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INTERNATIONAL AUTOMATIC AND SEMI-AUTOMATIC WORKING

TRANSMISSION CHARACTERISTICS OF AN ANALOGUE INTERNATIONAL EXCHANGE

ITU-T Recommendation Q.45 *bis*

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation Q.45 *bis* was published in Fascicle VI.1 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation Q.45 *bis*

TRANSMISSION CHARACTERISTICS OF AN ANALOGUE INTERNATIONAL EXCHANGE

1 Introduction

1.1 *General*

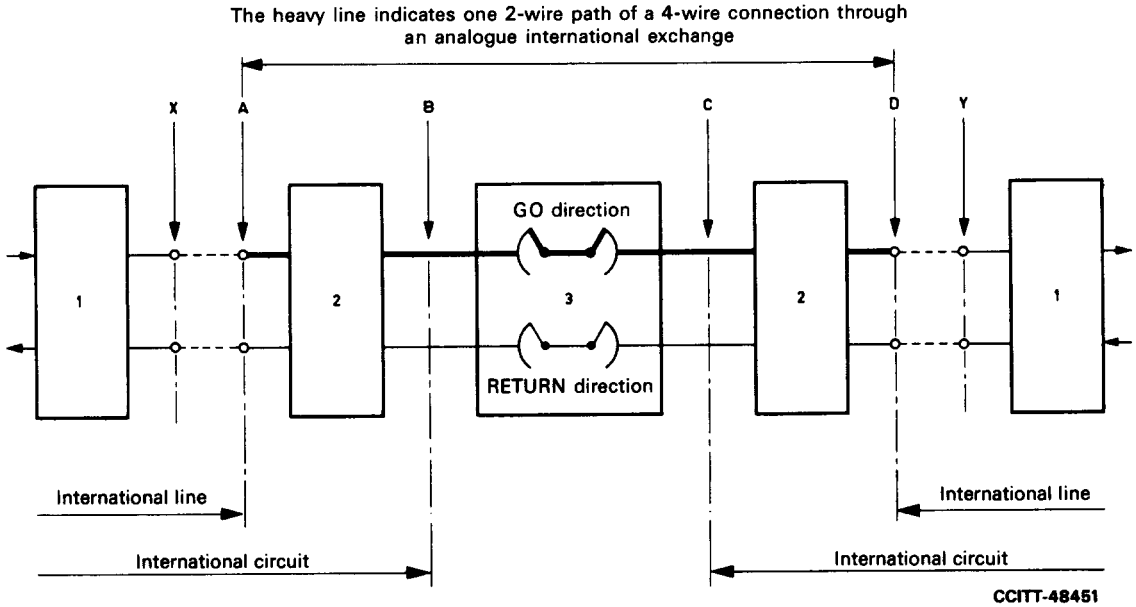
1.1.1 The concern of this Recommendation is the transmission performance of an analogue international exchange in terms of design objectives [1]. Related commissioning objectives [1] may be based on this Recommendation.

For the purposes of this Recommendation an analogue international exchange is a collection of equipment regarded as an entity by the Administration concerned. In the case of an analogue international transit exchange, it extends from the end of the incoming international line (point A of Figure 1/Q.45 *bis)* to the beginning of the outgoing international line (point D of Figure 1/Q.45 *bis).*

Exchange testing uses measuring points at boundaries of the same exchange individually agreed upon.

In contrast to exchange testing, circuit testing [2] is recommended between circuit access points expected to be located at or near by the actual analogue switching points (points B or C of Figure 1/Q.45 *bis*). For the purpose of circuit line-up and maintenance procedures, automatic international exchanges should be provided with circuit test access points.

Applying this Recommendation due account should be taken to the different constitution of the section of transmission under test compared to circuit testing [2].



1 = channel translating equipment
2 = incoming and outgoing relay set
3 = automatic switching equipment

Note – Between points X and A and points D and Y, there may be equipment such as echo suppresors, compandors, equalizers, line signal receivers, etc., in addition to the cabling.

