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APPLICATION NOTE

SONET TESTING WITH THE FTB-8000

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Introduction

In recent years, there have been many advances in technology that have changed the environment in which transport engineers and technicians find themselves. A major change that has come about in the last few years is the proliferation of IP-based services. As Internet protocol (IP) has progressed from being a means of transferring static data files between government and educational establishments to a ubiquitous technology used to transport voice, video and other demanding services, the performance requirements of the underlying transport network have become more stringent. Thus, testing and qualification of these transport networks has become more important and more challenging.

This application note is intended to provide guidance for proper testing methods for SONET-based networks as recommended by EXFO. It focuses on testing applications and techniques that will be helpful in meeting the challenges of today's complex networks. The testing strategy outlined below ensures that all aspects of a SONET network are characterized; this, in turn, allows you to ensure the availability and quality of your network's transport.

Physical-Layer Testing

Before going into a detailed description of the SONET tests necessary to qualify today's networks, it is important to understand that proper testing of any network–whether SONET or Ethernet, fiber or copper–should start from the bottom; that is, at the physical-layer level. A comprehensive suite of physical-layer tests should be completed prior to any testing in the digital domain. Although we will not be addressing these tests in this application note, it is essential to know what they are:

- Power loss
- Return loss
- Dispersion (for high-speed optical systems)
- Media profile (splice loss, attenuation, reflectance, etc)

Correctly performing these tests will ensure that future testing is not hindered by any problems in the underlying physical media, preventing the waste of valuable turn-up time searching for "hidden" glitches.

For guidance on these and other physical-layer testing applications, please refer to EXFO's Guide to WDM Testing Technology, available from your local EXFO representative or EXFO's website at www.exfo.com.

Testing Configurations

The tests described below will be discussed in the context of a generic SONET network. The following examples have been included for illustration purposes only.

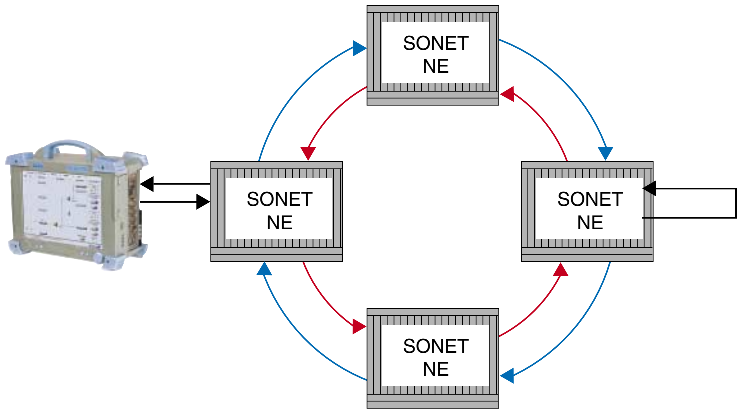


Figure 1.1. Configuration for continuity, BER testing, delay and alarm processing

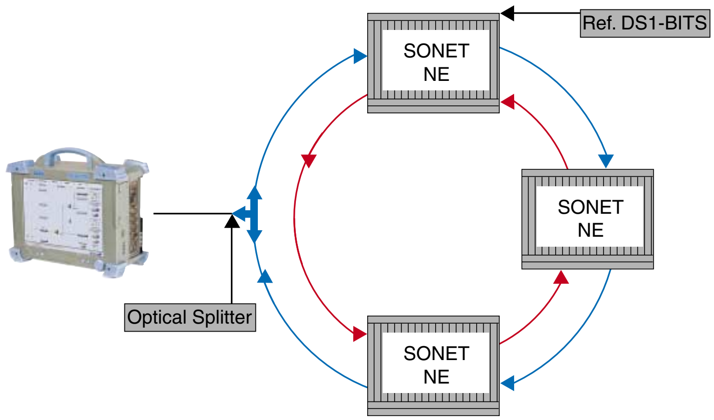


Figure 1.2. Configuration for synchronization measurement

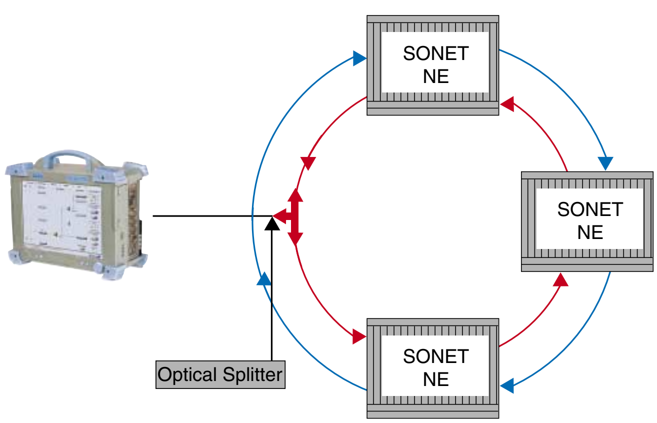


Figure 1.3. Configuration for APS Measurement

SONET Testing Applications

Continuity

Before beginning any complex testing procedure, it is important to take a moment to make sure that end-to-end connectivity is established and that the logical setup is correct. A convenient and thorough way of accomplishing this task is to set up a path trace using the J1 byte. The proper receipt of the transmitted path trace will verify that the configurations for framing, coding and synchronization are basically compatible throughout the network under test.

