JDSU

Application Note

SONET Testing

FST-2510a High Speed Optical Analyzer/FST-2310 TestPad SONET Services Module

All telecommunication service providers today face the same challenge: to supply more high-speed services at a reduced cost. These services demand comprehensive and easy-to-perform tests to verify network integrity before customer traffic can be commissioned.

As the telecommunications industry matures, requirements for the provisioning and maintenance of networks are changing. Improved efficiency in the design, deployment, and provisioning of service over today's networks is demanded as service providers and network managers face increasing pressure to turn up high quality service to users quickly, while being expected to improve and expand these services over time.

Synchronous optical network (SONET) is the transport technology commonly used in backbone and customer access networks. SONET is a set of standards defining the rates and formats for optical networks. A similar standard, synchronous digital hierarchy (SDH) has also been established in Europe. SONET and SDH are technically consistent standards. It is this standardization of rates and formats that lends SONET its primary advantage. Another key advantage of SONET is that it is synchronous and as such allows dynamic adding and/or dropping of signals within a single multiplexing process. SONET also integrates OAM&P in the network to further reduce the cost of management.

SONET configuration problems dominate the causes of degraded service and delayed turn-up of new services. Fortunately, during installation, these problems are relatively easy to isolate with simple end-to-end tests. Because network configuration and physical layer problems can be mistaken for higher layer problems, a comprehensive testing strategy covering all layers is needed to ensure satisfactory service. Verifying SONET configuration alone is not sufficient to provide trouble-free services over today's complex data networks.

This application note offers a review of SONET technology and proceeds to outline a testing strategy for SONET networks recommended by JDSU. With this foundation in place, specific SONET applications will be detailed. The objectives of each application and how they can aid in the efficient turn-up of SONET services are described. These applications and their benefits will be detailed with respect to the FST-2510a/FST-2310, including common test setup and results interpretation. The appendix provides a troubleshooting guide for resolving common SONET-related problems.

SONET Fundamentals

The SONET standard defines the rates and formats (the SONET layer), network element architectural features, and network operational criteria of a SONET network. Communication between various localized networks is costly because differences in digital signal hierarchies, encoding techniques, and multiplexing strategies can make such communication difficult. Transporting a signal to a different network requires a complicated multiplexing and coding process to convert a signal from one signal scheme to another.

Standardizing the rates and formats with SONET helps to solve this problem. The synchronous transport signal – level 1(STS-1) is the basic building block of SONET optical interfaces with a rate of 51.84 Mbps. An STS-1 consists of two parts, the STS payload and the STS overhead. The STS payload carries the information portion of the signal. The STS overhead carries the signaling and protocol information. This allows communication between intelligent nodes on the network, permitting administration, surveillance, provisioning, and control of a network from a central location. Coupling multiple STS-1 signals together and converting from electrical to optical produces a multiplexed SONET signal. Optical SONET signals are referred to as optical carrier – level n (OC-n) signals. Today's SONET networks are typically seen at OC-3, OC-12, OC-48, and OC-192 speeds.

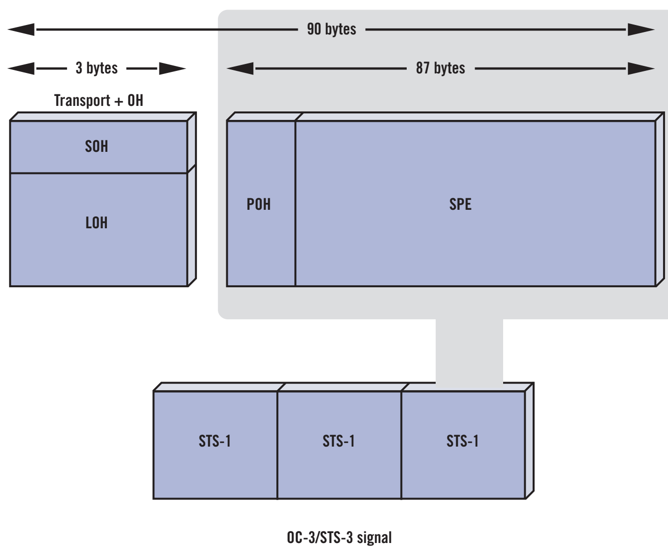

Figure 1 STS-1 frame structure

A signal is converted to STS and travels through various SONET networks in the STS format until it terminates. The terminating equipment converts the STS to the user format. A typical SONET end-to-end connection is shown in the following figure.

