PART II

SUPPLEMENTS TO THE SERIES O RECOMMENDATIONS

(Section 3 of the Supplements to the Series M, N and O Recommendations)

Blanc

MONTAGE: PAGE 206 = PAGE BLANCHE

3 Measuring equipment specifications

Supplement No. 3.1

MEASURING INSTRUMENT REQUIREMENTS —

SINUSOIDAL SIGNAL GENERATORS AND LEVEL-MEASURING INSTRUMENTS |

(Geneva, 1972; amended at Melbourne, 1988)

A. *Direct-reading, general-purpose, continuously variable sinusoidal generator (not sweep frequency)*

Table 1 is a list of the essential performance requirements of a range of direct reading, general purpose continuously variable sinusoidal generators.

If discrete frequencies are required, suitable nominal values for international purposes are given in Recommendation M.580 for telephone-type circuits and Recommendation N.21 for sound-programme circuits.

B. *Direct-reading, general-purpose wideband and selective level-measuring instruments (not sweep display or fixed frequency)*

Table 2 is a list of the essential performance requirements of a range of direct-reading, general-purpose wideband and selective level-measuring instruments.

Note — The specifications given in § 8 of Recommendation O.22 are recommended to be used for signal generators and level-measuring instruments to be used on telephone-type circuits.

For the convenience of the reader of this Book, this Supplement is republished from Volume IV.2 of the CCITT *Green book* , ITU, Geneva, 1973.

H.T. [T1.3.1]

TABLE 1
{
Essential performance requirements for sinusoidal signal generators
(not sweep generators)
}

	Telephone-type circuits	Sound-programme circuits	{ Groups, supergroups, and 12-, 60-, 120-, and 300-channel systems }	{ Mastergroups, super-mastergroups and 900- to 2700-channel systems }
1	2	3	4	5
Frequency				
a) range	200 Hz to 4 kHz	30 Hz to 20 kHz	4 to 1400 kHz	60 Hz to 17 MHz
{ b) accuracy of initial setting, without frequency counter, at 20 °C and nominal power supplies }	± | % | (+- | Hz	± | % | (+- | Hz	{ below 120 kHz: ± | .2 | | (+- | 00 Hz 120 kHz land above: ± | .2% | (+- | kHz }	± | .002% | (+- | 00 Hz
c) stability				
{ — per hour at 20 | (deC and with nominal power supplies }	± | %	± | %	± | .01% | (+- | 50 Hz	± | .005% | (+- | 50 Hz
{ — per 10 | (deC over a specified range of temperature and with nominal power supplies (Note) }	± | .1%	± | .1%	± | .1% | (+- | 50 Hz	± | .002% | (+- | 0 Hz
{ — per 10% change in power suppy at 20 | (deC }	± | .5%	± | .5%	± | .05% | (+- | 50 Hz	± | .001% | (+- | 0 Hz
Ouput level				
a) range	{ +10 to —40 dBm (+12 to —45 dNm) }	{ +20 to —40 dBm (+23 to —45 dNm) }	{ +10 to —60 dBm (+12 to —70 dNm) }	{ +10 to —60 dBm (+12 to —70 dNm) }
{				

b) accuracy at 0 dBm (0 dNm) and at the reference frequency at 20 | (deC and with nominal power supplies }	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .2 dB (± | .2 dNp)	± | .2 dB (± | .2 dNp)
{ c) accuracy at any level or frequency within the range }	± | .5 dB (± | .6 dNp)	± | .5 dB (± | .6 dNp)	± | .5 dB (± | .6 dNp)	± | .5 dB (± | .6 dNp)
d) stability				
{ — per hour at 20 | (deC and with nominal power supplies }	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)
{ — per 10 | (deC over a specified range of temperature and with nominal power supplies (Note) }	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)
{ — per 10% change in power supply at 20 | (deC }	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)	± | .1 dB (± | .1 dNp)
Purity of output				
{ Ratio of total output power to power of unwanted signals (noise, harmonic and non-harmonic frequencies) }	at least 40 dB (46 dNp)	at least 50 dB (57 dNp)	at least 46 dB (53 dNp)	at least 46 dB (53 dNp)
Output impedance				
{ a) nominal value (other values may be specified if required) }	600 ohms balanced	{		
600 ohms balanced or not greater than 6 ohms balanced for constant voltage techniques }	{			
75 ohms unbalanced or 150 ohms balanced or 600 ohms balanced }	50 or 75 ohms unbalanced			
{ b) return loss against the nominal value }	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)
{ c) balance about earth (where applicable) }	at least 40 dB (46 dNp)	at least 60 dB (70 dNp)	at least 40 dB (46 dNp)	

Tableau 1 [T1.3.1], p.1 à l'italienne

TABLE 2

Essential performance requirements of wideband and selective level-measuring instruments

(not sweep-display of fixed frequency)

	Telephone-type circuits	Sound-programme circuits	Groups, supergroups, and 12-, 60-,120- and 300-channel systems	Mastergroups, super-mastergroups and 900- to 2700-channel systems
1	2	3	4	5
Frequency				
a) range	200 Hz to 4 kHz	30 Hz to 20 kHz	4 kHz to 1400 kHz	60 kHz to 17 MHz
b) nominal bandwith for selective measurements (Note 1)	40 Hz	40 Hz	600 Hz and 4 kHz	600 Hz and 4 kHz
Range of input level				
a) wideband				
+20 to —50 dBm (+23 to —58 dNm) down to —70 dBm (—80 dNm) with reduced accuracy				
+20 to —50 dBm (+23 to —58 dNm) down to —70 dBm (—80 dNm) with reduced accuracy				
+20 to —50 dBm (+23 to —58 dNm)				
+20 to —50 dBm (+23 to —58 dNm)				
b) selective				
+20 to —80 dBm (+23 to —92 dNm)				
+20 to —80 dBm (+23 to —92 dNm)				
+20 to —90 dBm (+23 to —100 dBm) down to —110 dBm (—127 dNm) with reduced accuracy				
+20 to —90 dBm (+23 to —100 dBm) down to —110 dBm (—127 dNm) with reduced accuracy				