FIGURE 1/Q.45 *bis*

Analogue international exchange

1.1.2 The essential transmission requirements for an international exchange are:

a) The transmission loss through the exchange should be substantially constant with time and independent of the routing through the exchange.

b) Crosstalk and noise contribution should be negligible compared with other transmission sections in a world-wide connection [3].

c) The distortion introduced should be small. These include attenuation distortion, non-linear distortion and intermodulation products.

d) Impedance and balance with respect to earth at the points in the international exchange to which the lines are connected should be closely controlled.

1.1.3 This Recommendation applies to analogue automatic 4-wire international exchanges. It is desirable that it should also apply to analogue national 4-wire exchanges.

The following requirements are intended to be used only for type tests, acceptance tests, or for special investigations. They do not constitute a complete specification. Generally the recommended tests should be conducted on a sampling basis.

1.2 *Definitions*

1.2.1 **connection through an analogue international exchange**

A connection through an analogue international exchange comprises the 4-wire speechpath between the exchange boundaries denoted by points A and D of Figure 1/Q.45 *bis*. However with exception of crosstalk all transmission requirements are addressed to the 2-wire path of each direction. The GO direction is indicated by a heavy line in Figure 1/Q.45 *bis* and referred to as a typical section of transmission in the context of this Recommendation.

1.2.2 *Reference points*

1.2.2.1 **exchange input and output ports**

An exchange input and output port has to be defined for unidirectional measuring access. For the GO direction of transmission indicated by a heavy line in Figure 1/Q.45 *bis*, the boundary at the point A constitutes the input port and the boundary at the point D constitutes the output port respectively. For the RETURN direction of transmission the constitution is approached vice versa.

The exact location of each of the points A and D, and hence of input and output ports depends on national practice and therefore it is unnecessary for the CCITT to define it. Only the national authority responsible for each international transit exchange can fix the location of these points and thus define the boundaries of the exchange concerned.

1.2.2.2 **virtual analogue switching points (VASP)**

The virtual analogue switching points are theoretical points. They are fixed by convention as points where two circuits are considered to be directly connected without any additional loss or gain [4, 5]. Depending on the transmission loss T of the circuits to be connected the relative levels at the virtual analogue switching point can be different for the incoming and outgoing direction respectively. The relative levels agreed upon by CCITT are shown in a hypothetical arrangement in Figure 2a/Q.45 *bis*. The corresponding relative levels at actual switching points may differ in values, as for example indicated in Figure 2b/Q.45 *bis*.

