equipment, such that the bandwidth available, while not having any specific limits, is effectively the same throughout the length of the link.

Within the link there are no direct filtration points nor any through-connection points for groups, supergroups, etc., and the ends of the link are the points at which the band of line frequencies is changed in some way or other.

3.2 group link

F: liaison en groupe primaire

S: enlace en grupo primario

The whole of the means of transmission using a frequency band of specified width (48 kHz) connecting two terminal equipments, for example channel translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on group distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more group sections.

3.3 supergroup link

F: liaison en groupe secondaire

S: enlace en grupo secundario

The whole of the means of transmission using a frequency band of specified width (240 kHz) connecting two terminal equipments, for example group translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on supergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more supergroup sections.

3.4 mastergroup link

F: liaison en groupe tertiaire

S: enlace en grupo terciario

The whole of the means of transmission using a frequency band of specified width (1232 kHz) connecting two terminal equipments, for example supergroup translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on mastergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more mastergroup sections.

Note — As translating procedure 2 described under § 1 above does not enable mastergroups to be set up, the ‘‘mastergroup link’’ concept applies only in procedure 1.

3.5 **supermastergroup link**

F: liaison en groupe quaternaire

S: enlace en grupo cuaternario

The whole of the means of transmission using a frequency band of specified width (3872 kHz) connecting two terminal equipments, for example mastergroup translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on supermastergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more supermastergroup sections.

Note — As the frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 | 36 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 | 88 kHz), the basic supermastergroup link can transmit one supermastergroup or an assembly of 15 supergroups.

3.6 **15-supergroup assembly link**

F: liaison en assemblage de 15 groupes secondaires

S: enlace en agregado de 15 grupos secundarios

The whole of the means of transmission using a frequency band of specified width (3716 kHz) connecting two terminal equipments (supergroup modems permitting the setting-up of a 15-supergroup assembly). The ends of the link are the points on 15-supergroup assembly distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more 15-supergroup assembly sections.

Note — The notion of 15-supergroup assembly link relates to translating procedure 2 mentioned in § 1 above. It is the equivalent of the ‘‘supermastergroup link’’ concept of the translating procedure 1 (900 telephone channels).

3.7 **group section**

F: section de groupe primaire

S: secci´on de grupo primario

The whole of the means of transmission using a frequency band of specified width (48 kHz) connecting two consecutive group distribution frames (or equivalent points) via at least one line link.

3.8 **supergroup section**

F: section de groupe secondaire

S: secci´on de grupo secundario

The whole of the means of transmission using a frequency band of specified width (240 kHz) connecting two consecutive supergroup distribution frames (or equivalent points) via at least one line link.

3.9 **mastergroup section**

F: section de groupe tertiaire

S: secci´on de grupo terciario

The whole of the means of transmission using a frequency band of specified width (1232 kHz) connecting two consecutive mastergroup distribution frames (or equivalent points) via at least one line link.

Note — As translating procedure 2 described in § 1 above does not enable mastergroups to be set up, the ‘‘mastergroup section’’ concept applies only in procedure 1.

3.10 **supermastergroup section**

F: section de groupe quaternaire

S: secci´on de grupo cuaternario

The whole of the means of transmission using a frequency band of specified width (3872 kHz) connecting two supermastergroup distribution frames (or equivalent points) via at least one line link.

Note — As the frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 | 36 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 | 88 kHz), the supermastergroup section can transmit one supermastergroup or an assembly of 15 supergroups.

Figure 3/G.211, p.

3.11 **15-supergroup assembly section**

F: section d'assemblage de 15 groupes secondaires

S: secci´on de agregado de 15 grupos secundarios

The whole of the means of transmission using a frequency band of specified width (3716 kHz) connecting two consecutive 15-supergroup assembly distribution frames (or equivalent points) via at least one line link.

Note 1 — Same note as for definition 3.6 above.

Note 2 — In a country which uses procedure 1, a 15-supergroup assembly can be through-connected without difficulty at the supermastergroup distribution frame. In this case, the 15-supergroup assembly is through-connected to position *3* (8620-12 | 36 kHz) instead of position *1* (312-4028 kHz) as required by the definition of the through-connection point of such an assembly (see Recommendation G.242, § 6). This through-connection point does not therefore correspond to this definition and is not at the end of a 15-supergroup assembly section.

3.12 **through-group connection point**

F: point de transfert de groupe primaire

S: punto de transferencia de grupo primario

When a group link is made up of several group sections, they are connected in tandem by means of through-group filters at points called through-group connection points.

3.13 **through-supergroup connection point**

F: point de transfert de groupe secondaire

S: punto de transferencia de grupo secundario

When a supergroup link is made up of several supergroup sections, they are connected in tandem by means of through-supergroup filters at points called through-supergroup connection points.

3.14 **through-mastergroup connection point**

F: point de transfert de groupe tertiaire

S: punto de transferencia de grupo terciario

When a mastergroup link is made up of several mastergroup sections, they are connected in tandem by means of through-mastergroup filters at points called through-mastergroup connection points.

3.15 **through-supermastergroup connection point**

F: point de transfert de groupe quaternaire

S: punto de transferencia de grupo cuaternario

When a supermastergroup link is made up of several supermastergroup sections they are connected in tandem by means of through-supermastergroup filters at points called through-supermastergroup connection points.

3.16 through-15-supergroup assembly connection point

F: point de transfert d'assemblage de 15 groupes

S: punto de transferencia de agregado de 15 grupos secundarios

When a 15-supergroup assembly link is made up of several 15-supergroup assembly sections, these sections are interconnected in tandem by means of through-15-supergroup assembly filters at points called through-15- supergroup assembly connection points.

As an alternative when the 15-supergroup assembly equipment provides sufficient filtering (corresponding to the definition of through-connection equipments — see Recommendation G.242, § 6) through-15-supergroup assembly filters can be dispensed with.

Note — When a 15-supergroup assembly is connected by means of through-supermastergroup filters, the point of interconnection is the through-supermastergroup connection point and not a through-15-supergroup assembly connection point.

3.17 **regulated line section (symmetric pairs, coaxial pairs or radio-relay links, etc.)**

F: section de régulation de ligne (à paires symétriques ou coaxiales ou sur faisceau hertzien, etc.)

S: sección de regulación de línea (de pares simétricos o coaxiales, o por radio-enlaces, etc.)

In a carrier transmission system, a line section on which the line-regulating pilot or pilots are transmitted from end to end without passing through an amplitude-changing device peculiar to the pilot or pilots.

3.18 **main repeater station**

F: station principale de répéteurs

S: estación principal de repetidores

A station, always the terminal of a line link (see definition 3.1 above), where direct line filtering or demodulation or both together may take place. As a consequence, in such a station there are equalizers and it is possible to find points which are of uniform relative level independent of frequency (‘‘flat points’’).

Such a station, where all the supergroups, for example, are demodulated and brought into the basic supergroup position, is called a ‘‘main terminal station’’ and is of necessity at the end of a regulated-line section. A ‘‘main intermediate station’’ is a station within a regulated-line section where a direct through-connection takes place.

Reference

[1] CCITT Recommendation *8-channel terminal equipments* , Orange Book, Vol. III-1, Rec. G.234, ITU, Geneva, 1977.

Recommendation G.212

HYPOTHETICAL REFERENCE CIRCUITS FOR ANALOGUE SYSTEMS

GENERAL DEFINITIONS

1 hypothetical reference circuit

F: circuit fictif de référence

S: circuito ficticio de referencia

This is a hypothetical circuit of defined length and with a specified number of terminal and intermediate equipments, this number being sufficient but not excessive. It forms a basis for the study of certain characteristics of long-distance circuits (noise, for example).

2 hypothetical reference circuit for telephony

F: circuit fictif de r´ef´erence pour la t´el´ephonie

S: circuito ficticio de referencia para la telefon´ia

This is a complete telephone circuit (between audio-frequency terminals) established on a hypothetical international telephone carrier system and having a specified length and a specified number of modulations and demodulations of channels, groups, supergroups, these numbers being reasonably great but not having their maximum possible values. The hypothetical reference circuit has to reflect what is generally expected to be the practical application of the system.

Various hypothetical reference circuits for telephony have been defined to allow the coordination of the different specifications concerning the constituent parts of the multichannel carrier telephone systems, so that the complete telephone circuits set up on these systems can meet CCITT standards.

In order to take account of the variety of operating conditions and in particular the differences there may be in the size of the countries to be served, the CCITT has defined two categories of hypothetical reference circuits for telephony:

— a set of hypothetical reference circuits with a length of 2500 km,

— a hypothetical reference circuit with a length of 5000 km (see Recommendation G.215).

The former includes the following hypothetical reference circuits for telephony:

— on open-wire lines (see Recommendation G.311),

— on symmetric pair cable (see Recommendation G.322),

— on coaxial pair cable (see Recommendations G.332 to G.346 of sections 3.3 and 3.4).

The 5000 km hypothetical reference circuit is used in various types of carrier systems on coaxial cable and on radio relay systems.

The CCIR also has defined the following hypothetical reference circuits for telephony:

1) In line-of-sight radio-relay systems using frequency-division multiplex, with a capacity of 12 to 60 telephone channels or of more than 60 telephone channels (see Recommendation G.431 or CCIR Recommendations 391 [2] and 392 [3]);

2) On tropospheric-scatter radio-relay systems (see CCIR Recommendation 396 [4]);

3) For satellite systems (see CCIR Recommendation 352 [5]).

Each of these various hypothetical reference circuits has the same total length and they are all used in the same way. They are only a guide for planning carrier systems.

These hypothetical reference circuits allow designers to study through connection between different carrier systems at basic groups, supergroups, etc., as discussed in Recommendation G.211. Moreover, when they contain more than one pair of channel modulators and demodulators, they also allow the designers to study an international switched connection having the same total length.

3 homogeneous section

F: section homog`ene

S: secci´on homog´enea

A section without diversion or modulation of any channel groups, supergroups, etc., established on the system which is being considered except for those modulations or demodulations defined at the ends of the section.

All the hypothetical reference circuits defined above consist of homogeneous sections of equal length [6, 9 or 12 sections as the case may be].

It is assumed that at the end of each homogeneous section, the channels, groups, supergroups, etc., are connected through at random.

4 psophometric power

With the exception of the hypothetical reference circuits for satellite systems and for circuits of 5000 km.
The number is not specified for the tropospheric-scatter radio-relay systems.

F: puissance psophom´etrique

S: potencia sofom´etrica

Where square law addition (power addition) of noise can be assumed, it has been found convenient for calculations and design of international circuits to use the idea of psophometric power as defined below:

$$\text{psophometric power} = \frac{\mathit{psophometric\ \ voltage}\,)^2}{00}$$

or

$$\text{psophometric power} = \frac{\mathit{psophometric\ \ e.m.f.}\,)^2}{\times 600}$$

A convenient unit is the micro-microwatt or picowatt (pW), and this equation can then be given as follows:

$$\text{psophometric power} = \frac{(\text{psophometric e.m.f. in mV})^2}{.0024} \text{ (pW).}$$

References

[1] CCITT Recommendation *4-MHz valve-type systems on standardized 2.6/9.5-mm coaxial cable pairs* , Orange Book, Vol. III-1, Rec. G.338, ITU, Geneva, 1977.

[2] CCIR Recommendation *Hypothetical reference circuit for radio-relay systems for telephony using frequency-division multiplex with a capacity of 12 to 60 telephone channels* , Vol. IX, Rec. 391, Dubrovnik, 1986.

[3] CCIR Recommendation *Hypothetical reference circuit for radio-relay systems for telephony using frequency-division multiplex with a capacity of more than 60 telephone channels* , Vol. IX, Rec. 392, Dubrovnik, 1986.

[4] CCIR Recommendation *Hypothetical reference circuit for trans-horizon radio-relay systems for telephony using frequency-division multiplex,* Vol. IX, Rec. 396, Dubrovnik, 1986.