}
Measuring accuracy
{
a)
at 0 dBm (0 dNm) and at the reference frequency at 20 | (deC
and with nominal power supplies if internal calibration is provided
} {
± | .2 dB (± | .2 dNp)
± | .1 dB (± | .1 dNp)
} {
± | .2 dB (± | .2 dNp)
± | .1 dB (± | .1 dNp)
} {
± | .2 dB (± | .2 dNp)
± | .1 dB (± | .1 dNp)
} {
± | .2 dB (± | .2 dNp)
± | .1 dB (± | .1 dNp)
}
{
b)
at any level and frequency within the ranges
(Note 2)
} ± | .5 dB (± | .6 dNp) ± | .5 dB (± | .6 dNp) ± | .5 dB (± | .6 dNp) ± | .5 dB (± | .6 dNp)
{
Stability of indicated level
(Note 3)
}
{
a)
per hour at 20 | (deC and with nominal power supplies
} ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp)
{
b)
per 48 hours at 20 | (deC and with nominal power supplies
} ± | .3 dB (± | .4 dNp) ± | .3 dB (± | .4 dNp) ± | .3 dB (± | .4 dNp) ± | .3 dB (± | .4 dNp)
{
c)
per 10 | (deC over a specified range of temperature and with nominal
power supplies (Note 3)
} ± | .5 dB (± | .6 dNp) ± | .5 dB (± | .6 dNp) ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp)
{
d)
per 10% change in power supply at
20 | (deC
} ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp) ± | .1 dB (± | .1 dNp)
{
Level of unwanted signals
}
{
Generated by the instrument itself and appearing at the input
terminals relative to the lowest acceptable input level measured
at the
input terminals
} {
—20 dB (—23 dNp)
or lower
} {
—20 dB (—23 dNp)
or lower
} {
—20 dB (—23 dNp)
or lower

} —20 dB (—23 dNp) or lower }	{			

Tableau 2 [1T2.3.1], p.

TABLE 2 *(cont.)*

Groups, supergroups, and 12-, 60-, 120- and 300-channels systems } Mastergroups, super- mastergroups and 900- to 2700-channel systems }	Telephone-type circuits {	Sound-programme circuits	{	
1	2	3	4	5

Input impedance
{
a)
nominal value for terminated level measurements.
Other
nominal values may be specified if required
}
	600 ohms balanced	{		

600 ohms balanced or at least 20 | (mu | 0^{3} ohms balanced for constant voltage techniques }	{			
75 ohms unbalanced or 150 or 600 ohms either balanced or unbalanced }	50 or 75 ohms unbalanced			

{
b)
value for through-level measurements
}
	{			

at least 25 | (mu | 0^{3} ohms balanced }	{			
at least 20 | (mu | 0^{3} ohms }	{			
through-level measurements not recommended }	{			
through-level measurements not recommended }				

{
c)
return loss against nominal value (for terminated-level measurements)
}
	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)

{
d)
balance about earth where applicable through-level or terminated-level
}
	at least 40 dB (46 dNp)	at least 60 dB (70 dNp)	at least 40 dB (46 dNp)	

{
Image frequency rejection
}
	at least 50 dB (58 dNp)	at least 50 dB (58 dNp)	at least 60 dB (70 dNp)	{

at least 60 dB (70 dNp) }				

Note 1 — It is necessary to specify in some detail the response characteristic of the nominal bandwidth for selective measurements.

Note 2 — Although the actual return loss of the input impedance is specified to be not greater than 30 dB (35 dNp) the instrument should be arranged (when connected to a generator of exactly the appropriate nominal value) to indicate the level that would be developed across an impedance, with a return loss of at least 40 dB (46 dNp) against the nominal value.

Note 3 — The stability limits include the effects of frequency variation of any built-in local oscillator in selective measuring sets.

Note 4 — The range of temperature over which the apparatus must satisfactorily operate must be specified. This depends very largely on geographical location.

Tableau 2 (fin) [2T2.3.1], p.

Supplement No. 3.2

NOISE MEASURING INSTRUMENTS FOR TELECOMMUNICATION CIRCUITS

(For this Supplement, see page 534, Volume IV.2 of the *Green Book*)

Supplement No. 3.3

PRINCIPAL CHARACTERISTICS OF VOLUME INDICATORS

(For this Supplement, see page 548, Volume IV.2 of the *Green Book* ;

additional information on this subject is given in Recommendation O.51)

Supplement No. 3.4

CONSIDERATION OF INTERWORKING BETWEEN DIFFERENT

DESIGNS OF APPARATUS FOR MEASURING QUANTIZING DISTORTION

(For this Supplement, see page 85, Volume IV.2 of the *Orange Book*)

Supplement No. 3.5

(Cancelled. Replaced by Recommendation O.6)

Supplement No. 3.6

CROSSTALK TEST DEVICE FOR CARRIER-TRANSMISSION

ON COAXIAL SYSTEMS

(Melbourne, 1988)

(Information from the USSR Telecommunication Administration)

1 Introduction

This Supplement contains the description of a method and the basic technical parameters of a device for crosstalk ratio measurement intelligible crosstalk ratio in carrier-transmission coaxial systems.

2 Operation

The device measures propagation delay time of near-end crosstalk signals from different repeaters. Measurement of the test signal delay time in order to determine the distance from a repeater and the amplitude of the received signal make it possible to determine the repeater number and the near-end crosstalk ratio of this repeater.

The test signal is extracted from the noise and signals, coming from other repeaters, by means of time filtering (correlation processing). It is preferred that a special signal having a sufficiently narrow correlation function be used as a test signal. A sinusoidal test signal phase-modulated by a pseudorandom sequence (PRS) of pulses (phase-modulated signal) is used in the device.

A simplified block diagram and a frequency diagram of this device are given in Figure 1 and Figure 2.

Phase modulation of a sinusoidal signal f_1 from an oscillator G1 by a signal from PRS oscillator G2 is carried out in a modulator M1, the formed signal spectrum having no spectral component f_1 (suppressed by more than 54 dB). The modulating and test signals are shown in Figure 3, and the modulating signal spectrum is shown in Figure 4. A phase-modulated test signal in the band from f_{2m} to $f_{k\dm}$ is formed in a modulator M3. A signal from a quartz controlled oscillator at one of the frequencies in the band from f_2 to f_k, which are chosen in the spectrum of transmission systems under test, is used as a carrier. A test signal at $f_{k\dm} \pm f_{1m}$ as well as at f_{1m} contain no central spectral component. The signal $f_{k\dm}$ is applied to the input of an interfering link.

