Application Note

FST-2310 Jitter Testing

Wireless Application

Jitter testing verifies timing problems between wireless and synchronous networks

The wireless market has become extremely competitive, making it crucial for providers to offer the best service and the broadest coverage area. This trend has led to increased requirements for proper installation and maintenance of services. The ability to quickly and accurately diagnose and isolate network problems is key to a successful business.

Locating problems in your network is especially important if the lines are leased and finger-pointing issues need to be resolved. By verifying accurate transmission to the base transceiver station or call tower, the technician can sectionalize troubles and pinpoint RF problems for your base station to mobile devices. Timing problems in networks feeding the base transceiver stations can cause intermittent errors on DS1, DS3, or ATM interfaces. Left unchecked, these problems can degrade service to the customer, delay new service turn-up or lead to a total crash of the cell site. Although the probability of a timing related error may seem low, the relatively high cost of troubleshooting and fixing these problems justify enhancing conventional test methods to eliminate timing errors.

This application note provides an in-depth look into the causes and effects of timing problems and explains how jitter testing at tributary levels identifies these timing problems during installation or maintenance, in the field, at the mobile switching center, or in the lab. This document focuses on the following timing problems caused by SONET networks affecting wireless networks.

– Peak-to-Peak measurement

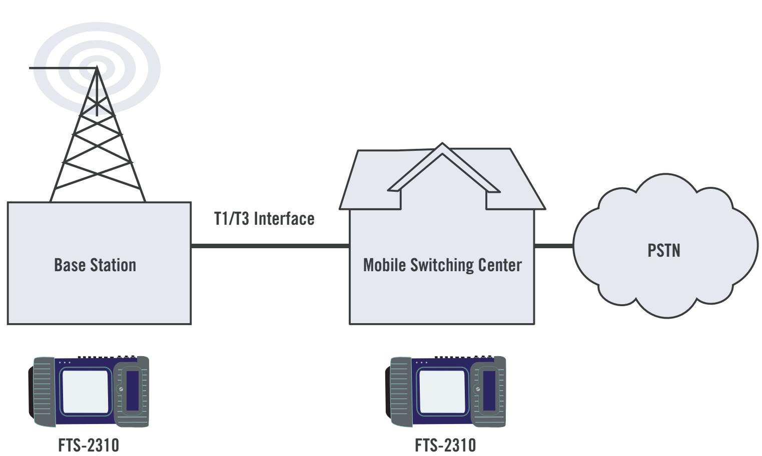
– Wide-Band/High-Band (simultaneous)

– Current and Maximum Values

– Phase Hits

– Selectable Jitter Hits Threshold

– Auto-Ranging (jitter amplitude range)



Why jitter test?

Because the true cause of synchronization problems cannot be determined by conventional transmission testing of the tributary signals, these problems are extremely difficult to troubleshoot during maintenance calls. However, enhancing conventional tests with jitter measurements isolates timing problems early on.

One of the most common SONET transport problems is synchronization. If the timing of a network element is allowed to drift for even a short period of time, it can cause intermittent errors on tributary DS1, DS3, or ATM signals. Timing problems are often caused by network elements that are left in holdover timing mode after installation. Dependent on the quality of the timing in the network element, side effects on the tributary signals may not be evident until days, or weeks, following installation. By this time, service is already affected. Symptoms of SONET timing problems range from intermittent transmission errors (muted voice in an embedded DS1/DS3 channel, for example) to the total breakdown of a transmission link.

The majority of SONET timing problems are caused by provisioning errors during installation of new networks, during enhancement of existing installations, or during maintenance calls. The clock quality is determined by the design of the timing architecture as well as the quality of reference clocks and underlying transport facilities. Mostly, though, clock quality is determined by the performance of the receiving clocks.

