ITU-T O.172 bridges the generation gap from PDH to SDH

As well as producing recommendations for high bandwidth SDH networks and network elements, the ITU (International Telecommunications Union) also produce recommendations for the test equipment used to verify the SDH infrastructure. One of the latest is ITU-T O.172 *"Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH)."*

This paper provides the background to ITU-T O.172, its relationship with ITU-T O.171, and the impact this new recommendation has for legacy network equipment that was designed, tested and installed using ITU-T O.171 compliant test equipment.

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Introduction

One of the major advantages that SDH networks have over traditional PDH networks is the standardization of its technology. Before the advent of SDH, ITU-T O.171 existed for test equipment used in testing PDH systems. In the early days of SDH, ITU-T O.171 was also used as the basis for designing SDH test equipment. However, it wasn't until ITU-T O.172 was introduced that the ITU addressed test equipment specifications for testing SDH optical signals from 52 Mb/s to 2.5 Gb/s and for electrical signal rates of 52 Mb/s and 155 Mb/s.

The objective of ITU-T O.172 is to clearly define test equipment requirements for verifying, to ITU-T G-series recommendations, that SDH network equipment:

- functions properly in the presence of defined (allowable) levels of jitter and/or wander
- does not generate excessive levels of jitter and/or wander

The following key elements of ITU-T O.172 are used to establish test equipment standards:

- an input phase tolerance test for test equipment
- more precise definition of jitter measurement filters than in ITU-T O.171
- the use of concatenated payloads filled with PRBS to emulate the worst case test scenario
- reduced intrinsic jitter levels for test equipment
- pointer sequence generation as per ITU-T G.783
- jitter generation levels to exceed ITU-T G.825 (jitter tolerance for network equipment)

It is worth noting that SDH tributary interfaces include those operating at PDH rates.

Input phase tolerance test

When performing tributary jitter measurements on PDH tributaries, ITU-T recommendations define specific measurement bandwidths for measuring 'in-band' jitter. The required bandwidth is selected in SDH measurement equipment by switching appropriate high pass and low pass filters. It has been found in practice that during periods of pointer activity there is a tendency for SDH network equipment to generate high amplitude, low frequency jitter/wander components. These are effectively 'out-of-band' components when appropriate measurement filters are used.

Figure 1 shows a typical jitter output spectrum present on a PDH tributary that has been dropped from an SDH signal experiencing an ITU-T G.783 pointer sequence. It can be seen from the diagram that much of the power is contained in the low frequency components (0.1 to 20 Hz).

Although these out-of-band elements are not expected to affect network equipment, the designs typically used in test equipment were dramatically affected. The result could be that the test equipment is unable to make a reading to its published accuracy when the large amplitude, low frequency elements are present. Any out-of-band components that are not effectively filtered out can potentially cause SDH measuring equipment to give erroneous results or completely lose lock.

To ensure that SDH test equipment will correctly measure the in-band jitter in the presence of any high amplitude, low frequency, out-of-band components, ITU-T O.172 specifies phase tolerance input limits for the various SDH tributary rates. The phase input tolerance test is designed to ensure that jitter measuring equipment can accurately measure tributary jitter in the presence of relevant worst-case pointer sequences. Therefore, ITU-T O.172 compliant SDH test equipment should be able to accurately measure the in-band jitter in the presence of out-of-band jitter components and thereby provide more reliable results. The ITU-T O.172 phase tolerance limits are shown below:

Bit rate (kbit/s)	Input phase Variation	
	Amplitude (UI pp)	Frequency (Hz)
1,544	FFS	FFS
2,048	30	0.5
34,368	22	5.0
44,736	FFS	FFS
139,264	75	1.5