[5] CCIR Recommendation *Hypothetical reference circuits for telephony and television in the fixed satellite service* , Vol. IV, Rec. 352, Dubrovnik, 1986.

Recommendation G.213

INTERCONNECTION OF SYSTEMS IN A MAIN REPEATER STATION

(Geneva, 1964; further amended)

The CCITT finds it necessary to define separation points between various types of equipment, both in cable systems and in radio-relay systems. These separation points are defined below and the CCIR has adopted the same definitions when preparing its Recommendation 380 [1] (see also Recommendation G.423).

See definitions of Recommendation G.211.

1 Definition of telephony input and output points for the line link

These are points (marked *T* and *T* ‘ in Figure 1/G.213) located in principle in a main repeater station where the standard conditions given below are found at the output and input of a line link (comprising a cable system or radio link). These standard conditions permit interconnection with other line links or with telephony equipment (including, where appropriate, direct through-connection filters as well as translating equipment).

At such a point, *T* , on the receiving side, the following conditions apply:

1) All the telephony groups (groups, supergroups, mastergroups, etc.) are still assembled in the positions in the frequency spectrum which they occupy on the line.

2) All the line-regulating, monitoring or frequency-comparison pilots on the H.F. line are, or can be, suppressed (the recommended suppression attenuations are given in Recommendations G.242 and G.243), according to whether the station is at the end of a regulated-line section or not

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The interconnecting point between a radio-relay system and a long cable system is always the terminal of a regulated-line section (CCIR Recommendation 381 [2] and hence all these pilots are suppressed at that point. For the distinction between a ‘‘short’’ and a ‘‘long’’ cable system, see Recommendation G.423, § 1.2).

3) The relative level of all the telephony channels is independent of frequency, i.e. any de-emphasis network is included in the line equipment.

4) No special suppression of additional measuring frequencies is foreseen (CCITT Recommendation G.423 for cable systems, CCIR Recommendation 381 [2] for radio-relay systems).

A similar point *T* ' | is defined for the sending side, where the following conditions are met:

a) All the telephony groups (groups, supergroups, mastergroups, etc.) are still assembled in the positions in the frequency spectrum which they occupy on the line, except where use is made of direct through-connection filters provided as part of the line equipment.

b) [Follows from the situation at *T* according to condition 2) above.]

c) The relative level of all the telephony channels is independent of frequency, i.e. any pre-emphasis network is included in the line equipment.

d) The additional measuring frequencies are transmitted.

FIGURE 1/G.213, p.

General remarks

Note 1 — Figure 1/G.213 gives an example only.

Note 2 — If the station is within a regulated line section, provision must be made for the line-regulating pilots to be passed through, either by means of the telephony direct through-connection filter itself or by means of a special pilot through-connection filter. To cater for this case, and for the case where the station forms a boundary between two regulated line sections, a pilot input to, and output from, the line link, separate from the telephony input and output points *T* and T ‘, should be provided; these are points P and P ‘ in Figure 1/G.213.

Note 3 — (Applicable to all systems, irrespective of the number of channels):

When there is direct through-connection of part of the groups, supergroups, etc. with the aid of the direct through-connection filters fitted into the line equipment for this purpose, it is up to each Administration to fix the relative levels at the filter access points (which are different from the access point *T* and *T* ‘ mentioned above).

Note 4 — The levels at points *T* and *T* ‘ have been chosen so as to permit the insertion of the various direct through-connecting and translating equipments which may be necessary in the main station. The difference in level between points *R* and *T* and between points *T* ‘ and *R* ‘ allows for the cabling interconnecting these points, which may be at some distance from each other and, in favourable circumstances, for a blocking filter having only a small loss in the passband.

2 Definition of the points of international connection at baseband frequencies of a radio-relay system

The points of international interconnection at baseband frequencies, called *R* ‘ and *R* , form the input and output of a radio-relay system, conforming to CCITT Recommendation G.423 and CCIR Recommenda tion 380 [1].

At the output of the radio-relay system (point *R*), the following conditions are found in the baseband:

1) All the telephony groups (groups, supergroups, mastergroups, etc.), and the pilots (line regulating, frequency comparison and monitoring pilots) included in the baseband are assembled in the position in which they are transmitted, as defined in the CCITT and CCIR Recommendations mentioned above.

2) All the continuity and switching pilots and other signals transmitted in a radio-relay system outside the telephony band, inherent to the radio equipment, are suppressed in accordance with CCIR Recommendation 381 [2].

3) Any radio-relay protection switching shall be performed as part of the radio-relay system. With diversity reception, the combined output of the receivers used corresponds to point *R* .

4) Any de-emphasis networks are part of the radio equipment, so that the relative levels of the telephone channels are independent of frequency, within the limits of the tolerances stated in Note 7 of CCIR Recommendation 380 [1] (± | dB relative to the nominal value).

A similar point *R* ‘ is defined for the baseband input of a radio-relay system, where similar conditions are to be met.

3 Relative levels recommended by the CCITT at the telephony output and input (Points *T* and *T* ‘ in Figure 1/G.213)

At the interconnection points *T* and *T* ‘ for telephony defined in § 1 above, Table 1/G.213 shows the relative levels which are recommended for cable systems, each of which is defined by the maximum number of telephone channels that it can provide. (Similar levels are recommended by the CCITT and the CCIR for radio systems of corresponding capacity — see Recommendation G.423 and CCIR Recommendation 380 [1].)

The cable systems to which this Recommendation applies are modern systems with transistor equipment and to new versions of other systems previously standardized by the CCITT.

The recommended levels at *T* and *T* ‘ make it possible to insert all the translating or direct through-connecting equipment which may be necessary; this does not define the relative levels in translating and direct through-connecting equipment, which depend on other considerations.

H.T. [T1.213]

TABLE 1/G.213

Recommended relative levels for interconnection of various cable systems

{		{ {		
24, 36, 48	150 (bal.)	—23	—36	
60 120	150 (bal.) or 75 (unbal.)	—23	—36	
300	75 (unbal.)	—23	—36	
600, 960, 1200 1260	75 (unbal.)	—23 or —33	—36 or —33	See note
2700 See also Recommendations G.333 and J.77 [3] }	75 (unbal.)	—33	—33	{
3600 See also Recommendations G.334 and J.77 [4] }	75 (unbal.)	—33	—33	{
10 | 00	75 (unbal.)	—33	—33	

Note — For 600, 960, 1200 and 1260 channel systems Administrations have the choice between the alternative pairs of level shown for points *T* and *T* ‘ which apply in the following circumstances:

1) —23 dBr at point *T* , —36 dBr at point *T* ‘, where conformity with well-established equipment using similar levels is necessary;

2) —33 dBr at each of the points *T* and *T* ‘, in other cases, for example, to new stations wholly equipped with transistor equipments.

Table 1/G.213 [T1.213], p.

References

[1] CCIR Recommendation *Interconnection at baseband frequencies of radio-relay systems for telephony using frequency-division multiplex* , Vol. IX, Rec. 380, Dubrovnik, 1986.

[2] CCIR Recommendation *Conditions relating to line regulating and other pilots and to limits for the residues of signals outside the baseband in the interconnection of radio-relay and line systems for telephony* , Vol. IX, Rec. 381, Dubrovnik, 1986.

[3] CCITT Recommendation *Use of a 12-MHz system for the simultaneous transmission of telephony and television* , Vol. III, Rec. J.73.

[4] CCITT Recommendation *Characteristics of the television signals transmitted over 18-MHz and 60-MHz systems* , Vol. III, Rec. J.77.

Recommendation G.214

LINE STABILITY OF CABLE SYSTEMS

(Mar del Plata, 1968)

Line regulation has a threefold purpose:

1) to keep actual line relative levels within such limits that thermal or intermodulation noise never exceeds acceptable values;

2) to keep levels at the ends of regulated-line sections within such limits that regulators of the following multiplex equipment are able to function;

3) to ensure that regulation is precise enough to make it generally unnecessary to provide an automatic group regulator and/or supergroup regulator for the group, supergroup, etc., links set up on a single regulated-line section.

It appears that all three objectives will be secured if levels at the end of the longest regulated section envisaged are stabilized to ± | dB at any frequency in the band transmitted.

The CCITT therefore *unanimously recommends that:*

Designers of line-regulating systems take account of the daily and seasonal variations in temperature to which the cables and repeaters are likely to be subjected, the predictable ageing of components, and also the nominal range of variation of power supplies, assuming that appropriate precautions are taken in the placing of the cable, in the design of buildings and in regulation of power supplies.

As a design objective for the residual effects of sustained power and temperature variations, and the predictable ageing of components, over the ranges expected in any period between two successive manual adjustments, the change in insertion gain of a regulated-line section at any frequency in the transmitted band should not exceed 1 dB.

For the purposes of this Recommendation, it is assumed that a regulated-line section will not be longer than a homogeneous section of the hypothetical reference circuit applicable to the type of system considered and that the interval between two successive manual adjustments will be not less than a fortnight.

The variations in gain of a regulated-line section in service is also affected by maintenance operations and adjustments. The design objective excludes these effects.

Moreover, the dynamic stability of the regulating system should be such that any swinging of the gain is damped and at a suitable rate as a result of an abrupt change in pilot level. If, for example, the pilot level is suddenly increased by 2 dB at the origin of the regulated-line section, the pilot level must not increase or diminish by more than 2 dB at the end of the regulated-line section. The resulting fluctuations in pilot level must fall off progressively.

Note — It may be desirable to specify immunity of the regulating system to interference from components of television signals when transmitted.

Reference

[1] CCITT Recommendation *Stability of transmission* , Vol. IV, Rec. M.160.

Stability of transmission is also the subject of Recommendation M.160 of Volume IV [1].

Recommendation G.215

HYPOTHETICAL REFERENCE CIRCUIT OF 5000 km

FOR ANALOGUE SYSTEMS

(Geneva, 1980)

1 Composition of the hypothetical reference circuit

This hypothetical reference circuit is 5000 km long and applies to various types of carrier systems on coaxial cable and radio-relay systems, specially designed for very long international circuits. It has, for each direction of transmission, a total of:

— one pair of channel modulators which includes translation from the audio-frequency band to the basic group and vice versa;

— three pairs of group modulators, each pair including translation from the basic group to the basic supergroup and vice versa;

— six pairs of supergroup modulators, each pair including translation from the basic supergroup to a higher order modem and vice versa;

— twelve pairs of higher order modulators, each pair providing the necessary modulation stages to and from the line frequency.

Figure 1/G.215 shows the principle of the hypothetical reference circuit.

This hypothetical reference circuit consists of 12 homogeneous sections of equal length (see Recommendation G.212). Two homogeneous sections may be connected in tandem without translating equipment at the junction if the transmission system has suitable line regulating capability and does not introduce undesirable noise and crosstalk into any telephone channel.

figure 1/G.215, p.

2 Design objectives for circuit noise

The same noise values as for the 2500 km HRC apply (Recommendation G.222, § 1).

Note 1 — This design objective is in line with Recommendation G.123, ''Circuit noise in national networks'', which in § 2.1.1 recommends that the line noise in channels used to provide very long-distance circuits (over 2500 km) should not exceed 2 pW0p/km.

Although the noise objective for the 5000 km HRC is in principle agreed, some countries will not be soon in the position to install equipment of the desired performance, and will continue to use existing systems on the very long national and international circuits, according to established planning and design practices.

Note 2 — Designers are expected to fit their noise distribution curves fall below all §§ 1.1 and 1.2 of Recommendation G.222.

Note 3 — In applying these design objectives, §§ 2.4 through 2.7 of Recommendation G.222 should be taken into account.

The subdivision of the total noise between the various sources of noise is left entirely to the designer of the system, within the limits of 2500 pW0p for the terminal equipment and 7500 pW0p for the line. This allocation is intended to permit the use of modulating equipment meeting the maximum values recommended in Table 1/G.222 of Recommendation G.222 as indicated in Table 1/G.215.

