



INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Series G

Supplement 22

(10/1984)

SERIES G: INTERNATIONAL ANALOGUE CARRIER
SYSTEMS

Transmission media – Characteristics

Mathematical models of multiplex signals

ITU-T G-series Recommendations – Supplement 22

Originally published in Red Book (1984) - Fascicle III.2

NOTES

- 1 Supplement 22 to the G-series Recommendations was approved in Málaga-Torremolinos (1984) and published in Fascicle III.2 of the *Red Book*. This file is an extract from the *Red Book*. While the presentation and layout of the text might be slightly different from the *Red Book* version, the contents of the file are identical to the *Red Book* version and copyright conditions remain unchanged (see below).
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DIGITAL CROSSTALK MEASUREMENT (METHOD USED BY THE ADMINISTRATIONS OF FRANCE, THE NETHERLANDS AND SPAIN)

(Geneva, 1980; referred to in Recommendation G.612)

In order to speed up crosstalk measurements, reduce their number and obtain measurement data which can be directly interpreted in relation to the system transmitted, a new digital measurement method has been developed; this method is in current use for 2 Mbit/s and 8 Mbit/s systems. It consists in sending a signal, simulating that of the system to be transmitted, simultaneously over a large number of interfering pairs of the cable to be measured. The induced noise is successively recorded on each of the pairs suffering interference, amplified in a device having the pre-emphasis characteristics of the system regenerator and measured by a voltmeter. In a variant method, the signal is converted into a measurable error rate. The measuring device is calibrated by sending the emitted signal directly to the receiver after filtering and attenuation in a calibrated network.

The measurement result may be expressed in dB if we consider the ratio between the received signal and a voltage proportional to the emitted signal or, more simply, directly in mV (or as an error rate) read on the receiver, since the emitted signal amplitude is a constant quantity for a given system.

If there are enough generators to send a signal over each of the interference pairs, it is sufficient to carry out a single measurement, in far-end or near-end crosstalk, on each of the pairs suffering interference.

For cables intended for the transmission of the 8 Mbit/s system, far-end crosstalk measurements are made on the pairs of each unit for elementary cable sections; near-end crosstalk measurements are conducted only on the longest sections, at both ends. The possibility of using the same method to measure factory lengths is being studied.

The digital measuring method is described in detail in the following articles:

Bibliography

SØRENSEN (P.): Measurement of digital crosstalk and behaviour of PCM regenerators against interference, *Electrical Communication*, pp. 293-294, 47 (1972) 4.

BOULVIN (J.), BEYNIÉ (C.), BARGETON (A.), PAYANT (A.) et COUTTY (B.): Mesures en régime numérique de la diaphonie sur des câbles à paires symétriques (Digital crosstalk measurements on symmetric cable pairs) *Cables et Transmission*, April 1975.

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MATHEMATICAL MODELS OF MULTIPLEX SIGNALS

(Geneva, 1980; referred to in Recommendation G.223)

1 Introduction

Signals which represent the multiplex load on an FDM system can be defined in terms of the distribution of short-term power or instantaneous voltage. Values of these parameters are time dependent, and significant variation in the value of these parameters is to be expected even during the busy periods of successive days. Nevertheless, a means of determining even an "average" busy period distribution for the values of these parameters would be of great assistance in ensuring that planning margins were maintained as the system load was altered by the introduction of different types of traffic. To be of value, an estimate of the multiplex load distribution must be based on primary data that can be measured directly, or obtained from adequately accurate sources, so that the effects of any proposed changes in the data can be correctly incorporated; and the estimate must be produced in such a fashion that a direct measurement of the actual distribution can be performed and used to check the validity of the estimates. Methods of estimation which meets these requirements are described below.

Section 2 describes in general terms a process which may be used to calculate the probability density function (p.d.f.) of multiplex load short-term powers. In § 3, a mathematical process based on the work of Holbrook and Dixon is described. However these methods are now considered inexact for the purposes of modelling. The advent of high-speed digital computers has led to the development of the method described in § 4, by which means the instantaneous voltage distribution of the multiplex signal can best be calculated.

The methods described in § 4 are however not yet complete, in that they assume that the FDM load consists entirely of speech signals. Further studies to determine suitable descriptions for the distribution of instantaneous voltage due to signalling, supervisory tones, data etc. are being continued.

2 Method 1 — Probability density function of multiplex load short-term powers

2.1 The events occurring in an unidirectional channel of a “speech-band” circuit may be classified as follows:

- 1) main conversations (*sm*);
- 2) minor (auxiliary) conversations (*sa*);
- 3) signalling (numerical signals) (*zn*);
- 4) supervisory tones (line signals) (*zl*);
- 5) miscellaneous (e.g. data, echo) (*md*, *me*);
- 6) idle (*i*).

Measurements of signals in each of the classes during an adequate number of busy periods yield information from which can be obtained parameters which define the statistical properties of the channel load.

These parameters are:

- 1) the various mean overall activity factor, $\bar{\tau}$ (e.g. $\bar{\tau}_{sm}$, $\bar{\tau}_{sa}$, $\bar{\tau}_{zn}$, etc.) which define the fractions of time during which each of the classifications is producing active power in the average busy period;
- 2) the various mean $\bar{y}$ (e.g. $\bar{y}_{sm}$, $\bar{y}_{sa}$, $\bar{y}_{zn}$, etc.) and standard deviation σ (e.g. σ_{ysm} , σ_{ysa} , σ_{yzn} , etc.) of the p.d.f.s of the levels of active power for each classification.

2.2 The p.d.f. of the levels of short term (20 ms) active power being produced during an average busy period is calculated for each classification. Neglecting the possibility of certain fault conditions, these p.d.f.s can be regarded as mutually exclusive. Summing the probabilities of occurrence of a given power over all classifications therefore gives the total probability of occurrence of that power during the average busy period. This p.d.f. $p(Z_{uc})$ gives a sufficient description, statistically, of the unidirectional channel load.

$p(Z_{uc})$ can alternatively be obtained by direct measurement. However, the effect of changes in any of the classifications on the overall p.d.f. $p(Z_{uc})$, cannot then readily be determined.

2.3 One direction of transmission of an FDM group is formed from 12 unidirectional channels, each of which yields a p.d.f., $p(Z_{uc})$. If, as is usual, the signals in each channel are generated by statistically similar sources, the types of traffic carried by each channel will be in the same ratio, and it is then sufficient, for many purposes, to assume that each of the 12 p.d.f., $p(Z_{uc})$ can be represented by the same p.d.f., $p(Z_{ic})$ which is the p.d.f. of the power in the “typical channel” of the f.d.m. group.

The set of p.d.f., $p(Z_{ic})$ are not, of course, mutually exclusive, and the multiplex load due to the 12 channels is produced by convolution of this set of p.d.f. to form $p(Z_g)$. If pre-emphasis is used in transmission, it is merely necessary to multiply the power range of each p.d.f. by the appropriate pre-emphasis factor, f_p , prior to convolution.

The p.d.f. of multiplex load short-term powers for supergroup and larger group combinations, is obtained by further convolution of the group p.d.f.

2.4 The effects of traffic from nonspeech and nonconventional telephony channels can be incorporated as required. If introduced at the channel stage — e.g. MCVF, TASI — the p.d.f. $p(Z_{uc})$ will be modified accordingly prior to convolution. If introduced at the group, or higher stage, — e.g. wide-band data — one or more of the group power p.d.f. $p(Z_g)$, will be modified prior to convolution. The effects of group and supergroup limiters, and the inclusion of pilot, etc., tones may be incorporated as necessary.