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Application Series

SONET Testing and Maintenance

302 Enzo Drive
San Jose CA 95138 USA
ph 1 408 363 8000
fax 1 408 363 8313
info@sunrisetelecom.com
www.sunrisetelecom.com

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INTRODUCTION

SONET technology is complex but testing, qualifying, and maintaining SONET need not be. This application note describes the tools built into the SONET standard and the functions of your SONET test equipment that make for straightforward SONET testing. The basics of network segmentation, performance monitoring, bit error ratio and network element testing are all outlined. Testing automatic protection switching is addressed in a separate application note, "Measuring APS in a SONET/ SDH Network."

NETWORK SEGMENTATION: SONET LAYERS

SONET segments the network into Section, Line, Path, and VT Path. This allows technicians to identify the probable location of an error or defect and provide a comprehensive view of the network's performance. Every element in the network, except for purely passive components like amplifiers, mark the start and end of a network Section. A Line begins and ends with any element, such as an add-drop multiplexer or digital cross-connect that is capable of integrating multiple traffic sources. The Path begins at the origin of the data stream and ends at its destination; VT Paths apply to lower-rate virtual tributaries, such as T1 and E1 circuits carried over SONET.

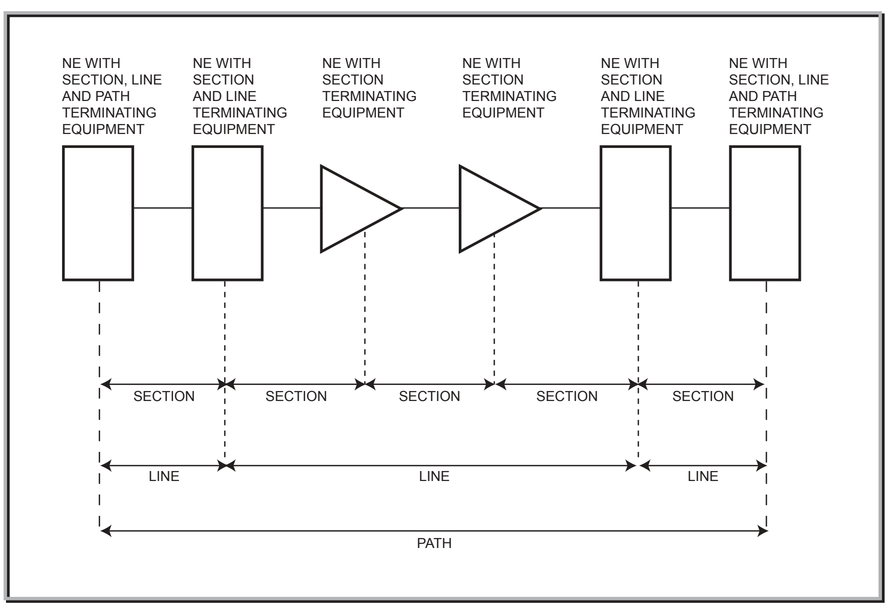
The SONET overhead is likewise divided into Section, Line, Path, and VT Path. Terminating equipment manipulates the overhead associated with its layer. Every network element is considered section terminating equipment, so they all affect the section overhead such as framing (A1, A2) and parity (B1). Line terminating equipment (LTE) has access to the section and line overhead, collectively called the transport overhead, including pointers (H1-H3), parity (B2), and protection switching (K1/K2). Path terminating equipment (PTE) mark the endpoints of the connection and is where the parity (B3) and other path overhead is originated. Virtual tributaries, primarily used for mapping DS1 signals, also have their own overhead including pointers (V1-V3) and parity (BIP-2, part of the V5 byte) that are controlled by VT path terminating equipment (VT PTE).

Physical Layer

Before connecting into any optical equipment, confirm that the transmitted power of the test set is within the acceptable range for the equipment, and visa-versa. When in doubt, use an attenuator or splitter. Typically a 10 dB pad, equivalent to the 10% side of a 90/10 splitter, is enough, though very high power, long haul equipment may require greater attenuation.