The timing architecture must provide an appropriate hierarchy, provide careful implementation of the building integrated timing supply (BITS) concept, and use the best transport facilities for timing signals. At the same time, it must avoid timing loops and must keep the cascading levels of the timing hierarchy within acceptable levels. Once the timing reference signals within the BITS are determined, respective SONET network elements need to be provisioned appropriately. Setting the timing of network elements requires selection of a timing mode (external, line, or through) and identification of the incoming port featuring the best clock quality. Another source of timing problems is caused by noisy line or clock cards. Although network equipment manufacturers test their line and clock cards for timing and other related problems, noisy cards are still encountered in the field. If timing differences exist between two SONET network elements, the payload is permitted to move around to adjust for the timing differences and to prevent the data from being corrupted or lost. Every time the payload changes, the pointer moves to track its new starting location. These movements are referred to as pointer adjustments (Figure 2).

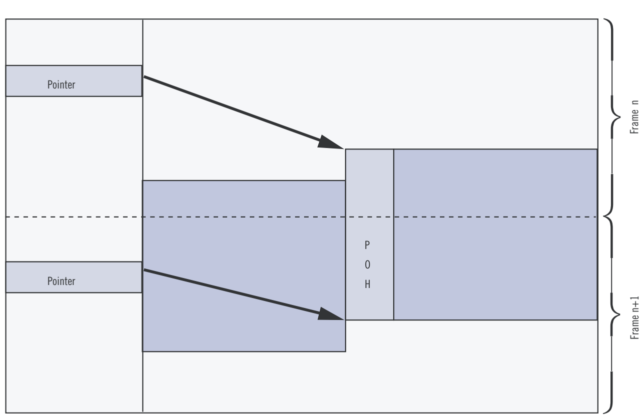


Figure 2 Tracking pointer adjustments

Although pointer adjustments protect the payload while it is within the SONET network, they may cause data errors when the signal exits the network. These errors occur when the tributary equipment has trouble synchronizing to the signal. The extent of which the asynchronous equipment will experience synchronization problems depends on many factors, including equipment type, payload type, and pointer adjustment frequency. Pointer adjustments can affect any type of asynchronous payload, such as ATM, DS1, or DS3. A few pointer adjustments will not cause problems on the tributary signals. However, pointer adjustments indicate that a timing problem exists, and timing problems can become worse over time. Therefore, it is wise to monitor the SONET signal and to verify that no pointer adjustments are occurringon the circuit. Unfortunately, there are often no monitor access points at the SONET level. There is, though, a reliable test method to capture timing problems at the tributary level. It is a jitter test. The pointer adjustments cause pointer jitters at the tributary level (DS1 and DS3). Excessive pointer adjustments cause large jitter amplitudes. Network elements include an elastic buffer to account for pointer adjustments. Excessive pointer adjustments, however, lead to buffer underflow or overflow causing bursts of errors. Large jitter amplitudes eventually lead to bit slips and bit errors. Left unchecked, large jitter amplitudes eventually lead to total loss of the connection at the tributary level. Loss of synchronization causes impacted network elements to switch to their internal timing holdover mode or free-run mode, if no holdover mode is available (mostly in private networks).

In holdover mode, network elements use historic data to track the lost reference timing. The tracking deteriorates with time, though, and eventually drifts to the edges of the frequency bands of their phase-locked loops. This frequency drift can take hours, or even days, to have a significant and reproducible quality effect on the service. The effect usually starts with intermittent errors and ends in permanent breakdown of the tributary link. Conventional bit error rate tests (BERT) are performed as part of SONET network turn-up and service provisioning. However, the limited amount of available testing time may mask timing problems, which have not become significant enough to cause bit errors. At early stages of timing problems, the visible effects of transmission problems are rare. There may be one or a few bit errors per frame per day, if any. Measuring jitter, in parallel with BERT, provides an early indication of timing problems. Synchronization problems are extremely difficult to troubleshoot during maintenance calls because the true cause cannot be determined by conventional transmission testing of the tributary signals. Conventional bit error tests may not reproduce intermittent transmission problems caused by timing problems. Another conventional method of identifying timing problems is checking for pointer adjustments at the SONET level. During maintenance calls in the field, technicians usually have no access to the SONET signal featuring excessive pointer adjustments. In addition, optical access is often not available within a central office environment. Even if it is available, it may be difficult to troubleshoot based on the number of observed pointer adjustments.