Test Procedure

1. Connect the FTB-8000 according to the applicable configuration (see Figure 1.1).
2. Verify if any alarms are present on the FTB-8000 or on the network elements.
3. If alarms are present, troubleshoot and eliminate them before proceeding.
4. Once all alarms are cleared, verify continuity throughout the network by updating and transmitting the path trace as illustrated. Verify that the received path trace is updated correctly.
5. Continuity is now established.

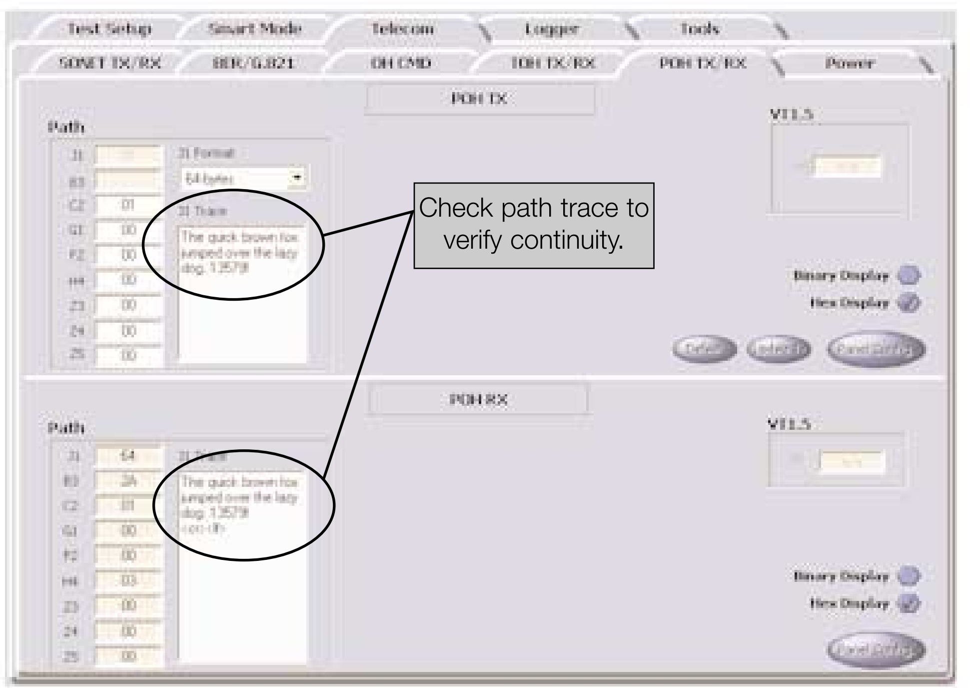


Figure 2. Path-trace verification

Bit-Error-Rate Testing

The bit-error-rate (BER) test provides a complete qualification of the payload-carrying ability of the SONET circuit. As this is always an out-of-service type test, it is vital that a complete BER test be passed prior to user traffic being commissioned onto the system.

The FTB-8000 allows test patterns to be sent at concatenated rates to allow for testing of the service's full payload, thus assuring full verification for all errors and defects. Or, if desired, each individual time slot may be tested sequentially in an automated fashion by utilizing the built-in macro recorder and scripting engine. During the test, the FTB-8000 records all events to generate a detailed report of circuit quality and SLA compliance. The report may also include performance standards described in ITU recommendations G.821, G.826 and others as required.

Test Procedure

1. Connect the FTB-8000 according to the applicable configuration (see Figure 1.1).
2. Set up the FTB-8000 with the appropriate test case (e.g., OC-192 with STS-192c mapping or OC-48 with STS-48c mapping).
3. Make sure the FTB-8000 reports no alarms. Some alarms may appear at the beginning of the test sequence due to initial synchronization. It may be necessary to reset the test (once) immediately after the test case starts to clear these errors.
4. Let the test run for a specified amount of time. The duration of the test can vary depending on internal requirements. A typical duration is 24 hours.
5. During or at the end of the test, consult the Logger for events, errors, and/or alarms. If errors or alarms occur during the test, troubleshoot the problem and then repeat the BER Test.