H.T. [T1.215]

TABLE 1/G.215

lw(72p) | lw(72p) | lw(42p) | lw(42p) . lw(72p) | lw(72p) | lw(42p) | lw(42p) . Total: 2500 pW0p

Note — This Table assumes two stages of modulation in the higher modulator.

Table 1/G.215 [T1.215], p.

2.2 General recommendations

Recommendation G.221

OVERALL RECOMMENDATIONS RELATING TO CARRIER-TRANSMISSION | fR SYSTEMS

(amended at Geneva, 1972 and 1980)

1 Characteristics of complete circuits

The characteristics of complete circuits, measured between audio-frequency terminals (overall loss in terminal service and in transit service, frequency bands effectively transmitted and attenuation distortion, variation of overall loss with time, phase distortion, stability, crosstalk, etc.) should meet the general conditons for 4-wire telephone circuits indicated in Section 1 of the Series G Recommendations.

2 Linear crosstalk

2.1 *Overall requirements*

The requirements as regards crosstalk ratio between circuits in the case of telephony are the subjects of Recommendation G.134 [1] and the Recommendation cited in [2]; for go-to-return crosstalk the Recommendation cited in [3] applies.

As carrier transmission systems are also used for setting up sound-programme circuits, the relevant requirements given in the Series J Recommendations should be taken into consideration. Recommendation J.18 [4] gives general guidance on how the higher crosstalk ratios appropriate to sound-programme transmissions are achieved in a telephone network.

In any case the near-end crosstalk ratio between the two directions of transmission at all frequencies used for the regulating and measuring pilots on carrier systems should be not less than 40 dB.

2.2 *Intelligible crosstalk caused by intermodulation with a signal which is a multiple of 4 kHz*

Intelligible crosstalk may arise between circuits by way of intermodulation with a signal which is a multiple of 4 kHz, e.g. a line-regulating pilot. A design objective is that the intelligible crosstalk ratio in a single homogeneous section of the appropriate hypothetical reference circuit should be not less than 74 dB.

3 Noise transmitted between interconnected systems

A failure or malfunction in a chain of repeaters may lead to large values of noise in one or several signal bands being transmitted by that chain. It is known that such high noise levels are generally caused by the operation of particular types of automatic line regulators. Given that such high noise levels may be transmitted to other chain links, and may overload those to which they are interconnected, it is desirable and recommended that care should be taken in the future in order to avoid such troubles.

Possible methods of dealing with this problem are described in Supplement No. 4 [5].

In respect of radio-relay links, it will be the concern of CCIR to enumerate suitable precautions.

4 Single tone interference

The Recommendation cited in [6] indicates a limit for the single tone interference level in telephone circuits. Depending on the origin of such interferences, wide-band services and non-telephony services (e.g. sound-programme circuits, etc.) may also be affected. This should be considered when defining limits for transmission systems.

Practical experience shows that broadcasting transmitters are the main external source of single tone interference. In order to be usable under normal environmental working conditions, the carrier transmission equipment should be designed in such a way that it allows a certain electromagnetic field strength in its vicinity, caused by transmitters. A figure of 0.5 to 0.7 V/m within a station should be tolerated by equipment which is installed as normally specified and working under normal conditions. Where higher field strengths are

known to be expected, suitable screening measures in the building may have to be adopted. Special attention should also be given to the stating cabling including power distribution and to the wiring of distribution racks to prevent interferences from entering the equipment via these points.

Note — The Supplement No. 27 contains some information on possible measures to reduce effects from interference and on measuring methods concerning interference.

5 Total interference power

In addition to the above limitation of the single tone interference, it should be ascertained that the total interference power in each telephone channel within the band 300-3400 Hz, for each individual case of interference, should be lower than —65 dBm0.

References

[1] CCITT Recommendation *Linear crosstalk* , Vol. III, Rec. G.134.

[2] CCITT Recommendation *General performance objectives applicable to all modern international circuits and national extension circuits* , Vol. III, Rec. G.151, § 4.1.

[3] *Ibid.* , § 4.2.

[4] CCITT Recommendation *Crosstalk in sound-programme circuits set up on carrier systems* , Vol. III, Rec. J.18.

[5] *Certain methods of avoiding the transmission of excessive noise between interconnected systems* , Green Book, Vol. III-2, Supplement No. 4, ITU, Geneva, 1973.

[6] CCITT Recommendation *General performance objectives applicable to all modern international circuits and national extension circuits* , Vol. III, Rec. G.151, § 8.

Recommendation G.222

NOISE OBJECTIVES FOR DESIGN OF CARRIER-TRANSMISSION SYSTEMS

OF 2500 km

1 Design objectives in respect of noise produced by the line and the frequency division modulating equipment on hypothetical reference circuits of 2500 km for telephony

In order to ensure that multichannel carrier systems on cable and on radio-relay links shall comply with standards of performance considered as equivalent in respect of noise, the following design objectives should apply to the noise *at a zero relative level point* in any telephone channel having the same composition as the hypothetical reference circuit on such systems.

1.1 To ensure adequate performance in respect of telephone speech and signalling on cable systems, the mean psophometric noise power over one minute shall not exceed 10 | 00 pW0p.

1.2 To ensure adequate performance in respect of telephone speech and signalling on radio-relay links:

1.2.1 the mean psophometric noise power over one minute shall not exceed 10 | 00 pW0p for more than 20% of any month;

1.2.2 the mean psophometric noise power over one minute shall not exceed 50 | 00 pW0p for more than 0.1% of any month;

1.2.3 the unweighted noise power, measured or calculated with an integrating time of 5 ms shall not exceed 1 | 00 | 00 pW0 (10^{6} pW0) for more than 0.01% (10^{D}lF261^{4}) of any month.

Note — For carrier transmission systems with one-minute mean noise power distributions which are not well defined, the inclusion of another one-minute mean noise clause would be desirable to ensure equivalent performance for all systems. This clause would specify that:

The mean psophometric noise power over one minute shall not exceed 20 | 00 pW0p for more than 3% of any month.

This clause has not been specifically included because the CCIR has determined that for radio-relay links, the application of clauses 1.2.1 and 1.2.2 are sufficient to ensure, with high probability, that the additional clause will also be satisfied.

1.3 If it is intended to use amplitude-modulated voice-frequency telegraph equipment for 50 bauds conforming to the Series R Recommendations and to obtain the quality shown in Recommendation F.10 [1], the mean nonweighted noise power over 5 ms must not exceed 10^{6} pW0 during more than 0.001% (10^{D}lF261^{5}) of any month, nor more than 0.1% of any hour, for cable systems and for radio-relay links.

If frequency-modulated voice-frequency telegraph equipment operating at 50 bauds is used, it is to be expected that the quality specified in §§ 1.1 and 1.2 respectively above will be satisfactory as far as the telegraph transmission is concerned.

The conditions under which the above design objectives should apply are given in § 2 below.

2 Conditions in which the design objectives for hypothetical reference circuits apply

2.1 The values mentioned in § 1 above are design objectives and it is not intended that they should be quoted in specifications for equipment or used for acceptance tests. The noise on a homogeneous section of an actual carrier system is dealt with in Recommendation G.226.

The following Recommendations specify the conditions in which these general objectives apply to different types of system, account being taken of the special characteristics of each system:

— symmetric pair cable systems (Recommendation G.322);

— symmetric pair cable ‘‘12 + 12’’ systems (Recommendation G.326);

— 4-MHz systems (Recommendation G.338 [2]), 12-MHz systems (Recommendations G.332 and G.339), 18 MHz systems (Recommendation G.334) and 60 MHz systems (Recommendation G.333) on 2.6/9.5-mm coaxial pairs;

— systems on 1.2/4.4-mm coaxial pairs (Recommendations G.341, G.343, G.344, G.345 and G.346);

— radio-relay links using frequency-division multiplex (Recommendation 393 [3] of the CCIR).

In particular, Recommendation G.442 lays down objectives for the use of amplitude-modulation voice-frequency telegraphy used in line-of-sight radio-relay systems.

Tropospheric-scatter radio-relay systems should meet the objectives of this Recommendation, or other objectives, according to the circumstances of operation (see CCIR Recommendation 397 [4]).

Other objectives are recommended for systems providing 12 carrier circuits on an open-wire pair (see Recommendation G.311).

2.2 Designers are expected to fit their distribution curves to fall below both points given in § 1.2.1 and § 1.2.2 above.

2.3 In connection with § 1.2.2 above, the CCITT would have preferred to indicate a figure of 100 | 00 pW0p (average psophometric power over one minute at a zero relative level point), not to be exceeded during more than 0.01% of any month. On account of difficulties in measurement, a figure of 50 | 00 pW0p for 0.1% of any month has been shown.

2.4 Within each homogeneous section of a hypothetical reference circuit, the telephone channels will occupy the same position in relation to each other. Within these sections, certain intermodulation products (those of odd order) tend to add on the basis of linear addition of voltages, but between sections it may be considered that in respect of noise a power-additive law applies exclusively.

In a part of a hypothetical reference circuit consisting of one or more equal homogeneous sections, the one-minute mean noise power not exceeded during 20% of any month shall be considered to be proportional to the number of homogeneous sections involved.

2.5 In parts of a hypothetical reference circuit consisting of one or more equal homogeneous sections, the small percentage of any month in which the one-minute mean power may exceed the design objective for 0.1% of the time or less shall be regarded as proportional to the number of homogeneous sections involved. This principle also applies to the objective mentioned in § 1.2.3 above.

2.6 Although in principle it is to be understood that the general noise objectives are all-embracing, in practice it is recognized that there will be abnormalities from time to time which will result in additional noise sources becoming evident. Often, such extra contributions can be accommodated within the margin available within the system design. In other cases, no concern need be felt provided that such additional contributions are small compared to the general objective, for example, less than 10% of the power or probability of occurrence respectively.

In any case, all necessary precautions should be taken during the installation and putting into service of the systems so that noises of external origin are reduced to a negligible value of, at the most, 10% of the limits fixed as objectives.

2.7 Recommendation G.223 gives the other hypotheses which are recommended for the calculation of the noise on the hypothetical reference circuits for telephony.

3 Circuits more than 2500 kilometres long

3.1 The CCITT recognizes that in order to meet national and international noise performance objectives some large countries have found it necessary to introduce terrestrial FDM carrier transmission systems that are based on the hypothetical reference circuit described in Recommendation G.215. The noise performance objective for these systems corresponds approximately to 5000 pW0p on the 2500 km hypothetical reference circuit instead of the 10 | 00 pW0p mentioned in §§ 1.2.1 and 1.2.2 above. These values include the noise contributed by multiplex equipment.

3.2 The basic hypothetical reference circuit for satellite systems is defined in CCIR Recommendation 352, and provisional noise objectives appropriate to the design of such systems in consideration of the values contained in § 1 above, are contained in CCIR Recommendation 353 [6].

4 Design objectives for noise produced by modulating equipments and additional equipments

The general objectives mentioned in § 1 above include the noise produced by modulating and additional equipments. The mean psophometric power, which corresponds to the noise produced by all modulating equipment mentioned in the definition of the hypothetical reference circuit in question and by all additional equipment, should not exceed 2500 picowatts at a zero relative level point. This value of psophometric power refers to the whole of the noise due to various sources (thermal noise, intermodulation, crosstalk, power supplies, etc.). Its allocation among the various equipments can to a certain extent be left to the discretion of design engineers. However, to ensure a measure of agreement in the allocation chosen by different Administrations, the maximum values given in Table 1/G.222 are recommended for the modulating equipments.

The allocation of a large part of the noise to channel-modulating equipment is justified because these equipments are the most numerous in a network and therefore are constructed as economically as possible.

For the through-filters a noise objective of a maximum of 10 pW0p is recommended. This value refers to the nominal band of the through-connected groups; the noise outside that band must be considerably lower, to avoid a significant contribution of noise to channels situated in adjacent frequency bands.

For other units of additional equipment (regulating equipment, equalizers, standby switching equipment, etc.) a value of about 15 pW0p is indicated as a guideline to the designer.