Therefore, enhancing the conventional tests with jitter measurements is recommended to isolate timing problems early on. Jitter tests can be performed in the field or at any tributary interface available at the mis-timed SONET network. Jitter standards provide pass/fail limits and timeframes, enabling the parties involved to prove the existence of a problem.

What is jitter and jitter testing?

"Jitter" is the term used to designate deviations of significant instances of a digital signal from the ideal, equidistant values (Figure 3). In other words, the transitions of a digital signal invariably occur either too early or too late when compared to a perfect square wave (reference clock). It is the job of the clock recovery circuitry used in network elements to correctly sample the digital signal. It must sample as close to the center of the bit as possible, using the recovered bit clock. If the digital signal and the clock both have identical jitter, then the position of the sampling instance doesn't change despite significant jitter errors. Sampling still occurs properly, and no bit errors occur. Strictly speaking, this is only the case with low-frequency jitter for which the clock recovery circuitry can keep up with digital signal phase variations with no problems. At higher jitter frequencies, however, the clock recovery circuitry cannot keep up with the fast phase variations of the digital signal. Phase shifts result, and for clock period values > 0.5 UI (UI = unit interval), the result is incorrect sampling of the bit stream and thus, bit errors. Due to additional digital signal distortion, the decision range is much smaller in reality. At very large jitter amplitudes, bit errors become so common that a loss of frame (LOF) occurs. To measure jitter effects, the incoming signal is regenerated to produce a virtually jitter-free signal, which is used for comparison purposes. No external reference clock source is required for jitter measurements. The unit for jitter amplitude is the unit interval (UI), where one UI corresponds to an error of the width of one bit. There are different sources of jitter, including interference, pattern jitter, phase noise, delay fluctuations, stuffing and waiting time jitter, mapping, and pointer jitter. This application note focuses on pointer jitter, the primary source associated with SONET timing problems. Another type of jitter involved in synchronous networks is mapping jitter. It is caused by mapping processes in synchronous network elements (NE). Bit stream gaps caused by bit stuffing lead to variations in the plesiochronous tributary signal. Phase-locked loop circuits used in the desynchronizing of NEs smooth out the phase steps. Remaining phase modulation is observed as mapping jitter at PDH interfaces. Pointer jitter and mapping jitter are observed in combination at tributary interfaces and are, therefore, referred to as combinational jitter. The portion caused by mapping jitter, though, is very minimal.

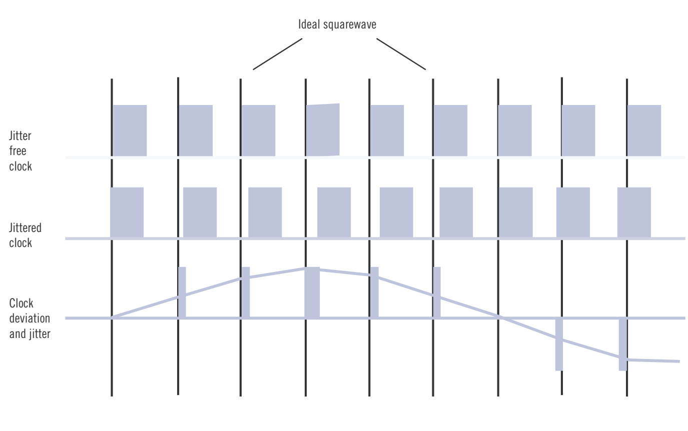


Figure 3 Jitter is the deviation of clock transitions from an ideal squarewave

Who benefits from jitter measurements?

Technical support groups, field installation crews, and switching center installation and maintenance groups are among those who benefit from jitter measurements.

