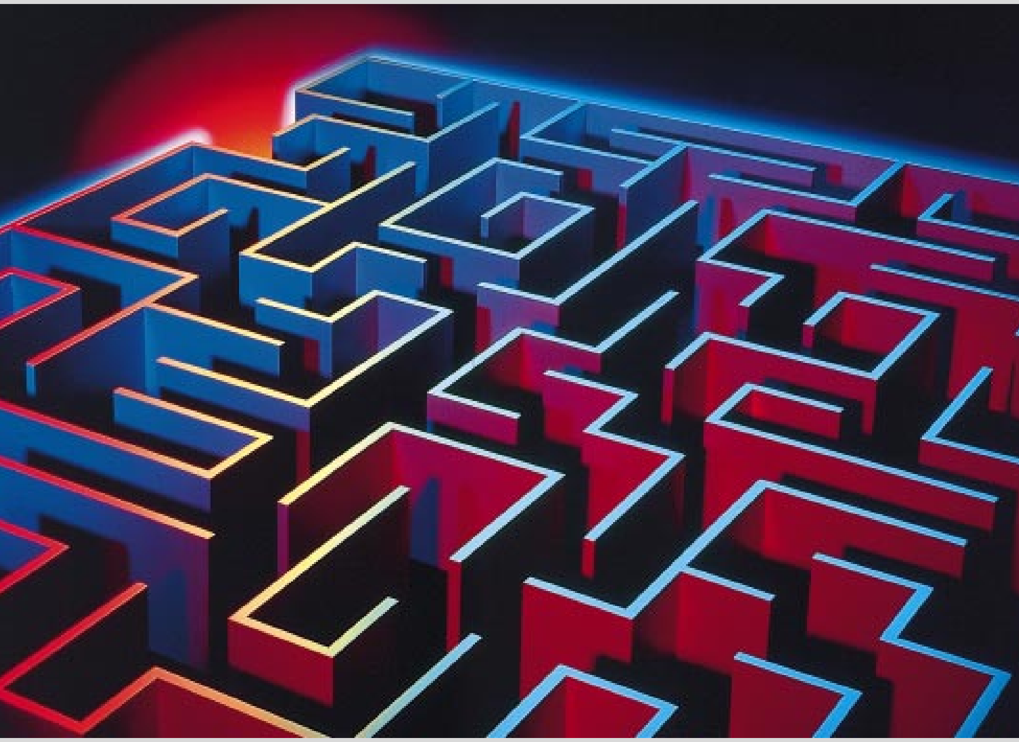
Conforming to the Maze of Network Standards



Application Note 59

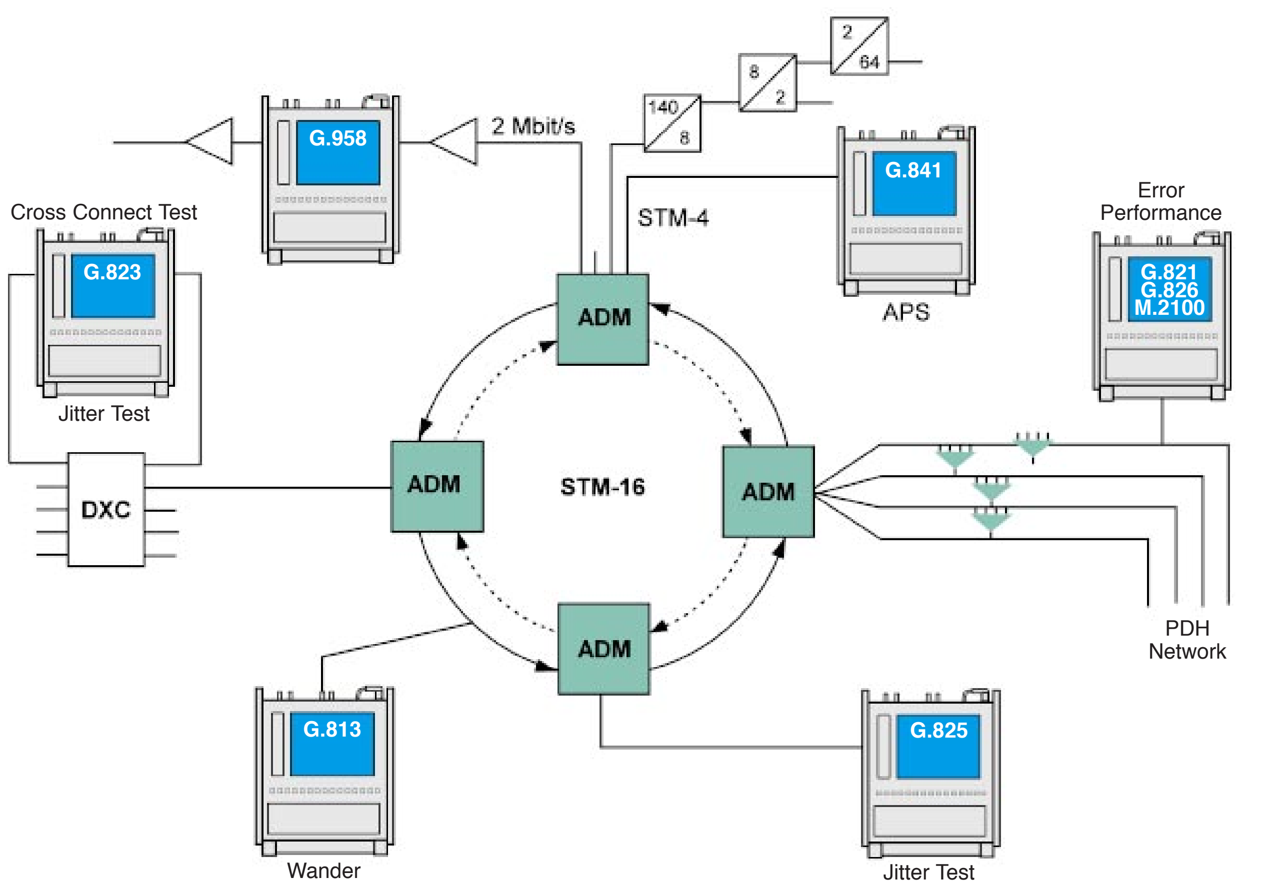
ITU-T Recommendations and Practical Applications in PDH/SDH Networks

Wandel & Goltermann
Communications Test Solutions

Why Do Recommendations Exist for SDH/PDH Networks?

Telecommunications networks are not built from technologies that are individually specified by each service provider. If they were, imagine how hard it would be to connect from one service provider to the next! The logical solution is to have a universal organization (or organizations) specifying transmission methods that are universally applicable to all service providers. One of these bodies is the International Telecommunication Union —Telecommunication Standardization Sector (ITU-T) formally known as CCITT. 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.

Many telecommunication networks use network elements that are specified by ITU-T Recommendations. The Advanced Network Tester (ANT-20) recognizes these Recommendations and carries out measurements to qualify them. This note will directly quote Recommendations from ITU-T and then apply them to practical applications performed on the ANT-20.



Recommendation G.783: Characteristics of Synchronous Digital Hierarchy (SDH) Equipment Functional Blocks

"This Recommendation defines a library of basic building blocks and a set of rules by which they may be combined in order to describe a digital transmission equipment. The library comprises the functional building blocks needed to specify completely the generic functional structure of the Synchronous Digital Hierarchy."

The Recommendation describes processes within the basic building blocks, the so called "atomic functions", for example the generation and evaluation of overheads used for performance monitoring.

The regenerator section termination and adaptation function acts as a source and sink for the regenerator section overhead (RSOH). The RSOH contains bytes A1, A2, B1, J0, E1, F1, D1 to D3 and bytes reserved for national use. This section acts as a maintenance entity between and including two regenerator termination functions.

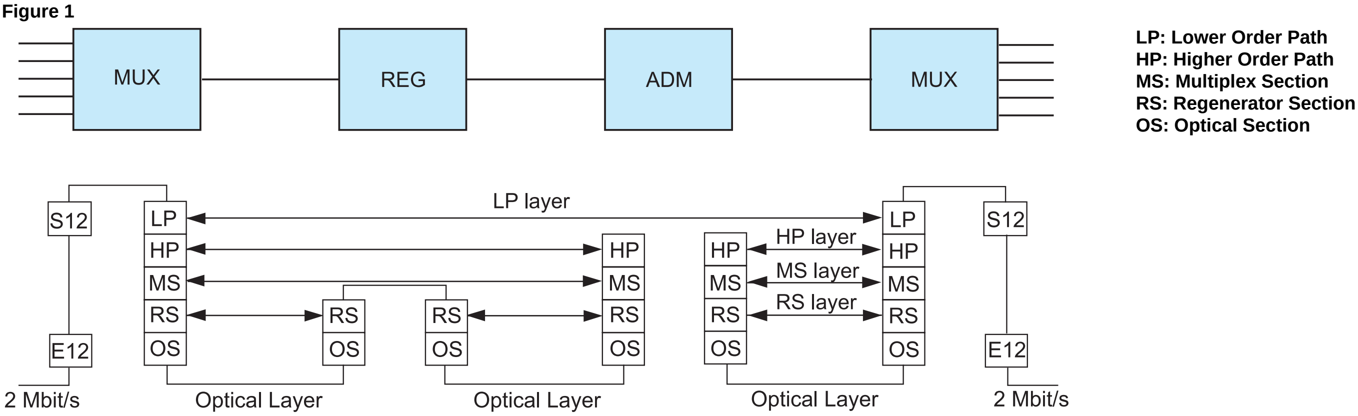
The multiplex section termination and adaptation function acts as a source and sink for the multiplex section overhead (MSOH). The MSOH contains bytes B2, K1, K2, D4 to D12, S1, M1, E2 and bytes reserved for national use. This section acts as a maintenance entity between and including two multiplex termination functions.

