Why the measurement of Wander is crucial for verifying the synchronization quality in a network

Background

Whether it is in a fixed telephone network or in the field of mobile telephony (with the new 3G systems), traffic in the network is constantly increasing. More and more information must be transported at higher and higher data speeds. Synchronization of the traffic in the networks is becoming more and more important.

How can you verify that your network is synchronized? And what are the consequences if it is not?

Synchronization of SDH networks

Reliable telecommunications is based on the data signals being synchronized and clocked using the same clock everywhere in the network. The basic clock in the European telecommunications networks (the SDH networks) is called E1, and must be exactly 2.048 MHz. In an SDH (Synchronous Digital Hierarchy) network, a cesium clock (2.048 MHz) is used as "master clock" or primary reference PRC (Primary Reference Clock). The PRC is distributed in the network with the data signals and regenerated in the network's nodes in "slave clocks" called SSU (Synchronization Supply Unit). The SSUs regenerates the signal after a chain of SECs and can also temporarily be used as a PRC if the connection to the master clock is interrupted. The SECs (SDH Equipment Clocks) are the clocks in the network elements (see figure 1).

Synchronization of the American SONET hierarchy is basically the same as for SDH. However another reference frequency (T1) of 1.544 MHz is used, and there is another terminology (Stratum 1 to Stratum 4 levels) instead of "PRC, SSU, SEC" hierarchical levels.

Please note that the basic E1-lines are normally multiplexed into data streams with higher bit rates, before they are transported in the network. A higher multiplexed bit stream is called E3 (34 Mbps) and is common in radio links, where microwave transmitters/receivers are used instead of optical fibres.

In some radio link network nodes, the E1-clock may not be available, and measurements have to be made on the E3 level instead.

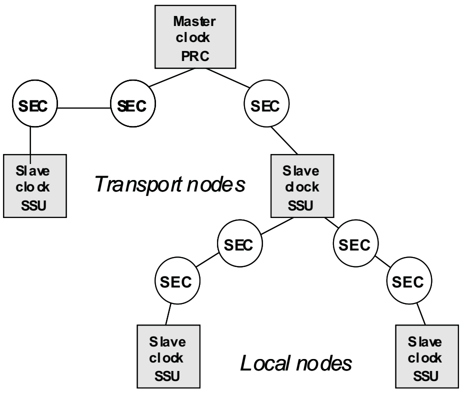

Figure 1: The clock in an SDH network is based on a caesium clock (PRC) which is distributed and regenerated in the network's nodes

Wander

Phase variations with a frequency content less than 10 Hz are wander. If you look at a signal with a lot of wander with an oscilloscope, you will perceive a "sharp" clock signal, which gradually "sways" to and fro. This is illustrated in Figure 2.

Why Wander occurs

There are many reasons why wander occurs in the networks. The clock regeneration in SDH networks is never completely perfect, but rather each regenerated clock will have variations in frequency and phase. The more nodes passed "en route" the less stabile the clock will be. Aging of the node clock oscillators and temperature changes can increase wander. Temperature changes cause the expansion and contraction of the transmission cables, which in turns generates Wander. For each degree Celsius that the temperature changes, 80 ps Wander is generated per km of optical fibre.

For copper cable the generated Wander is 725 ps per km for each degree Celsius change. This may not sound very much, but consider how much the temperature can change in one day and add how many km of optical fibre or copper cable there is and it soon adds up to a considerable amount of Wander.

Why Wander and not jitter is so crucial for the synchronization

Jitter, which is constant over time, might cause BIT errors. However, most of the jitter can be filtered out in the SSUs and SECs. Wander can only partly be filtered out in the network nodes and it accumulates in the network thus causing incorrect synchronization or even a total loss of the synchronization. Incorrect synchronization in transport networks may cause severe transmission problems. Voice calls (fixed or cellular) will be lost, fax machines will misprint, and data will be lost or frequently re-transmitted. The network operator will have increased service costs and may loose customers, or in other words money.

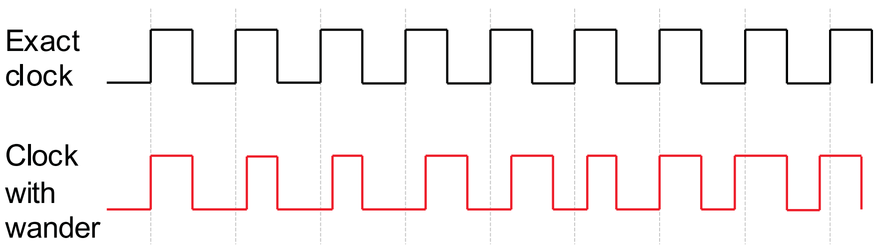

Figure 2: Comparison between an exact clock and a clock with wander.

