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GENERAL CHARACTERISTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

PLANNING OF MIXED ANALOGUE – DIGITAL CIRCUITS (CHAINS, CONNECTIONS)

Supplement 29 to ITU-T Series G Recommendations

(Previously "CCITT Recommendations")

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FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

Supplement 29 to ITU-T Series G Recommendations was revised by the ITU-T Study Group XII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

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CONTENTS

		Page
1	General	1
2	Planning principles	1
3	Objectives for the mixed analogue/digital chain of 4-wire circuits	2
3.4	Attenuation/frequency distortion	2
3.5	Group delay distortions	3
3.6	Non-linear distortions	3
3.7	Noise (total distortion)	4
3.8	Impulse noise	7
3.9	Short-time interruptions, phase jitter, amplitude and phase hits	7
3.10	Error performance	7
References		11
Annex A – Definitions		11
Appendix I –	Influence of errors in digital 2048 kbit/s streams on the noise in voice-frequency mixed circuits	14
I.1	Introduction	14
I.2	Noise power in a PCM voice-frequency circuit due to digital errors	15
I.3	Conclusion	18
References (to Appendix I)		19
Appendix II –	Calculation method of MOS equivalent to noise due to quantization distortion	19
Appendix III –	The effect of errors in 2048 kbit/s digital streams on appearance of impulse noise in mixed voice-frequency circuits	20

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Supplement 29

PLANNING OF MIXED ANALOGUE-DIGITAL CIRCUITS (CHAINS, CONNECTIONS)

(Melbourne, 1988; amended at Helsinki, 1993)

(referred to in Series G Recommendations)

1 General

In the period of transition from a fully analogue to a fully digital network, mixed analogue-digital circuits, chains and connections will take place on international and national networks for a fairly prolonged time.

The definition of notions of "mixed circuits, chains and connections" and examples of their possible structures are given in Annex A.

Structure of mixed circuits and moreover that of connections and chains, may be highly complex in comparison with circuits, chains and connections composed of transmission systems of one type (analogue or digital), that is, of homogeneous structure. The most favourable from the point of view of minimization of analogue-digital conversions is "overlay" strategy. Distortions and noise in mixed circuits to a great extent differ from those in circuits of the homogeneous structure, because in the case of mixed circuits distortions and noise typical for both analogue and digital transmission systems are combined taking into account the influence made on them by analogue-digital conversions. Measuring methods for distortions and noise in mixed circuits are of specific character as well. Factors mentioned above make the maintenance and operation of mixed circuits more complicated. Thus the task of developing planning rules for mixed circuits (chains, connections) becomes actual as well as studying the addition laws for distortions and noise.

2 Planning principles

Taking into account the above-mentioned, one should be guided by the following principles while planning mixed circuits:

– The number of analogue-digital conversions in mixed circuits, chains and connections should be as minimal as possible.

  For the purposes of minimization of analogue-digital conversions in mixed circuits, chains, connections, "overlay" strategy serves in the best way in the period of transition to a digital network.

– Quality of transmission on mixed circuits (chains, connections) should not deteriorate as compared to quality adopted by CCITT for analogue circuits. The objectives recommended for analogue circuits as a rule are observed.

  With this end in view when providing the mixed circuits (chains, connections), it is necessary to try to use the equipment of analogue and digital transmission systems, the distortion characteristics of which have some margin in relation to those ones which had been recommended by CCITT when designing this equipment based on the conditions of its application only in circuits of homogeneous structures. This primarily applies to such distortions as amplitude/frequency distortion, quantizing noise, non-linear distortions.

– For transmission planning to use the rating "Total distortion (noise)" which allows to define the permissible number of analogue-digital conversions at the specified length of an analogue portion of a mixed circuit or on the contrary, at the specified number of analogue-digital conversions to define the permissible length of an analogue portion of a mixed circuit.

  The procedure of using the rating "Total distortions (noise)" for planning the mixed circuits as well as the objectives for different parameters of mixed circuits are given below in clause 3.

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3 Objectives for the mixed analogue/digital chain of 4-wire circuits

3.1 Objectives for some mixed circuit parameters are contained in a number of G-, Q-, and M-Series Recommendations. However, these objectives do not take due account of the addition laws for distortions based on the multitude of mixed circuit structures and specific features of the measuring methods involved.

Considering the importance of retaining the transmission quality during the transition period and attaching great importance to the standardization of mixed analogue/digital circuits the multitudinous types of which emerge while using various kinds of analogue-to-digital conversions, it is worthwhile to have objectives for mixed analogue/digital circuits and 4-wire chains including both analogue and digital circuits.