In Brief

PDH signals are transported over four main SDH layers all of which play critical parts in certifying SDH transmission. The physical layer is classified as the fifth layer. The section overhead (SOH) is mainly built up from the RSOH and MSOH, which guide the payload of the STM-N signal between multiplex and regenerator elements within a network. With this particular asset of the STM-N technology, the overhead of the STM-N signal can be tested and in turn test the MST and RST functions.

Figure 1 illustrates the different layers which are passed by a signal when it is transmitted through a network. The different layers are terminated depending on the functions implemented in the network elements. For example, the regenerator layer guides the signal between the MUX and REG, then a new RSOH is generated at the output of the REG to guide the signal to the ADM, and so on. The lower path (LP) layer will come into play when the PDH tributaries are terminated at the DEMUX.

Figure 1



Application

G.783	APPLICATION
MSOH	Byte Functionality and BERT
RSOH	Byte Functionality and BERT

A suitable application for testing the RST and MST functions lies in the Anomaly/Defect generator and analyzer. SDH technology uses a maintenance interaction flow where different signals are transmitted through particular bytes of the overhead to indicate anomalies and defects. Messages are generated due to an interaction with corresponding layer errors. For example, if a LOF is generated in the RS layer then an AIS defect will display in the PDH layer. Test can be performed with the ANT-20 by sending out defects in the different layers and looking at the reactions in the corresponding layers. Figure 2 a/b illustrates two general setups which will result in two different error alarms being generated.

The black line setup will generate error alarms of a HP and MS layer nature if a RS defect was first generated. The red line setup will generate error alarms of PDH layer nature due to the fact that a PDH signal is examined.

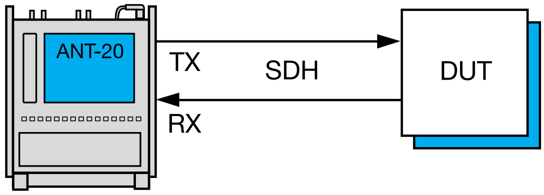


Figure 2a

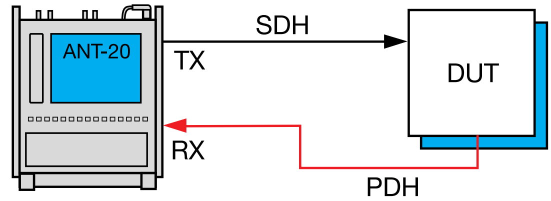


Figure 2b

Figure 3a:
The user interface window for generating different anomalies and defects.

Figure 3b:
Results in graphical format.

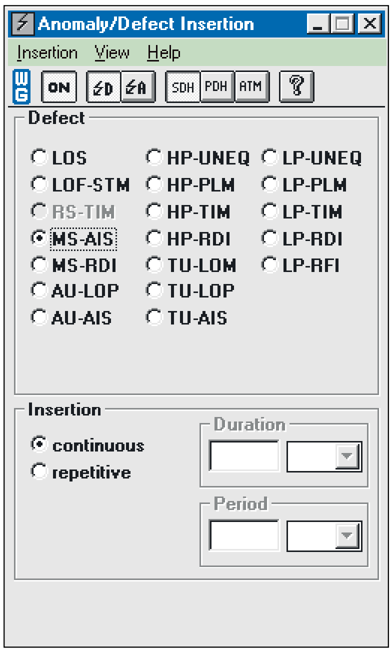


Figure 3a

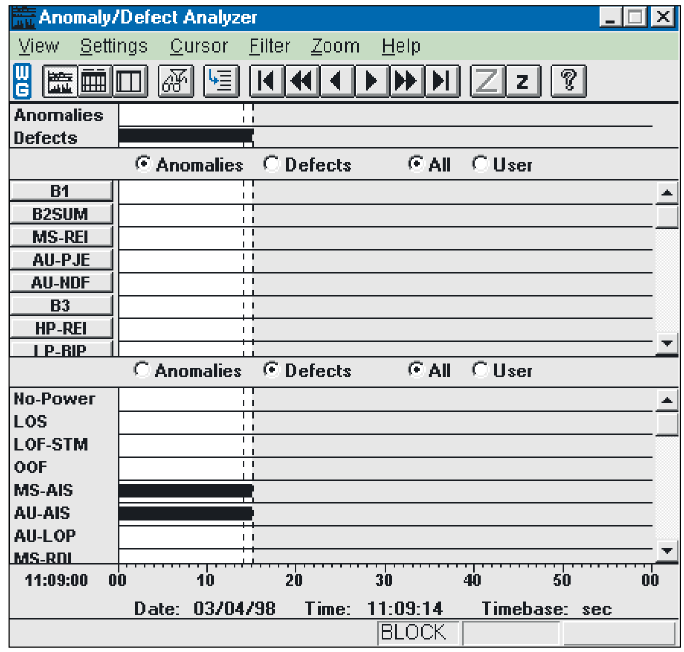


Figure 3b

Recommendation G.783: Section 10 Specification of Jitter and Wander

This section of recommendation G.783 specifies input and output jitter/wander requirements which directly refer to recommendations G.958, G.825 and G.813 which will be explained later in this note. This recommendation also specifies wander and combined jitter caused by PDH tributary mapping and pointer adjustments.

“The combined jitter arising from tributary mapping and pointer adjustments should be specified in terms of peak-to-peak amplitude over a given frequency band, under application of representative specified pointer adjustment test sequences, for a given measurement interval.”

A major factor that must be realized in this specification of mapping and pointer jitter on PDH interfaces is the definition of the filter characteristics. Most important is the specification of the highpass filter characteristics due to the low frequency components of pointer jitter. Tables 1a/1b show the filter characteristics for mapping jitter generation and combined jitter generation.

Table 1a: Mapping jitter

G.703 (PDH) interfaces	Filter characteristics			Maximum pk-pk mapping jitter	
kbit/s	f_1 high pass	f_3 high pass	f_4 low pass	f_1–f_4	f_3–f_4
1,544	10 Hz	8 kHz	40 kHz	(Note 1)	0.1 UI
2,048	20 Hz	18 kHz (700 Hz)	100 kHz	(Note 1)	0.075 UI
6,312	10 Hz	3 kHz	60 kHz	(Note 1)	0.1 UI
34,368	100 Hz	10 kHz	800 kHz	(Note 1)	0.075 UI
44,736	10 Hz	30 kHz	400 kHz	0.4 UI	0.1 UI
139,264	200 Hz	10 kHz	3,500 kHz	(Note 1)	(Note 2)

Notes
1. These values are for further study
2. A value of 0.075 UI has been proposed

Table 1b: Combined jitter

G.703 (PDH) interfaces	Filter characteristics			Maximum pk-pk combined jitter	
kbit/s	f_1 high pass	f_3 high pass	f_4 low pass	f_1–f_4	f_3–f_4
1,544	10 Hz	8 kHz	40 kHz	1.5 UI	(Note 1)
2,048	20 Hz	18 kHz (700 Hz)	100 kHz	0.4 UI	0.075 UI
6,312	10 Hz	3 kHz	60 kHz	1.5 UI	(Note 1)
34,368	100 Hz	10 kHz	800 kHz	0.4 UI 0.75 UI	0.075 UI
44,736	10 Hz	30 kHz	400 kHz	(Note 1)	(Note 1)
139,264	200 Hz	10 kHz	3 500 kHz	(Note 1)	(Note 1)

Note 1
These values are for further study

In Brief

Mapping and combined jitter occurs when PDH signals are transported over a SDH network. PDH tributaries need to be contained in the virtual container (VC) of a SDH transport module (STM). Accommodation of the PDH bit rate to the SDH clock requires a bit stuffing procedure during the mapping process. These stuffing phase steps lead to additional mapping jitter. The same thing, but with higher amplitude occurs if pointer adjustments are apparent. Both effects together result in combined jitter. The recommendation specifies values to which the MUX and DEMUX must adhere to ensure as little jitter in the system as possible. The recommendation also defines pointer test sequences which are used to test the performance of SDH equipment with regard to SDH tributary jitter. These pointer test sequences are illustrated in Figure 4.

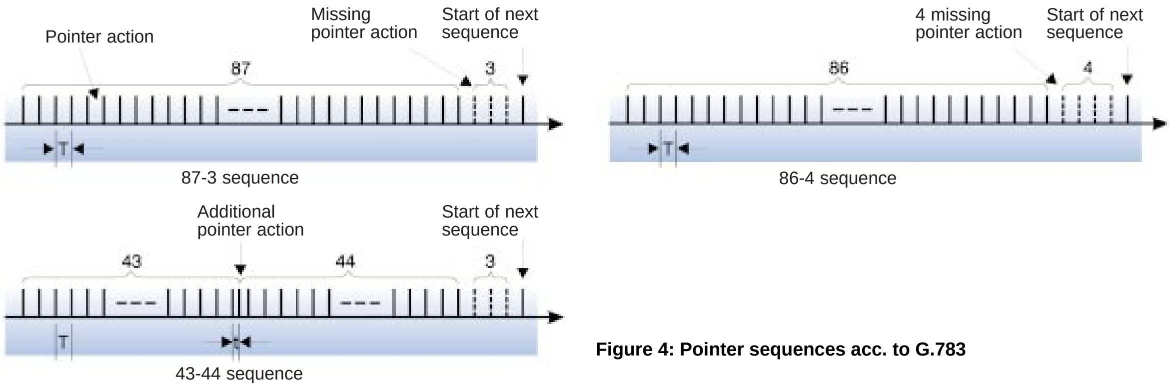


Figure 4: Pointer sequences acc. to G.783

Application

G.783 Section 10	APPLICATION
PDH interfaces	Jitter with pointer simulation

The ANT-20 has the advantage of generating AU and TU pointers simultaneously.
The application is set up to test the DUT's combined and mapped jitter limits. This is performed by inputting an STM-N signal and monitoring the PDH tributaries, (i.e. 2,8,34,140 Mbit/s). The ANT-20 will analyze jitter as illustrated in Recommendation G.783, but with the pointer test sequences activated simultaneously.