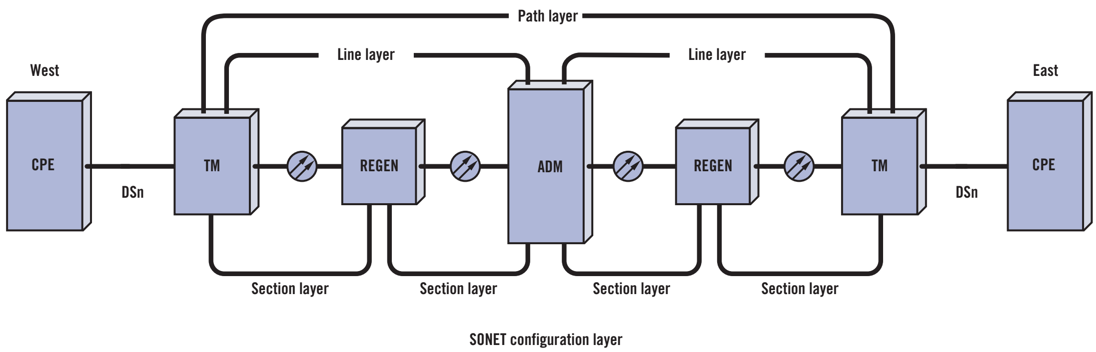

Figure 2 SONET network

The functionality of the equipment at either end of the network segment determines which layer of the SONET overhead is being originated and terminated over that segment. The three types of terminating equipment are described below:

Section terminating equipment (STE)

Section terminating equipment describes any two adjacent SONET network elements. STE can be a terminating network element or a regenerator. (All equipment listed in figure 2 can act as STE.) It can originate, access, modify or terminate the section overhead, or can perform any combination of these actions. Section BIPs are recalculated over the Line overhead, Path overhead, and SPE.

Line terminating equipment (LTE)

Line terminating equipment describes network elements that originate and/or terminate a line signal (add/drop and terminal multiplexers from figure 2). It can originate, access, modify or terminate the line and/or section overhead, or can perform any combination of these actions. Line BIPs are recalculated over the path overhead and SPE.

Path terminating equipment (PTE)

STS path terminating equipment describes network elements that can multiplex/demultiplex the STS payload (terminal multiplexer from figure 2). It can originate, access, modify or terminate the path, line and/or section overhead, or can perform any combination of these actions. For example, STS path terminating equipment assembles 28 1.544-Mbps DS1 signals and inserts path overhead to and from a 51.84-Mbps STS-1 signal.

Designating the different types of terminating equipment allows the network to be sectionalized for troubleshooting. For example, bit interleaved parity (BIP) calculations are done on SONET networks as an integrity check of the transmitted signal. These calculations are done at every network element on the transmission span. When a Path BIP error is received, the error is then known to be located somewhere between the PTEs on the span. Similarly, if line and/or section BIP errors are also seen, then the error can be further sectionalized to be between the two nearest LTEs/STEs on the span. The ability to sectionalize the network in this way is only possible because of these different terminating equipment designations.

A layered testing strategy

This application note is a comprehensive guide for service providers using the FST-2510a/FST-2310 to install and maintain SONET networks. In the case of difficulty in conducting any of these tests, the JDSU Technical Assistance Center (TAC) at 1-800-638-2049 will provide assistance. JDSU's TAC staff would appreciate any additional testing tips that would enhance the troubleshooting appendix.

The testing strategy outlined here provides an efficient, "bottoms-up" testing approach designed for systematic elimination of problems found at the SONET configuration layer, which can affect higher layer services. Unlike the layers in the open systems interconnection (OSI) basic reference model that describe protocol relationships, the layers referred to here represent categories of common problems and solutions gathered from numerous field installation and maintenance calls.

Physical layer testing

Before testing the SONET layer, the physical layer needs to be tested. Physical configuration layer testing consists of qualifying the fiber connecting the network. In order to do this, an optical power measurement is performed. Verifying that the signal is transmitting at the proper power levels will help eliminate problems with the physical fiber and connections transporting the SONET signal and reduce problems in higher configuration layers of the network.

SONET layer testing

SONET configuration layer testing eliminates common problems associated with SONET circuit setup. Tests include end-to-end BER tests, simulation of abnormal SONET conditions, SONET timing, SONET overhead byte manipulation, and in-service monitoring. These tests, detailed in this document, enable service providers to ensure the circuit is properly installed for the desired service. This testing will result in reduced turn-up time and fewer maintenance calls.