A crosstalk signal from the output of the return path (path subjected to interference) is applied to the input of the device. The signal is reconverted in modulator M4. The signal f_{1m} is then applied to an input of phase detector M2. The PRS signal from G2 shifted by the time interval of Δ"t with respect to the modulating signal in a time-delay circuit D1 is applied to the other input of the phase detector M2. If the present time interval coincides with the time delay of the crosstalk signal in a line being tested with respect to the test signal at the device output, a single-frequency sinusoidal signal f_1 will be obtained at the output of M2, the signal level then being measured by a selective level meter (SLM). When the present value of Δ"t does not coincide with the time delay of the crosstalk signal coming from the line, a signal having no frequency f_1 in its spectrum will be present at the output and input of the phase detector M2. By varying the value of the present time delay in D_1, tuning to a crosstalk signal from different repeaters on the section under test, a remote measurement of the crosstalk value of all repeaters is carried out.

It is preferred that the choice of parameters of the test signal be determined by the correlation function R (t) of the chosen signal (see Figure 5). For this purpose, R (t) is estimated at two levels: R (t) 0.1 corresponding to the zone of low correlation and R (t) = 0.607 limiting the high correlation zone.

Resolution between two adjacent signals is practical if the time shifts between them is outside the zone of high correlation. Therefore, the choice of the duration of an elementary PRS pulse is made depending on the minimum crosstalk time shift Δ"$t_{m\di\dn}$ of crosstalk from the adjacent repeaters, namely:

where

$l_{R\dS}$ is the minimum distance between the adjacent repeaters;

V is the electric wave propagation rate in the cable.

The pulse duration τ in the device depends on the scale oscillator frequency and may be adjusted for various cable types having different propagation rates. Adjustment is carried out by changing the scale oscillator frequency.

The repetition period of a pseudorandom sequence should ensure unambiguity of measurements, i.e. the time between two adjacent autocorrelation function maximums should be greater than the signal propagation time along the section $l_{S\dT}$ under test in both directions of transmission:

The minimum step of the time-delay circuit D1 is determined by taking into account the admissible error of tuning to the maximum of the autocorrelation function and may be equal to 0.1 τ (error not more than 5%). The maximum value of the time delay in D1 is determined by the length of the line section $l_{S\backslash dT}$ under test, i.e. by the time of signal propagation along the line in both directions of transmission:

To measure the crosstalk signal levels corresponding not only to low but also normal crosstalk attenuation of repeaters, the passband of the SLM must be sufficiently narrow (0.1 to 0.3 Hz) so that a test signal may be extracted from the noise. Such a passband may be realized by means of a synchronous phase filter.

3 Basic technical parameters of a device designed for transmission systems at frequencies less than 18 MHz

3.1 *Basic characteristics*

3.1.1 Maximum length of a section under test 400 km

3.1.2 Minimum distance between repeaters under test 1.0 km

3.1.3 Minimum step of setting distance to the repeater under test 0.1 km 3.1.4 Nominal carrier frequencies of a test signal 0.37; 1.1; 4.4; 7.9; 17.25 MHz

3.1.5 Minimum measurement level —120 dB

3.1.6 Time for localization of a faulty repeater

(with a maximum of 70 repeaters on a section under test) 20 min

3.2 *Several technical characteristics*

3.2.1 Number of elementary pulses in a pseudorandom sequence (PRS)

for the test signal phase modulation $2^9 - 1 = 511$

3.2.2 PRS repetition rate 4.2 ms

3.2.3 Test signal level range —59 dB to 0 dB

3.2.4 Scale oscillator frequency 2.4 to 2.5 MHz

3.2.5 Level measuring range —120 to —50 dB

3.2.6 Receiver bandwidth (at a 3 dB level) 0.3; 3 Hz 3.2.7 Steps of time delay 83.3 µs (10 km) 8.3 µs (1 km) 0.8 µs (0.1 km)

3.2.8 Reduction in the receiver indicator reading with respect to a value corresponding to the maximum when the PRS is shifted by 24.9 µs (3 km) more than 40 dB

3.2.9 Measuring error in the ‘‘—100 dB’’ range for the 0 dB reading less than ± | dB

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Figure 1, (N), p. 4

Figure 2, (N), p. 5

Figure 3, (N), p. 6

Figure 4, (N), p. 7

Figure 5, (N), p. 8

Supplement No. 3.7

A MEASURING SIGNAL (MULTITONE TEST SIGNAL) FOR FAST MEASUREMENT OF AMPLITUDE AND PHASE FOR TELEPHONE TYPE CIRCUITS

(Melbourne, 1988)

(Information submitted by the Federal Republic of Germany,
France and USSR)

In the following a brief description of a test signal is given, stating its particular advantages for measurement of amplitude and phase simultaneously.

1 The multitone test signal

1.1 *General description*

The multitone test signal (MTTS) consists of a spectrum of N discrete signals separated by frequency spacing of 100 Hz in the low frequency range.

The spectral lines are all of equal amplitude; their phase relationship to each other is chosen on the basis of mathematical considerations so that the energy of the test signal is distributed approximately evenly across the entire period of the test signal.

The transmission characteristics, i.e. the amplitude and phase distortion of a telephone line, produce changes in the test signal. On the receive side, these changes are measured and evaluated, e.g. by means of a Fourier analysis. The results may be displayed on a screen in the form of an amplitude and/or phase graph and also, for example, the group delay may be derived from this.

1.2 *Measuring principle*

The transmit signal consisting of N cosine waveforms is generated in digital circuits: a sufficient number of instantaneous values of the MTTS is read out of a ROM with a clock frequency. After passing through a D/A converter and a filter which suppresses the clock frequency, the composite signal is available:

where

A amplitude of a single waveform

f is 100 Hz (see Note 2)

ϕ phase of the single waveforms

n serial number of the single waveforms

t time

N total number of waveforms.

At *f* = 100 Hz, the duration of one period of the MTTS is 10 ms.

The MTTS is passed to the object to be tested which changes the properties of the MTTS, i.e. the amplitudes and phases of the single waveforms.

In the receiving section, the changed signal is passed to an evaluation circuit, where the signal is sampled with the clock frequency. The sampled analogue values are digitized and stored in a memory. The stored values of the time function are then transferred by means of the Discrete Fourier Transform into the frequency domain. All necessary calculations are performed in a microcomputer.

At measurements where the objects to be tested include carrier frequency systems, frequency shift of the measuring signal can appear. In such cases it is recommended to use window functions in the signal processing section of the receiver.

The characteristics of the object to be tested are derived from the deviation of the received values against the transmitted values.