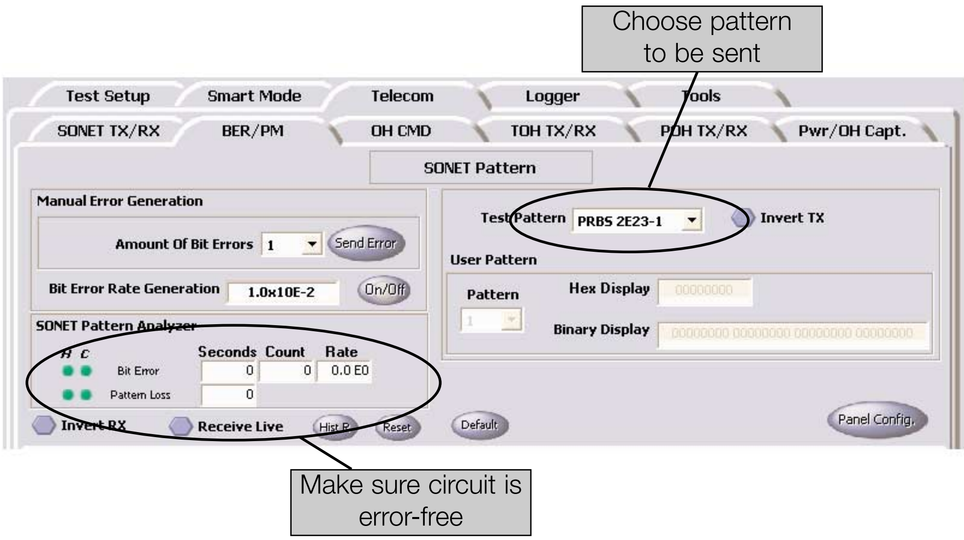


Figure 3. Bit-error-rate testing

Round-Trip Delay

Many of the services being transported by today's SONET networks are sensitive to a problem known as excess latency or delay. Latency is simply the time it takes for a piece of information to be transported from A to B. Although simple, this issue can cause huge problems in today's complex networks, as they are getting increasingly larger and contain more and more network elements. A customer's end-to-end circuit may travel many miles and go through a very large number of network elements before being delivered. This large distance and numerous optical/electrical conversions have a direct effect on the signal delay. This may, in turn, affect proper signal transmission. Cellular and IP traffic are especially sensitive to latency and as more services move to these formats, latency will become a bigger and bigger issue.

The goal of the test is to send a signal through the network and test the time it takes to return to the test equipment. This test is most often performed when a new customer service is turned up, and usually from the customer premise.

Test Procedure

1. Connect the FTB-8000 according to the applicable configuration. This test requires a loopback to facilitate return traffic (see Figure 1.1).
2. Set up a test case on the FTB-8000 according to the tested circuit (the signal must use an embedded DS1 or 64K signal to test round-trip delay).
3. Perform a round-trip delay test as illustrated below (refer to the FTB-8000 user guide for details).

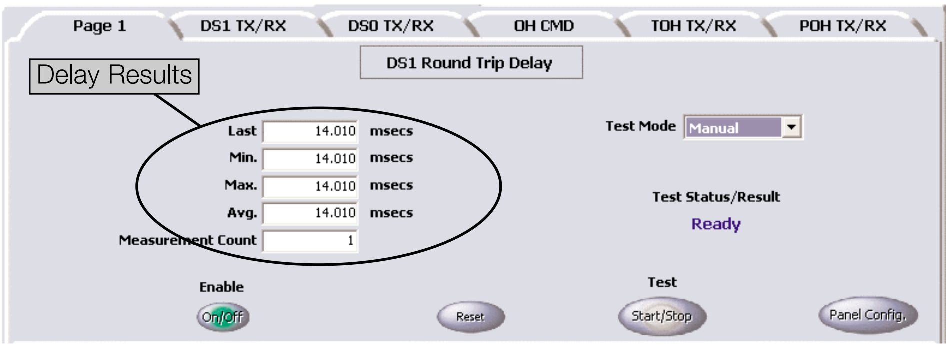


Figure 4. Round-trip delay test results

Synchronization

One of the greatest advantages of SONET is its synchronous nature. This import feature allows for things like tributary visibility, byte-interleaved multiplexing, and more. However, keeping a network synchronized is often a challenge and is one of the most common problems in SONET transport. If a SONET network is experiencing timing problems, the pointer bytes will try to compensate by keeping track of the payload and its movements. If the pointer bytes cannot keep up with the payload's movements, the payload may be "lost" and errors will start piling up.

There are a few methods available to test the timing and synchronization of a SONET network. Arguably, the most useful of these methods is the analysis of pointer activity through monitoring the H bytes in the line overhead. Some minor pointer adjustments may be expected in a network, but excessive adjustments may be indicative of incorrect timing configuration(s) and should be thoroughly investigated prior to turn-up.

Test Procedure

1. Connect the FTB-8000 to the network under test in monitor mode via an optical splitter (see Figure 1.2).
2. Press the Smart Mode button to scan the monitored signal and discover the configured mapping.
3. Select the proper time slot on the Smart Mode display and press Start Test.
4. Run the test for 24 hours to fully analyze the circuit.
5. Note pointer adjustments in the OH CMD page or in the Settings and Summary Report.