The above statement does not apply to line standby switching equipment whose noise has to be considered together with that of the line.

The load assumption of through-filters and additional equipments should be in line with Recommendation G.223, G.228 and G.230. Account should be taken of the possible presence of additional signals outside the nominal frequency band arising from adjacent channels.

Table 1/G.222 (maintenu) T1.222, p.

References

[1] CCITT Recommendation *Character error rate objective for telegraph communication using 5-unit start-stop equipment* , Vol. II, Rec. F.10.

[2] CCITT Recommendation *4-MHz valve-type systems on standardized 2.6/9.5-mm coaxial cable pairs* , Orange Book, Vol. III-1, Rec. G.338, ITU, Geneva, 1977.

[3] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit for radio-relay systems for telephony using frequency division multiplex* , Vol. IX, Rec. 393, Dubrovnik, 1986.

[4] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit for trans-horizon radio-relay systems for telephony using frequency division multiplex* , Vol. IX, Rec. 397, Dubrovnik, 1986.

[5] CCIR Recommendation *Hypothetical reference circuits for telephony and television in the fixed satellite service* , Vol. IV, Rec. 352, Dubrovnik, 1986.

[6] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit for frequency-division multiplex telephony in the fixed satellite service* , Vol. IV, Rec. 353, Dubrovnik, 1986.

Recommendation G.223

ASSUMPTIONS FOR THE CALCULATION OF NOISE ON HYPOTHETICAL REFERENCE CIRCUITS FOR TELEPHONY

(Remark of Recommendation G.222, Volume III of the | Red Book,

amended at Geneva, 1964; further amended)

1 Nominal mean power during the busy hour

To simplify calculations when designing carrier systems on cables or radio links, the CCITT has adopted a *conventional* value to represent the *mean absolute power level* (at a zero relative level point) of the speech plus signalling currents, etc., transmitted over a telephone channel in one direction of transmission during the busy hour.

The value adopted for this mean absolute power level corrected to a zero relative level point is —15 dBm0 (mean power = 31.6 microwatts); this is the mean with time and the mean for a large batch of circuits.

Note 1 — This conventional value was adopted by the CCIF in 1956 after a series of measurements and calculations had been carried out by various Administrations between 1953 and 1955. The documentation assembled at the time is indicated in [1]. The adopted value of about 32 microwatts was based on the following assumptions:

i) mean power of 10 microwatts for all signalling and tones (Recommendation Q.15 [2], gives information concerning the apportionment on an energy basis of signals and tones);

ii) mean power of 22 microwatts for other currents, namely:

— speech currents, including echoes, assuming a mean activity factor of 0.25 for one telephone channel in one direction of transmission;

— carrier leaks (see Recommendations G.232, § 5; G.233, § 11; G.235, § 5); and the Recommendations cited in [3] and [4];

— telegraph signals, assuming that few telephone channels are used for VF telegraphy systems (output signal power 135 microwatts (the Recommendation cited in [5])) or phototelegraphy (amplitude modulated signal with a maximum signal power of about 1 milliwatt (the Recommendation cited in [6])).

On the other hand, the power of pilots in the load of modern carrier systems has been treated as negligible.

The reference to ‘‘the busy hour’’ in § 1 is to indicate that the limit (of —15 dBm0) applies when transmission systems and telephone exchanges are at their busiest so that the various factors concerning occupancy and activity of the various services and signals are to be those appropriate to such busy conditions.

It is not intended to suggest that an integrating period of one hour may be used in the specification of the signals emitted by individual devices connected to transmission systems. This could lead to insupportably high short-term power levels being permitted which give rise to interference for durations of significance to telephony and other services.

Note 2 — The question of reconsidering the assumptions leading to this conventional value arose in 1968 for the following reasons:

— changes in the r.m.s. power of speech signals, due to the use of more modern telephone sets, to a different transmission plan, and perhaps also to some change in subscriber habits;

— change in the mean activity factor of a telephone channel due, *inter alia* , to different operating methods;

— increase in the number of VF telegraphy bearer circuits and sound-programme circuits;

— introduction of circuits used for data transmission, and rapid increase in their number.

During several Study Periods these points have been under study and various Administrations carried out measurements of speech signal power and loading of carrier systems. The results are shown in Supplement No. 5. These results indicate that there is no sufficiently firm information to justify an alteration to the conventional mean value of —15 dBm0 (32 µW0) for the long-term mean power level per channel.

Indeed, the steps envisaged by Administrations to control and reduce the levels of non-speech signals indicate a tendency to limit the effect of the increase in the non-speech services.

As regards the subdivision of the 32 µW into 10 µW signalling and tones and 22 µW speech and echo, carrier leaks, and telegraphy, again there is no evidence which would justify proposals to alter this subdivision.

As a general principle, it should always be the objective of Administrations to ensure that the *actual* load carried by transmission systems does not significantly differ from the *conventional* value assumed in the design of such systems.

Note 3 — The CCITT has agreed to the following rules concerning the maximum permissible number of VF telegraph bearer circuits:

1) For a *12-channel system* , both the load capacity and the intermodulation requirements are determined by the statistics of speech; hence there is no reason to limit the number of channels in a 12-channel system which may be used as VF telegraphy bearer channels.

2) For a *60-channel system* , the load capacity is determined by the statistics of speech but the intermodulation requirements for a mixed VF telegraph and speech loading become controlling when the VF telegraph bearers exceed about 30% of the total. Hence it is possible, without change of specifications, to allow up to 20 channels in this system to be used for VF telegraphy.

3) For a *120-channel system* , about 12% of the total could be allowed for VF telegraph bearers. The number of reserve circuits for VF telegraphy is excluded from these limits for both 60- and 120-channel systems. The number of channels for these systems should be distributed more or less uniformly throughout the line-frequency band.

4) For *systems with 300 or more channels* , the CCITT is not yet able to define any specific limit, owing to the many complicated factors such as mean power, peak power, overload capacity, intermodulation, noise-performance and pre-emphasis, which have to be taken into consideration.

5) For *groups* and *supergroups* no conclusion could be obtained. From information available, it would be unwise, without special consideration, to exceed two VF telegraph systems per supergroup in a wideband system.

6) For *transmission systems not exceeding 1000 km* the permissible number of telegraph systems may be increased if the power per telegraph channel is reduced according to Table 1/G.223.

A similar table in respect of transmission systems longer than 1000 km cannot be drawn up at this time. There is evidence to suggest that for systems considerably longer than 1000 km a reduction in telegraph signal power gives rise to unacceptable levels of telegraph distortion and character error rates.

Table 1/G.223 (maintenu) T1.223, p.

2 Loading for calculation of intermodulation noise

2.1 It will be assumed for the calculation of intermodulation noise below the overload point that the multiplex signal during the busy hour can be represented by a uniform spectrum random noise signal, the mean absolute power level of which, at a zero relative flat level point, is given by the following formulae:

$$10 \log_{10} P(n) = (-15 + 10 \log_{10} n) \text{ dBm0 for } n \geq 240$$

and

$$10 \log_{10} P(n) = (-1 + 4 \log_{10} n) \text{ dBm0 for } 12 \leq n < 240,$$

n being the total number of telephone channels in the system and $P(n)$ the power of the random noise signal in milliwatts.

Examples are shown in Table 2/G.223 of the results given by these formulae for some typical values of n.

Table 2/G.223 (maintenu) T2.223, p.

These results apply only to systems without pre-emphasis and using independent amplifiers for the two directions of transmission.

2.2 For 2-wire systems having common amplifiers for the two directions of transmission ($n + n$ systems), it is necessary to assume a different conventional loading. When the relative levels are the same for both directions of transmission the conventional load is given by the following formulae:

$$10 \log_{10} P(n) = (-15 + 10 \log_{10} 2n) \text{ dBm0 for } n \geq 120$$

and

$$10 \log_{10} P(n) = (-1 + 4 \log_{10} 2n) \text{ dBm0 for } 12 \leq n < 120,$$

where

$P(n)$ is defined in § 2.1 above and n is the number of channels in each direction of transmission.

2.3 When use is made of a call concentrator having the effect of multiplying the number of circuits established on a system by a coefficient a, for the determination of the conventional load, the number of channels should be multiplied by a and the activity coefficient should remain unchanged (see also Note 5 below). The following formulae then replace those given in § 2.2 above:

$$10 \log_{10} P(n) = (-15 + 10 \log_{10} an) \text{ dBm0 for } an \geq 240$$

and

$$10 \log_{10} P(n) = (-1 + 4 \log_{10} an) \text{ dBm0 for } 12 \leq an < 240,$$

n being the total number of telephone channels in the system and $P(n)$ the power of the random noise signal in milliwatts.

Note 1 — The mean absolute power level of a uniform-spectrum random noise test signal deduced from these formulae may be used in calculating the intermodulation noise on a hypothetical reference circuit, when there is no overloading. It is considered that these formulae give a good approximation in calculating intermodulation noise when $n \geq$" 60. For small numbers of channels, however, tests with uniform-spectrum random noise are less realistic owing to the wide difference in the nature of actual and test signals.

Note 2 — In view of the conventional character of these calculations, it was not considered useful to take into account the power transmitted for programme transmissions over carrier systems. Moreover, the mean value of 0.25 was assumed for the activity factor of a telephone channel and it was not deemed useful to study any deviations from this mean.

Note 3 — Care must be taken in interpreting the results of tests with uniform-spectrum random noise loading, especially in systems in which the dominant noise contribution in certain channels arises from a particular kind of intermodulation product (e.g. A—B). In such cases, the weighting factor used in relating the performance of the channel to that under real traffic conditions must be carefully determined. The curve given by the transfer function of the network used to define the conventional telephone signal (see Recommendation G.227) may be used in this case to determine the weighting factor for the wideband signal.

Note 4 — The formulae in § 2.2 above for ($n + n$) type 12-channel systems are the same as those given in § 2.1 above (4-wire systems), assuming that the number of channels is doubled but that there is no correlation between the channel activities in each direction of transmission. For the purposes of this assumption, the fact that in an ($n + n$) system the two directions of transmission of a telephone circuit are not active at the same moment is ignored. Calculations have shown that the resultant error is negligible and in any case is on the safe side.

Note 5 — The formulae in § 2.3 above are only valid in the case when all channels are equipped with call concentrators. They are not applicable when only some of the channels are equipped with call concentrators, because the distribution of these channels generally will not be uniform over the band of the multiplex signal.

3 Component characteristics and levels

The values of the characteristics of circuit components and the levels to be used in calculations will be the nominal values.

Note — When specifying equipments, a reasonable margin should be allowed for the ageing of components and for tolerances on levels, supply voltages, temperature, etc.

4 Psophometric weights and weighting factor

For calculating psophometric power, use should be made of the *Table of psophometer weighting for commercial telephone circuits* which is given in Table 4/G.223.

If uniform-spectrum random noise is measured in a 3.1-kHz band with a flat attenuation/frequency characteristic, the noise level must be reduced by 2.5 dB to obtain the psophometric power level. For another bandwidth, *B* , the weighting factor will be equal to:

$$\left(2.5 + 10 \log_{10} \frac{B}{3.1\ kHz} \right) \text{dB}$$

When *B* = 4 kHz, for example, this formula gives a weighting factor of 3.6 dB.

5 Calculating noise in modulating (translating) equipments

(See also Recommendation G.230.)

5.1 For group, supergroup, etc., *modulating equipments* , in calculating *intermodulation noise* (below the overload point), the following conventional values, already accepted, will be assumed for the load at a zero relative level point:

— for 12-channel group modulators: 3.3 dBm0;

— for 60-channel supergroup modulators: 6.1 dBm0;

— for 300-channel mastergroup modulators: 9.8 dBm0.

