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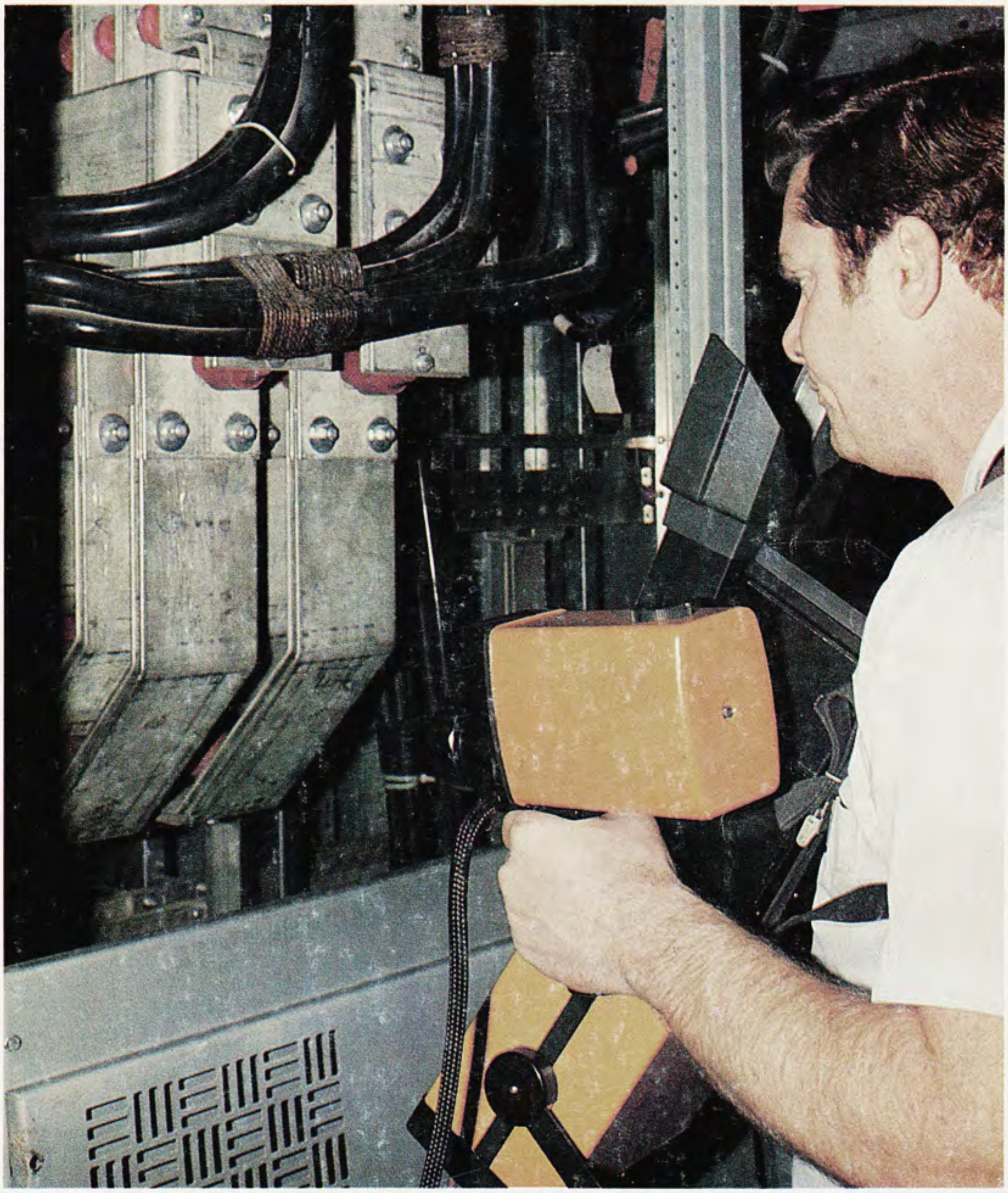
PERFORMANCE TESTING OF FIBEROPTIC SYSTEMS

MONITORING POWER FOR A COMPUTER

TESTING ASSURES POWER SYSTEM RELIABILITY

PORTABLE TOOL SPEEDS CIRCUIT TESTING



TEST INSTRUMENTS

PERFORMANCE TESTING OF FIBEROPTIC SYSTEMS

Brian J. McPartland, Associate Editor

Test procedures and equipment used by one electrical contractor verify and maintain specified performance for fiberoptic systems.

