The Importance of Bit Error Rate Testing to Fiber Optic Channels

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Overview Bit Error Rate Testing to Fiber Optic Channels

Bit Error Rate Testing (BERT) is a test methodology where a known sequence of bits is sent through a communications channel and the received bits are compared against the transmitted bits to determine what percentage of data is being communicated correctly.

Essentially, BERT is used to quantify BER (Bit Error Rates) for fiber optic data systems, Ethernet, or any system that transmits data over a network. Unlike other testing methods, BER assesses the full end-to-end performance and transmission reliability of a connectivity system, including the transmitter, receiver, and the optical fiber and/or copper cabling mediums.

BERT is imperative today, more than ever, to ensure flawless digital transmission, signal integrity, and low network latency as enterprises face ever-growing bandwidth demands, 4k HD video applications, and the inevitable migration from 10 to 40 to 100 Gb/sec speeds with 400 Gb/sec speeds on the near horizon. With BERT, network managers can rest assured that the fiber optic communications channel will be able to support these higher speed systems and applications.

Let's consider a typical fiber optic backbone Ethernet network scenario. In one building, there is a switch with multiple user computers connected to it via Cat-5e cable operating at 1Gbps per computer. In another building, there is a switch with servers connected to it via Cat-6A cabling operating at 10Gbps. The link in between the two buildings is an OM4 or single mode fiber optical cable with a pair of fibers, one fiber each supporting data transmission in each direction at a data rate of 10Gb/sec. Users are complaining that the network is slow, yet all switches show 1Gb/sec or 10Gb/sec links are active and operating at the specified data rate. The root cause of this problem could be with the fiber optic link wherein bit errors are being introduced by a poorly cleaned connector, for example, or a cable that is physically crushed at an unknown point in between the two buildings.

Fundamentally for fiber optic systems, bit errors mainly result from imperfections in the components used for the link, but can also result from optical fiber dispersion and attenuation or any noise or electromagnetic interference from any copper connectivity within the system. The bottom line is that bit errors cause signal and transmission degradation that have serious consequences to the performance of the network. Therefore, it is crucial that network managers should seek solutions from manufacturers that conduct Bit Error Rate Testing for optimum transmission reliability.

Why BERT is important for Ethernet fiber optic channels and today's enterprise networks

The first reason why BERT is significant to fiber optic channels is that Ethernet can overcome and mask physical problems in the network. By definition, the Bit Error Rate of an Ethernet link is zero. This is because Ethernet protocols have built in error-checking or error-correction. Packets that have been received with errors are retransmitted to assure the correct bits are received. For this reason, prior to today's high-bandwidth and mega transmission speeds, BERT has traditionally been seen as unnecessary for fiber optic channels carrying Ethernet traffic. Simply because the BER of Ethernet (an OSI layer 2 protocol) is zero does not mean the BER of the channel (the OSI layer 1 PHY) is zero. In the example above, retransmitted packets eat away at the maximum throughput of the channel. Moreover, a 1 bit error can cause up to 12,176 bits to be resent, significantly slowing down the network. A 10Gigabit

Ethernet link may only pass 7.5Gb/s of data if a quarter of the packets are arriving with errors. This can create the appearance of the network operating beyond capacity, thus creating congestion, when, in fact, the network could perform as designed if the channel was operating without this serious signal and transmission degradation.