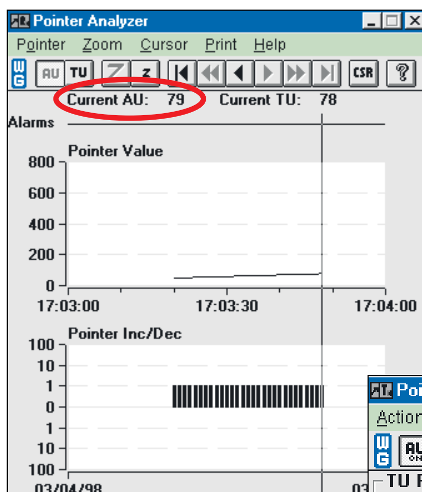


Figure 5a

Figure 5a: The pointer value in graphical format with the current value (shown ringed).

Figure 5b: The possible sequences that the ANT-20 may generate as specified by ITU-T Recommendation G.783.

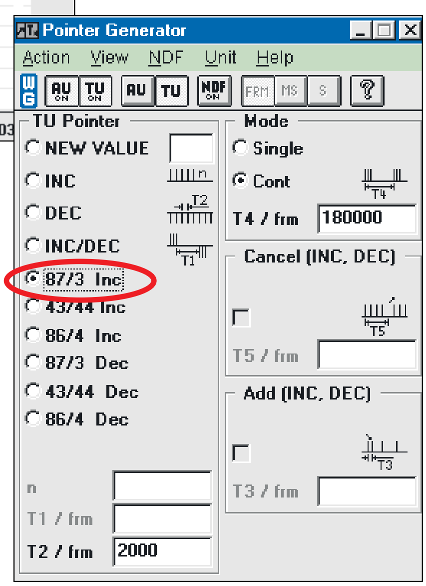


Figure 5b

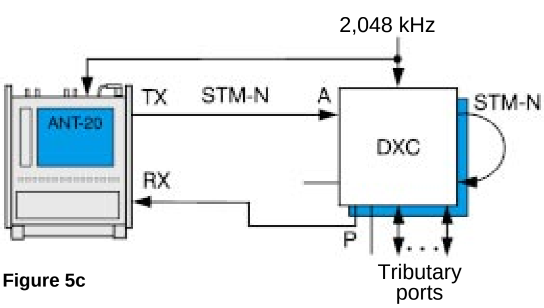


Figure 5c

Recommendation G.823: Control of JITTER and WANDER within Digital Networks Based on the 2,048 kbit/s Hierarchy

"The scope of this Recommendation is to define the parameters and the relevant values that are able to control satisfactorily the amount of jitter and wander present at the plesiochronous digital hierarchy (PDH) network interface."
The limits set for the maximum permissible levels of jitter at PDH interfaces within digital networks are illustrated in Table 2. The recommendation points out that the limits should be met for all operating conditions regardless of the amount of equipment preceding the interface. This recommendation covers also limits for wander influences that appear over the equipment interfaces of a PDH network.
The Recommendation states that "magnitudes of wander, being largely dependent on the fundamental propagation characteristics of transmission media and the aging of clock circuitry, can be predicted." For PDH interfaces the following limits apply.

Table 2: Jitter limits for PDH interfaces defining the corresponding filter bandwidth.

Parameter value	Network limit		Measurement filter bandwidth		
Digital rate (kbit/s)	B_1 unit interval peak-peak	B_2 unit interval peak-peak	Band-pass filter having a lower cut-off frequency f_1 or f_3 and an upper cut-off frequency f_4		
			f_1	f_3	f_4
64 (Note 1)	0.25	0.05	20 Hz	3 kHz	20 kHz
2,048	1.5	0.2	20 Hz	18 khz (700 Hz)	100 kHz
8,448	1.5	0.2	20 Hz	3 kHz (80 kHz)	400 kHz
34,368	1.5	0.15	100 Hz	10 kHz	800 kHz
139,264	1.5	00.75	200 Hz	10 kHz	3 500 kHz

Notes
1. For the codirectional interface only.
2. The frequency values shown in parenthesis only apply to certain national interfaces.
3. UI = Unit Interval

for 64 kbit/s	1 UI =	15.60 ns
for 2,048 kbit/s	1 UI =	488.00 ns
for 8,448 kbit/s	1 UI =	118.00 ns
for 34,368 kbit/s	1 UI =	29.10 ns
for 139,264 kbit/s	1 UI =	7.18 ns

B_1 is the permissible jitter with the band pass filter cut-off f_1 and f_4.
B_2 is the permissible jitter with the band pass filter cut-off f_3 and f_4.

Figure 6 illustrates the permissible maximum time interval error (MTIE) vs. observation period S for the output of a network node. MTIE is the maximum UI which was recorded at an instant of the period S. S can be a 10 sec observation time which makes up a 12 hour measuring period.

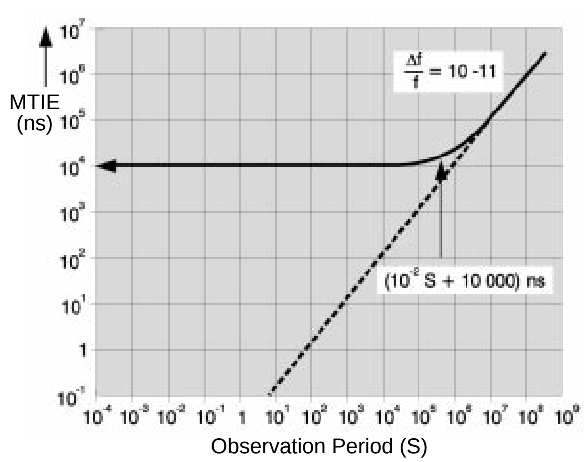


Figure 6: Permissible MTIE vs. observation period s for the output of a network node.

In Brief

This Recommendation focuses on networks containing equipment with PDH interfaces. When networks are designed, service providers need to take into account the values illustrated in Table 2 and Figure 6, ensuring that all network elements on line do not introduce any more jitter or wander into a PDH network system.

Application

G.823	APPLICATION
PDH interface	Jitter and Maximum Tolerable Jitter
PDH interface	Wander (MTIE)
PDH regenerators	Jitter Transfer Function

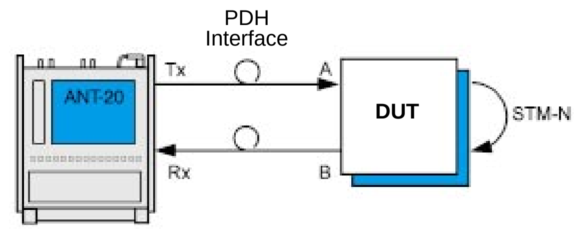


Figure 7

Figure 7 shows the setup to test the performance of the DUT's jitter capabilities for PDH signals. Jitter transfer function and maximum tolerable jitter tests can also be performed under this Recommendation. These two measurements are explained in more detail in the sections for Recommendation G.958 and G.825. For wander refer to G.813.
The jitter result window in Figure 8 is for manual mode. In this mode the user can set jitter amplitudes manually and observe the reaction of the DUT through errors and alarms. Phase hits occur when
a specific jitter threshold is exceeded. The results are recorded using a counter. Limits of the hit threshold may be set via the SET button.
The jitter generator/analyzer window allows the user to select the application measurement for maximum tolerable jitter (MTJ) or fast MTJ (FMTJ), jitter transfer function and wander analysis.

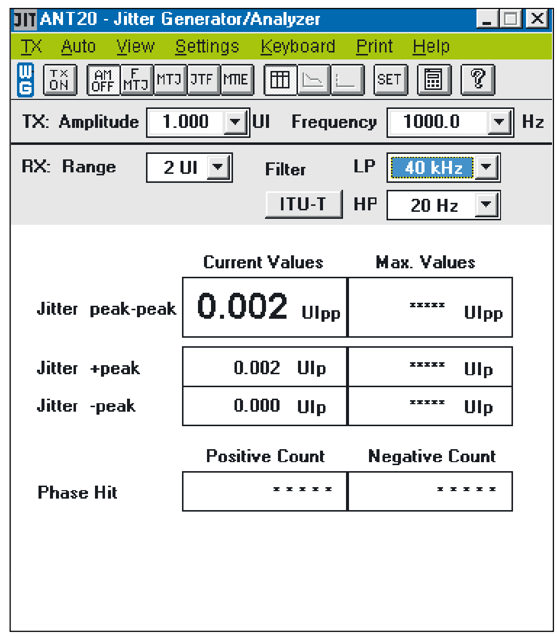


Figure 8: The results window for jitter for a PDH signal.

Recommendation G.825: Control of JITTER and WANDER within Digital Networks Based on the Synchronous Digital Hierarchy (SDH)

"The scope of this Recommendation is to define the parameters and the relevant values that are able to control satisfactorily the amount of jitter and wander present at the SDH network interface."
This Recommendation specifies the jitter limits applied to the SDH network interfaces. Network interfaces (e.g. international boundaries) must meet interface limits regardless of the individual carrier's choice of equipment. These limits are displayed in Table 3.

Table 3

STM level	f_1 (Hz)	f_3 (kHz)	f_4 (MHz)	B_1 (UIpp)	B_2 (UIpp)
STM-1 optical	500	65	1.3	1.5	0.15
STM-1 electrical	500	65	1.3	1.5	0.075
STM-4 optical	1,000	250	5	1.5	0.15
STM-16 optical	5,000	under study (Note 2)	20	1.5	0.15

Notes
1. UIpp = Unit interval
   for STM-1 UI = 6.43 ns
   for STM-4 UI = 1.61 ns
   for STM-16 UI = 0.40 ns
2. A value of 1 MHz has been suggested.
   B1 is the permissable jitter with the band pass filter cut-off f_1 and f_4.
   B2 is the permissable jitter with the band pass filter cut-off f_3 and f_4.

