THE VALUE OF SYNCHRONIZATION TESTING

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APPLICATION NOTE

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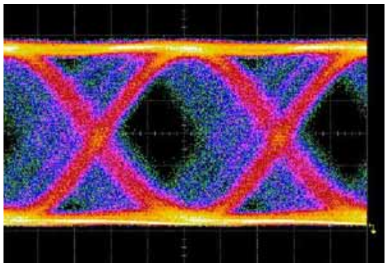
Introduction

In today's challenging telecommunications landscape, companies are seriously scrutinizing every expense to ensure they are receiving a proper return on their investments. Network service providers especially are keenly aware that, with access prices rapidly dropping, CAPEX and OPEX must be reduced if profits are to be achieved. On the other hand, service providers are also aware that most customers have a number of choices when it comes to choosing a provider. Therefore, to ensure the attraction and retention of a healthy customer base, the quality of the network must also be ensured. These two seemingly opposing goals set into sharp relief the need to evaluate or re-evaluate not only how network testing is performed, but also what is being tested. This article will explore this subject as it relates to ensuring the proper timing of a SONET/SDH network.

Nature and Importance of Timing in a SONET/SDH Network

Most recently deployed transport systems are synchronous in nature. Whether SONET (for North America) or SDH, these systems provide the highest bandwidth and most failure-resistant networks available. Due to their design, however, they put very strict demands upon the timing of the network.

At the interface level, network elements are often required to receive a signal, extract the correct timing, and correctly match the outgoing signal to the timing source. The ability (or lack thereof) to perform this action is generally referred to as jitter and is defined by Telcordia and ITU standards. There are a number of different sources of jitter (listed below), which are directly related to the design and quality of the network elements themselves.



Common Jitter Causes

- Re-timing imperfections in network elements
- PDH mapping/justification from multiplexing
- Tributary jitter due to pointer adjustments

Jitter causes a decrease in the quality of the digital signal, which can be seen as a closing of the horizontal axis when viewed on an oscilloscope. Jitter can either cause bit error directly or may result in a decreased system margin, which will make the equipment more susceptible to errors during operation.

At the network level, timing information from a primary reference clock (PRC/Stratum 1) is distributed to all network elements through a special synchronization network; this can be a totally separate network, multiplexed into the SONET/SDH signal, or a combination of both. The network consists of the PRC, secondary (SSU/Stratum 2) clocks and tertiary (SEC/Stratum 3) clocks. The PRC and SSUs are separate pieces of equipment, while the SECs are integrated into the network elements themselves. The network is hierarchical in that the SECs receive timing information from the SSUs, which receive it from the PRC. The PRC ultimately receives the reference timing from either a LORAN C or GPS signal; this signal, along with highly stable cesium oscillators, help to ensure the long- and short-term synchronization of the network. If the timing signals are lost or compromised, bit errors will result due to the network elements eventual improper transmission and/or sampling of the digital signal. These effects may be anywhere from moderate to severe in nature and will get progressively worse until the timing signal is properly restored. This is generally referred to as wander.

Due to the importance of maintaining the synchronicity of SONET/SDH networks, standards bodies have published standards to help ensure vendor interoperability and long-term stability. GR-253-CORE (Telcordia) and G.810, G.811, G.812, G.813, G.825, G.783 (ITU-T) delineate acceptable jitter and wander parameters and are guidelines that all equipment vendors must follow. Although jitter and wander have distinctly different sources, they are both the result of mis-timing in the network and are thus very closely related. They are differentiated by the frequency cut-off of 10 Hz with jitter being phase variations above 10 Hz and wander being phase variations below 10 Hz.

The key elements that are outlined within these standards are the following:

Jitter

- Output Jitter (Jitter Generation)–The jitter present on an output from a system in UI (unit intervals). It may be expressed as rms (average) or peak-to-peak (P-P). However, P-P is usually used, as it is the extremes that actually cause the problems.
- Input Jitter Tolerance–The amount of jitter a network element can tolerate without producing bit errors.
- Jitter Transfer Function–The amount of jitter transferred between the input and output of a network element. This can be a positive or negative number and is expressed in dB; typically limited to a gain of 0.1 dB.

Wander

- Time Interval Error (TIE)–Defined in ITU-T G.810 as “The difference between the measure of a time interval as provided by a clock (as recovered from a data signal) and the measure of that same time as provided by a reference clock.”
- Maximum Time Interval Error (MTIE)–The maximum peak-to-peak variation of TIE within a defined observation interval.
- Time Deviation (TDEV)–A measure of the spectral content of wander and is a function of the observation interval.
- Frequency Offset–A measure of the degree to which the clock frequency deviates from its ideal value.
- Frequency Drift Rate–A measure of how the frequency offset changes with time.