5.2 The mean noise power in channel translating equipments due to interference from channels adjacent to the disturbed channel will be calculated as follows. In all the terminal equipment of the hypothetical reference circuit there are six exposures to adjacent-channel disturbance. Five of these disturbing channels will be assumed to carry speech-like loading signals each having a mean power of 32 µW, i.e. an absolute power level of —15 dBm0 per channel at a zero relative level point, while the sixth disturbing channel will be assumed to carry telegraphy, phototelegraphy or data transmission with a conventional loading of 135 µW applied at the zero relative level point, i.e. an absolute power of —8.7 dBm0 uniformly distributed over the frequency range 380 to 3220 Hz.

The conventional telephony signal defined in Recommendation G.227 may be used to simulate the speech signals transmitted on the disturbing channels.

Note — Limitation of crosstalk caused by channels adjacent to the disturbed channel is governed by an additional clause in the channel equipment specification (see Recommendation G.232, § 9.2). In addition, the power of signalling pulses is restricted by Recommendation G.224.

5.3 In all cases allowance should, of course, be made for thermal noise.

6 Overload point of amplifiers , the equivalent r.m.s. power of the peak of the multiplex signal and the margin against saturation

6.1 **overload point**

The overload point or overload level of an amplifier is at that value of absolute power level at the output at which the absolute power level of the third harmonic increases by 20 dB when the input signal to the amplifier is increased by 1 dB.

This first definition does not apply when the test frequency is so high that the third harmonic frequency falls outside the useful bandwidth of the amplifier. The following definition may then be used:

Second definition — The overload point or overload level of an amplifier is 6 dB higher than the absolute power level in dBm, at the output of the amplifier, of each of two sinusoidal signals of equal amplitude and of frequencies A and B respectively, when these absolute power levels are so adjusted that an increase of 1 dB in both of their separate levels at the input of the amplifier causes an increase, at the output of the amplifier, of 20 dB in the intermodulation product of frequency 2A—B.

6.2 equivalent r.m.s. sine wave power of the peak of a multiplex telephone signal

This is the power of a sinusoidal signal whose amplitude is that of the peak voltage of the multiplex signal. Figure 1/G.223 shows the equivalent peak power level in terms of the number of channels. Up to 1000 channels, it is derived from Curve B, Figure 7 of Reference [7] taking into account the conventional value (—15 dBm0) allowed by the CCITT for the mean power per channel instead of —16 dBm0, i.e. an increase of 1 dB. Numerical values are given in Table 3/G.223.

Table 3/G.223 (maintenu) T3.223, p.

For systems having a capacity higher than 1000 channels, the equivalent peak power level may be derived from the following formula:

$$10 \log_{10} P_{eq} = \left[-5 + 10 \log_{10} n + 10 \log_{10} \left(1 + \frac{5}{\sqrt{n}} \right) \right] \text{ dBm0}$$

where

P_{eq} is the equivalent r.m.s. sine wave power in milliwatts and

n the number of channels.

Table 3a/G.223 gives corresponding numerical values for a few typical numbers of channels.

The curve in Figure 1/G.223 and the formula for numbers of channels exceeding 1000 are for use when there is no amplitude limiter at the channel input and when there is no pre-emphasis in the overall band of the multiplex signal; other cases are being studied.

Note — Mathematical models which enable calculations of the equivalent peak power level of multiplex telephone speech signals are described in Supplement No. 22 at the end of present fascicle.

6.3 Margin against saturation

In planning, a margin of a few decibels should be maintained between the absolute level of the equivalent power of the peak of the multiplex signal and the amplifier saturation point, to allow for level variations, ageing, etc. A national practice to estimate the signal load margin of systems and equipments is shown in Supplement No. 26.

Multiplex signals different from telephony — It is stressed that § 6.2 above relates to systems designed for telephony only, i.e. for a channel loading as described in § 1 above. It should be realized that when the characteristics of the multiplex signal differ significantly from those assumed in § 1 above, additional margins against saturation may be required.

Figure 1/G.223, p.

H.T. [T4.223]

TABLE 3a/G.223

{ Number of chanel, *n* }	1260	1800	2700	3600	10 | 00
{ Equivalent peak power level (dBm0) }	27.5	29	30.5	31.5	36

Table 3a/G.223 [T4.223] p.

Table 4/G.223 (maintenu) 1T5.223, p.

Table 4/G.223 (maintenu) 2T5.223, p.

References

[1] *CCITT collected documents on the volume and power of speech currents transmitted over international telephone circuits* , Blue Book, Vol. III, Part 4, Annex 6, ITU, Geneva, 1965.

[2] CCITT Recommendation *Nominal mean power during the busy hour* , Vol. VI, Rec. Q.15.

[3] CCITT Recommendation *Characteristics of group links for the transmission of wide-spectrum signals* , Vol. III, Rec. H.14, § 2.3.

[4] CCITT Recommendation *Characteristics of supergroup links for the transmission of wide-spectrum signals* , Vol. III, Rec. H.15, § 2.3.

[5] CCITT Recommendation *Basic characteristics of telegraph equipments used in international voice-frequency telegraph systems* , Vol. III, Rec. H.23, § 1.2.

[6] CCITT Recommendation *Phototelegraph transmissions on telephone-type circuits* , Vol. III, Rec. H.41, § 2.3.

[7] HOLBROOK (B. | .) and DIXON (J. | .): Load Rating Theory for Multichannel Amplifiers, *Bell System Technical Journal* , **18** , No. 4, pp. 624-644, October 1939.

Recommendation G.224

MAXIMUM PERMISSIBLE VALUE FOR THE ABSOLUTE POWER LEVEL

(POWER REFERRED TO ONE MILLIWATT) OF A SIGNALLING | fR PULSE

The CCITT recommends that, for crosstalk reasons, the absolute power level of each component of a short duration signal should not exceed the values given in Table 1/G.224.

Table 1/G.224 (maintenu) T1.224, p.

Reference

[1] CCITT Recommendation *Maximum permissible value for the absolute power level of a signalling pulse* , Vol. VI, Rec. Q.16.

Recommendation G.225

RECOMMENDATIONS RELATING TO THE ACCURACY OF | fR CARRIER FREQUENCIES

(amended at Geneva, 1964, and Mar del Plata, 1968)

1 Accuracy of the virtual carrier frequencies on an international circuit or on a chain of circuits

This Recommendation is the same as Recommendation Q.16 [1]; it applies both to national and to international signalling systems.

As the channels of any international telephone circuit should be suitable for voice-frequency telegraphy, the accuracy of the virtual carrier frequencies should be such that the difference between an audio-frequency applied to one end of the circuit and the frequency received at the other end should not exceed 2 Hz, even when there are intermediate modulating and demodulating processes.

To attain this objective, the CCITT recommends that the channel and group carrier frequencies of the various stages should have the following accuracies:

Virtual channel carrier frequencies in group ± | 0^{D}lF261^{6}

Group and supergroup carrier frequencies ± | 0^{D}lF261^{7}

Mastergroup and supermastergroup carrier frequencies:

— for the 12-MHz system ± | | (mu | 0^{D}lF261^{8}

— for the 60-MHz system (above 12 MHz) ± | 0^{D}lF261^{8}

Experience shows that, if a proper check is kept on the operation of oscillators designed to these specifications, the difference between the frequency applied at the origin of a telephone channel and the reconstituted frequency at the other end hardly ever exceeds 2 Hz if the channel has the same composition as the 2500-km hypothetical reference circuit for the system concerned.

Calculations indicate that, if these recommendations are followed, in the 4-wire chain forming part of the hypothetical reference connection defined in Figure 1/G.103 there is about 1% probability that the frequency difference between the beginning and the end of the connection will exceed 3 Hz and less than 0.1% probability that it will exceed 4 Hz.

Note 1 — In small stations, i.e. in stations which do not need supergroup carrier frequencies, the accuracy of the group carrier may be ± | 0^{D}lF261^{6}, which is the same as for channel carrier frequencies.

Note 2 — The modulating frequencies appropriate to (n + n) systems should have the accuracies recommended in the relevant Recommendations:

Recommendation G.311 for 12-channel open-wire systems;

Recommendation G.361 for 3-channel open-wire systems;

Recommendations G.326 and G.327 [3] for (12 + 12) cable systems.

2 Measure of alignment of the master oscillators

The recommendation in § 1 above cannot be met without some measure of alignment of the master oscillators at the various stations in which modulation occurs.

Carrier-transmission systems are formed into ‘‘partial networks’’ extending over the whole or a part of a country. Synchronization of the master oscillators of a partial network is ordinarily based on national frequency comparisons; international comparisons may be made if necessary.

2.1 *National frequency comparisons*

It is necessary that, within the same partial network of coaxial carrier systems, the master oscillators in stations where frequencies are generated should be ‘‘coordinated’’. This ‘‘coordination’’ can consist of a control of one oscillator with respect to another to give one of the following three conditions:

1) synchronization, i.e. identical frequency and fixed phase relationship;

2) isochronization, i.e. identical frequency only;

3) differential control to correct differences between the frequencies at intervals.

Also, automatic devices can be used to give an alarm if the difference in frequency between the checking pilot and a local oscillator exceeds a certain fixed value.

The CCITT has not recommended any particular method of comparing or controlling the master oscillators at different stations, and ‘‘routine frequency comparison’’ of the master oscillators may be thought sufficient; this comparison being followed if necessary by automatic or manual regulation, the master oscillators in each partial network being compared periodically with a national

In fact, the chain considered for these calculations comprised 16 (instead of 12) modulator/demodulator pairs to allow for the possibility that submarine cables with equipments in conformity with Recommendation G.235 might form part of the chain. No allowance was made, however, for the effects of Doppler frequency-shift due to inclusion of a non-stationary satellite; values for this shift are given in CCIR Report 214 [2].

frequency standard, if possible.

The routine comparison of the frequencies generated by the master oscillators is made by means of a ‘‘frequency check pilot’’ transmitted to line for this purpose. It is not necessary to compare phases.

2.2 *International frequency comparisons*

The case may arise, either of a country that has a national frequency standard with no facilities for distributing it throughout the country (particularly in an area in which a coaxial carrier system is to be set up), or of a country that has no national frequency standard. Recommendation M.540 [4], describes methods by which such countries may obtain a standard frequency by radio, or may have a controlled frequency sent over a telephone circuit.

References

[1] CCITT Recommendation *Hypothetical reference connections* , Vol. III, Rec. G.103, Figure 1/G.103.

[2] CCITT Report *The effects of doppler frequency-shifts and switching discontinuities in the fixed satellite service* , Vol. IV, Report 214, Dubrovnik, 1986.

[3] CCITT Recommendation *Valve-type systems offering 12 telephone carrier circuits on a symmetric cable pair [(12 + 12) systems]* , Orange Book, Vol. III-1, Rec. G.327, ITU, Geneva, 1977.

[4] CCITT Recommendation *Routine maintenance of carrier and pilot generating equipment* , Vol. IV, Rec. M.540.

Recommendation G.226

NOISE ON A REAL LINK

1 Cable systems

It should be appreciated that designers are usually concerned, not with particular circuits or links, but with plant that will be used for the establishment of many links. It is not practicable for the CCITT to specify the performance of every real link that may be established, or for the designer to contemplate changing his design to suit the various lengths or other conditions on different real links. The CCITT has therefore defined hypothetical reference circuits, so that designers can be sure that, if their particular design of plant is used throughout a real circuit made up in the same way as a hypothetical reference circuit, the performance specified by the CCITT for the hypothetical reference circuit will be realized on that real circuit.

A real international link usually has a different make-up from that of the hypothetical reference circuit, and often includes equipments of different design. For each of these two reasons the performance to be expected from real links cannot be deduced uniquely from the Recommendations relative to hypothetical reference circuits.

However, on a real homogeneous section it must be expected that the noise power measured at the time of commissioning, and with a conventional load as defined in § 2 of Recommendation G.223, will be about the same as that calculated taking into account the particular composition of the real homogeneous section and the real parameters as well as the implications of Recommendation G.222, § 2.6. There should be no cause for anxiety unless the measured noise power exceeds the calculated power by an appreciable amount, which might indicate a fault somewhere in the equipment. In such a case, every effort should be made to reduce the measured noise power to a value of the same order as that calculated.