1.2.3 *Relative levels*

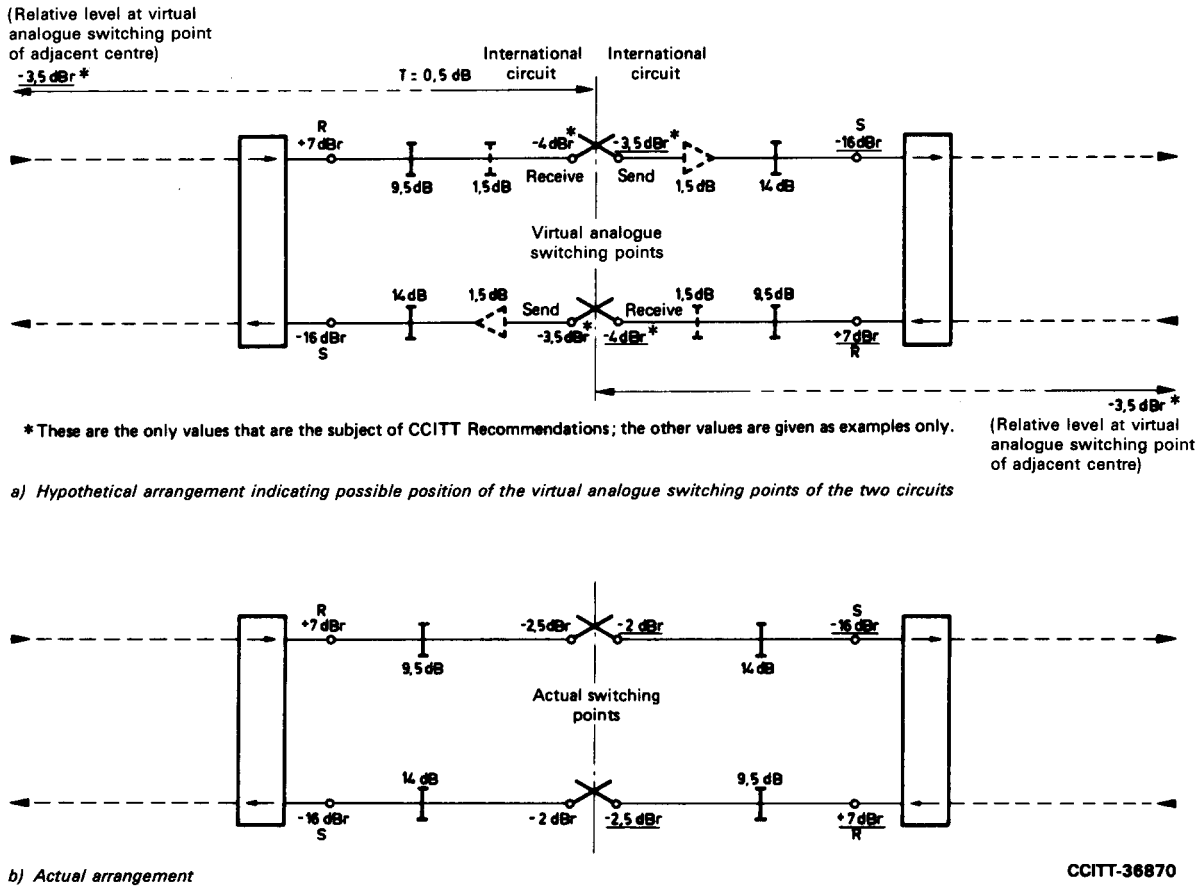
1.2.3.1 **nominal relative levels at exchange boundaries**

For the GO direction of transmission indicated by the heavy line in Figure 1/Q.45 *bis:*

- the nominal relative level at the exchange input port at point A is designated L_i;
- the nominal relative level at the exchange output port at point D is designated L_o.

For the RETURN direction of transmission the input port with its nominal relative level L_i is located at point D and the output port with its nominal relative level L_o is located at point A.

The values of the nominal relative levels L_i and L_o may be different for each 2-wire path of a 4-wire connection through the analogue international exchange.



Note – Underlined values of relative level refer to the circuit on the right of the point concerned. Values of relative level not underlined refer to the circuit on the left of the point concerned. In an actual switching centre the virtual analogue switching points would not physically exist.

FIGURE 2/Q.45 *bis*

Example showing a simplified representation of a transit connection in an international exchange with actual arrangement and possible location of virtual analogue switching points

(The recommended levels of channel translating equipment are stated according to Table 2/G.232, case 2)

1.2.3.2 **nominal relative levels at virtual analogue switching points**

The nominal relative levels at the virtual analogue switching points are defined to assure stability and to assist maintenance procedures [3] [4].

The difference of the nominal relative level at the end of the incoming 2-wire path and the nominal international through-connecting level, which is by convention -3.5 dBr, is the stability loss T assigned to a 2-wire path of a 4-wire circuit. By the value of this loss T the nominal transmission loss of a 2-wire path of a connection through an analogue international exchange is referred to its virtual analogue switching point.

1.2.4 *Measurement conditions*

1.2.4.1 **reference frequency**

The nominal reference frequency, on which relative levels, transmission loss, loss-frequency distortion etc. are

based, is 800 Hz or 1000 Hz alternatively [5].

Note - Since 1020 Hz is the recommended nominal frequency for techniques using digital processes this frequency should be preferred to harmonize into the evolving digital network [6].

1.2.4.2 **impedance**

Measurements shall be made under nominally matched conditions, i.e. the exchange boundaries are terminated with their nominal exchange impedance.

1.2.4.3 **test levels at exchange boundaries**

At the nominal reference frequency, test levels are defined in terms of the apparent power relative to 1mW. At frequencies different from the nominal reference frequency, test levels are defined as having the same voltage as the test level at the nominal reference frequency. Measurements are based on the use of a test generator with a frequency-independent e.m.f. and which has an impedance equal to the nominal impedance.