In Brief

This Recommendation applies to SDH service providers who need to test the quality of the SDH interfaces where SDH networks span a large area. Table 3 illustrates limits which any interface in the network will need to meet to ensure a quality network. Jitter and Wander limits for network elements without connection to the network are more stringend to meet the network interface requirements. Such limits are defined in Recommendation G.783 and G.958 for SDH network elements.

Application

G.825	APPLICATION
ALL SDH interface	Jitter, Maximum Tolerable Jitter

The setup to test the performance of maximum tolerable jitter (MTJ) at SDH network interfaces is shown in Figure 9. MTJ measurements are generally performed by increasing jitter amplitudes at certain scan frequencies and evaluating the number of errors that the DUT produces.
The ANT-20 performs this procedure in an automated way, thus generating different jitter amplitudes at certain frequencies and recording the jitter amplitude when the DUT failed, then comparing these values against the Recommendation mask.

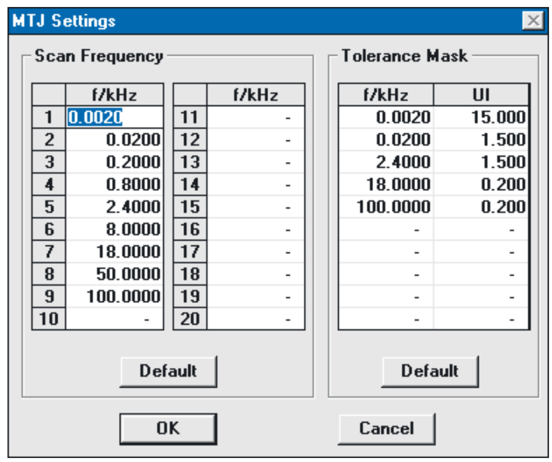


Figure 10: Different tolerance masks and scan frequencies can be user defined, by clicking on the "SET" button situated in the title bar.

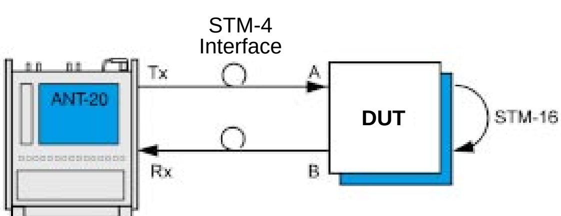


Figure 9

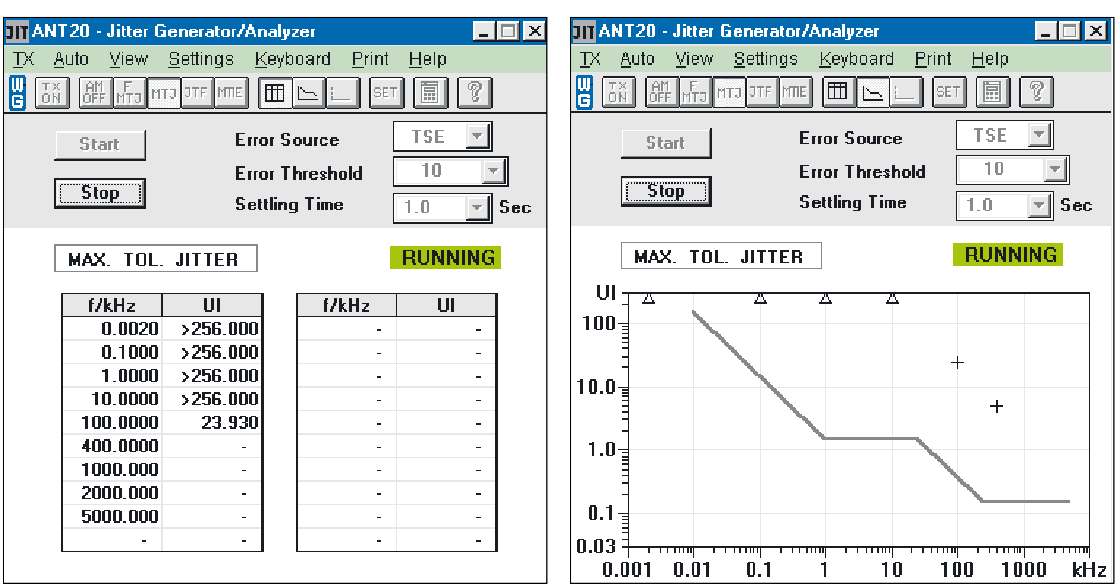


Figure 11: MTJ results recorded in tabular and graphical format against tolerance masks set by ITU-T.

Recommendation G.958: Digital Line Systems Based on the Synchronous Digital Hierarchy for Use on Optical Fiber Cables

"This Recommendation specifies characteristics of digital synchronous line systems based on the synchronous digital hierarchy (SDH) to provide transverse compatibility."
This Recommendation will focus on jitter generation, jitter transfer and jitter tolerance of regenerators.
"Jitter generation is defined as the amount of jitter at the STM-N output of SDH regenerators." The amplitude of the jitter present at the output of each regenerator should not exceed a specified limit value.
Table 4 displays the proposed figures from the revised draft of recommendation G.958 on STM-N jitter generation for output jitter at an STM-N interface assuming the absence of jitter at the input interface, thus intrinsic jitter.

Table 4: Intrinsic jitter limits

Interface	Measuring filter	Peak-to-peak amplitude
STM-1	500 Hz to 1.3 MHz	0.30 UI
	65 KHz to 1.3 MHz	0.10 UI
STM-4	1,000 Hz to 5 MHz	0.30 UI
	250 kHz to 5 MHz	0.10 UI
STM-16	5,000 Hz to 20 MHz	0.30 UI
	1 MHz to 20 MHz	0.10 UI
For STM-1 1 UI = 6.43 ns For STM-4 1 UI = 1.61 ns For STM-16 1 UI = 0.40 ns		

"Jitter transfer function (JTF) is defined as the ratio of jitter on the output STM-N signal to the jitter applied on the input STM-N signal vs. frequency." This factor indicates the degree to which jitter is amplified or attenuated by a regenerator. If the jitter amplification of several regenerators is too high, the accumulated jitter amplitude at the end of the line system may exceed the network limits.

STM-N level (type)	fc (kHz)	P (dB)
STM-1 (A)	130	0.1
STM-1 (B)	30	0.1
STM-4 (A)	500	0.1
STM-4 (B)	30	0.1
STM-16 (A)	2,000	0.1
STM-16 (B)	30	0.1

Table 5 illustrates the jitter transfer parameters for two classes of regenerators with different frequency bandwidths

STM-M Level	ft (kHz)	fo (kHz)	A1 (Uip-p)	A2 (Uip-p)
STM-1	65	6.5	0.15	1.5
STM-4	250	25	0.15	1.5
STM-16	1,000	100	0.15	1.5

Table 6 illustrates the jitter tolerance parameters

"Jitter tolerance is defined as the peak-to-peak amplitude of sinusoidal jitter applied on the input STM-N signal that causes a 1 dB optical penalty at the optical equipment."
Regenerators must be able to tolerate a specified jitter amplitude at the input without any errors occurring.

NOTE: Relevant parts of Recommendation G.958 including the jitter requirements of regenerators will in future be moved to section 10 of a revised version of Recommendation G.783.

In Brief

This recommendation focuses on the limits that SDH regenerators need to meet to be part of a quality network system. Each regenerator can introduce jitter resulting in jitter accumulation, affecting greatly the purity of the transported signal. Regenerators need to be within the required limits to reassure the performance of a network.

Application

G.958	APPLICATION
SDH regenerator interface	Intrinsic Jitter, Jitter Transfer Function, Jitter Tolerance
SDH regenerator	Wander

JTF measurements are of particular importance when dealing with regenerators. Checks are carried out to demonstrate that the jitter gain of a regenerator is below the defined value of recommendation G.958. If this is not the case, then "jitter runaway" occurs after several regenerators. JTF is measured by applying a signal with defined jitter modulation over the frequency range of the DUT. The jitter amplitude is selected so that the DUT can handle it at any frequency. The ANT-20 measures the resulting jitter amplitude at the output of the DUT at various TX jitter frequencies. The log of the ratio between input and output gives the jitter gain or attenuation.
Jitter transfer function measurements are improved by compensating for intrinsic jitter of the DUT and the ANT-20 by carrying out calibration measurements first. This improves the measurement accuracy.

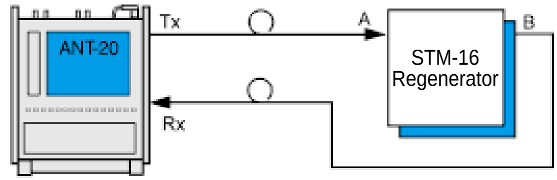


Figure 12: Jitter transfer function test of regenerators.

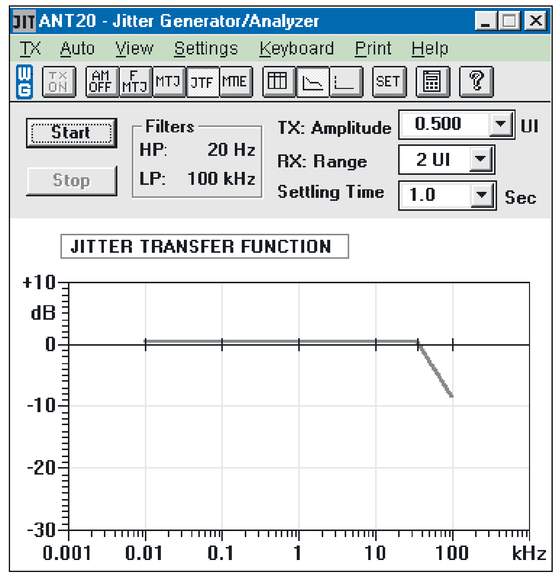


Figure 13: The results are displayed in graphical or tabular format.