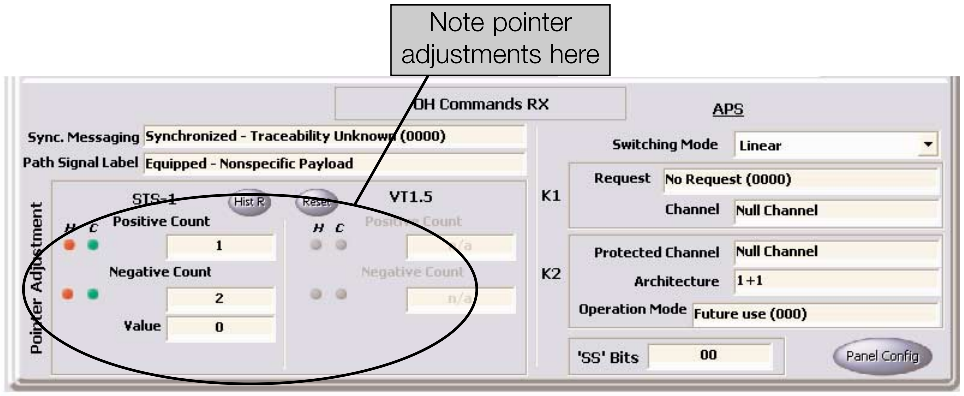


Figure 5. Pointer-adjustment results

Automatic Protection Switching

One of the primary goals of SONET is to provide a network with great resilience and automatic recovery from failure. The feature that was designed to facilitate this resilience is known as Automatic Protection Switching (APS). It provides for rapid restoration of traffic to a protection channel following network failures such as fiber cuts or hardware failures.

The ITU (G.841) standards body has set its requirement for the APS time of a channel to 50 ms; this allows minimum disruption of the traffic when a channel is switched. Many networks are characterized by long distances between nodes and complex ring configurations made of many network elements. These factors will influence the protection switch time. It is therefore important to verify that the APS time meets the 50-ms requirement.

There are a number of methods available to test the APS time. The most exacting method is the capture of the K1/K2 bytes, which control the APS functionality. This methodology is simple and accurate, and provides a clear determination of the switch time. It also allows for in-depth troubleshooting in case the switch does not meet standards.

Test Procedure

1. Connect the FTB-8000 to the protection channel of the network either in through mode or by using an optical splitter. An optical splitter may be preferred as this method is less intrusive (see Figure 1.3).
2. If desired, set the Trigger option to optimize the byte capture. A rule of “If different” with byte values of 00 h to 05h will ensure the APS time is first on the list.
3. Start the byte capture and provoke a protection-switch event through software, by disconnecting the fiber, or pulling the circuit pack.
4. Verify the protection-switch time by using the captured K1/K2 bytes (see Appendixes B and C for details).

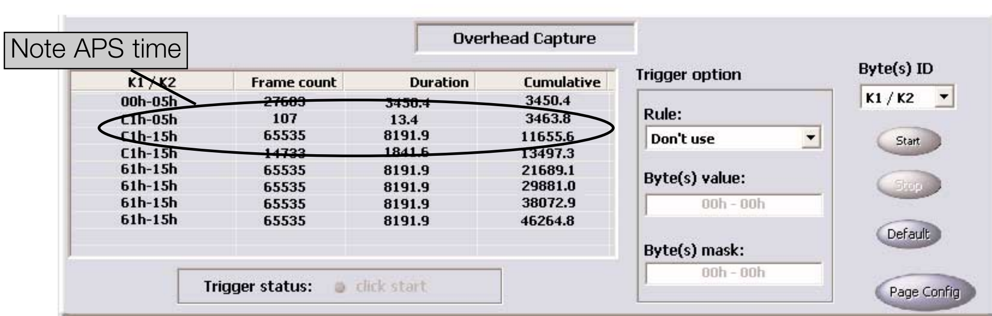


Figure 6. APS results

Alarm and Error Processing

SONET was designed to allow for transport equipment from different vendors to work together with little reconfiguration or modifications. While this is a goal that equipment vendors are striving for, perfect harmony is not always achieved. In those instances in which network elements of differing manufacturers are deployed together, it is sometimes necessary to test the ability of the network to properly process and forward errors and alarms. For best results, this testing should be done in a lab before deployment. However, verification of basic abilities after installation is often necessary.

Testing this functionality is accomplished by manipulating and monitoring various bytes in the SONET overhead to verify that critical alarms and errors are processed and reported correctly throughout the network and to the network operations center (NOC).

Test Procedure

1. Connect the FTB-8000 according to the applicable configuration (see Figure 1.1).
2. Set up the FTB-8000 with the appropriate test case.
3. Make sure no alarms are present.
4. Insert various alarm and errors, ensuring that they are carried through the network and received back to the test set in the proper fashion. Some common alarms are Alarm Indication Signal (AIS) and Remote Defect Indication (RDI), while common errors are Remote Error Indication (REI) and Bit-Interleaved Parity (BIP-8).