Measure the power level of the optical signal and verify that it falls within the power budget for the circuit.

- A power level that is too high can saturate the receiving equipment and cause a Loss of Frame, Loss of Signal, or even damage the optical receivers!
- A power level that is too low is more susceptible to noise, causing errors, or may dip below the sensitivity of the receiving equipment.



Simplified Diagram Depicting SONET Section, Line, and Path Definitions (taken from GR-253, Figure 2-1)

Performance Monitoring

Each of the SONET layers requires separate monitoring for errors and defects. Including both Near End and Far End, there are up to seven total layers of performance monitoring.

- Section (-S)
- Line, Near End (-L or -LNE)
- Line, Far End (-LFE)
- Path, Near End (-P or -PNE)
- Path, Far End (-PFE)
- VT Path, Near End (-V or -VNE)
- VT Path, Far End (-VFE)

There are five to six performance monitoring parameters for each layer.

- Severely Errored Frame Seconds (SEFS): A count of the seconds with a Severely Errored Frame (SEF). SEF occurs when four or more consecutive frames have errored framing patterns. SEFS only apply to the Section layer.

- Code Violations (CV): A count of the parity errors since the start of the test. Code violations are also called parity errors or B1/B2/B3/BIP-P errors depending if they occurred in the Section, Line, Path, or VT Path overhead bytes, respectively.

- Errored Seconds (ES): A count of the seconds with an error or defect.

- Severely Errored Seconds (SES): A count of the seconds with a defect, or error that exceeds a rate-dependent threshold. Refer to GR-253 SES threshold table.

- Unavailable Seconds (UAS): A count of the seconds during which the circuit is considered unavailable. Unavailable time begins after 10 consecutive SES and persists until the onset of 10 consecutive seconds without an SES.

- Failure Counts (FC): Any defect that persists for about 2.5 seconds is considered a failure. These failures are counted to distinguish them from transient defects that may have lasted for only a few moments. For example, over the course of a test, a system may experience 5 AIS defects that each lasted for 1 second. This would result in 5 Severely Errored Seconds but no defects. Conversely, a single AIS defect that lasted for 5 seconds would be 5 Severely Errored Seconds and 1 Failure Count.

The errors and defects that trigger ES and SES for each layer are illustrated in the table below:

Layer	Error	Defect
Section	B1	SEF, LOS
Line, Near End	B2	AIS-L
Line, Far End	REI-L	RDI-L
Path, Near End	B3	AIS-P, LOP-P
Path, Far End	REI-P	RDI-P
VT Path, Near End	BIP-2	AIS-P, LOP-V
VT Path, Far End	REI-V	RDI-P

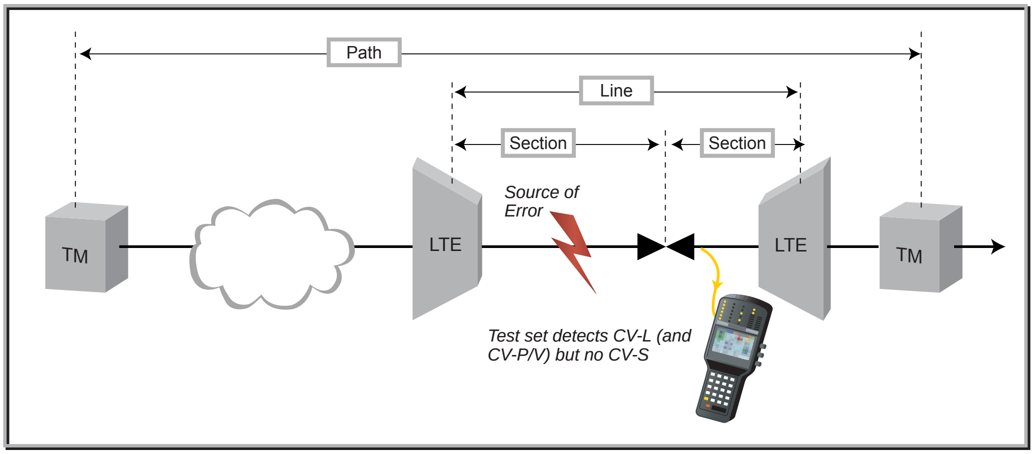
When using an Enhanced RDI (ERDI) specification for the Path or VT Path, UNEQ-P/V and TIM-P/V are included as Near End defects. Also, Far End defects include Server and Connectivity failures.