1.3 *Data of the multitone test signal*

Transmitter

Transmit frequencies

— 35 signals (cosine) simultaneously;

— $n \times 100$ Hz; n = 2 to 36 in steps of 100 Hz from 200 to 3600 Hz, or see Notes 1 and 2;

— Accuracy: $1 \times 10^{\mathrm{D}}$lF261^{4}

Transmit level (multitone test signal) +10 to —40 dBm.

This level corresponds to the level of a single sinusoidal signal which has the same peak value as the test signal.

— Accuracy at 1000 Hz 0.2 dB

— Frequency response 0.1 dB

— Harmonic distortion 40 dB

— Spurious distortion at +10 dBm 50 dB

— Phase constellation

H.T. [T1.3.7]

0	2π/7	4π/7	6π/7	8π/7	10π/7	12π/7	
n: 2, 3, 4, 5, 6, 8, 15, 22, 29, 36 } 10, 16, 18, 26, 28, 34 37 (Note 1) } 7, 17 38 (Note 1) }	{ 9, 12, 20, 24, 35 11, 13, 31, 33	 { 21, 23, 27, 32 1 (Note 1)	 14, 19, 25, 30	 {			

Note 1 — Serial numbers of 1, 37 and 38 are optional values.

Note 2 — The French Administration uses frequency steps of 101.56 Hz according to [26 | (mu | *n* —1)] | (mu | fIf , where *f* = 8000/2048. This is in accordance with the principle of frequency offset contained in Recommendation O.6 concerning PCM equipment.

Tableau [T1.3.7], p.9

Receiver

The receiver takes into account the level and the phase constellation of the transmitted signal.

2 Advantages of the multitone test signal

With the technical means available today the multitone test signal can be generated at low cost with excellent stability of frequency, amplitude and phase. The quantity of 35 discrete signals and thus test points in the frequency range 200 to 3600 Hz is quite adequate for the testing requirements occurring in practice. Optionally, the frequency band can be widened according to Note 1.

When the received signal is evaluated, e.g. with the aid of a Fourier analysis to determine amplitude/frequency response and/or phase or group delay, a test cycle time, allowing for processing time and screen display time, of only less than one second is needed. This short test cycle is of great advantage mainly when equalization work has to be done.

Because the MTTS is normally a continuous signal there are no settling time problems which occur using a sweep mode signal.

The MTTS is an ideal band-limited ‘‘noise signal’’ for determining the rms bandwidth of filters, for example for the filter (psophometric weighting) in Recommendation O.41 or for calibrating PCM instruments measuring quantizing distortion.

Considering the ripple at the frequency response curve one can recognize very clearly that there are frequency components caused by any non-linearity of an item under test.

Using the Fourier analysis to evaluate the received MTTS one can recognize both the amplitude and frequency of unwanted signals; that means, the procedure works like a swept selective receiver.

The period of this MTTS is 10 ms (which corresponds to one period of a 100-Hz fundamental). Since for Fourier analysis it is sufficient to sample just one period of the test signal, i.e. 10 ms, at the receiving side, and 10 ms plus at the sending side, measurements could be performed during correspondingly short gaps in the speech or data transmission signal. These gaps occur in any case in these signals, or they may be created by technical means.

The use of the MTTS in combination with the Fourier analysis makes it possible to provide measurements of parameters which normally require filters; e.g. weighted noise, quantizing distortion, selective crosstalk, etc. In these cases filtering is provided by appropriate calculations in the microcomputer carrier out for the frequency domain of the input signal.

For measurements including PCM sections it is not necessary to shift the frequencies in order to avoid submultiples of 8 kHz, in this case a MTTS without frequency shift leads into a frequency response with a ripple of up to ± 0.1 dB. With the help of an averaging procedure (e.g. 4 or 16 measuring cycles) the ripple can be reduced to a negligible value.

A further possibility to reduce the ripple is to use shifted frequencies of *n* | (mu | 01 | (mu | 6 Hz, according to Note 2.

In this case the ripple is less than ± | .05 dB after one measuring cycle; even this relatively small error can be reduced by an averaging procedure.

3 Practical experience

Since 1981, instruments using multitone test signals have been used by various Administrations all over the world.

Measurement results are obtained quickly and unambigously and are compatible with those obtained with conventional methods.

The USSR Telecommunication Administration is investigating theoretically and practically the MTTS in order to determine the best use for further applications.

Supplement No. 3.8

GUIDELINES CONCERNING THE MEASUREMENT OF JITTER

(Melbourne, 1988)

(Information assembled by SG IV and SG XVIII)

1 Definitions and causes of jitter

CCITT Recommendation G.701 [1] defines jitter as ‘‘short-term non-cumulative variations of the significant instants of a digital signal from their ideal position in time’’. This means that jitter is an (unwanted) phase modulation of the digital signal. The frequency of the phase variations is calle jitter-frequency It is defined as ‘‘long-term non-cumulative variations of the significant instants of a digital signal from their ideal position in time’’. Up to now there is no clear definition of the boundary between jitter and wander. Components of phase variation having frequencies below the range of 1 to 10 Hz are normally called wander.

Jitter may deteriorate the transmission performance of a digital circuit. As a result of signal displacement from its ideal position in time, errors may be introduced into the digital bit stream at points of signal regeneration. Slips may be introduced into digital signals resulting from either data overflow or depletion in digital equipment incorporating buffer stores and phase comparators. In addition, phase modulation of the reconstructed samples in digital-to-analogue conversion devices may result in degradation of the decoded analogue signals. This is more likely to be a problem when transmitting encoded wide-band signals.

A distinction must be made between the systematic and random jitter. Systematic jitter results from misaligned timing recovery circuits in signal regenerating devices or from inter-symbol interference and amplitude-to-phase conversion caused by imperfect cable equalization. Systematic jitter is pattern-dependent.

Random jitter originates from internal or external interferring signals such as repeater noise, crosstalk or reflections. Random jitter is independent of the transmitted pattern.

Low-frequency jitter produced in pulse justification demultiplexers arises from pulse justification synchronization; the mechanism by which the plesiochronous lower-rate signals are synchronized to a locally generated clock source. This jitter, which appears at the demultiplexer lower-rate output, is denoted ‘‘ justification jitter ´waiting time jitter

As systematic jitter is correlated with the transmitted pulse pattern at different regenerators, it accumulates coherently. Random jitter is uncorrelated at different regenerators and accumulates incoherently. In most existing lower-rate digital systems, systematic jitter is dominant. In some contemporary higher-rate systems the random component may become significant or even predominant.