Note: *Transport equipment documentation will likely be needed during this type of testing.*

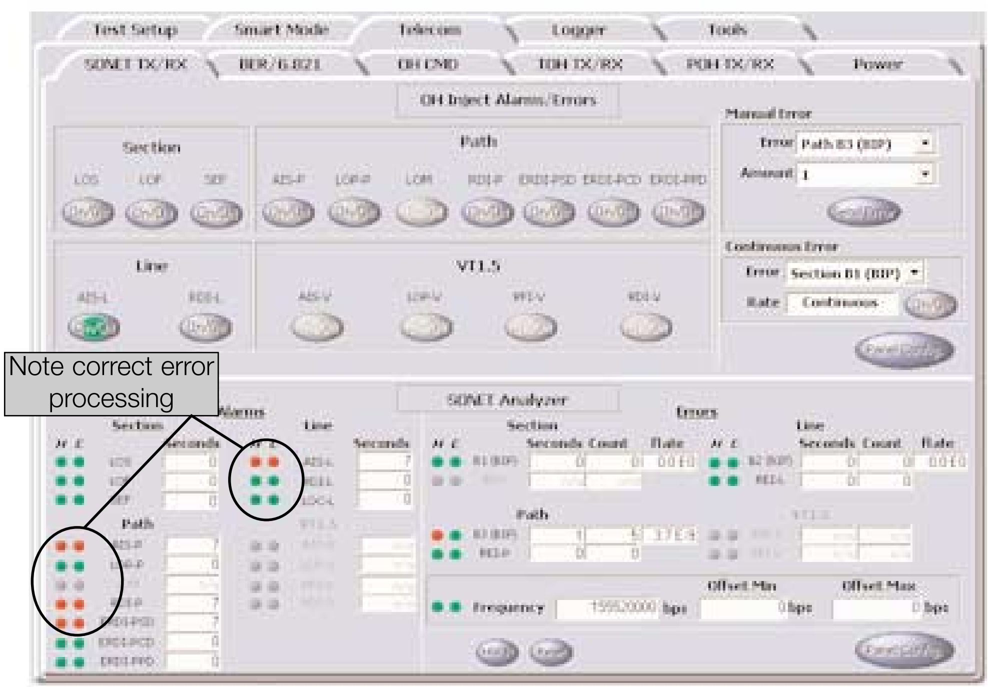


Figure 7. Alarm- and error-processing results

Test Automation

As mentioned above, the FTB-8000 has some built-in tools that help automate and make testing a SONET network much easier.

Auto-Discovery and Test Setup

The Smart Mode signal-discovery feature dramatically speeds up the configuration and setup of monitor-only-type tests, such as the pointer adjustment test described previously.

Test Procedure

1. Connect the FTB-8000s Rx port to the network under test–usually by using an optical splitter or other access point.
2. Press the Smart Mode button on the Test Setup page; or, from the Smart Mode page, select the appropriate interface a press Start Scan. If a virtual tributary or other sub-rate is desired, select the appropriate STS-1 and press Tributary Scan.
3. Select the appropriate time slot to be tested from the Smart Mode display and press the Start Test button.
4. The FTB-8000 will automatically configure the correct monitor-only test case.