The present objectives related to mixed 4-wire chain of circuits and the analogue/digital mixed connections arc those with analogue telephone sets at both ends.

It is based on the existing Recommendations for FDM channel equipment G.232, for PCM channel equipment G.712, for analogue switching centres Q.45, Q.45 *bis*, for digital switching centres Q.551 to Q.554, and takes account of other existing Recommendations of G- and M-Series.

Later on in accordance with the study results the present objectives will have to be supplemented by objectives for mixed chain of circuits formed with the help of various methods of analogue-to-digital conversion such as transmultiplexers (see Recommendations G.793, G.794), modems (see Recommendations G.941, V.37), transcoders (see Recommendation G.761), group codecs (see Recommendation G.795), DCME, as well as connections with a digital telephone at one end and an analogue telephone at the other end.

3.2 Objectives for the nominal value of the input/output impedance return loss, unbalance loss in respect of earth, nominal re levels can be found in Recommendations for switching equipment (see Q.45, Q.45 *bis*, Q.553), for FDM channel equipment (see G.232) and for PCM channel equipment (see G.712).

3.3 Objective for variations of transmission loss with time, single tone interference, products of unwanted modulation, intelligible crosstalk can be found in Recommendation G.151.

NOTES

1 For mixed chains the stability conditions improve on the one hand because of the existence of digital sections which have a higher stability than analogue ones, but on the other hand in the mixed circuits there is no possibility of a transit automatic regulation of analogue sections which deteriorates the overall stability.

2 Measurement of signal-to-crosstalk ratio between circuits can be performed without feeding an auxiliary signal into a channel affected by crosstalk (unlike that provided for in the Recommendation G.712). This can be explained by the fact that in a mixed circuits, as a rule, an analogue circuit noise will be presented at the input of analogue/digital converters.

3 The level of the interference at the sampling frequency should not exceed the value of $-50 + 10 \log n_2$ where n_2 is the number of analogue/digital converters.

3.4 Attenuation/frequency distortion

Attenuation/frequency distortion for the whole 4-wire chain should not exceed the values given in Figure 1/G.132.

For mixed chains (without consideration or switching centre distortions) the accumulation law of attenuation/frequency distortions is expressed by the following formula:

$$\Delta a = n_1 \, \overline{a}_{\mathrm{FDM}} + \sum_{i=1}^{n_2} a_{i\mathrm{PCM}} \pm \mathrm{K} \sqrt{\sigma^2 \mathrm{FDM} \cdot n_1} \qquad (3\text{-}1)$$

where

n_1 number of analogue sections;

n_2 number or analogue/digital conversions;

$\overline{a}_{\mathrm{FDM}}$ average value (determined component) of attenuation/frequency distortions of the analogue sections;

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σ_{FDM} r.m.s. deviation of attenuation/frequency distortions of analogue sections;

a_{PCM} attenuation/frequency characteristics of analogue/digital equipment;

K = 1, 2 or 3 factor defining the probability or maximum/minimum value or attenuation/frequency distortions.

"K" is usually taken as equal to 3. The justification or the choice for K = 3 depending on a given probability can be found in [1, 2].

NOTES

1 Attenuation/frequency characteristics or analogue/digital equipment or the same type are similar. That is why, if in a mixed/chain of circuits analogue/digital equipment or the same type is used, the sum formula [2, 3]

$$\sum_{i=1}^{n_2} a_{iPCM}$$

can be replaced by a product $n_2\, a_{PCM}$.

2 The analogue-digital equipment distortion limits recommended in 1/G.712 and Figure 1/G.712 and the FDM-channel equipment distortion limits recommended in 1/G.232 and Figure 1/G.232 meet the limits indicated in Recommendation G.132 for mixed circuits in which the number of sections does not exceed 4.

When composing mixed chains with 2 greater number of sections, it is advisable to utilize modern channel equipment the attenuation/frequency distortions of which are considerably lower than those indicated in Recommendations G.232 and G.712.

3 Attenuation/frequency distortions are measured relative to a reference frequency of 1020 (1000) Hz.

4 See 3.4/Q.45 and Recommendation Q.553 to take account of the switching equipment distortions. Some additional information is to be found also in [4].

3.5 Group delay distortions

Group delay distortions should not exceed the values indicated in Recommendation G.133 for the 4-wire chain.

The law of imposition of group delay distortions is expressed by the following formula:

$$\Delta_\tau = n_1\, \tau_{FDM} + \sum_{i=1}^{n_2} \tau_{iPCM} \qquad (3\text{-}2)$$

where

n_1 the number of analogue sections;

n_2 the number of analogue/digital conversions.