SONET networks are expected to meet the highest availability requirements. Therefore, installation of new rings, as well as major changes to the network, necessitates extensive levels of testing. The installation and upgrades of networks usually involve different groups associated with owners of the backbone, mobile switching centers, and base transceiver station. The combination of the complexity of the networks, the number of groups involved, and the scope of any problems makes extensive testing necessary.

Problems in SONET networks affect a variety of working groups and can lead to finger-pointing. Performing jitter tests during the installation of SONET networks, as well as during installations at base transceiver stations, ensures that timing problems are not present and eliminates potential finger-pointing issues among the different groups involved.

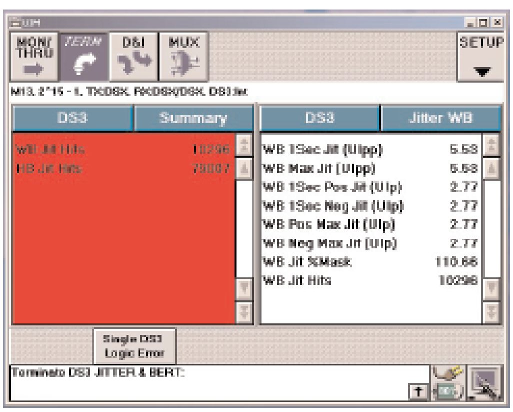
Installation of new rings involves extensive levels of testing. In addition, major changes to a network, including adding fiber, nodes, and optical bandwidth require renewed testing of the network to the greatest extent possible while under load. Typical tests include STS-N level testing and tributary tests. Optical power and sensitivity measurements are usually the starting points for the tests. They are followed by basic framing, coding, and alarm tests. The longest tests, bit error rate tests, are performed over a period of 24 hr, or more. These tests are also referred to as soak tests. During soak tests, a BERT test set applies a test signal at one tributary of the network. Loops are built at different nodes depending on the scope of the test as well as feasibility. The test signal is then looped back to the BERT test set. To conclude, the presence of timing problems has increasingly moved the testing groups to perform jitter testing at the tributary level.

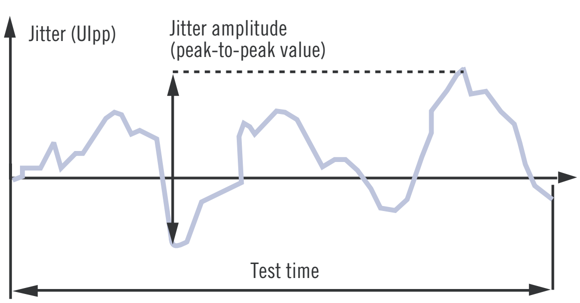
What is JDSU FST-2310 TestPad jitter enhancement?

DS1 and DS3 jitter measurements are cost-effective enhancements for the JDSU FST-2310 TestPad. The FST-2310 measures the peak-to-peak (UIpp) jitter values with appropriate filter settings (Figure 4).

Peak-to-peak jitter measurements and Wide-Band/High-Band (simultaneous)

Peak-to-peak jitter measurements capture the difference between the minimum and maximum jitter amplitudes during the measurement interval (Figure 5). Different jitter weighting filter combinations are used to differentiate high-frequency components, including high-band and wide-band jitter (Figure 6). For each particular measurement, a wide-band and a high-band filter combination of high-pass and low-pass filters are specified (Table 1). The measurement determines the positive and negative values for a phase variation, defining leading and lagging edges). In addition, the maximum values obtained during a measurement interval are also recorded and displayed. Measurement values should not exceed the limits under respective standards (ANSI, Telcordia, or ITU) for network interfaces or equipment.