Recommendation G.813: Timing Characteristics of SDH Equipment Slave Clocks (SEC)

"This Recommendation outlines requirements for timing devices used in synchronizing network equipment that operates according to the principles governed by the Synchronous Digital Hierarchy (SDH)."
In a normal SDH system, the SDH equipment clock (SEC) is synchronized to a primary reference clock (PRC). SECs have multiple reference inputs which the clock can refer to however, when links between the master and slave clocks fail, then the SEC's frequency will start to drift from that of the PRC at a rate dependent on the quality of the oscillator in the slave clock. This is referred to as "holdover". This Recommendation specifies requirements for two options. "Option 1", applies to SDH networks optimized for the 2,048 kbit/s hierarchy. "Option 2" applies to SDH network optimized for the 1,544 kbit/s hierarchy, which will not be referred to in this note.

"Noise generation of a SEC represents the amount of phase noise produced at the output when there is an ideal input reference signal or the clock is in holdover state." This is commonly known as wander generation and is measured in maximum time interval error (MTIE) and time deviation (TDEV). Figure 14 illustrates MTIE versus observation interval for constant and variable temperatures,

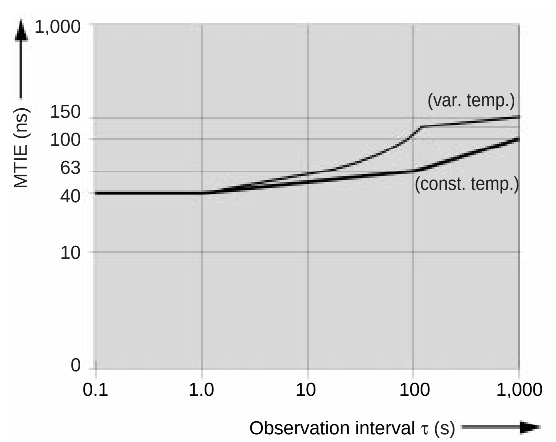


Figure 14: MTIE vs. Observation Time for constant and variable temperatures

where the menasurement needs normally a large period of time. From time interval (TIE) measurements the time deviation TDEV can be calculated. TDEV values are a measure of the phase error variation versus the integration time. Put simply, the time deviation is calculated for each point within a measurement time (T) for an instant that travels through the entire measurement time T_{Total}. Figure 15 shows TDEV versus observation interval for constant temperature.

This Recommendation also specifies limits for jitter generation on SDH output interfaces. The difference between G.958 and this Recommendation is that this recommendation defines limits for all network elements, excluding regenerators. The limits defined in this part of the recommendation are less stringent than the limits defined in G.958, as Table 7 shows.

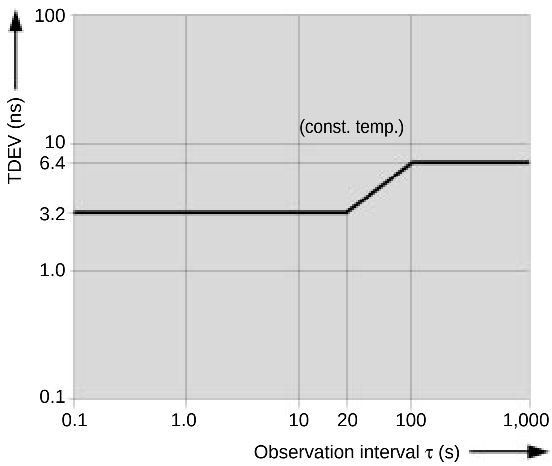


Figure 15: TDEV vs. observation time for constant temperature

"The noise tolerance of a SEC indicates the minimum phase noise level at the input of the clock that should be accommodated whilst:

– Maintaining the clock within prescribed performance limits.
– Not causing any alarms.
– Not causing the clock to switch reference.
– Not causing the clock to go into holdover."

Table 7

Interface	Measure filter	Peak-to-peak amplitude
STM-1	500 Hz to 1.3 MHz	0.50 UI
	65 kHz to 1.3 MHz	0.10 UI
STM-4	1,000 Hz to 5 MHz	0.50 UI
	250 kHz to 5 MHz	0.10 UI
STM-16	5,000 Hz to 20 MHz	0.50 UI
	1 MHz to 20 MHz	0.10 UI
For STM-1	1 UI = 6.43 ns	
For STM-4	1 UI = 1.61 ns	
For STM-16	1 UI = 0.40 ns	

The noise tolerance is also commonly known as wander tolerance and is characterized by MTIE and TDEV masks illustrated in Figures 16a/16b. Jitter tolerance limits are also specified in this recommendation for SDH network elements excluding regenerators, which G.958 covers. Figure 17 shows the maximum tolerable input jitter for 2,048 kHz and 2,048 kbits Synchronization interface.

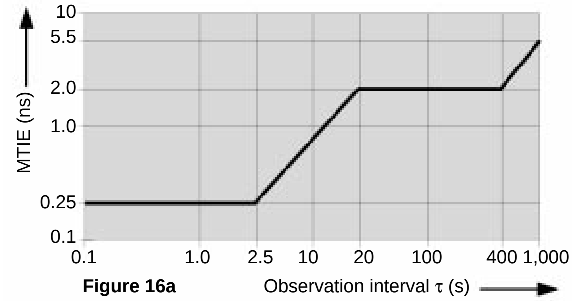


Figure 16a

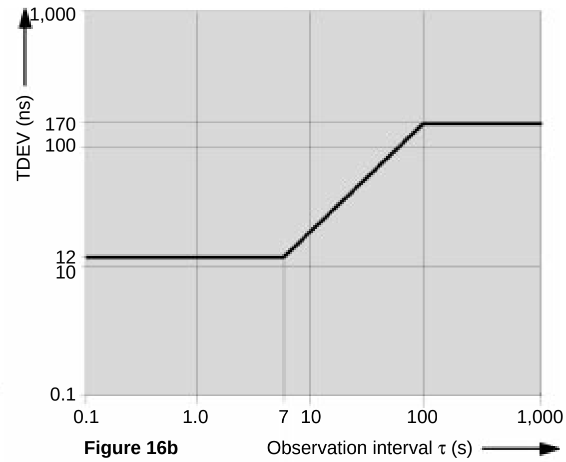


Figure 16b

Figures 16a/16b: The input wander tolerance mask (MTIE and TDEV).

"The noise transfer characteristics of the SEC determines its properties with regard to the transfer of excursions of the input phase relative to the carrier phase." In the passband the phase gain of the SEC should be smaller than 0.2 dB (2.3%). The Recommendation states, "The minimum bandwidth requirement for a SEC is 1 Hz and the maximum bandwidth requirement is 10 Hz."

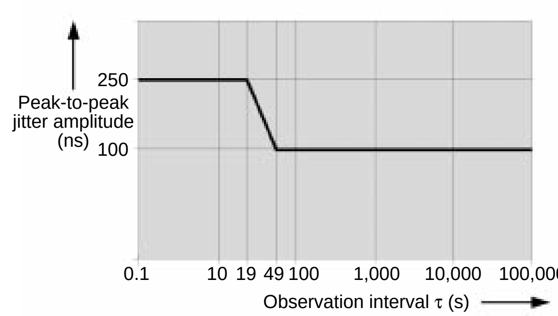


Figure 17: The lower limit of the maximum tolerable input jitter of 2,048 kHz and 2,048 kbit/s signals carrying synchronization to a SEC.

In Brief

SDH network elements use internal clocks (SEC) as timing sources. These clock sources should be synchronized to a PRC via the SDH line interface or via a 2,048 MHz clock line.

To check the quality of the timing signal and internal clock, the phase of the reference clock (PRC) is compared with that of the transmitted data signal or clock output signal. The long-term phase variation is referred to as wander.

Application

G.813	APPLICATION
SDH NE (SEC)	Wander
SDH interface	Jitter

ANT-20 can perform measurements on the whole range of interfaces from PDH to SDH. Due to the instrument's large storage capacity, long-term measurements can run up to 100,000 sec or longer. The measured values are displayed in the jitter generator/analyzer window as a graph of the time interval error (TIE) versus time. Numerical values of MTIE and TIE are shown above the graph, as illustrated in Figure 19.

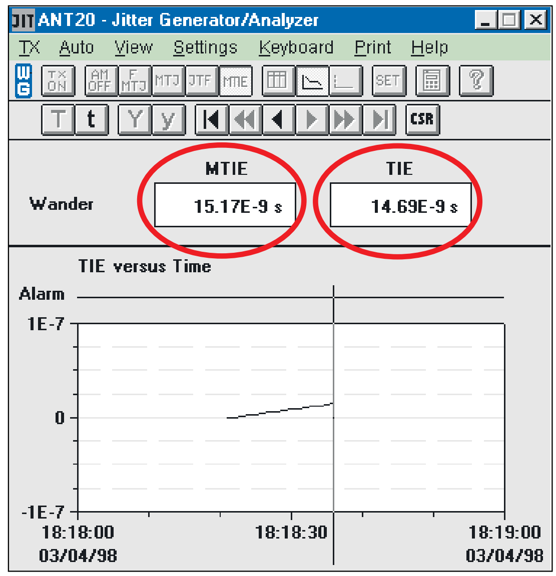


Figure 19: Result window illustrating ANT-20's wander measurement.