Example: An Errored Second on the Line Far End, or ES-LFE, is caused by an REI-L or an RDI-L.

	GR-253 SES Thresholds			
	B1	B2/REI-L	B3/REI-P	BIP-V/REI-V
OC-3	155	154	2400	600
OC-12	616	615	2400	600
OC-48	2392	2458	2400	600
OC-192	8854	9835	2400	600

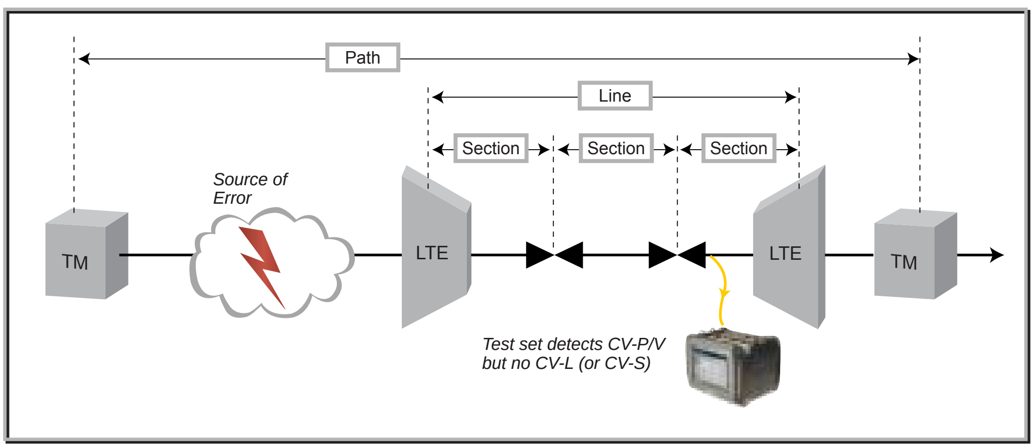
Segmentation of Code Violations

A bit error in the data will result in a Code Violation (CV) in the Section, Line, Path, and (if appropriate) VT Path. However, since section parity is recalculated at each network element, the CV-S will not appear further down the network. If a CV-L (and CV-P/V) is detected without a CV-S, the source of the error is between the closest network element and the last LTE.



B2 without B1 Diagram

Likewise, a CV-P (and CV-V) without a CV-L (and CV-S) has a source between the last LTE and the start of the path.



B3 without B2 Diagram

THRU MODE

Ideally, optical networks will have installed monitor points or splitters that allow a technician to monitor a live circuit without disrupting service. When these are not available or the power level is prohibitively low, the technician can send the signal through the test set. Line Thru is appropriate for live circuits without a monitor point. For out-of-service testing, Path Thru is usually the best choice, though the user may need to send the J0 and DCC bytes thru as well.

Line Thru

In line thru mode, the entire signal is passed through the test set. Here, injecting errors or manipulating SONET overhead bytes is not desired. Instead, every byte that is received is then transmitted from the test set intact without changes. Line thru is ideal for monitoring live circuits with minimal disruption. Any errors received and measured by the test set will not be removed and will be propagated through to the next network element.

Payload Thru

In payload thru mode, the test set passes through the SPE, including all Path overhead, and regenerates the Transport overhead. This allows a technician to change overhead bytes and inject errors and alarms on the Section and Line layers. For example, you can test an APS system by injecting B2 errors or you can test the alarm monitoring, propagation, and response by generating AIS-L.