2 Radio links

See CCIR Recommendation 395 [1].

Reference

[1] CCIR Recommendation *Noise in the radio portion of circuits to be established over real radio-relay links for FDM telephony* , Vol. IX, Rec. 395, Dubrovnik, 1986.

Recommendation G.227

CONVENTIONAL TELEPHONE SIGNAL

(Geneva, 1964; amended at Mar del Plata, 1968)

1 Principle

For the calculation or measurement of crosstalk noise between adjacent channels and, generally speaking, when it is desired to simulate the speech currents transmitted by a telephone channel , the CCITT recommends that a conventional telephone signal be used, the main characteristic of which is a shaping network as a function of the frequency.

This network is defined by the following transfer coefficient as a function of the frequency:

Figure 1/G.227, p.

$$\left| \frac{E}{V} \right| = \frac{8400 + 91238\,p^2 + 11638\,p^4 + p\,(67280 + 54050\,p^2)}{00 + 4001\,p^2 + p^4 + p\,(36040 + 130\,p^2)}$$

where $p = \mathrm{j}\,\frac{f\,(\mathrm{Hz})}{000\,Hz}$, E and V are defined by Figure 1/G.227.

The response curve of the network is shown in Figure 2/G.227, and an example of the design is given in Figure 3/G.227 with relevant values.

Care is needed in applying this conventional signal to simulate speech loading, since the statistics of a Gaussian noise signal and of real speech are different. A speech-simulating generator for loading purposes is given in [1].

Figure 2/G.227, p.

Figure 3/G.227, p.

2 Example of network design

The network is made up of three bridged *T* sections with a constant characteristic impedance equal to R_0 ohms.

Figure 3/G.227 represents the network and indicates the values of the various components normalized to R_0.

A tolerance of ± | % can be allowed on the value of each component.

Note — If θ_1, θ_2, θ_3 are the ‘‘composite’’ transfer coefficients of sections 1, 2 and 3 respectively, we have:

$$\frac{f\,IE\ |}{V\ |} = e\,(*h = e^{\theta_1+\theta_2+\theta_3}$$

with $e^{\theta 1} = \dfrac{6+90p+46p^2}{+90p+p^2}$

with $e^{\theta 2} = \dfrac{0+11p}{0+p}$

with $e^{\theta 3} = \dfrac{0+23p}{0+p}$

with $p = \mathrm{j}\,\dfrac{fIf\,(\mathrm{Hz})}{000\,Hz}$

Composite loss equals the insertion loss in this particular case since the source and the load impedances are equal. The minimum composite loss of the complete network lies in the vicinity of 600 Hz and equals $a_0 \tilde{}$ 2.9 dB for this example.

The curve in Figure 2/G.227 represents, as a function of frequency, the composite loss of the network in Figure 3/G.227 relative to the minimum loss a_0.

3 Signal at the network input

The network may be energized either by a uniform-spectrum random noise signal or by a closely spaced harmonic series. In the latter case, the following precautions are necessary:

1) Spacing of the harmonics should not exceed 50 Hz.

2) The measuring instrument must have an adequate integrating time with respect to the fundamental period of the harmonic series. Types of CCITT instruments in general use, such as the psophometer, are believed to be satisfactory in this respect.

3) The peak/r.m.s. ratio of the signal should not exceed 3.5. This requirement may be achieved, in the case of a particular generator, by means of an associated phase-changing network.

4) The energizing signals (uniform-spectrum random noise and harmonic series) could lead to different results for subjective, e.g. aural assessments at the receiving end, and such measurements should not, therefore, involve the use of the conventional telephone signal generator. That apparatus would be used solely for objective measurements, in which a psophometer served as measuring instrument.

Reference

[1] CCITT — Question 5/C, Annex 2, Green Book, Vol. III, ITU, Geneva, 1973.

Recommendation G.228

MEASUREMENT OF CIRCUIT NOISE IN CABLE SYSTEMS

USING A UNIFORM-SPECTRUM RANDOM NOISE LOADING

(Geneva, 1964; further amended)

The CCITT,

considering that

(a) it is desirable to measure the performance of cable systems for frequency-division multiplex telephony under conditions closely approaching those of actual operation;

(b) a signal with a continuous uniform spectrum (white noise) has statistical properties similar to those of a multiplex signal when the number of channels is not too small;

(c) the use of a signal with a continuous uniform spectrum to measure the performance of such cable systems is already widespread;

(d) it is necessary to standardize the frequencies and bandwidths of the measuring channels to be used for such measurements;

(e) for reasons of international compatibility it is necessary to standardize the minimum attenuation and the bandwidth of the stop filters which may have to be used in the white-noise generator;

(f) the CCITT has indicated, for the planning of telephone circuits, a mean value of signal power in the baseband of a multiplex telephone system to be taken into consideration during the busy hour (Recommendation G.223),

recommends that

1 The performance of frequency-division multiplex cable systems should be measured by means of a signal with a continuous uniform spectrum in the frequency band used for the telephone channels.

2 The nominal power level of the uniform spectrum test signal should be in accordance with the conventional load, specified in Recommendation G.223. If applied at the point of interconnection of the system corresponding to *T* ‘ of Recommendation G.213, the absolute power levels of interest are shown in column 4 of Table 1/G.228.

2.1 The sending equipment should be capable of providing, at the output of an inserted bandstop filter, a loading level at least up to +10 dB relative to the nominal power level defined above.

2.2 Within the bandwidth corresponding to the baseband of the system under test, the r.m.s. voltage of the white noise spectrum measured in a band of about 2 kHz should not vary by more than ± | .5 dB. This degree of spectrum uniformity should be met in the level range up to +6 dB relative to the nominal power level, indicated in Table 1/G.228, column 4.

2.3 The white noise test signal should be available at the output of the sending equipment with a peak factor of about 12 dB with respect to the r.m.s. value.

3 The nominal effective cut-off frequencies (the cut-off frequencies of hypothetical filters having ideal square cut-off characteristics and transmitting the same power as the real filters) and tolerances for the bandpass filters proposed for the various bandwidths of systems to be tested, should be as specified in Table 2/G.228. To reduce the number of filters required, compromises have been made between the nominal effective cut-off frequency and the system bandwidth-limiting frequency in some cases. The tolerances ensure that consequent calibration errors do not exceed ± | .1 dB and errors in measurement of intermodulation noise do not exceed ± | .2 dB assuming system pre-emphasis of about 10 dB.

Table 1/G.228 (maintenu) T1.228, p.

Table 2/G.228 (maintenu 1 corr. par Montage) T2.228, p.

3.1 The discrimination of a lowpass filter should be at least 20 dB at a frequency more than 10% above nominal cut-off and at least 25 dB at frequencies more than 20% above nominal cut-off. The discrimination of a highpass filter should be at least 25 dB at frequencies more than 20% below nominal cut-off.

3.2 To limit discrimination against measuring channels, the spread of losses introduced by any pair of highpass and lowpass filters should not exceed 0.2 dB over a range of frequencies which includes the upper and lower measuring channels.

4 Values of the characteristics for the discrimination in each stop-band at the output of a sending equipment are given in Table 3/G.228. These characteristics are intended to apply over a temperature range from 10 **|** (deC to 40 **|** (deC;

5 When the receiving equipment is connected directly to a sending equipment provided with bandstop filters which only just meet the requirements of § 4 above, the ratio of the noise power indicated by the receiving equipment when the bandstop filter is bypassed, to that indicated when the filter is in circuit, should be a minimum of 67 dB; this requirement applies when a conventional load is applied. The minimum effective bandwidth of the receiver should be 1.7 kHz; the maximum reading of absolute noise power arising from leakage given by a receiver of 1.74 kHz effective bandwidth and which just meets the foregoing leakage requirement is —85.6 dBm0p.

6 Additional measuring channels may be provided by agreement between the Administrations concerned.

Note — In Annexes A and B some general information is given on the measuring procedures, the choice of filter characteristics, correction methods and accuracy objectives.

Table 3/G.228 (maintenu 1 corr. par Montage) T3.228, p.

ANNEX A

(to Recommendation G.228)

Outline of the white noise measuring method

A.1 *General principle*

The principal components of the measuring setup are shown in Figure A-1/G.228.

Figure A-1/G.228, p.

A.2 *Measuring procedures*

Two methods for assessing the noise performance of a transmission system are in widespread use:

A.2.1 *Measurement of noise power ratio (NPR)*

The noise power ratio

$$\text{NPR} = 10 \log \frac{fIW_A fR \,|}{fIW_B fR \,|} \text{ dB} = $$

?63*a*

(A-1)

is measured at various levels of P_s. The r.m.s. level meter serves as an indicator only. The value W_A is the noise power in the measuring channel without taking account of the effect of frequency gaps between groups of channels in actual operation.

In an N -channel system the following definitions are introduced:

P_s = N | (mu | fI$P_{C\backslash dH}$

$P_{C\backslash dH}$ = variable signal power per channel

$p_{C\backslash dH}$ = —15 dBm0 + ?63p = load level per channel

—15 dBm0 is the conventional load per channel according to Recommendation G.223 for systems with N ≥" 240 | (mu | 63p (dB) is the excess load relative to —15 dBm0

p_n = weighted noise power level (dBm0p) measured at point T in a 3.1 kHz telephone channel.

The measured NPR values are usually plotted, as shown in Figure A-2/G.228, as a function of the excess channel loading ?63p .

figure A-2/G.228, p.

The relation between NPR values measured on a channel and the weighted noise power level referred to a zero relative level point is: p_n = (— NPR — 18.6 — 10 log k + ?63p) dBm0p (A-2)

k = B /4N (B in kHz) is a correction factor which takes account of the effect of the frequency gaps between groups of channels in the transmission system.

Table A-1/G.228 gives examples of the correction for some N-channel systems:

H.T. [T4.228]

TABLE A-1/G.228

N	300	960	2700	10	00
10 log k (dB)	0.14	0.22	0.46	1.08

table A-1/G.228 [T4.228], p.

A.2.2 *Direct measurement of weighted noise power level*

With the particular choice of the effective receiver bandwidth

?63*f* = 1.74 kHz (= 3.1 kHz | (mu | 0 —0.25),

the weighted noise power P_n in a telephone channel is:

$P_n = W_B$ (see Figure A-1/G.228)

and the weighted noise level p_n referred to a point of zero relative level becomes:

$$p_n = \left[10 \log \frac{fIW_B fR}{mW} + n_2 (\mathrm{dBr}) \right] \mathrm{dBm0p} \tag{A-3}$$

In this case the receiver (component 7 of Figure A-1/G.228) must be a calibrated power level meter.

A.3 *Examples of investigations using the white noise measuring method*

Two kinds of investigations can be made on a system (with length *L*) between flat relative level points *T* ‘ and *T* one [case a)] investigates the effect on the noise performance of load deviations at the input of the system, whereas the other [case b)] indicates the influence of level misalignments along the transmission line:

a) The test signal noise power P_s is varied and the weighted noise level p_n is determined in dBm0p. The result is plotted as indicated in Figure A-3/G.228.

Alternatively to the indication of the noise level for system length *L* in dBm0p, the noise power could have been indicated in pW0p/km.

figure A-3/G.228, p.

b) The relative levels on the transmission line are varied by insertion of attenuators —?63*n* and +?63*n* at the input and output of the system as is illustrated in Figure A-4/G.228 which is an excerpt of Figure A-1/G.228.

figure A-4/G.228, p.

The test signal noise power P_s is set to the conventional value (—15 dBm0/4 kHz) at point *T* ' and is kept constant. The noise power level in the measuring channel is determined at point *T* as a function of the relative level at the repeater output, for example. The result is plotted as shown in Figure A-5/G.228.

figure A-5/G.228, p.

