

Understanding IEEE 802.3ab 1000BASE-T Gigabit Ethernet symbol rate, spectrum and line code

Background

The balanced twisted-pair Gigabit Ethernet standard is known as IEEE 802.3ab. This standard is commonly referred to as 1000BASE-T (Gigabit Ethernet) and it was published in 1999. Publication of this standard resulted in a ten-fold increase in transmission rates compared with the IEEE 802.3u 100BASE-TX (Fast Ethernet) standard that preceded it. At the time that the IEEE Gigabit Ethernet standard was published, the recognized categories of cabling were Category 3 (1-10 MHz), Category 4 (1-20 MHz) and Category 5 (1-100 MHz).

During the development of the Gigabit Ethernet standard, Gigabit Ethernet equipment manufacturers (e.g., switches, network interface cards) discovered that it was necessary to qualify additional cabling system transmission parameters not previously qualified with Categories 3, 4 and 5 cabling (power sum near-end crosstalk [PSNEXT] and return loss [RL]). This resulted in some enhancement of the physical layer cabling infrastructure, resulting in a Category 5e standard.

The IEEE development of the Gigabit Ethernet standard was done in collaboration with standards development organizations (SDOs) such as the Telecommunications Industry Association (TIA) and International Electrotechnical Commission (IEC). This global collaboration resulted in the development of enhanced Category 5 cabling (Category 5e). These criteria apply to all Category 5e cabling components, installed cabling links and installed cabling channel requirements. These additional cabling requirements assured successful deployment of the IEEE 802.3ab, 1000BASE-T (Gigabit Ethernet) standard.

Cabling product frequency range of interest vs field testing frequency range of interest

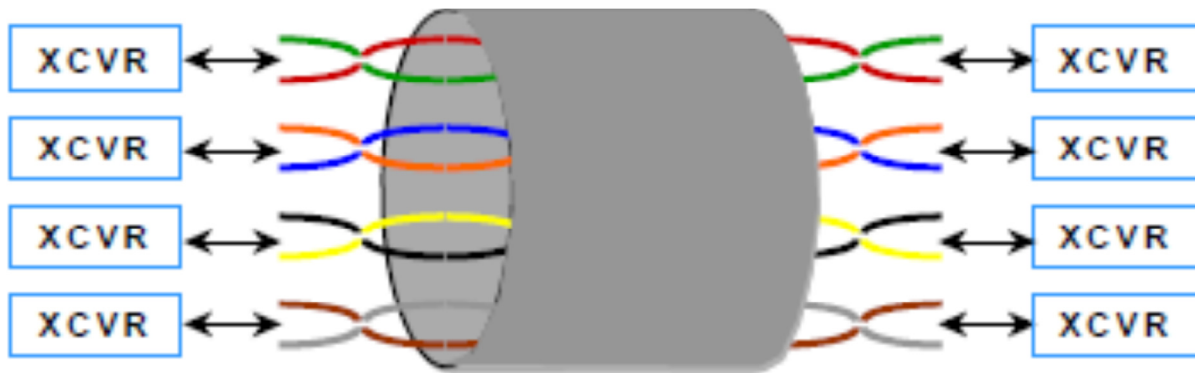
Manufacturers of Category 5e cabling components (e.g., cable, connecting hardware) may at their discretion, qualify their cabling components to frequencies beyond those specified by standards. An example of this is demonstrated by Category 5e cable that is “qualified” by a manufacturer to 350 MHz. One reason that manufacturers “qualify” their products to frequencies beyond the frequencies specified by standards is that transmission protocols such as the IEEE 802.3ab, 1000BASE-T standard operate in a frequency spectrum that extends well beyond 100 MHz (*see page 3*). Cabling components that have been properly “qualified” by the manufacturers who design and produce their products for transmission performance throughout these extended frequency ranges help to demonstrate stable cabling performance to support the transmission protocols (e.g., 1000BASE-T) that they were designed to support.

When field testing Category 5e cabling, it is not necessary to “qualify” the installed cabling system beyond 100 MHz because the standards define the link and channel limits based on a series of transmission parameters with pass/fail limits in the frequency range of interest (1-100 MHz). To field test a cabling system for the purpose of determining that it will support the IEEE 802.3ab, 1000BASE-T standard; the installer should confirm that Category 5e cabling is installed then field test to the Category 5e limits in the frequency range of interest (1-100 MHz).

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Transmission Methodology

In order to transmit 1000 Mb/s ([1 Gb/s] 1 Gigabit per second), the IEEE selected the enhanced TX/T2 line code for implementing 1000BASE-T. This line code was named; *Enhanced TX/T2* because this signaling scheme was based on the symbol rate and frequency spectrum of 100BASE-TX and based on the line code used by 100BASE-T2. 1000BASE-T achieves the full duplex throughput of 1000 Mb/s by transporting data simultaneously over all four pairs from both ends of each pair. Each pair carries a full duplex 250 Mb/s data signal encoded as 5-level Pulse Amplitude Modulation (PAM-5).



250 Mb/s on each pair in each direction
2 bits/symbol = 125 Msymbols/sec

Figure 1: 1000BASE-T transmission methodology

How it works

The 1000BASE-T physical layer devices consist of four identical transceivers; each cabling pair has its own transmitter and receiver (i.e., transceiver). Each transceiver operates at 250 Mb/s. This transmission methodology delivers 2 bits per symbol with a symbol rate of 125 Msymbols/s. The total throughput is therefore 250 Mb/s x 4 pairs = 1000 Mb/s = 1 Gb/s.