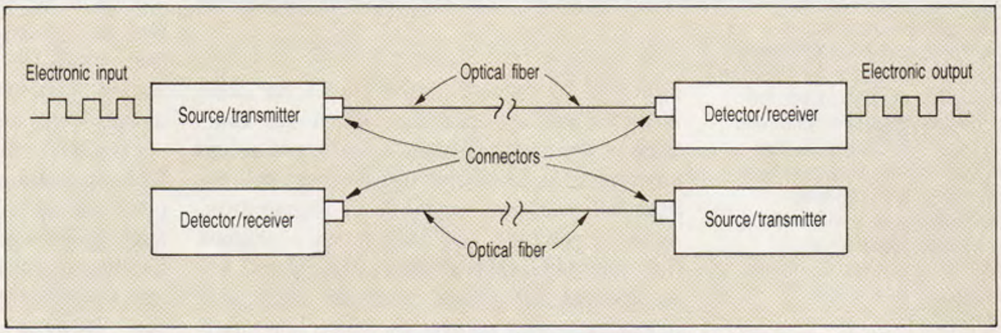


Fig. 1. Duplex, point-to-point optical fiber link is the most common application of fiberoptics in LANs.

PERFORMANCE TESTING of optical fiber control and data systems is critical to ensuring overall system integrity. As the use of this technology in local area networks (LANs) grows, more and more "traditional" electrical contractors are being called upon to install and maintain optical fiber video, voice, and data systems.

Barth-Gross Electric Co., Inc. of New York City, electrical contractors since 1919, is one of a growing number of electrical contractors who have realized the opportunity that exists in fiber technology and have branched out into this field. Acting as either prime or subcontractor, they have been involved in the installation of optical fiber systems since 1983. Testing is a major part of the firm's responsibility on such projects.

A typical system

Fig. 1 shows the components used in a typical fiberoptic link. Although these links can be run in a daisy-chain fashion, most LAN applications for optical fiber today utilize a duplex, point-to-point arrangement; that is, two optical fibers with a transmitter and receiver at each end.

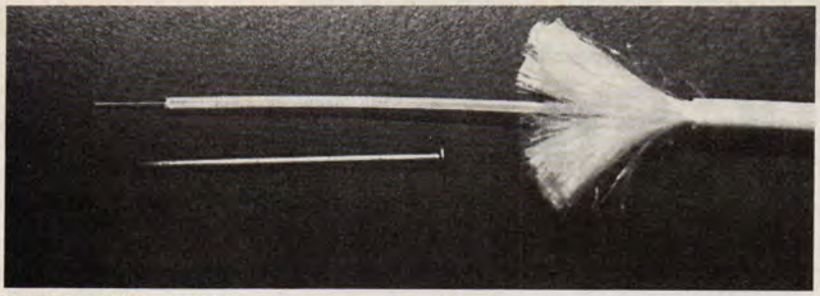
The operational sequence of the link is as follows: the transmitter receives electrical signals from a connected device and converts them to pulses of light using either a laser or light emitting diode (LED); the light pulses are injected into the optical fiber through the cable connector; light pulses are routed throughout the system via the optical fiber to the various receivers; a photodiode in the receiver is used to detect and convert the light pulses into electrical pulses; these electrical pulses are conditioned by a preamplifier and trigger circuit to provide an output electrical signal compatible with the connected computer, programmable logic controller (PLC), multiplexer (MUX), terminal, etc.

Because optical fiber technology as an industry is in its infancy, no standards have been established for performing startup and maintenance testing. This is especially true with the shorter optical links commonly used in LANs for business and industry. Opinions as to what tests and procedures should be required vary somewhat, but the consensus is that test requirements should be application dependent. If the given application is simple, and equipment and components are not being pushed to their operational limits, then testing does not need to be as extensive as the testing for more complicated applications.

Important characteristics

Based on manufacturer-recommended procedures and their own experience, Barth-Gross has developed an approach for testing optical fiber components and cables to ensure proper system operation. This comprehensive approach includes testing the optical fiber cable, connectors and splices, couplers and splitters (if used), sources and transmitters, detectors and receivers, and the system as a whole.