Bit rate (kbps)	Measurement mode	High-pass filter	Low-pass filter
1,544	W	10 Hz	40 kHz
	H	8 kHz	40 kHz
44,736	W	10 Hz	400 kHz
	H	30 kHz	400 kHz

Table 1 Jitter measurement bandwidths according to G.783, GR-253, or GR-499 standards

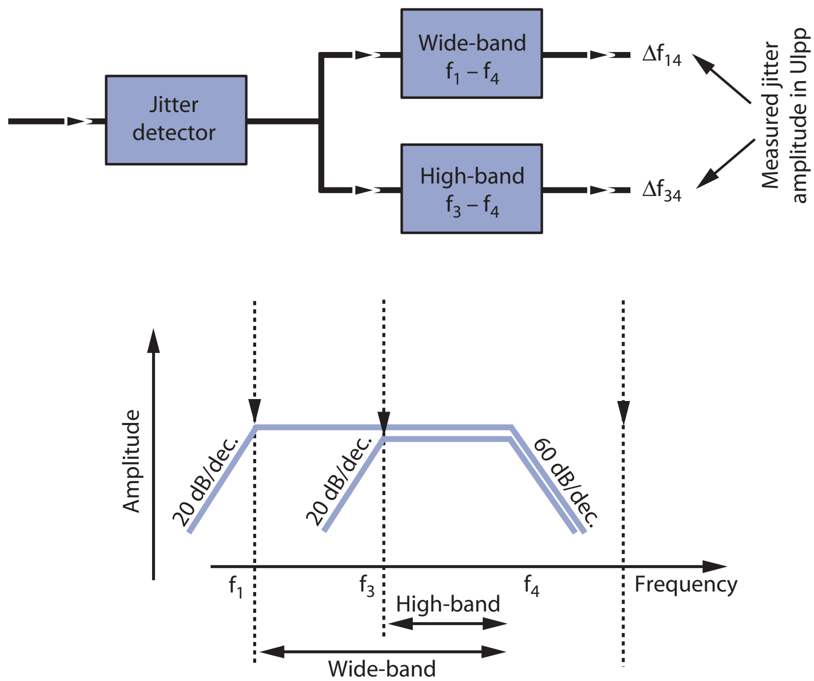


Figure 5 High-band vs. wide-band jitter measurements

The FST-2310 TestPad also provides a jitter percentage value as a ratio of measured jitter against a user-selected limit. Limits for jitter measurements can be obtained from the applicable standards. Table 2 lists those standards most relevant to jitter testing of SONET equipments. For reference, examples of jitter limits are listed in Table 3. They include peak-to-peak jitter limits for both DS1 and DS3 test signals.

Jitter standard	Name of standard
ANSI T1.105.03	Synchronous Optical Networks (SONET): Jitter at Network Interfaces
Telcordia GR-253-CORE	SONET Transport Systems Common Criteria
Telcordia GR-499-CORE	TSGR: Common Requirements
ITU-T G.824	The control of jitter and wander within digital networks based on the 1544 kbps hierarchy
ITU-T 0.172	Jitter and wander measuring equipment for digital systems based on synchronous digital hierarchy (SDH)

Table 2 Related jitter standards

Bit rate (kbps)	Wide-band jitter limits (UIpp)	High-band jitter limits (UIpp)
1,544	5	0.1
44,736	5	0.1

Table 3 Peak-to-peak jitter limits

Phase Hits

The FST-2310 TestPad also measures phase hits. Phase hits occur when a definable jitter ± peak thresholds is exceeded. The FST-2310's phase hit counter displays the number of recorded phase hits since the start of the measurement. A phase hit measurement, therefore, is a record of how often the tolerable jitter amplitudes are exceeded. Based on the number of phase hits, the user is able to better assess jitter behavior.

In Summary

In the past, jitter testing has been considered a measurement method that required a certain level of expertise in both operation and interpretation of test results. The FST-2310 TestPad has successfully alleviated this problem. Due to the ease of use of the FST-2310 for jitter measurements as well as the integration of jitter testing with other conventional transmission tests, jitter tests can be performed by a wide variety of working groups independent of their expertise level in transmission testing.

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