1.2.5 *Transmission loss*

1.2.5.1 **nominal transmission loss**

A connection through an analogue international exchange (see Figure 1/Q.45 *bis*) is established by connecting an input port located at one exchange boundary to an output port located at another exchange boundary in both directions.

The nominal transmission loss of a 2-wire path of a connection through an exchange is equal to the difference of the relative levels at the input and the corresponding output:

$$NL = (L_i - L_o) \text{ dB}$$

Note - The nominal transmission loss of the exchange may be different in the GO and RETURN direction of transmission.

1.2.6 **loss distortion with frequency**

The loss distortion with frequency is the logarithmic ratio of output voltage at the reference frequency, $U(\text{Ref})$, divided by its value at frequency f, $U(f)$:

$$LD = 20 \log \left| \frac{U(\text{Ref})}{U(f)} \right|$$

(See Supplement No. 1 to Volume VI, Fascicle VI.5, CCITT [6].)

2 VF-parameters of a connection through the exchange

2.1 *Impedance*

2.1.1 *Nominal value*

The nominal impedance at the input and output ports located at points A and D of Figure 1/Q.45 *bis* shall be 600 ohms, balanced.

2.1.2 *Return loss*

The return loss of one port located at point A or D of Figure 1/Q.45 *bis* has to be measured against the nominal impedance whilst all other ports of the connection through the exchange are terminated with the nominal impedance.

At any frequency from 300 to 600 Hz the return loss should be not less than 15 dB. The corresponding value from 600 to 3400 Hz should be not less than 20 dB.

2.1.3 *Impedance unbalance about Earth*

The impedance unbalance about Earth is measured as longitudinal conversion loss (LCL) according to Figure 1/O.9 [16] and as longitudinal conversion transfer loss (LCTL) according to Figure 2/O.9 [16] at the interfaces located at points A and D of Figure 1 /Q.45 *bis* using Z = 600 ohms and ZL = 150 ohms.

The measured values should not be worse than:

300- 600 Hz: 40 dB

600-3400 Hz: 46 dB

Note - Some Administrations guided by their knowledge of local conditions may feel a need to specify a value of impedance unbalance about Earth for a lower frequency, for instance, 50 Hz.

2.2 *Values of relative levels L_i and L_o*

2.2.1 *Basic nominal values*

Basic nominal values for the input level L_i and the output level L_o of a connection through an analogue international exchange are given in Table 1/Q.45 *bis.* For the purpose of demonstration, these values are valid under the following hypothetical assumptions:

- there is no transmission impairment between the points X and A and the points D and Y of Figure 1/Q.45 *bis;*
- the nominal relative levels L_i and L_o are determined by the corresponding nominal relative levels of the channel translating equipment recommended for two cases in Table 2/G.232 [7] corrected by the nominal per-channel loss of the international circuit, T = 0.5 dB.

TABLE 1/Q.45 *bis*

Basic nominal values of relative levels at the exchange boundaries of a connection through an analogue international exchange

Relative level	Channel translating equipment	
	Case 1	Case 2
L_i	+ 4 dBr	+ 7 dBr
L_o	-14.5 dBr	-16.5 dBr

Nominal values of relative levels will differ in practice from these basic nominal values by the impact of various equipment being inserted and the necessary cabling to interconnect the channel translating equipment to the exchange boundaries. Due account should be taken of this impact in specifying corresponding nominal relative levels, especially by cable length between points X and A and points D and Y in Figure 1/Q.45 *bis.*

2.2.2 *Offset of mean actual values*

The actual value of the output relative levels depend on the tolerances of components, i.e. mainly attenuation pads, and on the routing of a connection through an exchange via the switchblock (Points B and C in Figure 1/Q.45 *bis).*

The offset of the mean value of the distribution of the actual output relative levels L_o should be very close to zero but does not need to be specified.