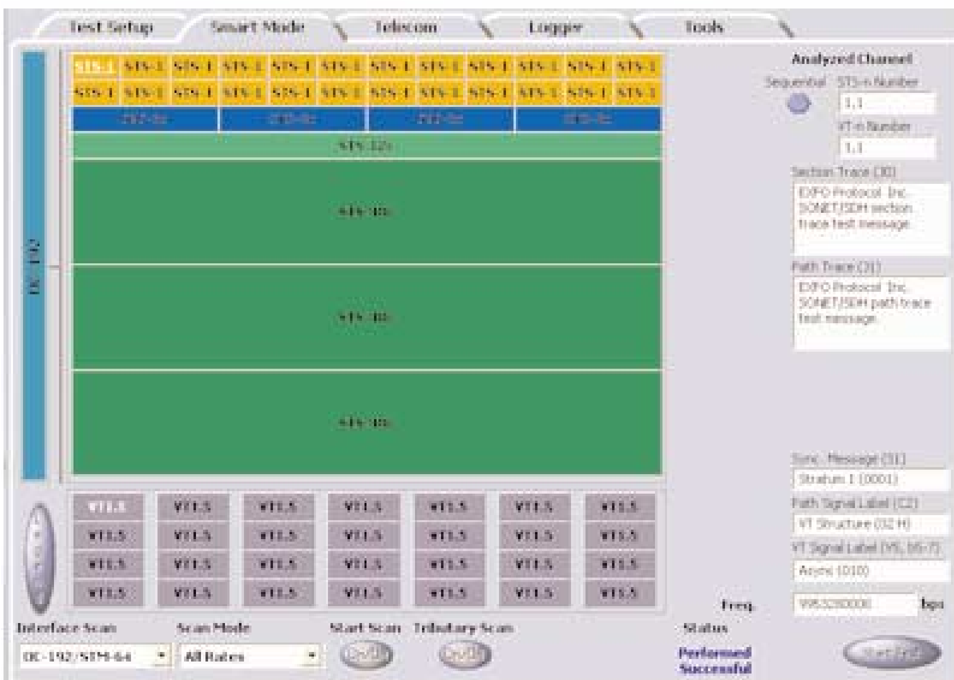


Figure 8. Smart Mode interface

Scripting and the Macro Recorder

The FTB-8000 features a flexible and easy-to-use scripting engine based on the common macro recorder/player design found in many other powerful commercial software programs. It allows for script generation and complex testing scenarios (such as sequential STS-1 time slot testing as mentioned previously) to be completely automated.

Test Procedure

1. Scripts may be created during actual testing, simulated testing in loopback, or offline with EXFO remote software.
2. Press the Record button on the Script page and name the new script.
3. Continue with the testing scenario you wish to automate by using the graphical user interface as you would during a normal test.
4. When complete, press the Stop button on the Script page to complete the script.
5. Use the Line Editing section to add advanced features such a loops, delays, etc., as needed.
6. Run the script by loading it from the hard disk and pressing the Play button.

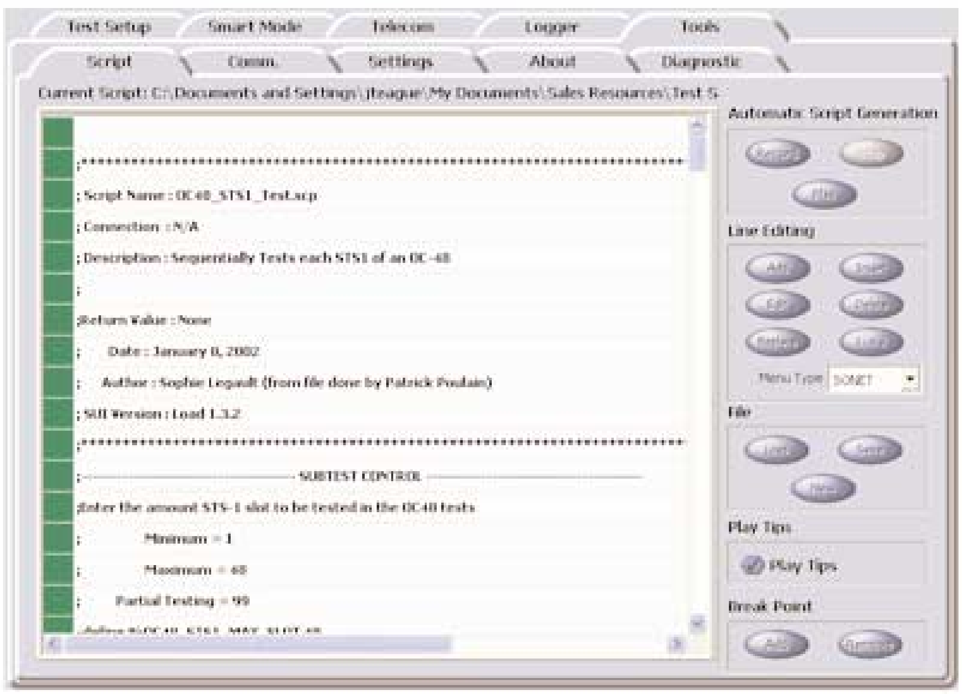


Figure 9. Scripting interface

Conclusion

SONET-based networks have proven to be the most robust data-transport technology available and will continue to be the transmission system of choice for carriers who demand a stable and resilient method of delivering broadband services.

By using the FTB-8000 and EXFO's proven test strategies, you can be sure that all-new SONET circuits placed in service are proven capable of handling any of the demanding services that may be placed on them in the future.

Appendix A
Performance-Monitoring Standards

The type and rate of errors are key factors in determining the transmission quality of telecommunications equipment. Therefore, the various standards bodies have developed a series of metrics for qualifying system performance based on the occurrence of errors. Amongst these important standards are G.821 and G.826. The different standards were not all developed at the same time. New recommendations were put together as networks evolved. Below is a summary of each of these standards.