Data layer testing

Properly verifying the correct configuration of the physical and SONET layers are necessary before moving on to identifying configuration problems at higher levels such as at the asynchronous transfer mode (ATM) and/or IP configuration layers.

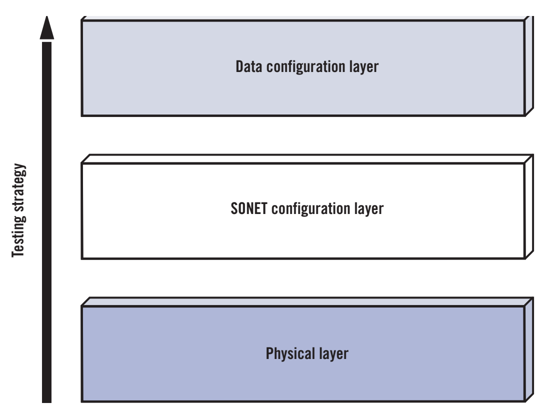

Figure 3 Layered testing strategy

Applications

End-to-End BER testing

Running a bit error rate test (BERT) on the network segment will identify physical and SONET layer problems. The bit error rate is the ratio of received bits that are in error, relative to the number of bits received.

By running a BERT prior to service turn-up, the quality of a network's physical characteristics can be qualified, aiding in the troubleshooting of other SONET problems that may be encountered later in the service turn-up process.

Checking that the power levels of the network are within the appropriate limits before performing a BERT is recommended. The FST-2510a/FST-2310 is then configured to run an end-to-end BER test at the appropriate rate using the pulldown menus. It is important to check the information in the SUMMARY category of the SETUP menu to verify all network settings match those on the test instrument.

Objectives for this test are:

– Verify proper optical power range
– Verify the proper SONET SIGNAL, FRAME, PATTERN and PATH PTR are received
– Verify network connectivity by transmitting and receiving logic errors
– Ensure no pointer adjustments are made due to timing inaccuracies
– Ensure bit error rate is below the system/services maximum allowable value

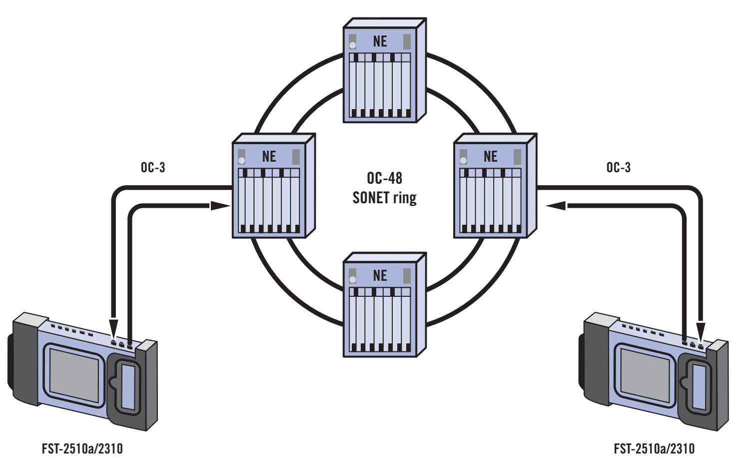

Figure 4 Performing end-to-end BER test

Simulation of abnormal network conditions

Error and alarm insertion

Simulating problems, such as errors and alarms, is the most effective way to test the error/alarm detection systems of a network, as well as verify connectivity through the network. By using the FST-2510a/FST-2310 in conjunction with a far-end loop, errors and alarms can be injected into the network segment and detected back at the test instrument. This test will verify the proper functioning of the network's error and alarm detection systems.

Error and alarm insertion is done with one of the action buttons on the main screen. Specifying which specific errors/alarms to insert into the network is done in the SUMMARY category of the SETUP menu.

Objectives for this test are:

- Verify the proper SONET SIGNAL, FRAME, PATTERN and PATH PTR are received
- Verify connectivity throughout the network by transmitting and receiving errors/alarms
- Verify errors and alarms are detected by network elements and the network operations center (NOC)

Pointer adjustments

If timing differences exist between two SONET network elements (NE), the payload is allowed to move around to adjust for the timing differences and to prevent the data from being corrupted or lost. These movements are referred to as pointer adjustments. Although pointer adjustments protect the payload data while it is within the SONET network, excessive pointer adjustments may cause errors (i.e. jitter) when the demultiplexed signal exits the network. Pointer adjustments indicate that a timing problem exists; and timing problems can become worse over time.