ANNEX B

(to Recommendation G.228)

Measuring accuracy considerations affecting the design of the measuring equipment

B.1 *Introduction*

The Recommendations relating to the measurement of circuit noise in systems artificially loaded with uniform spectrum random noise simulating FDM telephone signals were agreed after carefully coordinated studies by three CCI Study Groups concerned. The different Recommendations provided for the application of the white noise measuring method to cable systems (CCITT Recommendation G.228), radio-relay systems (CCIR Recommendation 399 [1]), satellite systems (CCIR Recommendation 482 [2]) and translating equipments (CCITT Recommendation G.230). The objective of the coordination was that the separately recommended measuring equipments should conform with common measuring accuracy objectives and, as far as possible, be compatible and interchangeable.

The overall accuracy objective of the measuring equipment when used for routine maintenance measurements is ± | dB. A higher accuracy of about ± | dB is desirable when measurements are made for the purpose of assessing the noise performance of a system in relation to required performance. This can be achieved by following certain procedures and applying corrections as described in B.4 and B.5 below.

This Annex states how certain characteristics of measuring equipments were related to measuring accuracy objectives; any future extensions of the Recommendations to provide for measurements on new transmission systems, as yet unstandardized, should take account of those relationships.

B.2 *Bandstop filters*

B.2.1 *Choice of centre frequencies*

In all cases the choice of nominal centre frequencies of band-elimination filters (i.e. of measuring channels) should take account of the need to minimize the combined discrimination of the pair of bandpass filters used when the bandstop filter provides a lower or upper measuring channel. Therefore, as a rule the centre frequency of a lower measuring channel should be at least 15% above the effective cut-off frequency of the highpass filter and the centre frequency of an upper measuring channel should be more than approximately 5% below the cut-off frequency of the lowpass filter involved. Under § 3.2 of the text of this Recommendation it is prescribed that ‘‘the spread of losses introduced by any pair of highpass and lowpass filters should not exceed 0.2 dB over a range of frequencies which includes the outer measuring channels’’.

B.2.2 *Leakage*

The discrimination of a bandstop filter in the neighbourhood of the centre frequency determines, jointly with the receiver selectivity the smallest noise-to-signal ratio that can be measured accurately, i.e. the ‘‘leakage’’ effect. The bandstop filter discrimination of 70 dB (Table 3/G.228) results in a ratio of the order of —67 dB being measured when the noise is actually negligible. Leakage effect in the receiver is adequately limited by requiring (see § 5 in the text of the Recommendation) that the NPR value should be a minimum of 67 dB when connected directly to a send equipment with bandstop filters which only just meet the discrimination requirements of Table 3/G.228 and when a conventional load of —15 dBm0/4 kHz is applied.

Note — According to Formula (A-2) of Annex A this value of NPR = 67 dB corresponds to a residual noise level of —85.6 dBm0p (i.e. 2.8 pW0p) at the most.

B.2.3 *Effective bandwidth*

The basic requirement for the stopband is the condition that the discrimination should be at least 70 dB in a bandwidth of at least 3 kHz. The effective bandwidths (approximately the 3-dB points) recommended in Table 3/G.228 have been found to be technically feasible and lie in the order of 5% or less of the system bandwidth with coil-capacitor type filters and are less than 0.5% with crystal-type filters. It would present economic difficulties to reduce the relative bandwidth of the coil-type filters or to increase the relative bandwidth of the crystal-type filters.

B.2.3.1 *Third order nonlinearity products*

The attenuation of the noise loading signal in the vicinity of the measuring channel introduced by a bandstop filter causes an under-indication reading, erring on the low side, of third order nonlinearity noise power in that measuring channel. This under-indication is directly proportional to the effective bandwidth of the elimination filter.

Assuming that procedures B.4.3 and B.4.4 below are both observed, the under-indication of third order products in a system using no pre-emphasis is about 0.05 dB for a top measuring channel filter, the effective bandwidth of which is 1% of the system bandwidth. The error associated with a particular filter is at its maximum when the filter provides the top measuring channel of a system. When the same filter is used in wider band systems (thus corresponding to an intermediate measuring channel of the system) its bandwidth is a smaller proportion of the system bandwidth and the associated error is smaller.

When pre-emphasis is used but total signal power is unchanged the error is increased by the ratio of the signal density near the measuring channel of the pre-emphasized system to that of the system without pre-emphasis.

The effective bandwidths of crystal-type bandstop filters are so small that their effect on measurement errors is negligible.

The recommended effective bandwidths for coil-capacitor bandstop filters (Table 3/G.228) are such that the under-indication of third order nonlinear noise powers, when the filters provide top measuring channels of systems without pre-emphasis, falls in the range 0.25 to 0.30 dB. This range of errors becomes 0.60 to 0.90 dB for systems emphasized by 8 to 10 dB as is the case in FDM radio-relay systems (CCIR Recommendation 275 [3]) or in wideband systems on coaxial cables.

B.2.3.2 *Second order nonlinearity products*

In long transmission systems third order nonlinearity products normally form a more significant proportion of the total system noise than those of second order. For this reason the recommended maximum effective bandwidths of bandstop filters have been determined on the basis of accuracy objectives for the measurement of third order nonlinearity products.

Nevertheless, measuring equipments may still be used for investigations of cases where second order nonlinearity products dominate. Corrections for known filter bandwidths may be made on the following basis:

a) Again assuming that procedures B.4.3 and B.4.4 below are observed, the error in a reading of second order nonlinearity products introduced by the bandstop filter is an excess reading, rather than the under-indication in the case of third order nonlinearity products.

b) The excess reading is directly proportional to the effective bandwidth of the bandstop filter expressed as a percentage of the system bandwidth. The approximate proportionality, assuming no system pre-emphasis:

— for measuring channels located near the lower limit of the system bandwidth, an effective bandwidth of 1% system bandwidth causes an excess reading of 0.05 dB for second order intermodulation noise power;

— for measuring channels located in the middle, or near the upper limit, of the system bandwidth, an effective bandwidth of 1% system bandwidth causes an excess reading of 0.1 dB.

c) The effect of system pre-emphasis in the case of a bandstop filter near the lower limit of the system bandwidth, i.e. where the density of second order nonlinearity products tends to be greatest, is to reduce the error attributable to a given filter bandwidth in the same proportion that the signal density at that frequency is reduced by pre-emphasis.

B.3 *Bandpass filters*

In order to reduce the number of different filters, compromises have been made in some cases between the nominal effective cut-off frequency and the system bandwidth limiting frequency (cf. § 3 of the text).

For the larger systems there may also be a significant difference between the frequency bandwidth $4N$ kHz (N being the system capacity expressed in telephone channels) and the system bandwidth (Table 2/G.228).

Both these facts are taken into account by the correction factor k introduced in equation (A-2) of Annex A and in Table A-1/G.228.

The recommended tolerances on the nominal values of cut-off frequencies are such that the actual and nominal bandwidths of the signal load cannot differ by more than 1%. This ensures that calibration errors (in NPR measurements) due to this particular imperfection do not exceed about 0.05 dB.

The tolerances on the effective lowpass cut-off frequencies are in all cases less than 1.0% of the nominal system bandwidth and in most cases less than 0.8%. A difference of 0.8% leads to an error, in third order nonlinearity noise measurement, of 0.1 dB, this allowing for a pre-emphasis of 8 dB. Even allowing for a greater degree of pre-emphasis, the maximum error from this cause should not exceed 0.15 dB.

B.4 *Procedures for high accuracy measurements*

The following measuring procedures are recommended for high accuracy type of measurements, for example checks that transmission system noise performance objectives are being achieved.

B.4.1 *Signal load adjustment*

The loading power should be adjusted to the nominal value by means of a true r.m.s. level measuring device. The maximum error, including reading error, should not exceed ± | .15 dB.

B.4.2 *Receiver calibration*

B.4.2.1 Using the NPR method (§ A.2.1) the receiver should be set with reference to the received signal immediately before insertion of a bandpass filter.

B.4.2.2 Using the direct noise power measuring method (§ A.2.2) the receiver calibration error could be decreased to ± | .15 dB at the particular measuring slot by checking the reading with the aid of a white noise signal and a d.c.-calibrated true r.m.s. level meter.

Note — The accuracy of measurements related to the zero relative level point (dBm0p or pW0p) also depends on how precisely the relative level at the measuring point (n_2 of Figure A-1/G.228) is known.

B.4.3 *Insertion of bandstop filters*

Only one bandstop filter should be inserted at a time. This limits errors in measurement of intermodulation noise.

B.4.4 *Readjustment of signal load*

Normally, the signal load should be readjusted to the nominal value after the insertion of a bandstop filter. When measurements are specifically to investigate second-order intermodulation, or when this is known to dominate, greater accuracy is obtained by readjusting only for the specified passband insertion loss of the bandstop filter and not for the loss of spectrum energy in the measuring slot.

Note — The effect of the measuring slot bandwidth is negligible with crystal-type bandstop filters.

B.4.5 *Measurement at the receiver*

B.4.5.1 Using the NPR method the noise power ratio is now measured as the change required in the setting of an attenuator (?63*a* in Figure A-1/G.228) to restore the pointer of the indicating instrument to the original setting.

B.4.5.2 Using the direct measuring method the weighted noise level can be read in dBmp (or pWp) from the instrument. Optional means may be provided, e.g. to shift the calibration by setting a switch to the relative level n_2 of the measuring access point *T* so that the dBm0p or pW0p values are indicated.

B.5 *Corrections for high accuracy measurements*

The effects of the following error sources can be reduced by applying corrections to the measured values:

B.5.1 *Receiver calibration in connection with NPR method*

B.5.1.1 *Irregularity of the noise source*

The tolerance for the spectrum regularity is ± 1.5 dB. A calibration table (or curve) should be available for each noise generator.

B.5.1.2 *Errors of effective system bandwidth*

A correction in the conversion of NPR values into noise levels (in dBm0p) by application of the correction factor k in equation (A-2) allows first, for the difference between nominal occupied bandwidth of the system under test and actual bandwidth *B* between bandpass filter effective cut-off frequencies and secondly, for the difference between nominal occupied bandwidth and the total bandwidth actually occupied by telephone channels (i.e. 4*N* kHz).

B.5.1.3 *Passband attenuation distortion of bandpass filters at the measuring frequency*

The corrections in §§ B.5.1.1 and B.5.1.2 should ensure calibration to an accuracy of ± | .2 dB.

B.5.2 *Bandstop filter effects*

If coil-capacitor type bandstop filters are used, it might be worthwhile to assess the error of the measured intermodulation noise due to the effective bandwidth of these filters. To this end the rules quoted in B.2.3.1 and B.2.3.2 above should be applied.

Approximate corrections for this error are thus possible when the proportion of third- and second-order intermodulation noise has been determined.

B.6 *Limitations of the noise loading measurement technique*

B.6.1 Very low noise levels of less than about —83 dBm0p (about 5 pW0p) cannot be expected to be measured with an error of less than 2 dB, where the inherent noise leakage of the white noise measuring set is at the limit corresponding to NPR ≥" 67 dB as explained in B.2.2 above.

B.6.2 Although the measurements made at the specified frequencies may confirm that the design objectives are met, the noise performance of a system between these frequencies cannot always be inferred accurately from these measurements. Whether this interpolation is justified or not has to be established for the system under consideration. An approximate indication of the frequency dependency can be gained from the frequency characteristic of the basic noise (without loading) which can be measured with the aid of a selective level meter and continuously varying the frequency. The total noise performance of a system may be evaluated, when necessary, by carrying out measurements using additional test equipment.

Bibliography on accuracy of white noise measuring methods

MUELLER (M.): Noise loading test errors due to finite slot width, *Data and Communications design* , pp. 20-24, March-April 1973.

SPINDLER (W.): Noise loading measuring procedures and error sources, *Telecommunications* , pp. 32C-32F, July 1974.

References

[1] CCIR Recommendation *Measurement of noise using a continuous uniform spectrum signal on frequency-division multiplex telephony radio-relay systems* , Vol. IX, Rec. 399, Dubrovnik, 1986.