G.821

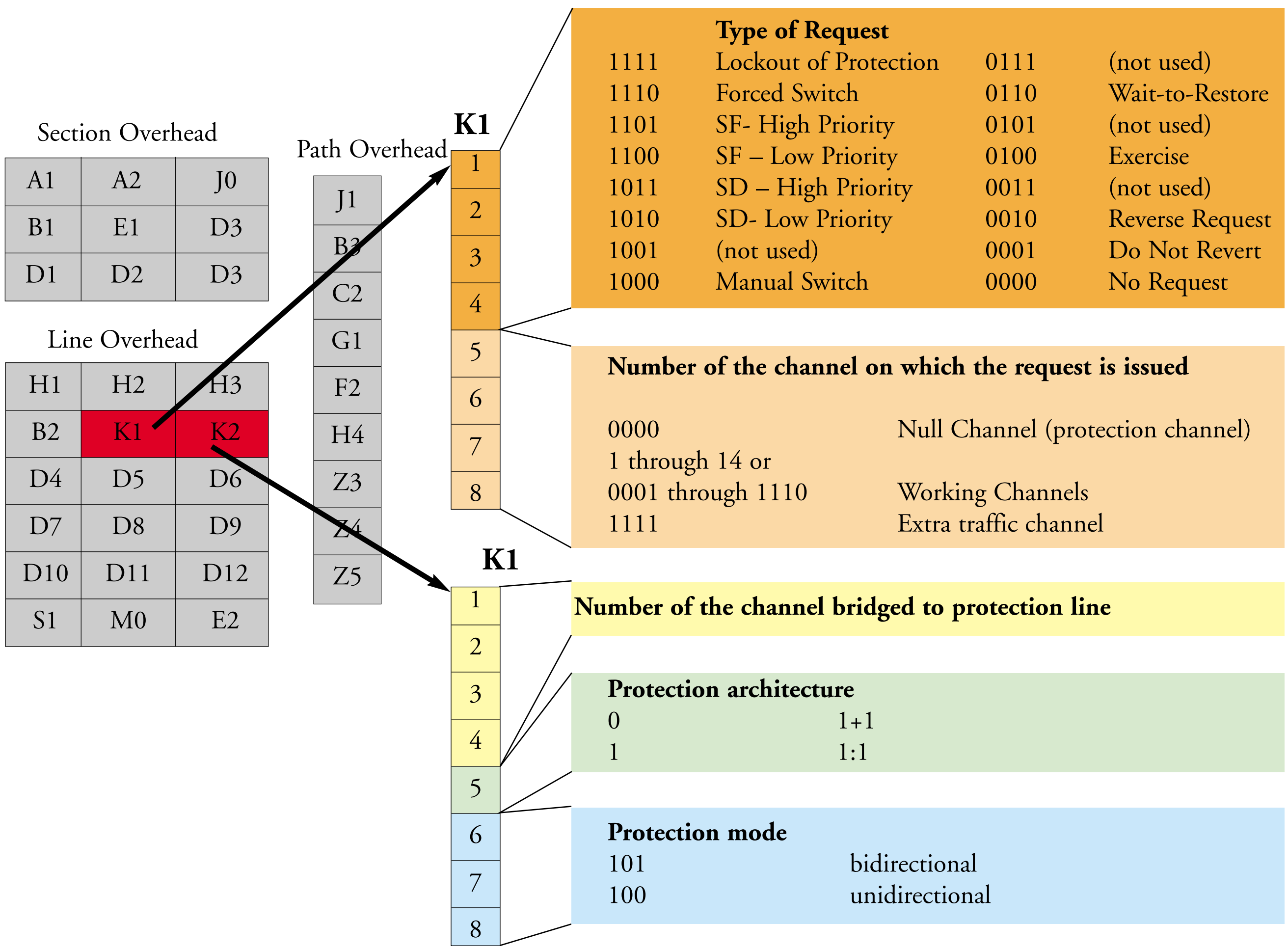
- Designed for digital connections below 2 Mb/s (but also used for higher rates)
- Based on bit-error-ratio measurements
- Out-of-service measurement done with test pattern
- Performance events:
  - ES: one-second period with one or more bit errors
  - SES: one-second period with BER ≥ 1x10-3 or with an LOS or an AIS defect detected
- Performance parameters:
  - Errored Second Ratio (ESR): ES/(Total Seconds – UAS)
  - Severely Errored Second Ration (SESR): SES/(Total Seconds – UAS)xDegraded Minutes: A one-minute period (not counting UAS or SES) in which the cumulative bit error rate exceeds 1
- Measurement period: one month (72 hours also suggested)

G.826

- For digital paths at or above 2 Mb/s
- Based upon a block-based measurement concept using Error Detection Codes (EDC) inherent to the path under test (for example, Byte-Interleaved Parity in SONET).
- May apply to T-Carrier, SONET and other types.
- Focused on in-service measurement capability (because of EDC). Out-of-service measurements can also be taken.
- Performance events:
  - Errored Block (EB): A block with one or more bit in error.
  - Errored Second (ES): one-second period with one or more EB or at least one defect.
  - Severely Errored Second (SES): one-second period with EB ≥ 30 % or at least one defect.
  - Background Block Error (BBE): EB not part of a SES
- Performance parameters:
  - Errored Second Ratio (ESR): ES/(Total Seconds – UAS)
  - Severely Errored Second Ratio (SESR): SES/(Total Seconds – UAS)
  - Background Block Error Ratio (BBER): BBE/[(Total Seconds – UAS – SES) * blocks/s] (i.e., exclude blocks during unavailable time and during SESs).
- Availability state: same concept as for G.821.
- Bidirectional paths: same concept as for G.821
- Far-end path monitoring:
  - In some cases RDI and REI can be used.
- Measurement period: one month (72 hours also suggested)