Incrementing/decrementing the pointer is done with an action b utton on the instrument's main screen. The value of adjustment (INC or DEC) is set in the POINTER category of the SETUP menu.

Objectives for this test are:

- Verify the proper SONET SIGNAL, FRAME, PATTERN and PATH PTR are received
- Verify that pointer adjustments (both increments and decrements) are properly reported throughout the network

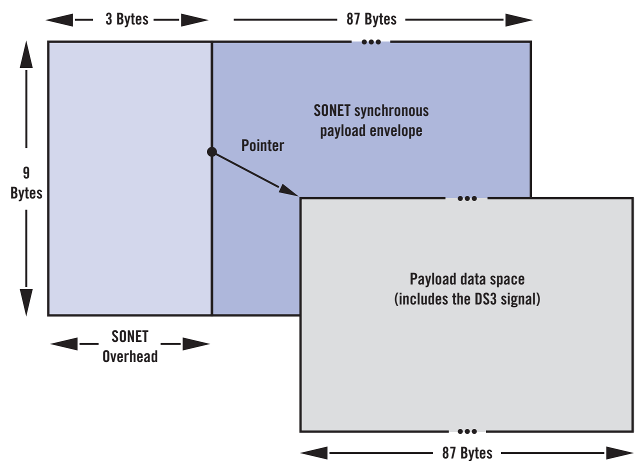

Figure 5 Overhead/payload pointer

Timing synchronization

One of the most common SONET transport problems encountered is synchronization. If the timing of a SONET network element is allowed to drift for just a short period of time, it can cause intermittent errors on tributary DS1 or DS3 signals. Synchronization problems are also extremely difficult to troubleshoot during maintenance calls, because the true cause cannot be determined by examining the tributary signal alone.

The FST-2510a/FST-2310 allows users to verify the external BITS clock of a SONET network. The nodes of a SONET network must be timed from the same source. SONET network nodes can have one of two timing inputs – from an external BITS clock or an embedded DS1 signal – so proper timing provisioning is very important. Selection of the appropriate SONET timing source is done in the TIMING category of the SETUP menu.

Objectives for this test are:

– Verify that the proper SONET and DS1 SIGNAL and FRAME are received

– Verify that no timing slips occur within the network

SONET overhead byte manipulation

Another useful tool for verifying SONET network functionality is the manipulation of the overhead bytes within the SONET signal structure.

The analysis of many different network characteristics can lead back directly or indirectly to the value of bytes within the SONET overhead, such as the correlation of the K1/K2 bytes to the automatic protection switching of a SONET ring.

The transmitted values of the SONET overhead can be accessed in the SOH category in the SETUP menu. Values for bytes within a received SONET signal can be viewed in the "Overhead" RESULTS category.

Objectives for this test are:

- Verify the proper SONET and DS1 SIGNAL and FRAME are received
- Verify the correct settings for APS Msg Count, APS Request Msg, APS Switch Mode, and APS Bridged Line are seen corresponding to the K1/K2 byte settings
- Verify the correct path trace character string is received corresponding to the J1 byte settings (path trace)
- Verify proper transmission of any SONET overhead byte and the corresponding messaging to the receiving node

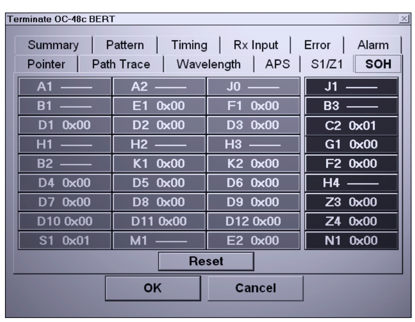

Figure 6 SONET overhead byte manipulation table

In-service monitoring of circuits

It is important to apply regular maintenance to a SONET network through the use of in-service monitoring. In-service tests with the FST-2510a/FST-2310 allow the user to make basic measurements of key network parameters to ensure that the quality of service being supplied to the customer meets the specifications of the network.

Monitoring of OC-n signals

The FST-2510a/FST-2310 allows the user to monitor an optical carrier – level n (OC-n) signal to verify proper network operation. This test utilizes the MON/THRU application of the FST-2510a/FST-2310. Select MON/THRU, then the proper access rate and mappings from the pulldown menu. Reference the SUMMARY category in the SETUP menu to verify correct network configuration and use the RESULTS display windows and LEDs to verify the test objectives below.