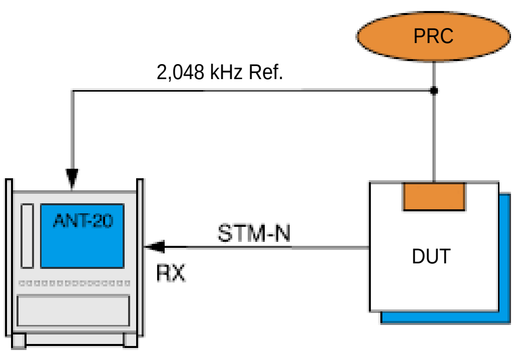


Figure 18

The wander generation setup consists of the ANT-20 connected as in Figure 18. Wander tolerance can be tested by generating wander over the DUT and then observing the output for any errors and alarms. The wander that is placed over the DUT is in the form of a sinusoidal wave, as defined in Recommendation G.813.
The results of wander generation tests which are displayed in Figure 19 can be imported into the ANT-20's offline analyzer software. In this program the MTIE and TDEV are calculated as a function of the observation interval. These results are then compared to predefined standards and to user-defined tolerance masks which determine the clock quality.

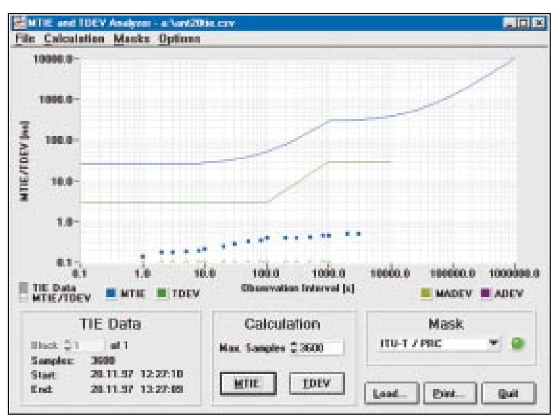


Figure 20: The offline analyzer for MTIE and TDEV.

Recommendation G.826: Error Performance Parameters and Objectives for International, Constant Bit Rate Digital Paths at or above the Primary Rate:

"Recommendation G.826 specifies error performance events, parameters and objectives for digital paths operating at bit rates at or above the primary rate. Paths are used to support services such as circuit switched, packet switched and leased line services." Specifications that refer to bit rates that are n × 64 kbit/s (n < 24 or 32 resp.) are in Recommendation G.821.

"Recommendation G.826 is based upon the error performance measurement of blocks. A block is a set of consecutive bits associated with the path, each bit belongs to one and only one block. Consecutive bits may not be contiguous in time." These blocks can be monitored in two different modes. In-service monitoring or out-of-service monitoring. In-service monitoring allows measurement while the system is operational. Error detection codes e.g. BIP or CRC are evaluated to assess performance parameters. Out-of-service measurements are mainly used for aligning newly setup communications equipment. The parameters monitored are errored second, severely errored second and background block error.

Events

- **Errored Second (ES):** A one second period with one or more errored blocks or at least one defect.
- **Severely Errored Second (SES):** A one-second period which contains ≥ 30% errored blocks or least one defect. SES is a subset of ES.
- **Background Block Error (BBE):** An errored block not occurring as part of an SES.

Parameters

- **Errored Second Ratio (ESR):** The ratio of ES to total seconds in available time during fixed measurement interval.
- **Severely Errored Second Ratio (SESR):** The ratio of SES to total seconds in available time during a fixed measurement interval.
- **Background Block Error Ratio (BBER):** The ratio of Background Block Errors (BBE) to total blocks in available time during a fixed measurement interval. The count of total blocks excludes all blocks during SESs.

Table 8: End-to-end error performance objectives for 27,500 km international digital HRP.

Rate Mbit/s	1.5 to 5	>5 to 15	>15 to 55	>55 to 160	>160 to 3500
Bits/block	800–5,000	2,000–8,000	4,000–20,000	6,000–20,000	15,000–30,000
ESR	0.04	0.05	0.075	0.16	
SESR	0.002	0.002	0.002	0.002	0.002
BBER	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	10^{-4}

Table 9: Error performance Recommendation

	G.821	G.826	M.2100
Purpose	Error Performance OOS	Error Performance ISM/OOS	BIS Limits ISM/OOS
Technology	N-ISDN	PDH/SDH/Cell-based	PDH
Min. bit rate	64 kbit/s	1.5 Mbit/s	64 kbit/s
Max. bit rate	<primary rate	SDH rates	140 Mbit/s
Evaluation period	30 days	30 days	specified in M.2110
Measurement	Bit error based	Block error based	Bit/Block error based

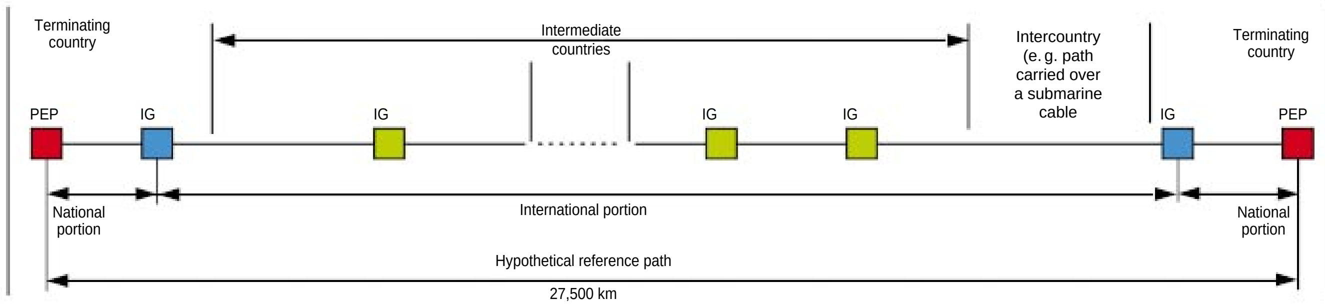


Figure 21: The hypothetical reference path (HRP) for which error performance objectives are defined

IG is the international gateway that connects the national portion to the international portion which usually corresponds to a DXC, higher order MUX or a switch. The international portion of an end-to-end path begins in one terminating country and ends in the second terminating country. It is not possible to have less than or more than two terminating countries for an international path.

In Brief

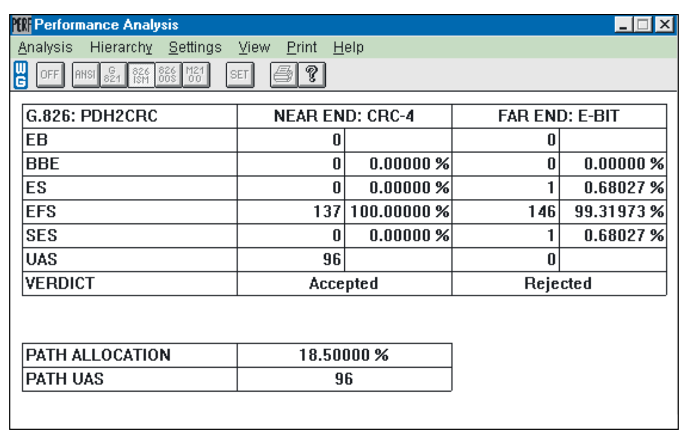
Every SDH path has an embedded error performance monitoring capability from which a number of standard parameters are calculated within the network element. The management needs these parameters for several reasons, as follows:

– Verification of contracted performance of paths with clients;
– Verification of the performance of manufacturer's equipment over its lifetime;
– Identification of performance degradations in order to prompt remedial maintenance action;
– Provision of black spot analysis information for network quality improvement programs.

The ANT-20 carries out a performance analysis for three recommendations: G.821, G.826 and M.2100. The ANT-20 can perform the G.826 test in out-of-service or in-service mode.

Application

The G.826 measurement interface allows the user to view the EB at the near and far end of the transmission path. ES, EFS SES are also included as the parameters for the overall transmission performance results. The "VERDICT" box gives a direct indication as to whether the communications path meets the requirements of the recommendation depending on the path allocation.



G.826: PDH2CRC	NEAR END: CRC-4		FAR END: E-BIT	
EB	0		0	
BBE	0	0.00000 %	0	0.00000 %
ES	0	0.00000 %	1	0.68027 %
EFS	137	100.00000 %	146	99.31973 %
SES	0	0.00000 %	1	0.68027 %
UAS	96		0	
VERDICT	Accepted		Rejected	

PATH ALLOCATION	18.50000 %
PATH UAS	96

Figure 22: Result display ANT-20 G.826 performance analysis

Out-of-Service

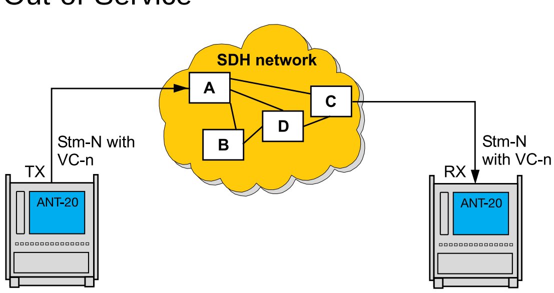


Figure 23a: Near end measurements (A to C) B1, B2, BIP2 are included.

In-Service

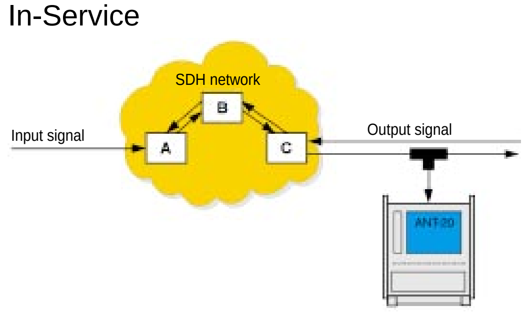


Figure 23b: Far end measurements (C to A) RDI, RDI are included.