2.2.3 *Dispersion of actual values*

The dispersion of actual values of the output relative level L_o is mainly due to the diversity of paths in the switchblock. The standard deviation of a representative distribution of the actual output relative levels measured at the nominal reference frequency should be as small as practicable. For purpose of calculation a value of 0.2 dB may be assumed.

In order to confirm this value, it is considered sufficient that for purposes of design and acceptance testing, the difference between the actual relative output levels at the nominal reference frequency of the shortest and longest paths from point B to point C in Figure 1/Q.45 *bis* in no case exceeds 0.8 dB. For a practical assessment of the average value of the actual relative output level, the influence of the switchblock between points B and C can be achieved using the arithmetically computed mean of the maximum and minimum actual relative output levels.

These values apply for connections routed directly, and once only, through the switchblock. If special re-entrant trunking arrangements are used, requiring the connection to pass through the switchblock twice (this may be a convenient way to extend the availability of the switching network or to introduce additional equipment, e.g. echo suppressors), the distribution of the actual relative output levels will be increased to lower values. In view of this, the re-entrant technique should not be used to such an extent as to decrease significantly the mean value of the actual relative output level distribution.

2.3 *Basic nominal values of transmission loss*

In accordance with the definition in § 1.2.5.1 and the basic nominal values of relative levels quoted in § 2.2.1 the following basic nominal values of transmission loss result for the purpose of demonstration:

case 1 : NL = +4 dB - (-14.5) dB = 18.5 dB

case 2 : NL = +7 dB - (-16.5) dB = 23.5 dB.

2.4 *Response to frequency and input level*

2.4.1 *Loss distortion with frequency*

The loss distortion with frequency according to the definition in § 1.2.6 measured on any 2-wire path of connection through the exchange between points A and D of Figure 1/Q.45 *bis* should lie within the following limits:

300- 400 Hz: -0.2 dB to +0.5 dB

400-2400 Hz: -0.2 dB to +0.3 dB

2400-3400 Hz: -0.2 dB to +0.5 dB.

2.4.2 *Variation of output level with input level*

The actual output level measured on any 2-wire path of a connection through the exchange between points A and D of Figure 1/Q.45 *bis* should follow the input level with a variation not more than 0.2 dB in the range of the input level from -40 dBm0 to +3.5 dBm0, using the reference frequency.

2.4.3 *Group delay distortion with frequency*

According to the definition of group delay [9], the group delay distortion measured on any 2-wire path of a connection through the exchange between points A and D of Figure 1/Q.45 *bis* over the frequency band 600 to 3000 Hz should not exceed 100 microseconds.

2.4.4 *Intermodulation*

The intermodulation products shall be measured on any 2-wire path of a connection through the exchange between points A and D of Figure 1 /Q.45 *bis.*

The intermodulation products to be taken into account for end-to-end multifrequency signalling and for data transmission are those of the third order, of type $(2f_1-f_2)$ and $(2f_2-f_1)$ where f_1 and f_2 are two signalling frequencies.

For a measurement of the intermodulation products, the two frequencies applied to an input are f_1 = 900 Hz and f_2 = 1020 Hz (see [8]). With each frequency f_1 and f_2 at a level of -6 dBm0, the difference at the output between the level of either frequency f_1 or f_2 and the level of either of the intermodulation products at $(2f_1-f_2)$ or $(2f_2-f_1)$ should be at least 40 dB.

2.5 *Noise*

For a 4-wire international exchange, noise measurements should be performed on a connection through the exchange between points A and D of Figure 1/Q.45 *bis* during the busy hour [10]. Each port should be terminated with 600 ohms. The noise should be measured at the output port of each 2-wire path and should be referred to a point of zero relative level. Thus in Figure 1/Q.45 *bis* the noise in the 2-wire path of the GO direction is measured at point D and the noise in the 2-wire path of the RETURN direction is measured at point D and the noise in the 2-wire path of the RETURN direction is measured at point A. A sufficient variety of connections should be chosen to ensure that the measurements are representative of the various possible routes through the exchange.

2.5.1 *Weighted noise*

The mean value of the psophometrically weighted noise over a long period during the busy-hour should not exceed - 67 dBm0p (200 pW0p).