FFS denotes that the value is for further study

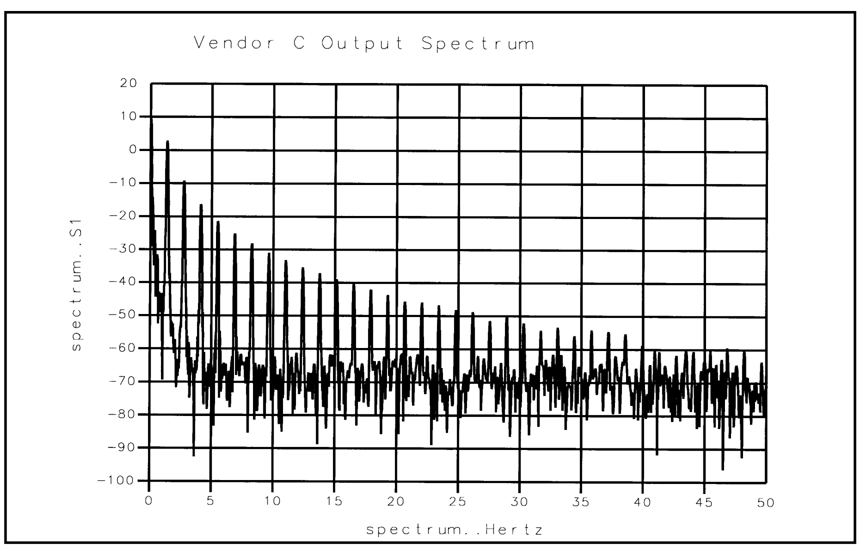

Figure 1. Jitter output spectrum

Jitter measurement filters

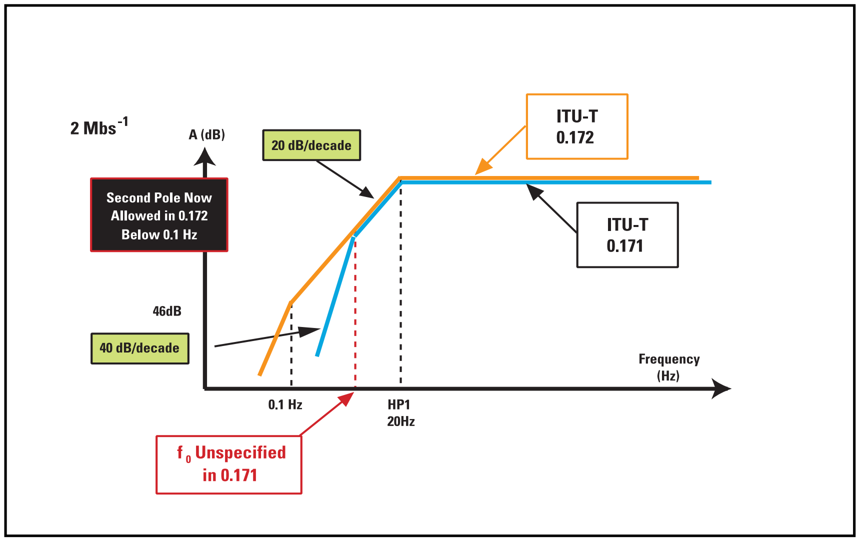

Figure 2. ITU-T O.172 v O.171

Jitter in PDH networks is well understood and has been found, by experience, to be predominantly repetitive. When performing jitter measurements in PDH systems, high pass and low pass filters are used for measuring jitter over a specified bandwidth of jitter frequencies. These filters are defined in ITU-T O.171. Until ITU-T O.172 was adopted, these filters were also used in SDH test equipment for measuring SDH tributary jitter. However, due mainly to the different nature of SDH tributary jitter—that is, transient rather than periodic—some network equipment generated significant jitter/wander components in the 0.1 Hz to HP1 3 dB point range. This had serious implications for the design of high pass filters in jitter measurement equipment. A more precise definition of the measurement filters was therefore required for SDH measuring equipment.

Any practical implementation of a high-pass filter must have a second pole at some frequency point where the attenuation rolls off at a steeper rate, that is, 40 dB/decade. In ITU-T O.171, the point at which a second pole could occur was not specified (f0 in figure 2).