Adherence to the specifications outlined in the standards documents helps to guarantee that synchronous operation can be achieved. However, actually deploying and maintaining a well-synchronized network can be a challenge.

Arguably, the most critical metric, when it comes to short-term signal timing, is the jitter transfer of network elements. After all, it is the jitter transfer function that either mitigates or exacerbates jitter in a network using line timing synchronization. Historically, regenerator manufacturers have had to choose between two different designs, either Type A/Low-Q or Type B/High-Q. See the table below for a comparison.

Type A	Low-Q	Wide Bandwidth	Typically manufactured using Surface Acoustic Wave or dielectric resonator filters.	High jitter tolerance with wider-band jitter transfer and more high-frequency line jitter
Type B	High-Q	Narrower Bandwidth	Typically designed using Phase-Locked Loops (PLLs).	Reduced jitter tolerance to high-frequency jitter, with narrower jitter transfer.

While either type, deployed correctly, can produce acceptable results, the end result is a reduced jitter performance compared to more modern designs. Manufacturers today have been able to produce hybrid regenerators, which exhibit both the high jitter tolerance of Type A systems, as well as the narrower jitter transfer of Type B systems. These systems have allowed engineers to virtually eliminate the propagation of jitter throughout the network even when using line timing synchronization techniques. Therefore, on the rare occasion that a circuit pack may be defective and have either high jitter generation or low jitter tolerance, the trouble will be easily isolated to the faulty device.

How Jitter and Wander Can Affect Tranmissions

As mentioned earlier, jitter and wander are both timing issues and are very closely related. The ultimate end result of both jitter and wander can be higher bit error rates. See table below for comparison.

	Jitter	**Wander**
Frequency range of phase variations	>10 Hz	0 to 10 Hz
Primary disruption	Bit errors	Synchronization problems
Reference clock source for measurement	Not required	Absolutely necessary
Unit for amplitude	UI (Unit Interval)	Ns
Test times	Minutes	Hours/days

Excessive jitter, being a high-frequency phenomenon, will cause an immediate and steady BER, while wander, with its low-frequency nature, may only manifest at irregular and potentially widely spaced (hours to days between events) intervals.

Also, the issue of clocking is different between jitter and wander. While jitter is easily controlled by re-timing and the judicious placement of SSU/BITS clocks, wander is a problem within the timing network itself. Therefore, while jitter can be effectively eliminated through effective engineering designs, wander cannot.

This is not to say that jitter testing is not important. It is absolutely crucial for system designers and manufacturers in order to validate designs as well as to implement quality control measures. It is also a very good idea for service providers who are evaluating new transport systems or architectures to verify these in a meticulous manner with jitter being an important part of a battery of tests. Good lab verification of system compatibility will ensure successful deployments in the field.

The Importance of Monitoring Wander

In contrast to jitter, wander is a much more subtle and potentially elusive issue. Wander occurs at low frequencies and can accumulate over relatively long periods of time (hours to days) and will result in a quick burst of errors that can be severe enough to produce loss of frame (LOF) situations and induce protection switch events. This low-frequency nature means that a wander problem may not manifest itself during standard deployment evolutions and may become a recurring problem that just won't go away. While for some carriers a burst of errors of a frame slip every now and then may be acceptable, recurring ring switches and/or LOF alarms are issues that cannot be easily ignored. Also, if improperly diagnosed, a wander problem can cause a lot more than just annoyance; it will cost many dollars in man hours spent troubleshooting and, ultimately, can result in the loss of customers and revenue.

Also, as mentioned earlier, wander, unlike jitter, is a problem with the synchronization network itself with the clocks being the source of the problem. And because wander may be induced or exacerbated by very slight differences in reference clocks between two networks, noise in the clock oscillator, or even changing environmental conditions, wander can never be truly eradicated from a network with certainty.

Medium	**Wander Generation: ps/km** (for each °C)
Optical Fiber	80 ps
Copper Cable	725 ps

It is therefore important to monitor a timing network for excessive wander at regular intervals to ensure the quality of the system. In fact, the ITU-T Recommendation M.2130 "Operational procedures for the maintenance of the transport networks" lists the procedures for synchronization troubleshooting as follows:

- Testing for loss of reference signal input to a clock (SSU, SEC)
- Checking for the holdover operation of a clock (SSU, SEC)
- Testing frequency offset of an input (SSU)
- Testing for excessive wander on an input (SSU)

For these reasons, EXFO provides the FTB-8080 Sync Analyzer, which has been designed to provide a very high-value synchronization testing solution. It provides both a portable solution for deployment, troubleshooting, and periodic maintenance applications, as well as a rack-mountable solution for long-term, remote monitoring of the network. The FTB-8080 Sync Analyzer has been designed to be affordable and will pass the high-value evaluation that is required in today's highly competitive and challenging telecommunications environment.

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