Unlike some other impairments, disturbing jitter can be reduced by regenerators or by the use of ‘‘ de-jitterizers ´circuit. Regenerators can only reduce jitter frequency components above the cut-off frequency of the clock recovery circuits. At lower jitter frequencies, the output signal or a regenerator follows the input jitter. In this case jitter is ‘‘transferred’’ which means that a regenerator behaves like a low-pass filter. This characteristic behaviour leads to the typical jitter tolerance templates as shown in Figure 1.

Figure 1, (N), p.

It can be seen from the considerations above that jitter can severely deteriorate the performance of digital transmission systems. On the other hand, jitter cannot be avoided completely. To evaluate whether jitter is kept within the allowed limits is the task of jitter measurements.

2 Test environment

In order to facilitate repeatable and accurate measurements, and to allow comparisons between measurements made at different times, it is necessary to minimize variations in the test environment. Several test environment parameters which may vary widely within their allowed ranges and may significantly affect jitter measurement results (depending upon the type of equipment involed) include the data pattern, data rate, pulse shape, and cable characteristics. The characteristics of these parameters should be controlled as appropriate. Additionally, there are secondary test environment parameters which may also affect jitter performance, that should be maintained at nominal levels to facilitate repeatable measurements.

In order to verify worst-case equipment performance, it may be necessary to stress the equipment under test with multiple changes in the test environment. However, this type of test does not necessarily provide meaningful jitter performance data due to lack of control of the particular parameter(s) which may be causing errors, as well as their effect on other non-jitter related equipment failure mechanisms. Therefore, multiple changes in test environment should not be used to characterize the jitter performance of the equipment under test.

2.1 *Controlled data patterns*

Some measurement procedures require the application of controlled data patterns. When the controlled data pattern is intended to approximate live traffic encountered in the network, a pseudo-random bit sequence (PRBS) is recommended. Four pseudo-random patterns are specified in Recommendations O.151 and O.152 namely 2^{11} — 1, 2^{15} — 1, 2^{20} — 1 and 2^{23} — 1 length sequences. To ensure that a particular PRBS will generate adequate jitter spectral line density within the jitter half-power bandwidth of typical clock recovery circuits at the applicable hierarchical level, the PRBS word length should be much greater than the data rate divided by the jitter half-power bandwidth. The CCITT recommends that the PRBS word length be at least 100 times greater than the data rate divided by the jitter half-power

bandwidth [2] (see Note). The pseudo-random bit sequence of 2^{15} — 1 bit length specified in Recommendation O.151 for bit error measurements may generate an inadequate spectral line density for jitter measurements a speeds above the primary rate. Moreover, this pattern has poor binary run properties. Therefore, for bit rates at and above the primary rate, the pattern length should be no less than 2^{20} — 1, and have a well balanced binary run characteristic [3].

Note — Further study of jitter spectral line density sufficiency is desirable.

2.2 *Bit rate*

The bit rate must be maintained within the specifications for digital interfaces as specified in Recommendation G.703 [4]. For convenience, the bit rates are repeated below:

— basic rate: | 64 kbit/s

— primary rate: 1 | 44 kbit/s ± 50 ppm

2 | 48 kbit/s ± 50 ppm

— secondary rate: 6 | 12 kbit/s ± 30 ppm

8 | 48 kbit/s ± 30 ppm

— tertiary rate: 32 | 64 kbit/s ± 10 ppm

34 | 68 kbit/s ± 20 ppm

44 | 36 kibt/s ± 20 ppm

— quaternary rate: 139 | 64 kibt/s ± 15 ppm

2.3 *Pulse shape and cable characteristics*

Pulse shape affects jitter performance by impacting the accuracy of the decision making process in a block recovery circuit. Pulse shape is typically specified by a pulse template at an output interface or at a cross-connect [5] and may vary at the equipment input due to cable effects, resulting from operating within the specified range of cable lengths and specified cable type(s). It is recommended that the pulse shape to be used in jitter tests be centered within the pulse template specified, rather than being at the extreme allowable values (see Note).

Note — A pulse template appropriate for jitter testing needs further study.

2.4 *Secondary test environment parameters*

Other test environment parameters which may affect jitter performance include temperature, cross-talk, and noise. Temperature affects jitter performance by altering the resonant fequency of clock recovery circuits, oscillators, and phase smoothing circuits, as well as changing the filtering properties of analog circuitry. Cross-talk may affect jitter performance when signals in a cable, backplane, or circuit board affect one another to a noticeable degree. Noise affects the decision making process in a clock recovery circuit by decreasing the decision eye margin.

In order to obtain accurate and repeatable jitter measurements and ensure that the effects of jitter applied to the quipment dominate measurement results, it is recommended that these secondary parameters be maintained at their nominal levels.

3 Glossary or test configuration functional block components

This glossary defines the functional block components employed in the test configurations described in the following sections. Note that these functional blocks may be incorporated in various combinations within different test equipment.

— *Attenuator:* | A device which reduces the amplitude of a digital signal in order to decrease the signal-to-noise ratio.

— *Digital signal generator:* | A signal source which provides a digital network hierarchical signal at the appropriate bit rate with proper output impedance, pulse shape, line coding, and frame format. This functional block component is capable of providing several data patterns, must have a clock and data output, and may accept an external clock input.

— *Digital signal receiver:* | An instrument which terminates a digital network hierarchical signal and monitors for bit errors, errored seconds, or bit error ratio (BER).

— *Equipment under test (EUT):* | A circuit or system that is being tested with a controlled data pattern.

— *Frequency synthesizer:* | An extremely stable frequency source of high accuracy. Some frequency synthesizers are capable of adding phase or frequency modulation (PM or FM) to the primary output while providing an unmodulated secondary output.

— *Jitter generator:* | An instrument which produces a hierarchical rate clock modulated by sinusoidal jitter of adjustable frequency and amplitude. A modulation input provides for external jitter control, and an optional clock input provides for external data rate frequency control.

— *Jitter receiver:* | An instrument which demodulates and measures the jitter present on a hierarchical clock or data signal. An output provides a voltage proportional to the demodulated jitter.

— *Low-pass filter:* | A circuit used to attenuate unwanted spectral components above a given frequency.

— *Jitter measurement filter:* | A circuit which attenuates jitter spectral components outside a specified or desired passband.

— *Network under test:* | A circuit, system, or network that is being tested using live traffic.