DCC and J0 Thru

When connecting any test set in a payload thru mode, there is a danger that the network element at the far end will go into error or alarm because the Section DCC (D1-D3), Line DCC (D4-D12), and/or Section Trace (J0) is disrupted. This error condition may not be obvious to a technician but may be detected at a network operations center. To avoid this, the test set should allow the DCC and J0 bytes to pass through while still being able to control the other Section and Line overhead bytes.

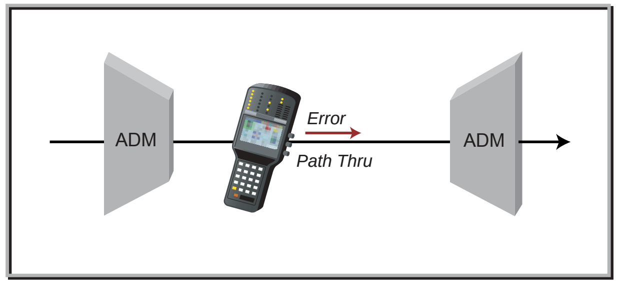
BER TESTING

Bit error testing is always performed on an out-of-service circuit or tributary. It is possible to test a circuit carrying live customer traffic provided there are unused, idle, or unequipped channels on which to run the test. For example, on an OC-48 circuit, STS# 1 through 24 may be carrying traffic but STS# 25 through 48 may be left unequipped as backup. In this case, those channels can also be used for bit error testing.

For OC-48c and OC-192c concatenated rates, the 2^{31}-1 pattern provides the greatest number of non-repeating bits. For lower rates, 2^{23}-1, 2^{20}-1, QRSS, and 2^{15}-1 patterns work well. For DS1 channels carried over DS3 and VT1.5, the standard DS1 test patterns, such as 1-in-8 and 55 Daly, can also be used.

Clock and Pointers

To maintain the synchronicity of the SONET circuit, the test set should use the same timing as the network. Typically, this is done by setting the test set's transmit clock to the signal received from the network. Alternatively, the test set can use the same Building Integrated Timing Source (BITS) as the network; simply plug the T1 BITS clock into the test set. Lastly, the test set itself could be used as the master clock with the network elements slaved to its signal, but because test set clocks are typically not as accurate as network and BITS clocks, this is not recommended.

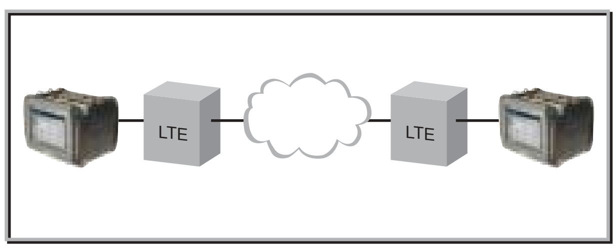


Path Thru Diagram

If the test set and network elements use different clocks, such as the set using internal timing, pointer adjustments will occur. These adjustments will be a steady increase or decrease in the pointer value, perhaps one adjustment per second. Rarely do these adjustments cause problems—the job of pointers is to compensate for timing differences—but they do complicate the test results and are best avoided if possible.

Dual-Ended

This end-to-end test verifies the entire Path between two points. Each test set sends a test pattern and the test set at the other end counts the number bit errors while performing the standard performance monitoring measurements. The Bit Error Ratio (BER) is the ratio of errored bits to total number of bits. Only the test payload is counted—overhead bytes do not factor into BER measurements.