Objectives for this test are:

- Verify the proper SONET SIGNAL, FRAME, and PATH PTR are received
- Monitor the network for appropriate level measurements, proper framing, BIP errors, and path pointer adjustments

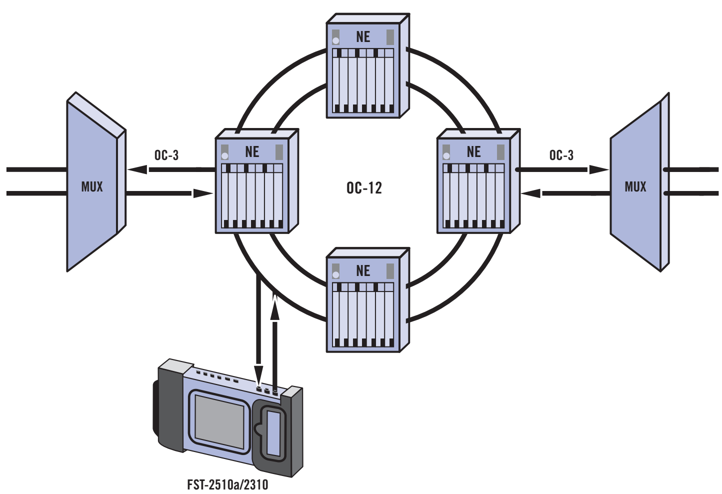

Figure 7 In-service monitoring

Appendix A: General setup

Equipment and options required

In order to perform the procedures detailed in this application note the following equipment is required:

- Fiber Optic Cleaning Kit (Part #2550)
- Two FST-2510a/FST-2310 TestPads with one of the following configurations:
- Four fiber optic cables with proper connector (FC/PC, ST, or SC on FST-2310 top panel)

Configuring the instrument
Configuring the instrument for a particular test is easily done using the FST-2510a /FST-2310's application-driven menu structure. First select the application, then the access line rate and payload mappings and the test setup is complete. It is important to verify that the network parameters, such as the signal's framing is selected properly on the test instrument. This can be done using the summary property sheets, under the setup menu in the upper right-hand corner of the test instrument.

Connecting the circuit
Once the configuration of the test instrument is complete, the user must now connect to the circuit-under-test. When configured, the test instrument will guide the user where to connect via the active port LEDs on the top panel of the module.

Running the test
With the test instrument configured and the proper connections made, the user is now ready to run the test. Depress the LASER ENABLE action button followed by the RESTART softkey to clear any errors and begin a new test. Navigate the results categories to verify the test objectives.

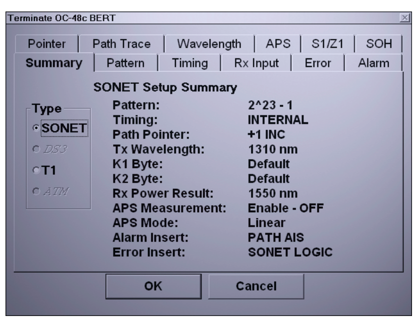

Figure 8 Screenshot of summary property sheets

Appendix B: Troubleshooting tips

This appendix provides a list of items to check when a test setup or test results do not match those described in this application note.

RX PULSES on top panel connector does not illuminate

- Replace possibly defective optical patch cord
- Clean optical fiber and test set connector
- Verify optical connector keys are lined up at both ends of the jumper cable
- Verify carrier signal test setup
- Verify physical layer and SONET configuration

SIGNAL LED on front panel does not illuminate

- Verify carrier signal test setup
- Verify proper line rate is selected and test connections are correct
- Verify physical layer and SONET configuration

SUMMARY category indicates "Path Pointer Size"

- This indicates that the SONET NE is incorrectly configuring the pointer size bits of the H1 byte in the SONET overhead. Interconnecting this signal with other vendors' equipment may cause some SONET NEs and ATM switches to alarm with loss of pointer (LOP).

SONET BIP errors

- Use the BIP error designations (path, line and/or section) to troubleshoot the network and sectionalize the problem.
- BIP errors indicate that the end-to-end carrier signal is suffering parity errors. This can cause DS3 parity errors, excessive retransmission of ATM traffic, and ultimately a congested network. Verify the physical and configuration test layers.
- For an optical carrier signal, check power levels to verify that the fiber and connector performance are within specifications

Excessive pointer adjustments

- Verify that all SONET network elements are set to the correct timing source – "BITS Clock", "Recovered", or "Internal")

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