2.5.2 *Unweighted noise*

Unweighted noise has to be measured with a device having a uniform response curve throughout the frequency band 31.5 Hz-16 kHz [11].

The mean value of the unweighted noise over a long period during the busy-hour should not exceed -40 dBm0 (100,000 pW0).

2.5.3 *Impulsive noise*

For measurement procedure of impulsive noise see Annex A of this Recommendation.

Noise counts should not exceed 5 counts in 5 minutes at a threshold level of -35 dBm0.

Note - Figure 3/Q.45 *bis* shows the maximum number of impulsive noise counts acceptable in a 5-minute period.

2.6 *Crosstalk*

Crosstalk should be measured in exchanges at a frequency of 1100 Hz in accordance with Recommendation G.134 [12].

2.6.1 *Crosstalk between different connections*
(Inter-connection crosstalk)

In an analogue international 4-wire exchange the signal to crosstalk ratio measured at points A and D of Figure 1/Q.45 *bis* between any 2-wire paths of different 4-wire connections through the exchange should be 70 dB or better.

This limit of 70 dB should normally apply to the most unfavourable case, in which two connections have parallel paths throughout the exchange. It should be noted that this does not occur in practice, because normal cabling layout in such that when, at one switching stage, two connections use adjacent switches, in the following stage the two connections generally use switches which are not adjacent.

2.6.2 *Go-to-return crosstalk of the same connection*
(Intra-connection crosstalk)

The signal-to-crosstalk ratio between the GO and RETURN 2-wire path of the same 4-wire connection through the exchange should be 60 dB or better.

3 Use of cables specified by the IEC

The cables for telephone exchanges in accordance with IEC (International Electrotechnical Commission) publication 189 [13] will meet the electrical characteristics required by the CCITT (especially as regards crosstalk) for ordinary exchanges, but this may no longer hold good for larger exchanges with considerable lengths of cable.

In accordance with Recommendation G.231 [14], it will be for the Administrations or the contractors to check whether standard cables will be satisfactory in equipping an exchange which requires telephone cables of exceptional length.