Recommendation M.2100: Performance Limits for Bringing-into-Service and Maintenance of International PDH Paths, Sections and Transmission Systems

Parameter (Note)	End-to-end PRO (maximum % of time)
Errored Seconds (ES)	4.0
Severly Errored Seconds (SES)	0.1

Table 10: End-to-end error reference performance objectives at 64 kbit/s

Table 10 displays the values which are specified for 64 kbit/s. The RPO is based on 40 % of the end-to-end RPO taken from Recommendation G.821. RPO stands for the reference performance objective, upon which other performance objective values are based.

Network level	Maximum Errored Seconds (ES) % of time	Maximum Severely Errored Seconds (SES) % of time
Primary	2	0.1
Secondary	2.5	0.1
Tertiary	3.75	0.1
Quaternary	8	0.1

Table 11: End-to-end error performance objectives at or above the primary rate

Primary, secondary, tertiary and quaternary stand for the relevant levels in the Plesiochronous Digital Hierarchy. The PRO figures given in the table are equal to 50% of the performance objectives given in Recommendation G.826.

"Recommendation M.2100 provides limits for bringing-into-service and maintenance of international sections, paths and transmission systems at every level of the plesiochronous digital hierarchy from 64 kbit/s. Error timing and availability performance are considered.

"This recommendation uses certain principles which are the basis of the maintenance of a digital network:

– It is desirable to do in-service, continuous measurements. In some cases (e.g. bringing-into-service), out-of-service measurements may be necessary.

– A single set of parameters must be used for maintenance of every level of the hierarchy (this principle does not apply to limits).

– Error performance limits of transmission systems are dependent on the medium used. However, due to the many possible network structures, error performance limits on paths are independent of the medium."

In Brief

This Recommendation indicates the limits to quantify an international digital network and its elements. These limits are to be used to indicate the need for actions during maintenance and bringing-into-service of network paths.

Application

The same setup can be used as illustrated in the figure below for out-of-service in Recommendation G.826.
The analysis in general, including all G.826 measurements, provides separate results for the "NEAR END" and the "FAR END". This simply means that errors occurring directly in the path are analyzed as well as errors occurring in the return path which are indicated by a remote error indicator message (e.g. E-bit at 2,048 Mbit/s) or remote defect indication. This allows both directions to be monitored at one end of a path.

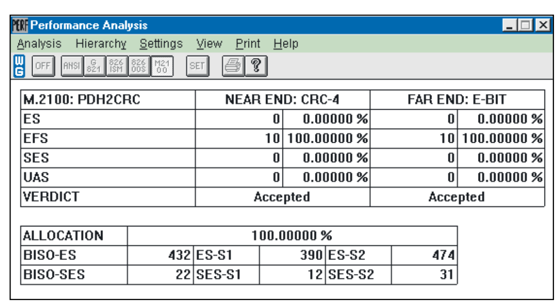


Figure 24: Result display ANT-20, M.2100 performance analysis

Recommendation G.841: Types and Characteristics of SDH Network Protection Architectures

"This recommendation provides the necessary equipment-level specifications to implement different choices of protection architectures for Synchronous Digital Hierarchy (SDH) networks. ... Physical implementations of these protection architectures may include rings, or linear chains of nodes. Each protection classification includes guidelines on network objectives, architecture, application functionality, switching criteria, protocols, and algorithms."
A series of mechanisms, designed to prevent prolonged transmission path downtimes in the event of a defect, is defined for SDH networks.

In Brief

Keeping the downtimes of SDH paths to an absolute minimum is extremely important for network operators, since the quality of the services they offer is the main feature that distinguishes the many different providers.

1. MS dedicated protection ring
An MS dedicated protection ring consists of two counter-rotating rings, each transmitting in opposite directions relative to each other. In this case, only one ring carries normal traffic to be protected while to other is reserved for protection of this normal traffic (see Figure 26a). The normal traffic for example is carried only in the clockwise direction. It is protected by beeing simultaneously transported in the opposite direction. If the normal traffic is interrupted, the terminating network element switches to the protection channel (in the example shown here: failure between B and C -> network element E switches over to the protection channel). MS dedicated protection ring would also require using the APS bytes, K1 and K2, for protection switching.

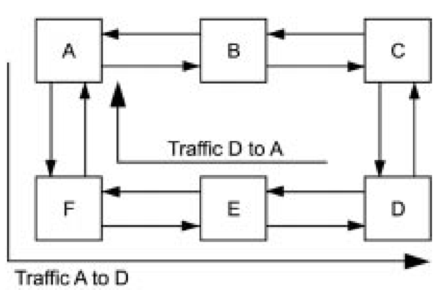
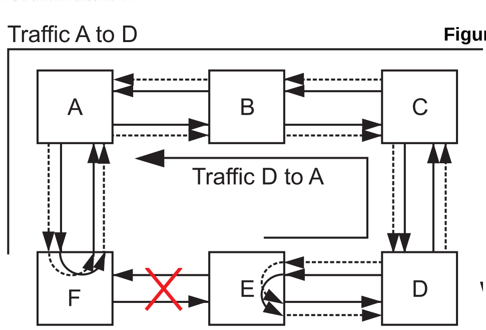


Figure 25a

Figure 25b


The generic term for these mechanisms is APS (Automatic Protection Switching). System resources which during normal operation are either not used at all or only for very low-priority traffic are made available for this purpose. If a defect occurs, the "normal" traffic is then diverted automatically to these spare paths. In addition to the correct sequence of this switchover procedure, which may involve more than 10 different network elements, the time from the interruption of traffic to when the connection is restored is a critical factor. According to ITU-T Recommendation G.841, this time should be less than **50 ms**.

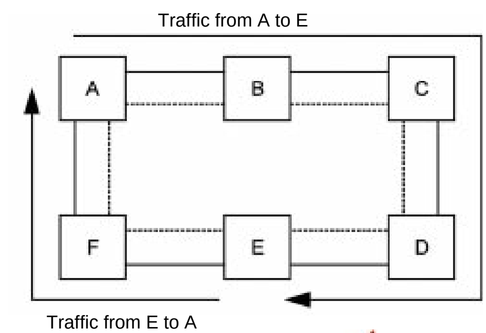


Figure 26a

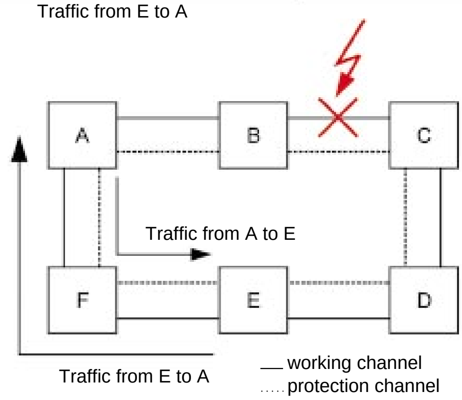


Figure 26b

2. MS shared protection ring
MS shared protection rings can be categorized into two types: two-fiber and four-fiber. The ring APS protocol accommodates both types.
For MS shared protection rings, the working channels carry the normal traffic signals to be protected while the protection channels are reserved for protection of this service. Normal traffic signals are transported bidirectionally over spans: an incoming tributary travels in one direction of the working channels while its associated outgoing tributary travels in the opposite direction but over the same spans.
– Two-fiber shared protection ring
This protection architecture requires only two fibers for each span of the ring. Each fiber carries both working channels and protection channels. On each fiber, half the channels are defined as working channels and half are defined as protection channels. The normal traffic carried on working channels in one fiber are protected by the protection channels traveling in the opposite direction around the ring (see Figure 25a). This permits the bidirectional transport of normal traffic.

In the event of a cable cut, normal traffic transmitted toward the failed span is switched at one node to the protection channels trasmitted in the opposite direction (away from the failure). This bridged traffic travels the long way around the ring on the protection channels to the other node where the normal traffic from the protection channels is switched back onto the working channels. In the other direction, the normal traffic ist bridged and switched in the same manner. Figure 25b illustrates a ring switch in response to a cable cut.

– Four-fiber shared protection ring

Two out of the four glass fibers transport the working channels and two the protection channels. One fiber pair (working + protection) travels clockwise around the ring, while the other pair travels around it in the counterclockwise direction. Thus, bidirectional connections can be operated.

There are two possible mechanisms if a defect occurs. One of them functions in the same way as with the two-fiber shared protection ring. The traffic is switched over in the network elements located closest to the fault and transported via the protection fiber for the opposite direction ("ring switching").

The second mechanism is known as "span switching." In the event of a defect the traffic is transported via the protection fiber that operates in the same direction as the faulty working fiber. Consequently, only the link segment that is actually faulty is switched over to standby.

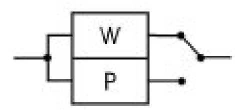
Recommendation G.841 Section 7.1 (G.783 Annex A): Linear Multiplex Section Protection (MSP)

Section 7.1 of the revised Recommendation G.841 contains the protocol for the switchover procedure of the APS mechanisms compatible with 1: n operation.

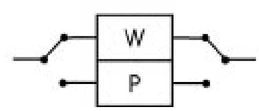
Annex B of G.841 describes the MSP protocol optimized for 1+1 operation. Linear MSP was specified in Annex A of G.783 which is now included in the new revised Recommendation G.841.

In Brief

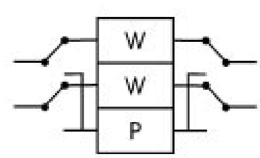
1+1 operation:
The traffic is transported simultaneously via the working path and the protection path. The receiving end then decides which of the two paths is to be used.



1:1 operation:
The spare path can only be used if a switchover takes place at both the transmitting end and the receiving end.



1:N operation:
A 1:N configuration represents a more cost-effective solution than the other two mechanisms described above. N working channels are protected by one protection channel. If there are no defects in the network, this protection channel can be used to transport low-priority traffic.