— *Noise source:* | An instrument which generates a signal having a near Gaussian amplitude distribution with a flat power spectrum to approximately three times the half-power bandwidth of the retiming circuit.

— *Sine wave generator:* | A waveform generator which provides a low distortion frequency and amplitude controlled sine wave.

— *Spectrum analyzer:* | An instrument which measures and displays signal power as a function of frequency over a selected frequency range. A tracking oscillator output provides an adjustable amplitude swept frequency sinusoid which tracks the instantaneous measurement frequency of the spectrum analyzer.

— *Voltmeter:* | An instrument which measures DC, true rms, or true peak-to-peak voltage as required. Here true peak-to-peak voltage is defined as the difference between the most positive and the most negative instantaneous voltages recorded during the entire measurement interval.

4 Jitter tolerance measurement

Jitter tolerance (also known as jitter accommodation) is defined in terms of the sinusoidal jitter amplitude which, when applied to an equipment input, causes a designated degradation of error performance. Jitter tolerance is a function of the amplitude and frequency of the applied jitter.

Jitter tolerance requirements are specified in terms of jitter templates which cover a specified sinusoidal amplitude/frequency region. Jitter templates represent the minimum amount of jitter an equipment *must accept* without causing the designated degradation of error performance (see Note).

The intended relationship of an equipment's actual tolerance to input jitter and its associated jitter tolerance template is illustrated in Figure 1.

Note — In CCITT terminology, the jitter tolerance template represents the ''lower limit of maximum tolerable input jitter''.

4.1 *Actual tolerance*

The sinusoidal jitter amplitudes that an equipment actually tolerates at a given frequency are defined as all amplitudes up to, but not including, that which causes the designated degradation of error performance.

The designated degradation of error performance may be expressed in terms of either bit error ratio (BER) penalty or onset of errors criteria. The existence of two criteria arises because the input jitter tolerance of an individual digital equipment is primarily determined by the following two factors:

— The ability of the input clock recovery circuit to accurately recover clock from a jittered data signal, possibly in the presence of other degradations (pulse distortion, cross-talk, noise, etc.).

— The ability of other components to accommodate dynamically varying input data rates (e.g., pulse justification capacity and synchronizer or desynchronizer buffer size in an asynchronous digital multiplex).

The BER penalty criterion allows environment independent determination of the decision circuit alignment jitter allocation, which is critical for evaluating the first factor. A detailed discussion of the BER penalty criterion may be found in References [6], [7]. The onset of errors criterion is recommended for evaluating the second factor.

4.1.1 *Bit error ratio penalty technique*

The bit error ratio (BER) penalty criterion for jitter tolerance measurements is defined as the amplitude of jitter, at a given jitter frequency, that duplicates the BER degradation caused by a specified signal to noise ratio (SNR) reduction.

This technique is separated into two parts. Part one determines two BER versus SNR reference points for the equipment under test. With zero jitter applied, noise is added to the signal, or the signal is attenuated, until a convenient initial BER is obtained. Then the noise, or signal attenuation, is decreased until the SNR at the decision circuit is increased the specified amount of dB (and consequently, the decision circuit is performing with an improved BER). Part two uses the BER versus SNR reference points; at a given frequency, jitter is added to the test signal until the BER returns to its initially selected value. Since a known decision circuit eye width margin was established by the two BER versus SNR points, the added equivalent jitter is a true and repeatable measure of the decision circuit jitter tolerance performance. Part two of the technique is repeated for a sufficient number of frequencies such that the measurement accurately represents the continuous sinusoidal input jitter tolerance of the EUT over the applicable frequency range. The test equipment must be able to produce a controlled jittered signal, a controlled SNR on the data stream, and measure the resulting BER from the EUT.

Figure 2 illustrates the test configuration for the BER penalty technique. The equipment outlined in dashed lines is optional. The optional frequency synthesizer is used to provide a more accurate determination of frequencies utilized in the measurement procedure. This may be particularly important for repeatability of measurements for some types of equipment; i.e., asynchronous digital multiplexes. The optional jitter receiver is used to verify the amplitude of generated jitter.

Figure 2, (N), p.

Procedure

i) Connect the equipment as shown in Figure 2. Verify proper continuity and error-free operation.

ii) With no applied jitter, increase the noise (or attenuate the signal) until at least 100 bit errors per second are observed.

iii) Record the corresponding BER and its associated SNR.

iv) Increase the SNR by the specified amount.

v) Set the input jitter frequency as desired.

vi) Adjust the jitter amplitude until the BER returns to the value recorded in step (iii).

vii) Record the amplitude and frequency of the applied input jitter, and repeat steps v) to vii) for a sufficient number of frequencies to characterize the jitter tolerance curve.

4.1.2 *Onset of errors technique*

The onset of errors criterion for jitter tolerance measurements is defined as the largest amplitude of jitter at a specified frequency that causes a cumulative total of more than 2 errored seconds, where these errored seconds have been summed over successive 30 seconds measurement intervals of increasing jitter amplitude.

This technique involves setting a jitter frequency and determining the jitter amplitude of the test signal which causes the onset of errors criterion to be satisfied. Specifically, this technique requires:

1) isolation of the jitter amplitude ‘‘transition region’’ (in which error-free operation ceases),

2) one errored second measurement, 30 seconds in duration, for each incrementally increased jitter amplitude from the beginning of this region, and

3) determination of the largest jitter amplitude for which the cumulative errored second count is no more than 2 errored seconds.

The process is repeated for a sufficient number of frequencies such that the measurement accurately represents the continuous sinusoidal input jitter tolerance of the EUT over the applicable jitter frequency range. The test equipment must be able to produce a controlled jittered signal and measure the resulting errored seconds caused by the jitter on the incoming signal.

Figure 3 illustrates the test configuration for the onset of errors technique. The optional frequency synthesizer is used to provide a more accurate determination of frequencies utilized in the measurement procedure. The optional jitter receiver is used to verify the amplitude of generated jitter.

Figure 3, (N), p.

Procedure

i) Connect the equipment as shown in Figure 3. Verify proper continuity and error-free operation.

ii) Set the input jitter frequency as desired, and initialize the jitter amplitude to 0 UI peak-peak.

iii) Increase the jitter amplitude in gross increments to determine the amplitude region where error-free operation ceases. Reduce the jitter amplitude to its level at the beginning of this region.

iv) Record the number of errored seconds that occur over a 30 second measurement interval. Note that the initial measurement must be 0 errored seconds.

v) Increase the jitter amplitude in fine increments, repeating step iv) for each increment, until the onset of errors criterion is satisfied.

vi) Record the indicated amplitude and frequency of the applied input jitter, and repeat steps ii) to iv) for a sufficient number of frequencies to characterize the jitter tolerance curve.