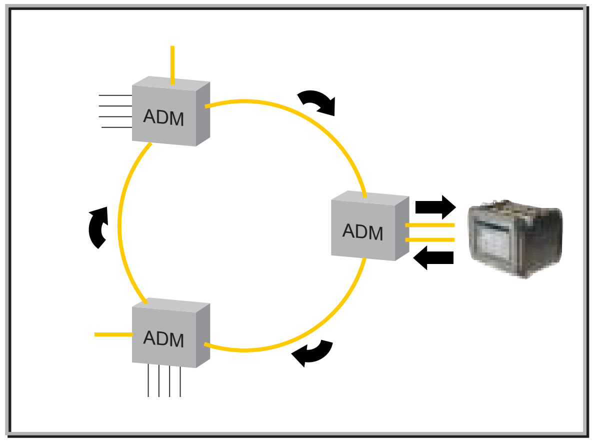
Dual-Ended Diagram

To verify the end-to-end connectivity, send a bit error or B3/CV-P error from one test set and it will be detected by the other. Depending on the elements between the test sets, injected B2 or B1 errors may or may not reach the end.

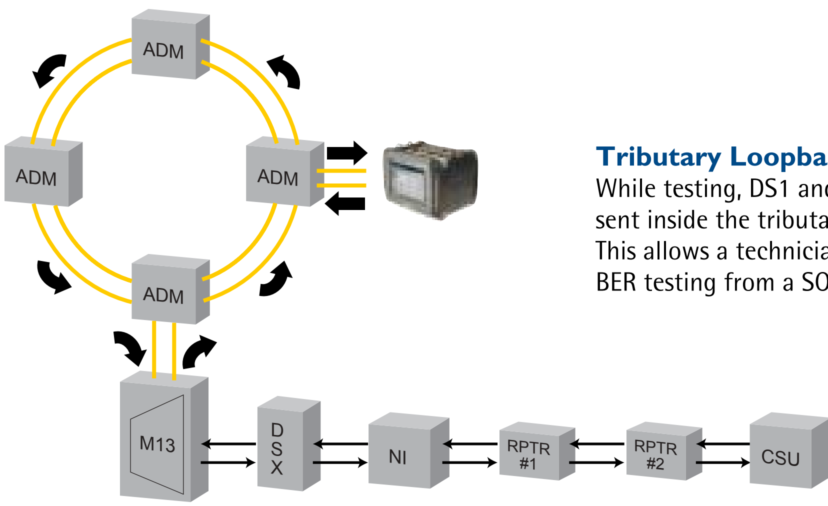
Ring BERT

In this scenario, the test signal travels through a SONET ring, returning to its starting position. This tests the full integrity of a unidirectional ring. For a bidirectional ring, simply perform the test twice, once in each direction.

To test the protection switching time of the ring, invoke a switch manually or insert a switching condition, such as a Loss of Signal or parity errors. While the ring performs the switch, service will be disrupted and measured by the test set as bit errors and a loss of pattern. Typically the length of the service disruption must be 50 ms or less.



Ring BERT Diagram



Tributary Loopback Diagram

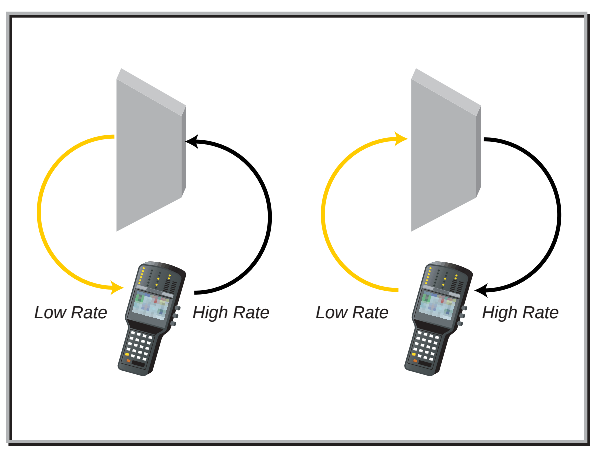
Tributary Loopback

While testing, DS1 and DS3 loopback commands can be sent inside the tributary channel of the SONET network. This allows a technician to perform full path T-carrier BER testing from a SONET access point.