Optical fiber cable. Used in these systems, this cable has several characteristics that are of concern. They are attenuation per unit length (in dB/km), which indicates the inherent amount of signal loss in the fiber due to scattering and absorption of the light pulses; bandwidth and wavelength, which determine the speed at which the system can operate and its information carrying capacity; numerical aperture, a number that indicates how effectively



The glass fiber used in fiberoptic cables is extremely fine (about the size of a human hair). This contributes to the reduced weight and diameter of the cable. However, the cable also requires precision in handling, splicing, and terminating, or it will develop excessive losses. Careful testing is required at various stages of installation.

light will be coupled in and out of the fiber; diameter and concentricity, which are functions of the manufacturing process; and actual environmental conditions of use—how well the fiber will work over a range of temperature, humidity, altitude, and installation conditions (i.e., bend radii, cable stresses, etc.). Most LAN applications for optical fiber are multimode (multichannel) in nature; therefore, the cutoff wavelength, which is a concern in single-mode (single-channel) systems, need not be considered.

Splices. The characteristics of interest are attenuation or loss in decibels (dB) per splice and environmental conditions of use.

Connectors. In addition to loss and environmental considerations, other concerns include repeatability, which indicates a connector's capability to be unmated and remated without causing a substantial increase in loss; and degradation, which tells how many times a connector can be unmated and remated and still retain its repeatability. Because most connectors are not keyed, the loss caused by a change in orientation of the connectors with respect to each other, called rotational variation, must be considered. For properly installed connectors, the rotational variation is usually quite small—a few tenths of a dB.

Couplers and splitters. For point-to-point LAN applications using optical fiber links, couplers and splitters are not required. In those applications where they are used, the characteristics of concern are attenuation or loss per unit (in dB), and the life expectancy or mean-time between failures for that particular device.

Sources and transmitters. The characteristics of concern are output power, which will determine the amount of light injected into the fiber; bandwidth and wavelength of the transmitted light pulse, which will determine the

Test equipment

The equipment used for performing optical fiber system tests is relatively new but is easy to use. Optical fiber test equipment ranges from simple to complex. Among the instruments used are the following.

Optical power meters. These devices range in size and cost from inexpensive handheld meters to very expensive laboratory units with computer interface capabilities. Optical power meters utilize a detector similar to those in fiberoptic receivers and have an adjustable sensitivity rating. They indicate actual optical power, even if it is below the operating threshold of system detectors. Readouts are based on either watts or decibels (dB), and better units are adjustable down to the μW or dBm range.

LED and laser sources. Light sources for testing fiber systems utilize either an LED or laser and are available with different light wavelengths. The light source and wavelength selected for testing any system should be the same as those used in actual operation. That is, if a system is based on an 820-nm wavelength and LED-source transmitter, then all testing should be performed with a similar wavelength and source type.

Microscopes. These devices provide a quick and easy method for visually inspecting connectors. These microscopes have built-in illuminators, a means for holding the connector to be inspected, and provide for head-on and angular viewing of the connector. They are used to determine whether the connector is clean and properly polished or damaged and not suitable for use, and to check the fiber for imperfections.

Auxiliary equipment. Various items used in conjunction with other test equipment are the launch cable, attenuators, and adapters. The launch cable is a short length of optical fiber cable connected between the test source and the component to be tested. It provides a repeatable launch condition and reference for all testing. Attenuators are connector inserts that provide a known, fixed amount of loss when tied into a system. The most common and least expensive are the so-called "end gap" type. Attenuators are used to simulate system losses when testing operation of sources, transmitters, detectors, and receivers. The connector adapters allow any of the various types of cable connectors used with these systems to be properly attached to the test source and power meter.

Optical time domain reflectometer (OTDR). The OTDR is used to determine system losses and cable faults by monitoring light intensity. A high-powered laser source injects an optical pulse into the fiber and an integral optical receiver looks at the return light. By measuring the amount of "backscattered" light, signal attenuation is determined and graphically displayed as dB vs distance.

The advantages to using a complex instrument such as an OTDR for testing or troubleshooting optical fiber systems are: access is only required at one end of the fiber; the OTDR renders a graphic display of fiber, splice, and connector loss; it can locate faults or breaks; and it gives distance to fault or break.

While it is possible to perform most system tests and troubleshooting with other test equipment, the OTDR is without equal for locating breaks and faults in optical fiber cable. The major disadvantage with the OTDR is its high cost.

speed at which the system can operate and its information capacity; and environmental conditions.

Detectors and receivers. Devices used in these systems are evaluated for sensitivity, which is the minimum signal level that the detector requires for operation; bandwidth, which indicates the speed at which the detector and receiver can operate; and environmental conditions.

While most of these characteristics are a function of the manufacturing process or system design, the installer of these systems is usually required to verify that the installed system will perform as expected by testing certain individual component characteristics.