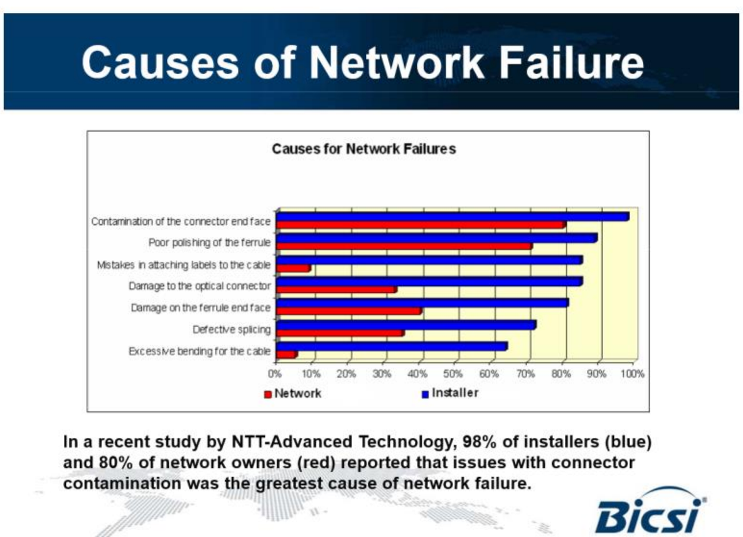
The second reason BERT is vitally important for today's enterprises and vertical industries is that not all protocols sent over fiber are Ethernet; neither are all protocols error-correcting. Many broadcast venues use fiber optics to stream the advent of 4k HD video signals from the cameras back to the control room. Bit errors can cause picture quality degradation; and enough bit errors can cause the transmission to cease altogether. Anyone who has tried to watch Direct Satellite Broadcast at home during a heavy rainstorm has experienced the effects of BER on video quality first hand, and a similar phenomenon can occur in the fiber optics at the broadcast venue.

Many industrial plants use fiber optics to transport serial data so that legacy sensors can be used with upgraded, EMI (electromagnetic interference) proof cables back to the monitoring office. These legacy sensors and data streams are not error-corrected and a false reading, due to bit errors, could have serious repercussions to the plant.

Virtually every vertical industry, including hospital and healthcare facilities, can benefit greatly by adopting a manufacturer that conducts BERT under real-world installation and network conditions for its solutions. With 4k Ultra HD video and the continued growth of video telemetry and teleconferencing through which physicians globally collaborate remotely and in real-time to diagnose and treat patients often in emergency situations, bit errors that would drop frames and cause media and audio loss could generate even life and death consequences.

BICSI analysis of major causes of network failure

As explained earlier, bit errors mainly result from imperfections in the components used for the link in fiber optic systems. The findings in a recent study and posted by BICSI points to the cleanliness and polishing of connectors as the top 2 culprits of network downtime and failure.



The study brings to light an important consideration when incorporating pre-terminated cable assemblies and jumpers into the fiber optic link. Since the reliability of the connectors are so very crucial for optimum transmission performance, network managers and installers would be well advised to purchase pre-terminated assemblies and Plug-and-Play solutions that undergo Bit Error Rate Testing. At OCC, for example, BERT is being deployed to optimize connector polishing and termination procedures to ensure that assemblies demonstrate optimum connectivity performance over and beyond standards normally met by other manufacturers. Additionally, OCC has used BERT to quantitatively demonstrate that a single dirty connection can affect the BER of a network by 50x or more!

How can network managers and installers be certain that a particular installation will carry traffic and transmit reliably at given requirements and high data rates?

A typical BERT setup consists of a loopback at one end of the inter-building cable and the BERT at the other. As part of the testing procedure, a known bit sequence is sent that compares the received bits against the transmitted bits with a calculation of the rate at which those bits arrive at the receiver incorrectly. The BER is given in scientific notation as a very small number, such as BER = $1x10^{-15}$. For BER, smaller values are better. If your network design specification document has a BER value listed as a "shall" requirement, extensively executed BERT is required to demonstrate compliance with that requirement. This extensive test requires expensive BERT hardware and can take significant amount of time to determine that a given BER is possible.

However, there is a faster, albeit less precise, way to gain confidence that the fiber optic channel will work properly. The Eye Diagram is a powerful tool for studying how the bits are being received at the far end of the channel. Most BERT devices will produce an Eye Diagram, but in the field, a digital oscilloscope and an unspecified sequence of bits can also produce a usable Eye Diagram.

