The Significance of Propagation Delay and Propagation Delay Skew Measurements for Structured Wiring

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Relationship of Generic Cabling Standards to Emerging 100Mbps Network Standards

Over the last several years, there has been a rapid migration towards the practice of installing high quality structured wiring systems in order to support anticipated future bandwidth requirements for the next generation of high speed LANs. Two of the most closely followed new high speed LAN standards are 100VG-AnyLAN (IEEE 802.12) and 100Base-T (IEEE 802.3).

Both of these standard LANs are designed to work over a range of copper cabling options, including UTP cabling down to the category 3 performance level as defined in the TIA 568A generic telecommunications wiring standard. Both standards also support operation over higher quality UTP cabling as per the category 5 specification from the same TIA 568A document (roughly equivalent to the ISO 11801Class D cabling specification).

In specifying the characteristics of the supported UTP cable options, both the 100VG and the 100Base-T specifications incorporate by reference the limits for cable performance parameters detailed in the ISO generic cabling document. Both the 100VG and the 100Base-T standards, however, require the specification of cabling delay parameters above and beyond those contained in the ISO generic cabling standard due to specialized implementation requirements inherent in these protocols.

In other words, in order for cabling to be suitable for carrying either 100VG or 100Base-T traffic, it must comply with both the ISO cabling performance parameters and meet supplemental delay limits incorporated in the new IEEE standards. The table below summarizes which LAN standards impose additional delay limitations for horizontal cabling runs.

Supplemental Delay Specifications	**Propagation Delay for Horizontal Wiring Runs**	**Propagation Delay Skew for Horizontal Wiring Runs**
100VG-AnyLAN IEEE 802.12	**Required** due to hub-to-end station MAC protocol timers. Maximum: 1.2 uSec one way total 5.7 nSec/meter one way	**Required** due to multiple pair half duplex transmission mechanism. Maximum limit: 67 nSec
100Base-Tx IEEE 802.3	**Required** due to worst case collision delay budget. Maximum: 556 nSec one-way (Assumes category 5 media only)	Not applicable
100Base-T4 IEEE 802.3	**Required** due to worst case collision delay budget. Maximum: 570 nSec one-way total 5.7 nSec/meter one way (Measured between 2 and 12.5 MHz)	**Required** due to multiple pair half duplex transmission mechanism. Maximum limit: 50 nSec (Measured between 2 and 12.5 MHz)

Figure 1. Relevance of Propagation Delay and Delay Skew Specifications to Emerging 100 Mbps IEEE[1] *Standards*

Propagation Delay Specifications For Horizontal Wiring Runs

This parameter refers to the time it takes for a transmitted data bit to travel across a horizontal wiring run (typically from the hub in the wiring closet to the NIC in the user location). Although both the 100Base-T and 100VG-

AnyLAN specifications define limits for this parameter, the limit for 100Base-T is more critical. This is because the 100Base-T limit is derived from the concept of a maximum network delay budget within which the two most widely spaced stations in a repeated domain can reliably detect collisions. The total delay budget is determined by timers inherent in the IEEE 802.3 medium access layer (MAC) protocol.

The overall delay budget limit is important because it guarantees efficient and reliable operation of the network segment. If a network is configured in violation of this limit, there will be late collisions, necessitating retransmissions, ultimately limiting the effective bandwidth of the network segment.

In order to simplify configuration rules, the 100Base-T specification allocates a portion of the overall delay budget to each of the elements used in building compliant networks. A portion of the delay budget is allocated to cable propagation delays, a portion to repeater delays, etc. Under this framework, the 100Base-T specification places limits on the propagation delay of horizontal cabling runs.