Testing

Optical fiber cable, connectors, splices, couplers, and splitters contribute to signal loss within these systems. The losses that these components cause are considered during the design phase by a study called the "system loss budget" or "power budget." This study calculates the total losses expected from the use of each component and the maximum acceptable total loss that will ensure adequate optical power at the system receivers.

The primary purpose for testing components is to ensure that the "system loss" or power budget has not been exceeded, by verifying that delivered equipment meets design specifications and that additional losses were not introduced by improper installation techniques.

In optical fiber systems, loss values are expressed in dB. The relationship is: Loss in dB = 10 log (power out/power in). If the power meter utilized measures power (watts), then actual dB values will have to be calculated.

The testing of the cable and components used in optical fiber links is conducted at various times before, during, and after installation. These tests can be broken down into installation and startup testing and maintenance troubleshooting. Whether a test is conducted before, during, or after installation, the equipment used and test procedures remain the same.

Each reel of fiber cable is required to have been tested by the manufacturer prior to shipping. If the fiber cable received at the job is not accompanied by a report of those test results, then the fiber is not installed until this report is received. Optical fiber cable is first tested for loss per unit length (dB/km) by Barth-Gross upon delivery to the jobsite. This ensures that the cable, as received, meets design specifications and has not been damaged during shipment or handling.

The test procedure (Fig. 2) used to determine system losses requires selecting an appropriate light source, LED or laser, injecting

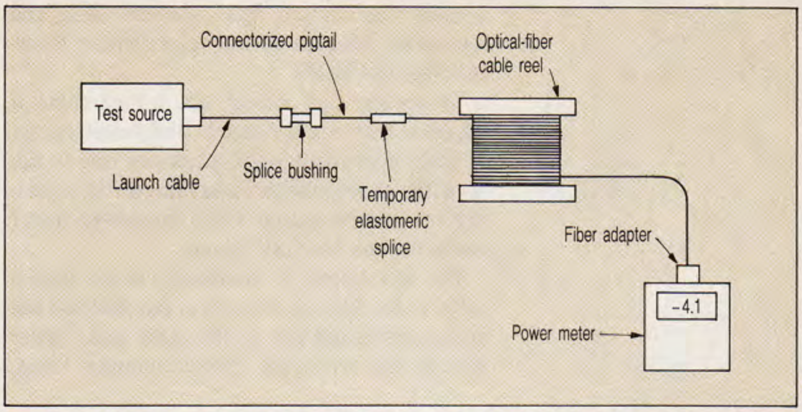
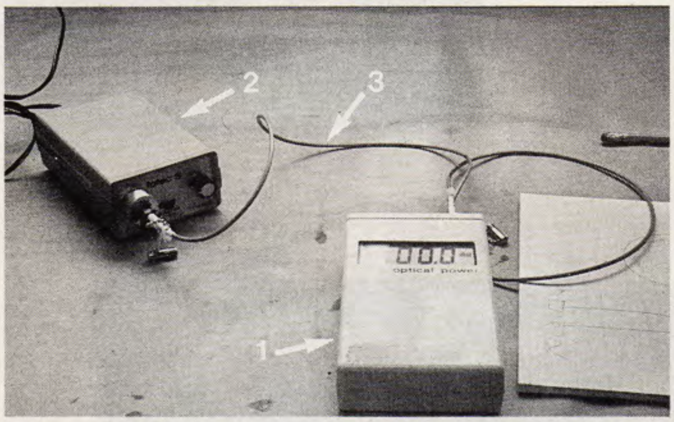
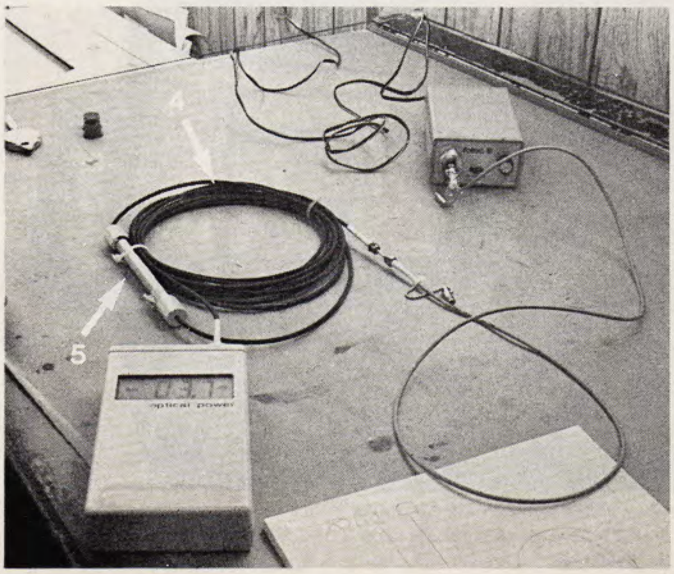