[2] CCIR Recommendation *Measurement of performance by means of a signal of a uniform spectrum for systems using frequency-division multiplex telephony in the fixed-satellite service* , Vol. IV, Rec. 482, Dubrovnik, 1986.

[3] CCIR Recommendation *Pre-emphasis characteristic for frequency modulation radio-relay systems for telephony using frequency-division multiplex* , Vol. IX, Rec. 275, Dubrovnik, 1986.

Recommendation G.229

UNWANTED MODULATION AND PHASE JITTER

(Geneva, 1972, further amended)

1 Unwanted modulation by harmonics of the power supply and other low frequencies

1.1 *Requirements on carrier transmission systems*

To enable the limit indicated in the Recommendation cited in [1] to be met, it is recommended that a minimum side component attenuation of 45 dB should be obtained when a signal is transmitted over a channel having the same composition as the 2500 km hypothetical reference circuit for the system concerned.

This limit is subdivided as indicated in §§ 1.2 and 1.3 below into allocations to terminal and to line equipment.

1.2 *Combined effect due to all translating equipment*

The combined effect due to all translating equipment on the hypothetical reference circuit should correspond to a minimum side component attenuation of 48 dB.

For each translating equipment, send and receive side taken separately, and measured at the signal output, a side component attenuation of at least 63 dB should be obtained under normal operating conditions. Under adverse power supply conditions a minimum of 60 dB should be met. It is expected that then an overall value of 48 dB, indicated above, will only rarely be exceeded.

Note — The above requirements are derived from the hypothetical reference circuits for the 4 MHz, 12 MHz and 60 MHz systems. The same figures may be applied to other systems provided that their hypothetical reference circuit does not differ significantly from those referred to above.

1.3 *Combined effects due to all line equipment*

The combined effects due to all line equipment on the hypothetical reference circuit should correspond to a minimum side component attenuation of 48 dB.

Line equipments can be subject to two types of interference which will cause side components on a transmitted signal:

— Effects from power supplies (for example, a residual mains frequency ripple may be superimposed on the d.c. power feeding current). These are potentially systematic on the complete length of the circuit.

— Effects from voltages caused by induction (for example, from railway traction currents). They are not expected to occur as systematically as the effects from the power supplies.

The influence caused by *power supply ripple* should be such that a minimum side component attenuation of 51 dB is observed for the combined effect of all line equipment on the hypothetical reference circuit. It is recommended that on a single power feeding section, the side component attenuation should not be less than 51 + 10 log k dB, where k is the number of power feeding sections on the hypothetical reference circuit.

Note — Based on the assumptions that some power feeding sections may be powered from battery supplies and that adverse cumulation over the full length of the hypothetical reference connection is unlikely, it can be expected that the limit of 51 dB will be observed with a high probability.

The influence caused by *induced voltages* should be such that a minimum side component attenuation of 51 dB is observed for the combined effects of all line equipment on the hypothetical reference circuit. However, voltages caused by induction vary considerably with time. The effect of a source of induction is very often confined to one power feeding section. It seems very unlikely that the induced voltage reaches its maximum value in more than one section at the same instant.

It is recommended that the r.m.s. value of the longitudinal voltage in a power feeding section caused by induction under normal operating conditions (excluding short circuits and arcing on railways, etc.) should not exceed 150 volts. (This limit has been recommended regarding safety aspects and is contained in [2]. It seems reasonable to adopt the same value for the present purpose.)

Calculations indicate that an allowance of 6 dB for the combined effect of several sections under the influence of induction should cover the majority of likely cases. It is therefore recommended that a minimum side component attenuation of 57 dB should be observed on a power feeding section under the influence of the maximum allowed induced voltage. It is estimated that then the value of 51 dB on a circuit of 2500 km would only be exceeded in rare circumstances and infrequently, particularly in view of the fact that only a fraction of the total length would be exposed to interference by induction.

2 Phase jitter due to translating equipments

For each translating equipment, send and receive sides taken separately, a phase jitter on a signal should not exceed 1° peak-to-peak when measured on the output of the equipment. The measurement should be of all phase jitter components on each side of the signal in the frequency band 20-300 Hz, i.e. equivalent to the frequency band indicated in Recommendation 0.91 [3].

Note 1 — The above requirement is derived from a consideration of data signals on a telephone-type circuit over a 2500-km hypothetical reference circuit. Conforming to this requirement will ensure a high probability that the overall phase jitter from this source will not exceed 6° peak-to-peak. This performance will also ensure a high probability that for telephone speech transmission the phase jitter will be below the detection threshold of a majority of listeners.

Note 2 — In practice it is expected that phase jitter of the magnitude given above will occur only on translating equipments using high frequency carriers and that correspondingly lower phase jitter will be caused by translating equipment using lower frequency carriers.

Note 3 — Where the phase jitter is caused mainly by random noise a peak-to-peak/r.m.s. ratio of 10 should be assumed.

References

[1] CCITT Recommendation *General performance objectives applicable to all modern international circuits and national extension circuits* , Vol. III, Rec. G.151, § 7.

[2] CCITT manual *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines* , Chapter IV, §§ 6, 7 and 71, ITU, Geneva, 1963, 1965, 1974, 1978.

[3] CCITT Recommendation *Essential clauses for an instrument to measure phase jitter on telephone circuits* , Vol. IV, Rec. O.91.

2.3 Translating equipment used on various carrier-transmission systems

Recommendation G.230

MEASURING METHODS FOR NOISE PRODUCED BY MODULATING EQUIPMENT AND THROUGH-CONNECTION FILTERS

(Geneva, 1976 and 1980)

Considering the provisions of Recommendation G.222, § 4 and the assumptions for the calculation of noise of Recommendation G.223, the following methods for measuring the noise produced by modulating equipments are recommended:

1 12-channel translating equipments

For the measurement of noise produced by 12-channel translating equipments, eleven incoherent noise random signals with a normal (Gaussian) level distribution and with a power distribution according to Recommendation G.227 should be used. As a provisional value, the peak/r.m.s. ratio of each of the noise signals should be about 12 dB. The allocation on the 12-channel inputs of the conventional load of 2140 µW0 (+3.3 dBm0) should be as follows:

1 channel being measured 0 µW0
2 adjacent channels at 32 µW0 (—15 dBm0) each 64 µW0
9 channels at 230 µW0 (—6.4 dBm0) each 2070 µW0
2134 µW0

2 Higher order translating equipments

2.1 *Allocation of loading*

For the measurement of noise produced by higher order translating equipments (groups, supergroups, etc. translating equipment), the values for the allocation of the conventional load to the different translating equipments are given in Table 1/G.222.

The number of incoherent band-limited white noise signals is assumed to be equal to the number of the input ports of the groups, supergroups, etc. translating equipment under measurement. In certain circumstances, however, the number of noise signals may be smaller than the number of group input ports.

2.2 *Measuring frequencies*

The measuring frequencies in Table 1/G.230 are recommended.

table 1/G.230 (maintenu) T1.230, p.

2.3 *Filter characteristics*

The following filter characteristics are recommended:

2.3.1 bandpass filters (see Table 2/G.230);

2.3.2 bandstop filters (see Table 3/G.230).

Note — Measuring frequencies of Table 1/G.230 and filter characteristics of Tables 2/G.230 and 3/G.230 (with the exception of the 70-kHz filter) are the same as in CCIR Recommendations 399 [1] and 482 [2] and CCITT Recommendation G.228 used for line system arrangements. Annex B to Recommendation G.228 deals with the subject of corrections, if any, to be applied to measurements to allow for filter effects.

table 2/G.230 (maintenu) T2.230, p.

H.T. [T3.230]

TABLE 3/G.230

Bandstop filters

{	{ { Notes 70 dB	55 dB	30 dB	3 dB	0.5 dB	
| 70	±1.5	± 1.7	± 2.0	± 5	± 10	
| 98	±1.5	± 1.8	± 2.1	± 4	± 9	a)
| 31	±1.5	± 2.7	± 4.0	± 17	± 30	
| 34	±1.5	± 3.5	± 7.0	± 15	± 48	b)
1 | 02	±1.5	± 4.0	± 9.0	± 27	± 90	a)
1 | 48	±1.5	± 4.0	±11.0	± 35	±110	b)
1 | 30	±1.5	± 4.2	±14.0	± 48	±155	a)
3 | 86	±1.5	± 1.8	± 3.5	± 12	±100	b)
3 | 86	—	±15.0	±30.0	±110	±350	
9 | 73	±1.5	± 2.7	± 5.8	± 18	±250	
11 | 00	±1.5	± 3.0	± 7.0	± 20	±300	b)

a) CCIR Recommendation 482 [2].

b) CCIR Recommendation 399 [1].

table 3/G.230 [T3.230], p.

2.4 *Measuring procedures*

The measuring procedures should comply with Recommendation G.228. Measurements must be carried out with the regulators, if any, not included and with the levels at the nominal value.

Note — Some Administrations have chosen for groups and supergroups not being tested in conformance with Table 1/G.230 higher values of the load, but only for testing equipments with some margin to take account of the application where higher than nominal activity is to be expected.

As a consequence, in such cases, higher noise limits have to be admitted than those indicated in Recommendation G.222, § 4).

3 Through-connection filters

3.1 *Allocation of loading*

For the measurement of noise produced by through-connection filters the values for the allocation of the conventional load according to Table 2/G.223 to the different filters are given in Table 4/G.230.

H.T. [T4.230]

TABLE 4/G.230

Filter for the basic Band of the noise spectrum (kHz) } Level of the noise power (dBm0) }	{ {	
Group | 12 to | 52 | 60 to | 08 } + 6.1 (=ˆ | 60 channels) + 3.3 (=ˆ | 12 channels) }	{ {	
Supergroup | 60 to 1 | 96 | 16 to | 52 } + 9.8 (=ˆ | 00 channels) + 6.1 (=ˆ | 60 channels) }	{ {	
Mastergroup + 12.3 (=ˆ | 30 channels) }	| 16 to 2 | 00	{
Supermastergroup 15 supergroup assembly	4 | 70 to 17 | 00 | 16 to 8 | 60	+ 17.6 (=ˆ 1800 channels) + 17.6 (=ˆ 1800 channels)

Note 1 — Group and supergroup through-connection filters require two measurements. One with ''broadband loading'' with components outside the pass-band, and an additional one with loading in the passband only. Since in these cases the number of transmitted channels is smaller than 240 (the range where the power level of the conventional load is not proportional to 10 log 1 0 | fIn , see § 2.1 of Recommendation G.223) the proportional part of the broadband loading transmitted in the passband gives a loading which is lower than the conventional load for 12 or 60 channels respectively.

Note 2 — The choice of the correct load figure for the measurement of the noise produced by the through-supermastergroup filter requires careful consideration bearing in mind that band limiting filters for a bandwidth complying with actual load conditions are not available.

Table 4/G.230 [T4.230], p.

3.2 *Measuring frequencies*

See § 2.2.

3.3 *Filter characteristics*

Highpass and lowpass filters complying with Table 2/G.228 and [3] can be used to limit the frequency of the noise spectrum. For bandstop filters, see Table 3/G.230.

3.4 *Measuring procedures*

The measuring procedure should comply with Recommendation G.228. For through-group and through-supergroup filters, two measurements have to be carried out in the appropriate measuring slots in the passband.

References

[1] CCIR Recommendation *Measurement of noise using a continuous uniform spectrum signal on frequency-division multiplex telephony radio-relay systems* , Vol. IX, Rec. 399, Dubrovnik, 1986.

[2] CCIR Recommendation *Measurement of performance by means of a signal of a uniform spectrum for systems using frequency-division multiplex telephony in the fixed satellite service* , Vol. IV, Rec. 482, Dubrovnik, 1986.

[3] CCIR Recommendation *Measurement of performance by means of a signal of a uniform spectrum for systems using frequency-division multiplex telephony in the fixed satellite service* , Vol. IV, Rec. 482, Table I, Dubrovnik, 1986.