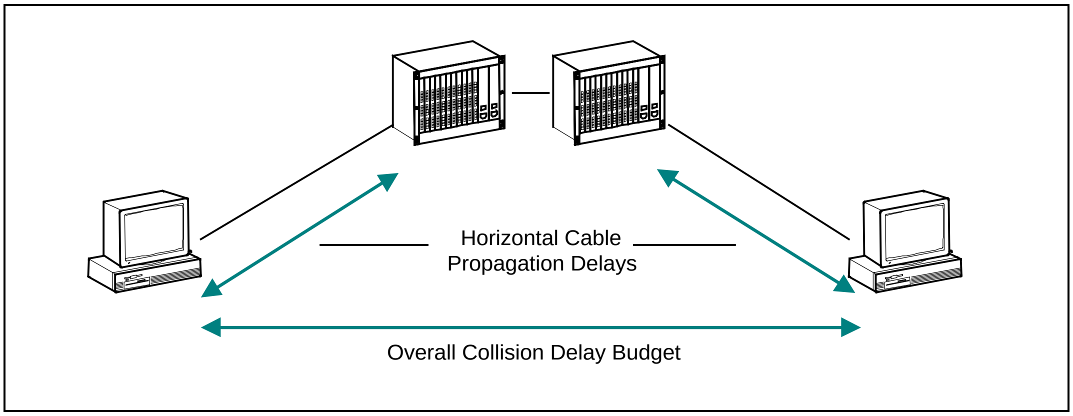

Figure 2. Relationship of 100Base-T Cable Propagation Delays to Overall Collision Budget

The portion of the overall delay budget allocated to horizontal cable propagation delays was chosen to encompass a reasonable worst case estimate of the performance of a hypothetical 100 meter cable run. In practice, the actual delay of 100 meter cable runs can vary substantially, since propagation velocities, or the rate at which signals travel along these cables vary among manufacturers and among cable grades. This variance is caused by variations in cable construction methods (i.e. twist construction) and insulation materials. In the field, there is the additional complication in that sometimes it may be necessary to install cable runs that are slightly longer than the 100 meter limit due to site requirements.

For these reasons, it is useful to be able to directly test horizontal cable run propagation delays in the field to verify compliance with the IEEE specifications.

Propagation Delay Skew Specifications for Horizontal Cabling Runs

This parameter, also referred to as *Pair Skew*, describes the difference in propagation delay between the fastest and the slowest pairs in a four pair UTP horizontal cable run. Propagation delay skew is an important parameter if a cabling run is intended to support networks which transmit simultaneously over multiple cable pairs. Both 100Base-T4 and 100VG-AnyLAN fall into this classification.

Propagation delay skew arises from the fact that for many four pair cables, each pair is intentionally constructed with a different twist length in order to minimize the crosstalk coupling between pairs. Propagation delay for any pair is in part a function of twist length, so delays vary between pairs.

The 100Base-T4 and 100VG-AnyLAN draft standards support a wide range of cable grades, including Category 3 UTP, the lowest grade of cable commonly used. Until recently, Category 3 cabling had only been thought to be adequate up to 10Mbps.

Both the 100Base-T4 and 100VG-AnyLAN specifications cleverly maximize the limited bandwidth of Category 3 by splitting the 100 Mbps data stream into multiple lower speed data streams, each of which travels on one of the 4 pairs found in each UTP cable. This strategy maximizes the data integrity and minimizes radio frequency emissions over poor quality wiring, but it creates an additional requirement that the cabling meet certain propagation delay skew limits in order to ensure consistent operation.

It is critical that the parallel lower speed data streams transmitted on the individual cable pairs arrive at approximately the same time at the far end of the cable so that they can be successfully recombined without losing synchronization. In order to ensure that this happens, it is important that the four pairs in any cable link have propagation delays which do not deviate from each other by more than the maximum limits listed in figure 1.