Fig. 2. Test configuration for initial field testing of fiberoptic cable. The test procedure used to determine system losses requires selecting an appropriate light source, LED or laser, injecting a known amount of light into the fiber, and measuring with an optical power meter to determine loss in dB. Losses caused by the splice bushing and temporary elastomeric splice must be considered when evaluating test results.



Zeroing the power meter (arrow 1) is the first step in testing fiberoptic cable. As shown in photo above, power meters that read in dB are zeroed by attaching a test source (arrow 2) to the power meter via a launch cable (arrow 3) and adjusting the source output until the meter reads 00.0 dB. Testing of a short length of fiberoptic cable (arrow 4) and a mechanical splice (arrow 5) is shown in photo below. The total loss of the fiber, connectors, and splice is -3.7 dB. Connector adapters are installed on the power meter and test source. These auxiliary test components make it possible to connect the test equipment regardless of the connector used.



a known amount of light into the fiber, and measuring with an optical power meter to determine loss in dB.

To prepare for testing, the launch cable is attached between the source and power meter. If the power meter used measures loss in dB, then the power meter is calibrated by adjusting the source output until the power meter reads 00.0 on the μdB range.

The test source is connected via the launch cable to the fiber under test at one end and the power meter directly to the other end. Power meters that read dB give a number value, usually a negative number, that indicates actual loss in that fiber. If the power meter used gives readouts in watts, the readout must be converted to dB.

These test results are compared with the results given in the manufacturer's test report. If the measured value is not within approximately 1 dB of the specified value, then rejection of the fiber is required.

After it has been installed and before it has been connectorized, the fiber is again tested in the same manner to ensure that the cable has not been damaged by improper handling or installation techniques. A problem introduced during installation will manifest itself as a dramatic increase in the amount of loss. The cause must be determined, located, and repaired.

After the cable has been connectorized, spliced, split, or coupled, it is once more tested for loss in the same manner to ensure that these tasks have been properly completed. Testing of sources and transmitters involves verifying that the optical output is within specifications and sufficient to deliver adequate power to the detectors and receivers throughout the system. This is done in one of two ways.

The first method utilizes attenuators to simulate cable loss and the second method, which is preferred, is accomplished using the installed fiber cable. Regardless of which method is employed, the power directly output by the system source and transmitter must be determined first.

Using a power meter and the appropriate launch cable, connector adapter, and splice bushing, the optical power output is measured at the system source and transmitter. If the measured value is not within specs, then the source and transmitter must be replaced.

If the attenuator method is used, an attenuator whose value approximates the system's losses to the system source and transmitter is attached. A power meter is connected to the attenuator and optical power is measured to ensure that an adequate level of signal is available. If the measured value is below the sensitivity rating of the system detectors and receivers, troubleshooting is required to isolate the problem.

The other way of testing the system source and transmitter, known as the "loop-back" method (Fig. 3), is preferred because it actually tests the installed system components as opposed to simulating system losses.

The transmit and receive fibers at the detector and receiver location are tied together by installing a splice bushing between the connectorized fibers. A system source and transmitter are connected via the launch cable to the transmit fiber, and a power meter to the receive fiber.

Transmitters and receivers are part of a completed fiberoptic cable system. The losses and operating characteristics of these components must be accounted for. A check of the whole system after installation is required.

Test equipment for fiberoptic systems can range from relatively simple handheld instruments to sophisticated testers that are used for troubleshooting as well as checking out total systems.

Optical power is then measured to determine if there is adequate signal level for system detector and receivers. If not, signal tracing from the detector and receiver location is needed until the problem area is located.

Causes of high dB losses

Optical links used in LANs are usually relatively short, and the majority of the overall system losses are connector related. Unless there is a break in the optical fiber cable, problems with excessive signal loss are most likely associated with one of the following connector loss factors.

Installation related losses are: end gap, which is an excessive amount of space between connectorized fibers resulting from improper connectorizing or mating techniques; finish and dirt, caused by improper polishing and cleaning of the connector; end angle, caused by a nonperpendicular cleave of the fiber; and axial runout, which can result when the fiber becomes physically bent within the connector.