4.2 *Jitter tolerance template compliance*

Equipment jitter tolerance is specified with jitter tolerance templates. Each template defines the region over which the equipment must operate without suffering the designated degradation of error performance. The difference between the template and actual equipment tolerance curve represents the operating jitter margin, illustrated in Figure 1.

The template compliance measurement is performed by setting the jitter frequency and amplitude to the template value, and observing that the designated degradation of error performance does not occur.

A sufficient number of template points are measured to assure compliance over the entire frequency range of the template.

Figure 2 or 3, as applicable, illustrates the test configuration for the jitter tolerance template compliance technique.

Procedure

i) Connect the equipment as described in § 4.1.1 or 4.1.2, as applicable. Verify proper continuity and error-free operation.

ii) Set the jitter amplitude and frequency to a template point.

iii) When the onset of errors technique is used, confirm that 0 errored seconds occur. When the BER penalty technique is used, confirm that the designated degradation of error performance is not reached.

iv) Repeat steps ii) and iii) for a sufficient number of template points to verify jitter tolerance template compliance.

5 Jitter transfer characteristic measurement

The jitter transfer characteristic of an individual digital equipment is defined as the ratio of the output jitter to the applied input jitter as a function of frequency.

If the relationship between the jitter appearing at the input and output ports of a digital equipment can be described in terms of a linear process (a process which is both additive and homogeneous), the term ‘‘jitter transfer function’’ is used. The relationship between jitter appearing at the input and output ports of some types of digital equipment cannot be described in terms of a jitter transfer function. In such cases, different measurement techniques may be necessary to obtain meaningful results.

5.1 *Linear processes*

Jitter transfer measurements are commonly required for clock recovery circuits and desynchronizer phase smoothing circuits. Measurement of the jitter transfer function of a linear clock recovery circuit is generally straightforward. However, measurement of the jitter transfer function of a linear desynchronizer phase smoothing circuit requires specialized techniques because it is embedded in a non-linear asynchronous digital multiplex.

5.1.1 *Clock recovery circuit*

Clock recovery circuits are an essential component of individual digital equipment input ports. Of particular interest is the jitter transfer function of clock recovery circuits which dominate the transfer of jitter from the input to output ports. Characterization of linear clock recovery circuits embedded in non-linear equipment (i.e., asynchronous digital multiplexes) are not addressed because they typically do not dominate the overall equipment jitter transfer characteristic.

5.1.1.1 *Basic technique*

This technique involves applying swept sinusoidal jitter at a fixed tolerable amplitude over a selected frequency range to the EUT, and observing the output jitter amplitude over the applied frequency range. The process is repeated for a sufficient number of frequency ranges to characterize the jitter transfer function of the EUT.

Specifically, this technique utilizes a spectrum analyzer to set a jitter frequency range and corresponding tolerable jitter amplitude. Initially, the EUT is bypassed to establish a 0 dB amplitude reference trace for the test equipment. The EUT is then re-connected, and the 0 dB amplitude reference trace subtracted from the overall jitter transfer measurement to obtain the EUT jitter transfer function. Use of a spectrum analyzer with a tracking oscillator output is required to determine the input jitter frequency and amplitude while making a narrow-band measurement of the output jitter. To achieve a high degree of accuracy, the spectrum analyzer bandwidth must be sufficiently narrow to obtain the desired amplitude resolution and dynamic range in each frequency band measured. For example, to verify less than 0.1 dB peaking, and a 20 dB per decade roll-off from 350 Hz to 20 kHz, a spectrum analyzer with 0.1 dB resolution, 3 Hz bandwidth, and 40 dB dynamic range may be required.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. The optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

Figure 4, (N), p.

Procedure

i) Perform a jitter tolerance measurement of the EUT over the desired frequency range, as described in § 4.

ii) Connect the equipment as shown in Figure 4, bypassing the EUT. Verify proper continuity, linearity, and error-free operation.

iii) Set the frequency range on the spectrum analyzer as desired. Adjust the tracking oscillator output level on the spectrum analyzer to produce a tolerable jitter amplitude over the selected frequency range, which is large enough to ensure adequate measurement accuracy, yet sufficiently small to preserve linear operation.

iv) Setting the spectrum analyzer bandwidth as narrow as feasible, sweep the desired frequency range, and record the 0 dB amplitude reference trace of the test equipment. (Setting a narrow spectrum analyzer bandwidth may allow a reduction in applied jitter amplitude with no loss in measurement accuracy.)

v) Reconnect the EUT as shown in Figure 4. Verify proper continuity, linearity, and error-free operation.

vi) Use the spectrum analyzer to sweep the selected frequency range and record the magnitude of the overall (test equipment and EUT) jitter transfer function.

vii) To obtain the EUT jitter transfer function, substract the 0 dB amplitude reference trace from the overall jitter transfer function recorded in step vi).

viii) Repeat steps i) to vii) for a sufficient number of frequency ranges to characterize the overall frequency range of interest.

5.1.2 *Desynchronizer phase smoothing circuit*

In general, a non-linear process characterizes the relationship between the jitter appearing at the input and output ports of an asynchronous digital multiplex. However, most phase smoothing circuits are intended to operate linearly, and therefore may have a transfer function associated with them. Two techniques have been developed which enable the determination of the jitter transfer function for a linear desynchronizer phase- smoothing circuit using standard multiplex interfaces. The first technique utilizes interfaces at the multiplexer low-speed input and the demultiplexer low-speed output. The second technique utilizes the interfaces at the demultiplexer high-speed input and low-speed output. The second technique utilizes the interfaces at the demultiplexer high-speed input and low-speed output.