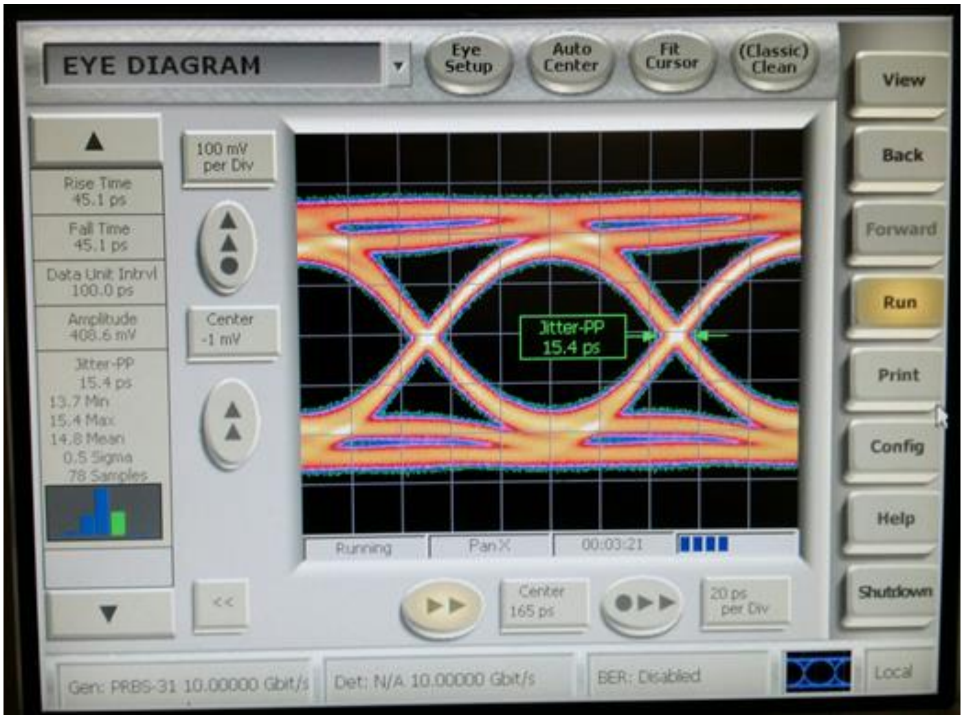


Figure 1: Screenshot of the BER Tester displaying an Eye Diagram.

The eye diagram takes the bitstream received and graphs it in increments of 3 bits: Oscilloscope traces of the bit patterns 000, 001, 010, 011, 100, 101, 110, and 111 are all overlaid on top of each other to produce the shape shown in Figure 1.

The center of this diagram is shaped like an eye, hence the name. More than just a pretty picture, there is a lot of information that can be gleaned from this diagram. The two easiest values to calculate that affect network performance are Jitter per Bit Interval and Eye Closure Penalty (ECP)

Jitter describes the variation in the delay of received packets. Because of network congestion, configuration errors, or other causes, the delay between packets can vary instead of remaining constant. Jitter can affect the desired performance of desktops or servers and even cause loss of transmitted data between network devices.

The cursors in Figure 1 are measuring jitter, as 15.4pSec. Jitter is the width at the crossover points at the corners of the eye. The eye spans exactly 5 divisions, or 100pSec. Therefore, the Jitter per Bit Interval is calculated as 15.4/100, or 0.154. In general, the lower the Jitter per Bit Interval, the better.

Analytical measurement of the screenshot of the eye diagram reveals the following data: The overall average height of the diagram (from the middle of the horizontal band at the top to the middle of the horizontal band at the bottom) is 4.25 divisions, or 425mV. The overall interior height of the eye is 2.63 divisions, or 263mV. ECP is calculated as 10 log (Average Height / Interior Height). In this case, the ECP is 2.08. In general, the lower the ECP, the better.

While jitter and ECP should be minimized as a standard practice, research indicates that there are some practical values that should be attained. For 10Gbps Ethernet at 1310nm wavelength to operate properly, the Jitter per Bit Interval should be less than 0.3, and that the ECP should be less than 2.2. The eye diagram shown in Figure 1 meets both of these recommendations. Therefore, the user can be confident that the channel will work at 10Gbps without having measured the actual BER of the channel! And, that includes the confidence that all connectors within the system are reliable for optimal transmission reliability and network performance.

OCC provides the engineering expertise, resources, and the products available to help design a network that meets your particular vision. With pioneering expertise in providing the government and military with more reliable and secure cabling and connectivity solutions that test beyond industry standards, we pass that expertise to customers spanning virtually every vertical industry—ensuring the best in transmission reliability for your network. For more information, please check out our website at www.occfiber.com.