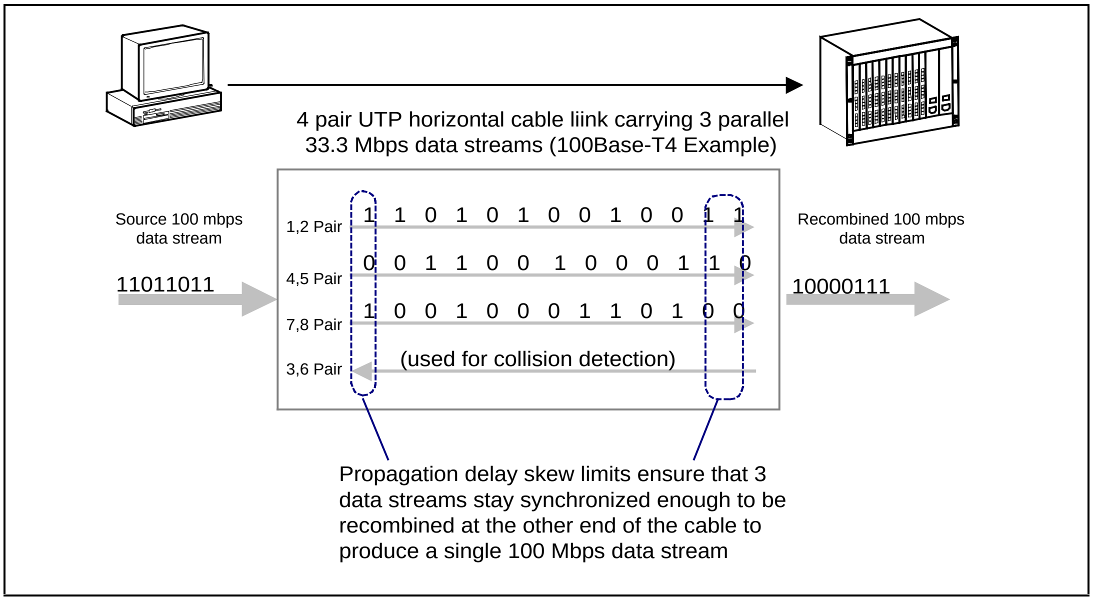

Figure 3. Importance of Propagation Delay Skew Limits for 100Base-T4 and 100VG-AnyLAN Networks

Longer UTP cable runs, particularly those using category 3 cable, are most at risk of not complying with the 100VG-AnyLAN and 100Base-T limits.

The TIA 568 generic telecommunications building wiring standard does not specify propagation delay skew limits for horizontal cabling runs. For this reason, both the 100Base-T4 and 100VG-AnyLAN specifications define limits for this parameter.

As part of the process of verifying that new or existing installed cabling can support both of these emerging network standards, it is advisable to verify this parameter in the field.

Field Measurement of Propagation Delay and Delay Skew

Both the WireScope 100 and the WireScope 155 support direct field measurement of propagation delays for each pair in four pair cables. The maximum delay skew is automatically calculated and displayed on the same results screen (shown below).

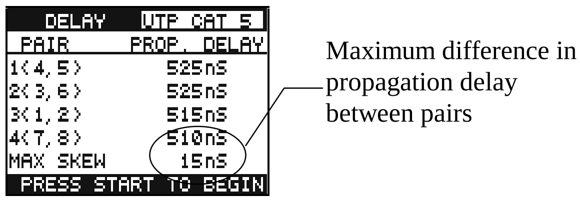

Figure 4. WireScope Propagation Delay and Delay Skew Results Display Screen

The WireScope 155 allows you to add application-specific network pass/fail criteria to the autotest function by selecting the "networks" option under the autotest settings menu. When this setting is selected, the cable performance data is compared against both the generic cable specification requirements (i.e. Category 5 or Class D), but also against the specific requirements of up to 25 network application specifications (i.e. 100BaseT4, ATM155 etc.).

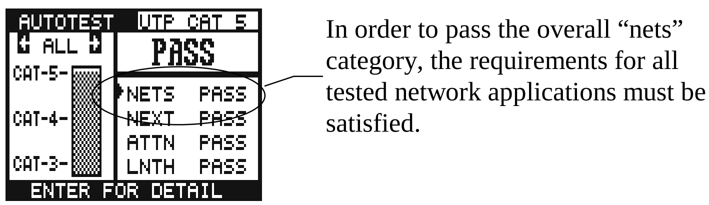

Figure 5. Overall Autotest Results Screen for "Networks" Option Enabled

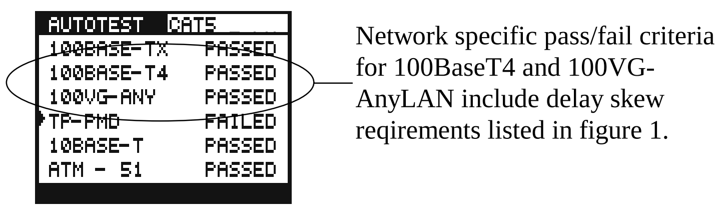

Figure 6. Autotest Detail Screen Listing Individual Network Application Pass/Fail Results

The WireScope 155 applies the delay skew requirements listed in figure 1 when determining an overall pass/fail result for the 100BaseT4 and 100VG-AnyLAN applications. In this way, the WireScope 100 and WireScope 155 provide a simple and comprehensive means of verifying that pair delay skew limits are maintained.

[1] Propagation delay and pair delay skew limits for 100Base-T and 100VG-AnyLAN specifications drawn from:

IEEE 802.3u 100Base-T Draft 3, 10/31/94

IEEE 802.12 Draft 5, 11/4/94

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