1000BASE-T Signaling

The IEEE engineering community decided to make the 1000BASE-T signaling compatible with the 100BASE-TX signaling in order to facilitate the development of a dual data rate 100/1000BASE-T transceiver. The symbol rate of 1000BASE-T is 125 Msymbols/s, this is the same symbol rate of 100BASE-TX.

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Advantages of implementing a 100BASE-TX/1000BASE-T system:

- Having equal symbol rates for 100 Mb/s and 1000 Mb/s operation allows common clocking circuitry to be used for both data rates.
- The frequency spectra of both signals are similar with a null at 125 MHz (Figure 2). The null in the spectrum of a baseband signal occurs at the frequency equal to the symbol rate. 1000BASE-T and 100BASE-TX signals exhibit similar spectral shapes because these baseband networks both operate at the same symbol rate.

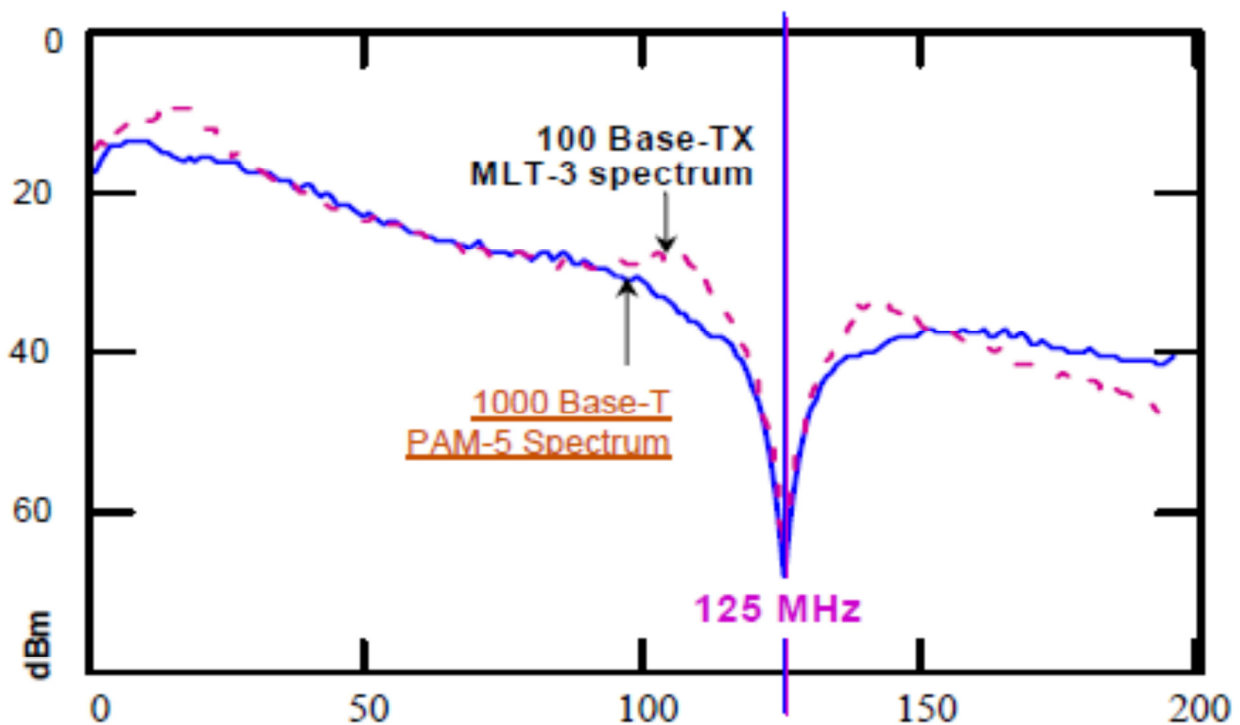


Figure 2: Superimposed spectrum of 1000BASE-T and 100BASE-TX

Signal-to-Noise Ratio (SNR) Margin

SNR margin is a good measure of an Ethernet network communications system's immunity to noise. This noise may be expressed as:

- Pair-to-pair crosstalk (measured as near-end or far-end crosstalk [NEXT, FEXT])
- Power sum crosstalk (calculated as power sum near-end or power sum far-end crosstalk [PSNEXT, PSFEXT])

SNR margin is expressed in dB and represents the level of additional noise that an Ethernet network communications system can tolerate before violating the Ethernet network communications system's Bit Error Rate (BER). In structured cabling system components, links and channels, SNR is often expressed as Attenuation-to-Crosstalk Ratio (ACR).

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Example:

With an SNR margin of 3 dB, this means that if the noise level is increased by 3 dB, the system would be subject to excessive errors. In network cabling infrastructure terms; the greater the ACR margin in the components, links and channels; the less likely that an increase in noise levels will adversely affect the Ethernet network communications system's performance.

The higher the Ethernet equipment SNR or cabling infrastructure ACR margins; the more robust the Ethernet system or cabling infrastructure system.

Example:

If network A has an SNR margin of 3 dB and network B has an SNR margin of 10 dB, then network B can tolerate 7 dB more noise than network A without violating the required BER.

If cabling infrastructure A has an ACR margin of 3 dB and cabling infrastructure B has an ACR margin of 10 dB, then cabling infrastructure B can tolerate 7 dB more noise than cabling infrastructure A without violating the required BER of the Ethernet network communications system.

Conclusion

The highest concentration of an Ethernet network communications systems spectral energy and signal strength is focused at the 125 MHz frequency. While spectral energy and signal strength are spread across a wide frequency band, transmission performance characteristics between 100 MHz and 150 MHz clearly dominate an Ethernet networks communications systems performance. Cabling infrastructure that delivers significant ACR performance margins within this narrow range help to assure robust, Ethernet network communications system performance.