Moreover, test equipment manufacturers could implement a second pole at arbitrary frequencies below the 3 dB cut off frequency. This, combined with the existence of significant jitter elements in the low frequency range, could result in differences in tributary jitter measurements between test equipment vendors.

ITU-T O.172 resolves this problem by allowing a second filter pole at a frequency of less than 0.1 Hz, where the roll-off characteristic can increase to 40 dB/decade.

Compared with ITU-T O.171 filters, the increased measurement band-width of ITU-T O.172 filters will give *higher* readings than measurements using ITU-T O.171 filters if there are significant low frequency jitter elements present on the signal being measured. This has implications for much legacy network equipment that was originally designed and tested using ITU-T O.171 filters.

Aware of this anomaly, the ITU-T O.172 study group issued the following liaison statement: *"Note: The reduced bandwidth of ITU-T O.171 compliant test equipment may give lower readings than equivalent ITU-T O.172 compliant test equipment. For this reason care should be taken in selecting jitter test equipment."*

Of course, SDH test equipment that complies to ITU-T O.172 will provide more consistency across vendors due to the more precisely defined measurement filters.

Concatenated payloads for jitter testing

The scrambling method used in SDH systems does not limit the length of runs of zeros or ones in the transmitted signal. However, in the rare event that data emulates the scrambling pattern, for example, by producing a long run of ones or zeros, it may be difficult for test equipment to continue to make accurate measurements. For this reason, a representative worst-case test signal is used for performing jitter measurements. ITU-T O.172 states: *"Concatenated payloads provide the worst case scenario for STM-N test signals. For bulk filled concatenated signals with a 2^{23}–1 PRBS filling the container, the result of scrambling this data is a worst case run of 30 consecutive identical zeros/ones (i.e. there will be 30 clock periods with no transitions on the line signal). For non-concatenated payloads generated by SDH test sets, the byte interleaving of the VC-4 containers reduces the maximum length of runs produced."*

Test equipment providing concatenated payloads is vital for representative jitter testing and increased accuracy. In addition, like the network equipment, this is the most severe condition that jitter test equipment is likely to have to deal with. Hence, the intrinsic jitter levels have been defined assuming that this is the test signal applied to the input of the tester.

Low intrinsic jitter levels

A key consideration when selecting jitter measuring equipment is the accuracy of the measurements that can be made. The intrinsic jitter in the measuring equipment's own circuitry can have a significant impact on measurement accuracy and because of this, ITU-T O.172 defines limits for fixed error in jitter measurements.

For measuring jitter at some of the PDH rates, the intrinsic jitter values given in ITU-T O.171 were inappropriate to make measurements to the more recent G-series of recommendations. For example, ITU-T G.783 proposes a tributary jitter limit of 0.075 UI (with HP2) for a 140 Mb/s SDH tributary. However, ITU-T O.171 specified the intrinsic jitter for a 140 Mb/s test instrument as 0.085 UI. Clearly, it would not be possible to accurately measure jitter levels below 0.075 UI using test equipment with intrinsic jitter levels of 0.085 UI. ITU-T O.172 has rectified this andintrinsic jitter is now 0.025 UI (140 Mb/s).

Jitter generation to exceed G.825

Network equipment must be able to perform error free in the presence of jitter and wander as defined in ITU-T G.825. ITU-T O.172 now specifies that SDH jitter test equipment should be able to generate jitter and wander in excess of that required in G.825.

Pointer sequence tests

For the sake of clarity, ITU-T O.172 now includes a reference table of recommended pointer sequences for tributary jitter measurement of various tributary rates (1.544, 2.048, 6.312, 34.368, 44.736 and 139.264 Mb/s).

ITU-T also clarifies the need to perform tributary jitter testing independently for AU and TU pointer sequences, a requirement which was not explicitly stated in ITU-T G.783.

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