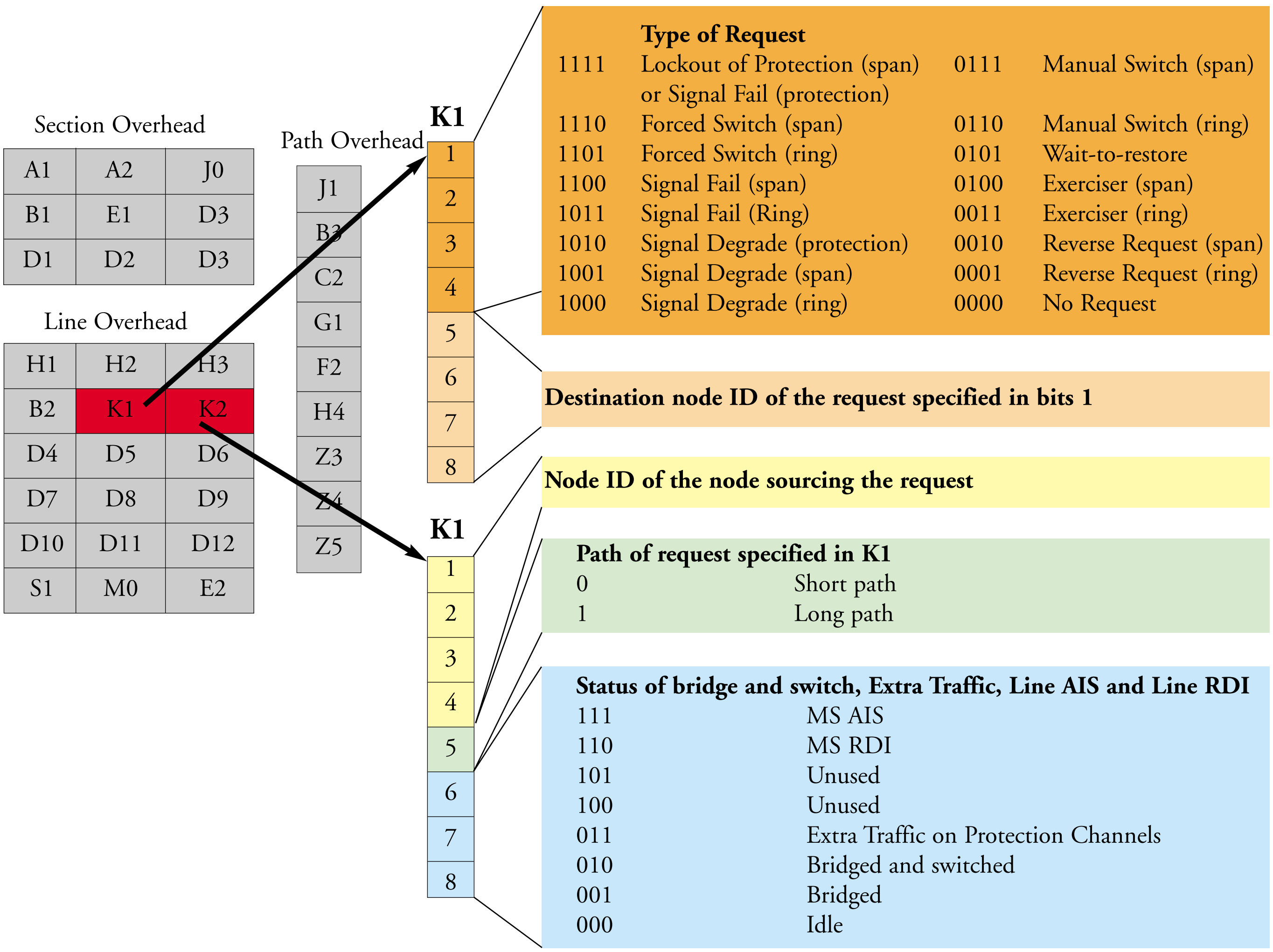
Note: *Amongst other standards, the FTB-8000 SONET/SDH Analyzer Module does support G.821 and G.826 under the "PM" Telecom Tab of the GUI. Results for these standards are also printed as part of the FTB-8000 Test Results Summary Report.*

Appendix B
Linear 1+1 and 1:1 K1/K2 bytes protocol



EXPERTISE REACHING OUT

Appendix C
Ring K1/K2 bytes protocol



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