MUX Testing

Any equipment that maps or multiplexes a low-rate signal, such as a DS1, to/from a higher rate signal, such as SONET, including an Add Drop Multiplexer or a Digital Cross Connect, should be tested for errors and proper channel mapping. With a single test set, MUX testing is performed in one direction at a time; with two test sets, bidirectional BER testing can be performed.

There is always a one-to-one mapping between any given low rate port and the tributary channel in the high rate signal. If the mapping of the channels is unknown, scan the higher-rate tributaries until the port and channel under test is found. When testing the high-to-low, demapping path, you can broadcast the same test pattern on all the channels, but this will hide any mis-mapping between tributary channel and port. In general, it is best to leave the tributaries not under test as unequipped.



MUX Test Diagram

POINTER TESTING

Pointer Monitoring

Each STS and VT tributary possesses its own pointer. These pointers keep SONET synchronous by compensating for timing differences without using stuff bits. Pointers are allowed to move up or down once every three frames, though the actual rate of pointer movement should be much slower. The test set can count the number of positive and negative pointer adjustments in addition to the total justification. In typical operation when there is a constant timing difference, the pointer value will slowly drift up or down, resulting in all positive or all negative pointer adjustments.

A New Data Flag (NDF) indicates when the pointer value is being reset to a new value rather than a single increment or decrement. During normal operation, an NDF is not required and the presence of an NDF represents a significant disruption to the network timing, such as a buffer overflow.

Pointer Adjustments

To test the pointer handling capabilities of a network element, the test set can send pointer adjustments as follows:

- Send a pointer increase
- Send a pointer decrease
- Send a new pointer value, with or without the proper NDF
- Send an invalid pointer value, which should result in a Loss of Pointer (LOP) condition.

Pointer Test Sequences

When qualifying or installing network elements, pointer test sequences stress the elements and verify that pointer movements do not cause jitter on DS3 and DS1 tributaries carried in STS or VT containers. This application requires two test sets: one to generate pointer test sequences that stress the system and one on the other side of the network element to measure the tributaries for jitter or jitter-related errors.

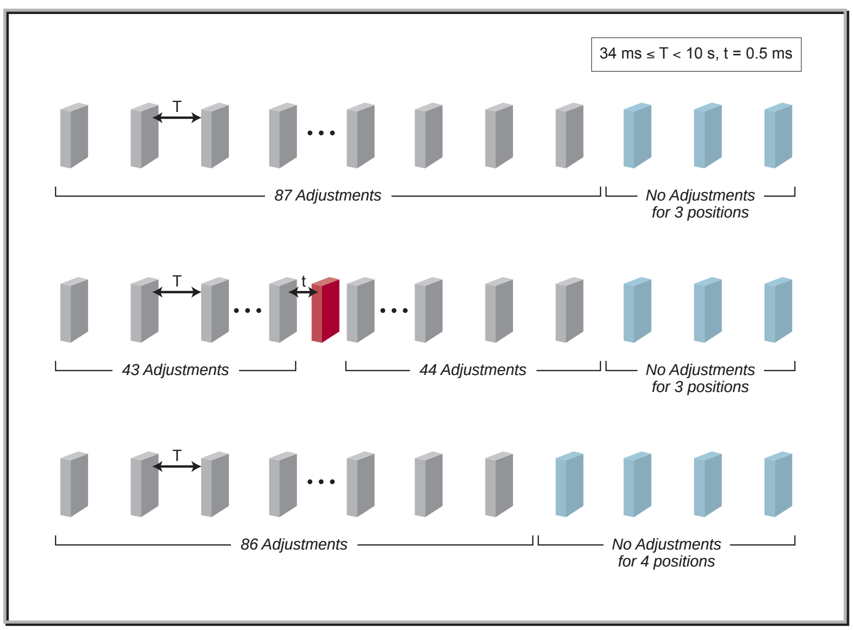
Telcordia, ANSI, and ITU-T standardized and custom sequences are available. The sequences send predicable pointer adjustments in specified patterns. In addition, anomalies to these patterns, such as an extra pointer adjustment added to the sequence or an adjustment removed from the pattern, stress the network element's pointer processor. The user can specify the period between pointer adjustments, the number of adjustments, the cycle time, and the position of anomalies (added or canceled adjustments) of each sequence.