NOTES

1 If, in a mixed chain, analogue/digital equipment of the same type is used, then the sum

$$\sum_{i=1}^{n_2} \tau_{iPCM}$$

is substituted by a product $n_2 \cdot \tau_{PCM}$

2 It is expected that the group delay distortion in mixed chains will be less than that of a fully analogue link of any combination of analogue and digital sections. But nevertheless the characteristics of distortion (symmetry) can change considerably. This should be taken into account when transmitting data on mixed circuits containing group delay equalizers.

3 Group delay distortions art measured with reference – to a frequency situated at the lower band end of the analogue channel, i.e. 190-200 Hz.

4 Switching centre distortions are negligible and can be ignored.

3.6 Non-linear distortions

The existing Recommendations for analogue circuits (see 2.11/M.1020), for switching equipment (see 6.1/Q.45) and Recommendation G.712 for analogue/digital equipment contain different specifications for non-linear distortions, the methods of their measurement differ too. The Recommendations for digital centres (Q.551 to Q.554) do not contain specifications for non-linear distortions.

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At present it is not possible to recommend permissible values of non-linear distortions and a method for measuring mixed chains of circuits. This question needs to be studied.

3.7 Noise (total distortion)

The notion of noise in mixed circuits due to analogue-to-digital conversions producing quantization distortions which accompany the signal has lost its initial meaning and therefore instead of the term "noise" applicable to mixed circuits the term "total distortions" is very often used. This is stipulated by the fact that the measurement of quantization distortions (Recommendation Q.132) includes part of non-linear distortions and single-frequency interferences.

Total distortions in mixed circuits include analogue section noise which depends on the length of the sections in case of terrestrial transmission systems and the quantization distortions which are determined by the number and type of analogue-to-digital conversions and noise due to digital errors in the digital section which depends on the average bit error ratio.

The addition law of total distortions is expressed by the following formula:

$$P_{\Sigma} = 10 \lg (10^{-9} W_{FDH} + W_q \cdot m + W_e) \text{ (dBm0p)}$$

where:

W_{FDM} is the psophometric noise power of analogue sections (pW0p);

$W_{FDM} = W_0 L$; W_0 is expressed at $\frac{\text{pW0p}}{\text{km}}$, L in km.

W_q is the psophometric quantization distortion power of one 8 bit analogue-to-digital conversion (mW0p) when total distortion is measured with test signal:

$$W_q = 10^{0.1} [S - (S/N)] \text{ (mW0p)}$$

S is the test signal level of the frequency 1000 Hz (dBm0). To eliminate non-linear distortion the value of S should be no more than –10 dbm0 (S/N) signal-to-quantization distortion ratio.

When distortions are measured without test signal that:

W_q is the unloaded codec noise power (idle circuit noise) according to Recommendation G.712;

m total number of Quantization Distortion Units (qdu's) according to Recommendation G.113;

W_e psophometric noise power due to digital errors in the 2048 kbit/s stream with frame structure according to Recommendation G.732 (mW0p):

$$W_e = 10^{0.1P_e}$$

P_e noise power level due to digital errors is determined in Appendix I.

The permissible value of P_{Σ} is determined from the necessity of providing the same transmission quality over mixed analogue/digital circuits as over the FDM circuits. This means that in case of the equal lengths of a Mixed analogue/digital circuit and an FDM circuit the permissible level of total distortions P_{Σ} should not exceed the noise level in the FDM circuit. And in addition to these effects of influence of quantization distortion, caused by codecs, on the transmitted signal should be taken into account. Table II.1 gives the dependence of speech level-to-white noise level ratio on the number of codecs obtained on the basis of MOS-equivalent method. Based on this dependence, the Table 1 shows level values of total distortion P_{Σ} in a mixed circuit for various numbers of codecs and various lengths of the analogue part. Taking the value of P_{Σ} as being equal to the value of noise in the FDM circuit which corresponds to the length of a mixed analogue/digital circuit one can determine the permissible number of codecs in a mixed circuit in case of the specified length of the analogue part, or vice-versa, in case of the specified number of codecs one can determine the permissible length of the analogue part. The equivalent noise curves which are built based on the data from Table are given in Figure 1. It follows from this Figure for instance that if the total length of a mixed circuit is 20 000 km (curve 1) and length of the analogue part is 5000 km, then not more than 11 analogue/digital conversion of 8 bit PCM (11 qdu) are permissible.

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