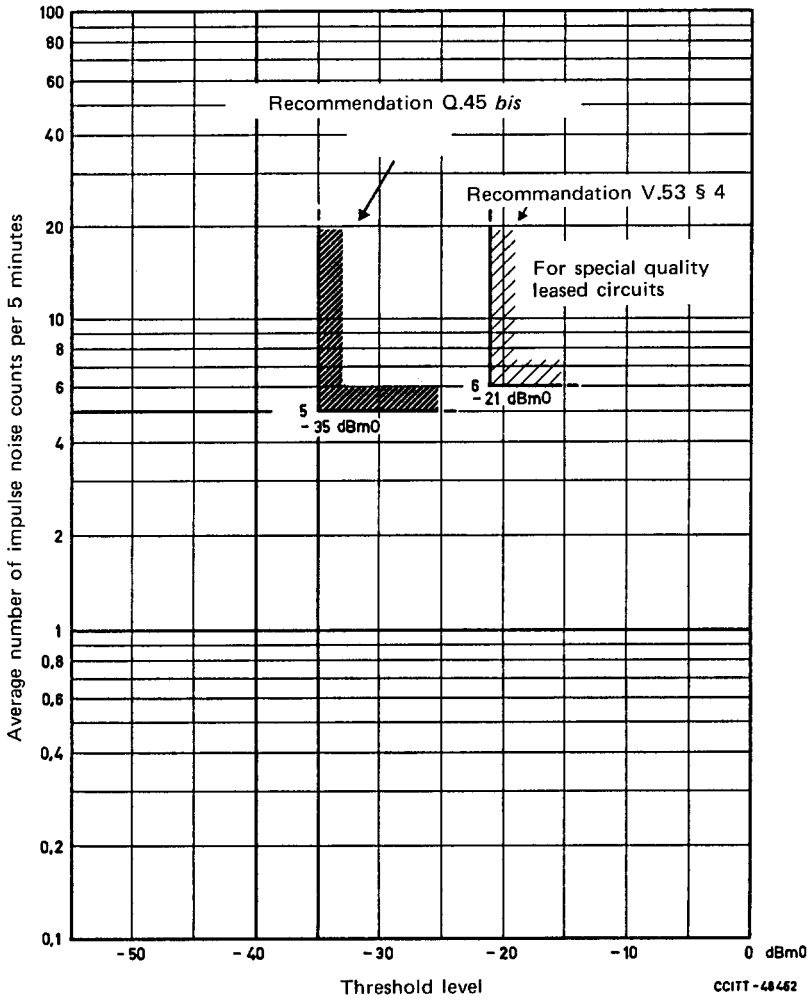


FIGURE 3/Q.45 *bis*

Acceptable noise counts for 4-wire exchanges

ANNEX A

(to Recommendation Q.45 *bis*, § 2.5.3)

Procedure for impulsive noise measurement

A.1 A test circuit should be formed by setting up a connection across the switching unit and terminating the connection on the exchange input by the nominal impedance and on the exchange output by the impulse measuring device in parallel to the terminating nominal impedance. Those terminated ports should be at points A and D in the diagram of Figure 1/Q.45 *bis* which includes the switching equipment of the exchange. Where it is the desire of an Administration, measurements may be made at points X and Y if precautions are taken to ensure that the result apply only to the automatic switching equipment, signalling equipment, echo suppressors, relay sets, pads and cabling of the exchange.

A.2 The measurements should be made using the device specified in Recommendation O.71 [15]. The 600-3000 Hz filter network should be in the circuit.

A.3 The measurements should be made at times when the probability of noise occurring is at its highest, that is normally during the busy-hour.

A.4 The time of observation for each test should be five minutes.

Note - The number of different test circuits set up through the exchange for measuring should take into account the size and complexity of the switching unit and should be representative for all various routes through the exchange. See also the documents cited in [15] and [17].

References

[1] CCITT Recommendation *Transmission performance objectives and Recommendations,* Vol. III. Fascicle III.1, Rec. G.102, §§ 3 and 4.

[2] CCITT Recommendation *Circuit testing,* Vol. IV, Fascicle IV.1, Rec. M.110, § 1.

[3] CCITT Recommendation *The transmission plan,* Vol. III, Fascicle III.1, Rec. G.101, §§ 2.1 and 5.4.

[4] CCITT Recommendation *Loudness ratings (LR) in an international connection,* Vol. III, Fascicle III.1, Rec. G.111, § 1.1.

[5] CCITT Recommendation *The transmission plan,* Vol. III, Fascicle III.1, Rec. G.101, § 5.3.5.

[6] CCITT Recommendation *Transmission characteristics of digital exchanges,* Vol. VI, Fascicle VI.5, Recs. Q.551 and Q.553 (including Supplement No.1).

[7] CCITT Recommendation *12-channel terminal equipment,* Vol. III, Fascicle III.2, Rec. G.232, Table 2/G.232.

[8] CCITT Recommendation *Characteristics of compandors for telephony,* Vol. III, Fascicle III.1, Rec. G.162, § 5.2.

[9] CCITT Definitions: *Group delay,* Vol. I, Fascicle I.3 (Terms and definitions)

[10] CCITT Definitions: *Busy-hour,* Vol. I, Fascicle I.3 (Terms and definitions)

[11] CCITT Recommendation *Psophometer for use on telephone-type circuits,* Vol. IV, Fascicle IV.4, Rec. O.41, Figure 1/O.41

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

[13] Publication 189 of the IEC.

[14] CCITT Recommendation *Arrangement of carrier equipment,* Vol. III, Fascicle III.2, Rec. G.231.

[15] CCITT Recommendation *Impulsive noise measuring equipment for telephone-type circuits,* Vol. IV, Fascicle IV.4, Rec. O.71.

[16] CCITT Recommendation *Measurement arrangements to assess the degree of unbalance about Earth,* Vol. IV, Fascicle IV.4, Rec. O.9.

[17] *Measurements of impulsive noise in a 4-wire telephone exchange,* Green Book, Vol. IV-4, Supplement No. 7, ITU, Geneva, 1973.