About Wander measurements

Wander ought to be measured at installation, routine controls and as soon as changes in network topology has been made. In the fist stage of detecting a synchronization fault, wander on the SSU input is measured. Maintenance should be done to check that the performance is with in the limits specified in G.822.

Wander variations occur over a period greater than 0.1 s (10 Hz), and varies over time. Therefore the measurements of Wander need to be performed over a longer period of time (e.g. 24h).

Wander measurements, unlike jitter measurements, require a very stable reference clock (Cesium or Rubidium clock).

Wander is measured in TIE and evaluated in MTIE and TDEV.

The basic measurement TIE (Time Interval Error) is the time interval between the actual and the theoretically exact clock pulse edge. TIE is shown graphically as a value measured over the course of long and medium-long periods (minutes to days), and is expressed in ns or µs.

MTIE stands for "Maximum TIE" and is calculated from the TIE curve measured. It expresses the "worst conceivable TIE change" for different observation periods (tau). The MTIE value tells you something about the dimensions of the buffers. If the MTIE value is exceeded, there is a risk of frame slips. The number of expected slips per day is equal to (freq offset) x (frames/s) x (seconds/24h)*.

TDEV stands for Time Deviation and is also calculated from the TIE curve measured. It expresses the "rms variations in TIE" for different observation intervals. Clear periodicities in the TIE curve will show up as "bulges" in the TDEV curve. For example a 10 s periodicity in the TIE curve will show as a peak in the TDEV curve for = 10 s. TDEV gives information about the short-term stability, such as random noise.

Frequency offset

Wander is the slow phase variation over time. The accumulated phase changes in the node clock result in a frequency offset, which ideally should be zero over very long observation periods. At least this is true for a node clock that is properly locked to the nearest higher level in the hierarchy. An unlocked clock, running in hold-over mode, may have a substantial frequency offset, and a frequency drift that could be very high.

But also a locked clock can have a measurable frequency offset over shorter observation times.

The frequency offset is revealed in the MTIE graph. The higher the frequency offset for a certain time, the higher MTIE-value for the same time (τ).

In the ITU-T recommendation M.2130 "Operational procedures for the maintenance of the transport networks" the first stage of synchronization faultfinding includes:

- Loss of reference signal input to a clock (SSU, SEC)

- Holdover operation of a clock (SSU, SEC)

- Frequency offset detection on an input (SSU)

- Excessive wander detection on an input (SSU)

Therefore it is essential to measure and display also frequency offset together with the wander - TIE vs t – (as in the WM-10/11).

Summary

Incorrect synchronization in digital communication networks can cause severe transmission problems. The main cause for synchronization problems in transport networks is wander of the synchronization clock. Quality control of the synchronization clock requires monitoring of wander over a longer period (hours or days) using an ultra-stable clock as reference.

Pendulum Instruments offer two Wandermeter models;

WM-10, a very accurate and easy-to-use portable Wandermeter, designed for wander measurements on E1 clock and data signals.

WM-11, a multi-application synchronization testing tool for SDH/PDH (E1, E3, STM-0), SONET (DS-1, DS-3, STS-1), Video and frequency reference distribution networks. Comes with Ethernet interface for remote monitoring and –48V DC supply.

And last but not least, both models come with an affordable price. No need anymore to refrain from preventive maintenance of wander, due to budget restrictions.

WM-10 and WM-11 could be used for several purposes:

- As an *accurate certification tool*, to document conformance to standards (ANSI T1.10x, ITU G811-813, ETS 300 462) for telephone network operators, network leasers, and buyers and sellers of synchronization services.

- As a *preventive (diagnostic) maintenance tool* in local exchange stations like SONET, SDH, or PDH.

- As a *quick trouble-shooting tool* in SONET, SDH, PDH or networks when a node is suspected not to operate correctly. Both models can be used both by the transport network owners and all users of the network, e.g. radio link services and GSM network operators.

** A signal of 2,048Mbit/sec is send with 8000 frames per second and there is 86400 sec in a day. Frequency offset = MTIE(τ)/τ*

pendulum