Application

Proper interworking of the network elements requires the proper response on the part of the APS signaling to changes in the signal status or to the appropriate switching commands from network management. The ANT-20 makes this test simple and reliable by interpreting the protocol elements in plain text. APS commands can also be generated in the descriptor directly from the menu, without complicated bit manipulations.

The ANT-20 understands the K1/K2 codes for linear MSP conforming to ITU-T G.783 as well as those for MS SPRING to ITU-T G.841.

We measure the switchover time out-of-service (OOS) on the PDH or SDH/SONET tributaries of the ADMs (add-drop multiplexers). Depending on the configuration, alarms and bit errors (Test Sequence Errors, TSE) appear on the tributary ports for the duration of the switchover procedure. What customers are interested in is the interruption time on the tributary and not just the K1/K2 switchover according to the APS protocol.

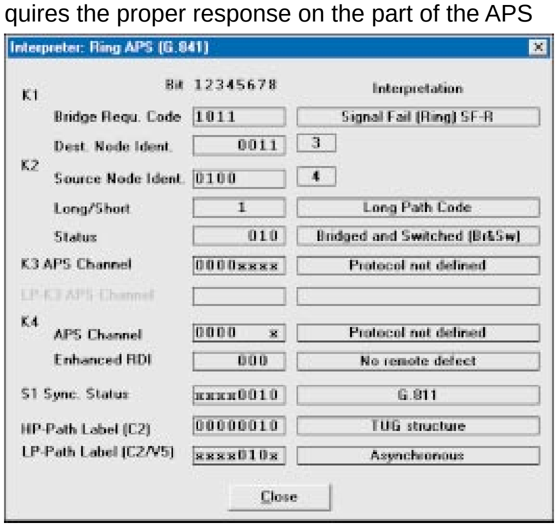


Figure 27: ANT-20 interpreter for ring switching

The ANT-20's solution is flexible and lets you select different events as your measurement criterion:

- SDH: MS-AIS, AU-AIS, TU-AIS, TSE
- SONET: AIS-L, AIS-P, AIS-V, TSE

The switchover time is specified as 50 ms. The ANT-20 measures the duration of the event on the tributary with a resolution of 1 ms, even if the signal has bit error ratios up to 2×10^{-4}. A second ANT-20 can be used to generate the APS.

In through mode, the instrument generates the alarm types SF (B2 $>1 \times 10^{-3}$) and SD (B2 $>1 \times 10^{-6}$), and in OOS mode also LOS, LOF, MS-AIS (AIS-L). The procedure is as follows:

1. Set the signal structure using the ANT-20's signal structure editor. Start the APS time measurement.
2. Activate APS by manually interrupting the working channel, by generating an event with a second ANT-20 in through mode, or using a network management setting.
3. Measure the interruption time. Compare it with the expected value. Result interpretation is simple: "passed" or "failed".

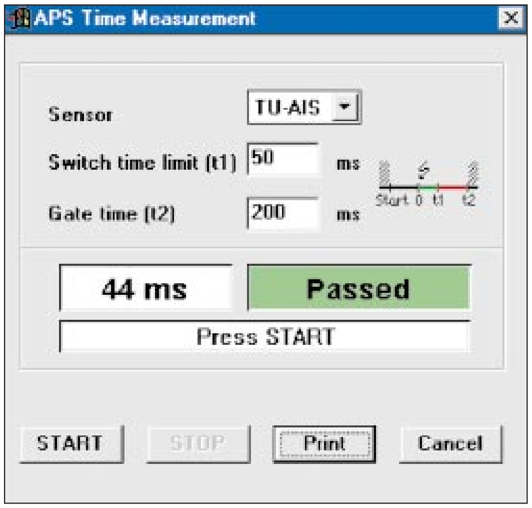


Figure 28: Result from the switch-over measurement

If the switch-over time is exceeded or communication between the network elements is not reliable, we must find the reason. With its byte capture function, the ANT-20 enables detailed analysis of the SOH bytes. Up to 265 changes in the K1/K2 combination are recorded. The ANT-20 can be configured to measure in monitor mode or in through mode in the protection channel of the SDH ring.

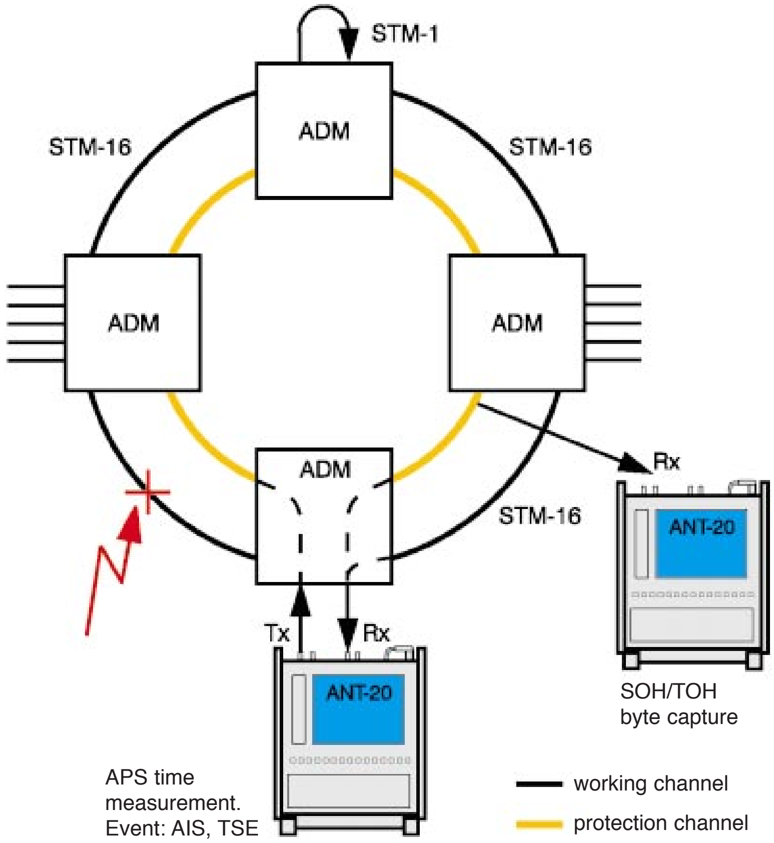
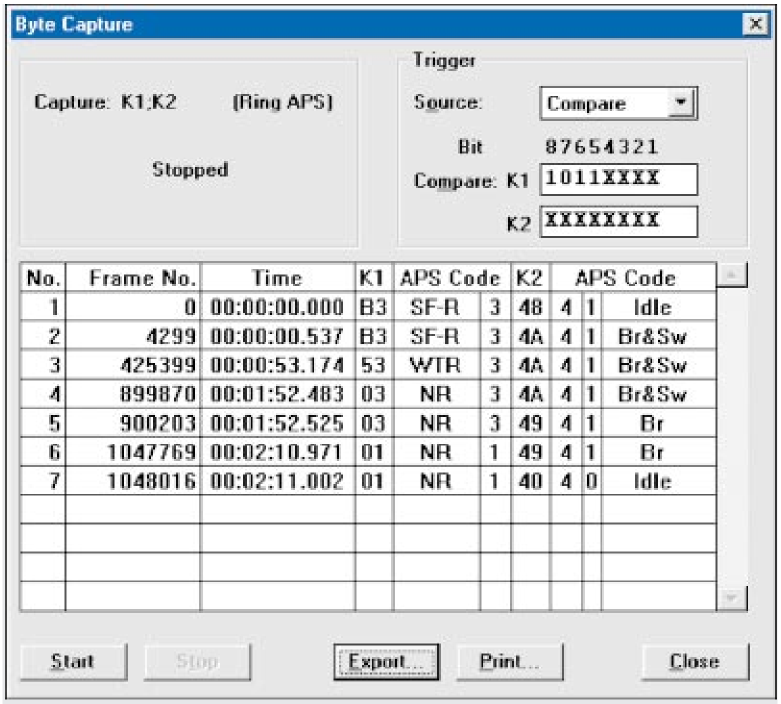


Figure 29: Measuring switch-over time

Figure 30: Byte capture shows content of K1/K2 bytes in plain text



Abbreviation list:

ADM	Add & Drop Multiplexer
AIS	Alarm Indication Signal
APS	Automatic Protection Switching
BBE	Backround Block Error
BBER	Backround Block Error Ratio
BIP	Bit Interleaved Parity
BIS	Bringing Into Service
CRC	Cyclic Redundancy Check
DEMUX	Demultiplexer
DXC	Digital Cross Connect
ES	Errored Second
ESR	Errored Second Ratio
EFS	Error Free Second
FMTJ	Fast Maximum Tolerable Jitter
IG	International Gateway
ISM	In Service Monitoring
JTF	Jitter Transfer Function
HP	High Order Path
LOF	Loss Of Frame
LP	Low Order Path
MS	Multiplex Section
MSOH	Multiplex Section Overhead
MSP	Multiplex Section Protection
MST	Multiplex Section Termination Function
MTJ	Maximum Tolerable Jitter
MTIE	Maximum Time Interval Error
MUX	Multiplex
OOS	Out of Service
OS	Optical Section
PDH	Plesiochronous Digital Hierarchy
PEP	Path End Point
RDI	Remote Defect Indication
PRC	Primary Reference Clock
UI	Unit Interval
REG	Regenerator
RS	Regenerator Section
RST	Regenerator Section Termination Function
RSOH	Regenerator Section Overhead
SES	Severely Errored Second
SESR	Severely Errored Second Ratio
SD	Signal Degradation
SDH	Synchronous Digital Hierarchy
SEC	Synchronous Equipment Clock
SF	Signal Failure
STM	Synchronous Transport Module
TDEV	Time Deviation
VC	Virtual Container

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