5.1.2.1 *Multiplex technique*

This technique attempts to ‘‘linearize’’ the multiplexing process by applying appropriate constraints to the applied input jitter amplitude and frequency. Sinusoidal jitter of a selected amplitude and frequency is applied to the multiplexer low-speed output is observed at the applied frequency. The process is repeated for a sufficient number of frequencies to characterize the desynchronizer jitter transfer function. Specifically, when sinusoidal jitter modulates the phase of the input signal to one of the multiplexer low-speed inputs, the jitter spectrum appearing at the corresponding tributary outputs, in addition to containing other waiting time jitter components at discrete locations throughout the spectrum, contains a discrete component at the frequency of the input jitter. This technique involves making the amplitude of the input jitter sufficiently large to ensure that this discrete component in the output jitter spectrum at the applied frequency dominates the other

waiting time jitter components in the measurement bandwidth. However, it should not be so large as to saturate the multiplexer stuffing mechanism (onset of saturation). The smallest magnitude of frequency deviation, $f(t)$, which causes onset of saturation is determined from the smaller magnitude of:

$$f(t) = f_{s\dc} — f_{n\do\dm}$$

$$f(t) = —f_m + f_{s\dc} — f_{n\do\dm}$$

where

$f_{s\dc}$ represents the multiplexer average synchronous data bit read clock rate,

f_m represents the maximum rate at which pulses can be stuffed into an incoming pulse stream, and

$f_{n\do\dm}$ refers to the nominal incoming line rate.

To achieve a high degree of accuracy, the spectrum analyzer bandwidth must be sufficiently narrow to obtain the desired amplitude resolution and dynamic range in each frequency band measured (see § 5.1.1.1). It is also assumed that the transfer function of the multiplexer low-speed input clock recovery circuit does not alter the applied jitter in the frequency range of interest.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. The optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

Procedure

i) Perform a jitter tolerance measurement over the desired frequency range.

ii) Connect the equipment as shown in Figure 4, bypassing the EUT. Verify proper continuity, linearity, and error-free operation.

iii) Manually set the test frequency on the spectrum analyzer.

iv) Adjust the tracking oscillator output level on the spectrum analyzer to produce the largest tolerable jitter amplitude which will not cause onset of saturation (as defined in this paragraph) at the selected frequency.

v) Set the spectrum analyzer bandwidth as narrow as feasible, and record the 0 dB amplitude transfer reference level of the test equipment.

vi) Reconnect the EUT as shown in Figure 4. Verify proper continuity and error-free operation.

vii) Record the magnitude of the overall (test equipment and EUT) jitter transfer function. Averaging is generally required to remove the effects of waiting time jitter on the measurement.

viii) To obtain the magnitude of the EUT jitter transfer function, substract the 0 dB amplitude transfer reference level from the overall magnitude obtained in step vii).

ix) Repeat steps iii) — viii) for a sufficient number of frequencies to characterize the jitter transfer function of the EUT.

5.1.2.2 *Demultiplexer technique*

This technique involves applying sinusoidal jitter of a selected amplitude and frequency to the demultiplexer high-speed input, and observing the jitter amplitude at the demultiplexer low-speed output at the applied frequency. The process is repeated for a sufficient number of frequencies to characterize the desynchronizer jitter transfer function. Specifically, when sinusoidal jitter modulates the phase of the input signal to the demultiplexer, the output jitter spectrum contains a discrete component at the frequency of the input jitter, in addition to the intrinsic waiting time jitter components already present. This technique involves making the amplitude of the applied input jitter sufficiently large to ensure that its contribution to the output jitter spectrum at the applied frequency dominates that of the waiting time jitter, but does not exceed the demultiplexer input jitter tolerance. It is also assumed that the transfer function of the demultiplexer high-speed input clock recovery circuit does not alter the applied jitter in the frequency range of interest.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. It should be emphasized that the following procedure *cannot calibrate out the effects of the low-speed receive circuitry contained in the jitter receiver functional block component* , and therefore requires that this circuitry has flat response.

It should be noted that the digital signal applied to the high-speed input of the demultiplexer must contain framing information to allow proper operation of the equipment under test. ‘‘Framed’’ signals can either be taken from an appropriate digital signal generator or may come from the corresponding digital multiplexer. In the latter case, a transparent jitter modulator has to be inserted between the high-speed multiplexer output and the demultiplexer input. The jitter modulator superimposes jitter on the jitter-free signal coming from the multiplexer.

Procedure

i) Follow the procedure provided in § 5.1.1.1 using Figure 4, scaling the applied jitter in unit intervals (UI) by the ratio of the demultiplexer high-speed input to low-speed output data rates.

5.2 *Non-linear process*

This area requires further study.

6 **Ouput jitter measurement**

Output jitter measurements fall within two categories:

1) network output jitter at hierarchical interfaces, and

2) intrinsic jitter generated by individual digital equipment.

Measurements of output jitter may be in terms of rms and peak-to-peak amplitudes over designated frequency ranges, and may require statistical characterization.

Output jitter measurements utilize either live traffic or controlled data patterns.

6.1 *Live traffic*

Output jitter measurements at network hierarchical interfaces typically use a live traffic signal. For pre-service testing, in which controlled data patterns are used, see § 6.2. This technique involves demodulating the jitter from the live traffic at the output of a network interface, selectively filtering the jitter, and measuring the true rms or true peak-to-peak amplitude of the jitter over the specified measurement time interval.

Figure 5 illustrates the test configuration for the live traffic technique. The optional spectrum analyzer allows observation of the output jitter frequency spectrum.

Figure 5, (N), p.

Procedure

i) Connect the equipment as shown in Figure 5. Verify proper continuity and error-free operation.

ii) Select the desired jitter measurement filter and measure the filtered output jitter, recording the true peak-to-peak jitter amplitude that occurs during the specified measurement time interval.

iii) Repeat step ii) for all desired jitter measurement filters.

6.2 *Controlled data patterns*

Measurement of intrinsic jitter in individual digital equipment requires the application of controlled data patterns. Controlled data patterns are generally applicable in laboratory, factory, and out-of-service situations. The ‘‘basic technique’’, described below, details how such measurements may be performed.

Where it is desirable to obtain more detailed information regarding output jitter power (specifically, jitter generated in digital regenerators), jitter may be further categorized in terms of random and systematic components. The primary reasons for distinguishing between random and systematic jitter are to enable the comparison of measurement results with theoretical computations, and to refine regenerator design. The ‘‘enhanced technique’’ [6] describes how random and systematic jitter may be measured.

6.2.1 *Basic technique*

This technique is indentical to that described in § 6.1, except for the application of an unjittered controlled data pattern to the EUT. In Figure 5, the optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

Procedure

i) Connect the equipment as shown in Figure 5, using the digital signal generator to provide an unjittered controlled data pattern to the EUT. Verify proper continuity and error-free operation.

ii) Select the desired jitter measurement filter and measure the filtered output jitter, recording the true peak-to-peak jitter amplitude that occurs during the specified measurement time interval.

iii) Repeat step ii) for all desired jitter measurement filters.

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