For example, in the 87-3 pattern for STS pointers, 87 pointer adjustments are sent at regular intervals followed by three intervals with no adjustment (refer to Pointer Test Sequences screens on the following page). The total time between the start of each successive sequence is 30 seconds or more. An extra pointer adjustment can be added shortly after the 43rd adjustment; this is sometimes called a "43-44" pattern. Alternatively, the 87th adjustment can be removed, resulting in what some call an "86-4" pattern.

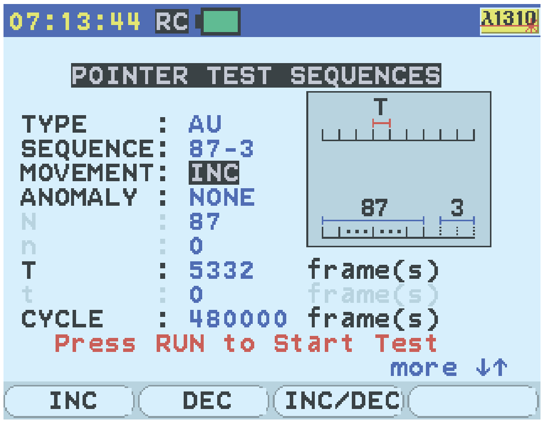
Each sequence should be run once with positive adjustments and once with negative adjustments. To achieve the most effect, these tests should be run using the maximum allowable frequency offset both above and below the nominal frequency.

Initialization is followed by a cool-down period of 30 seconds with no pointer movements. Both of these steps are integrated into the test set's procedure. After cooling down, the pointer test sequences and measurement begin.

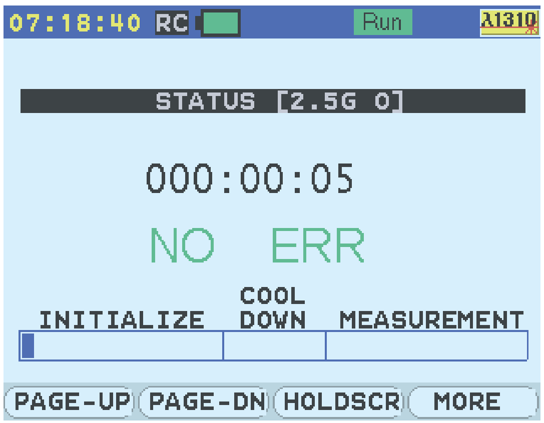
Begin the test by initializing the pointer processor by sending periodic adjustments for at least 60 seconds.



87-3 Pattern for STS Pointers



SunSet SDH Pointer Test Sequences Screen



SunSet SDH Pointer Test Sequences Status Screen

SUMMARY

Sunrise Telecom SONET test sets take full advantage of the testing capabilities written into the SONET standards to make testing effective and easy. The Application Note described the basic test features available to the operator, along with a few more advanced test features.

A few of the basic test features include fault isolation, severity level, and thru mode testing. By taking advantage of the network segmentation, the location of an error or defect can be isolated. Varying levels of network error or defect severity can also be determined, again following the SONET standards. A rich set of thru mode options is available, allowing the operator to perform the desired testing while preventing alarms on the network.

In SONET, timing and synchronization are very important. The test set has various timing source options and can also stress the network timing and synchronization circuits. The operator has the flexibility to test various network topologies such as dual-ended, single-ended with a far end loopback, and rings. Multiplexers/Demultiplexers and Cross Connects are tested by making a connection to both the low rate side and the high rate side, then BER testing through the network element. Proper channel selection can also be verified.

While SONET technology may be complex, by understanding a few of the basics and using your Sunrise Telecom test set, installing, qualifying, and maintaining SONET circuits can be a breeze.

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