Manufacturing-related losses are: concentricity, which is a core offset in the fiber; and coaxiality, which actually refers to a lack of coaxiality in the fiber or connector.

Two other causes of excessive loss are the result of mismatching fiber with different numerical apertures or core sizes. Either of these two problems can be recognized by the fact that loss values are significantly different when the fiber is tested in both directions.

In the interest of providing a system with the lowest possible loss and to save time (if cleaning does not significantly reduce the loss level of a connectorized cable), Barth-Gross reconnectorizes the fiber. It has been their experience that under these circumstances, repolishing will do little to reduce the amount of loss, and reconnectorizing will be required.

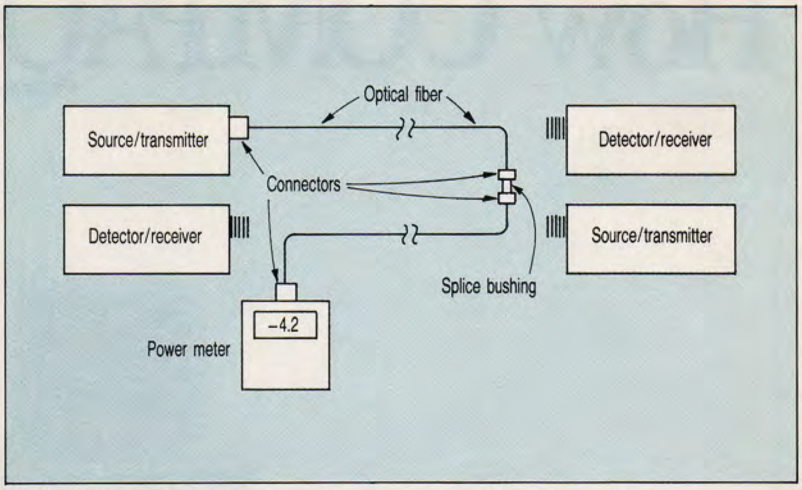


Fig. 3. Loop-back method for testing installed point-to-point optical fiber links is preferred because it actually tests the installed system components as opposed to simulating system losses. Actual test results will be approximately 3 to 5 dB higher because of additional losses introduced by the splice bushing used to tie the connectors together.

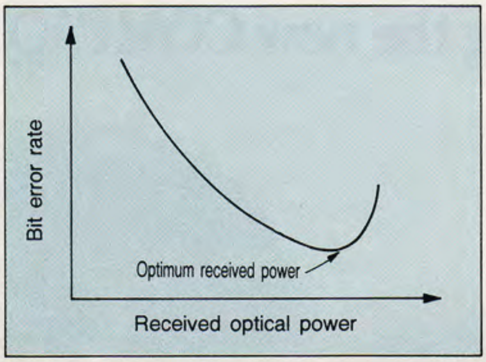


Fig. 4. Bit error rate (BER) vs received optical power. As power increases, the BER decreases. However, the detectors used within receivers in optical fiber systems are semiconductors. When power increases above a certain level, the photodiodes are driven into saturation, and the BER increases at an extremely rapid rate.

Bit error rate

Field testing for the detectors and receivers, whether at startup or for troubleshooting, confirms that these devices will operate when adequate power is available at the receiver location. At startup, these procedures are used for fine tuning to achieve an optimum level of received optical power. This is extremely important because system performance, which is defined as the number of bits that are transmitted erroneously and referred to as the "bit error rate" (BER) is directly related to received optical power.

The BER as a function of received optical power can be seen in Fig. 4. Systems designed to perform with a given BER must be operated at an optimum value of received optical power.

Using either the system source and transmitter or a test source, a test signal is put on the fiber. A power meter at the detector and receiver location measures the power available. If there is insufficient power available, the signal must be traced back towards the source until the problem area is located.

If the power is adequate (based on the received power and the detector's sensitivity rating) an attenuator is selected that reduces the power level to a value that will give the desired system BER. It is installed between the power meter and the detector and receiver connector. The optical power level is again checked with the power meter. If it is within the desired optimum value of received power, then the power meter is disconnected, the system detector and receivers reconnected, and their operation verified. If the received power is too high or low, an attenuator of either higher or lower value is selected and the system is rechecked with a power meter.

Once the system is operating, monitoring for an increase of the BER will alert personnel to any component degradation. Isolating the cause of the increase in BER is done by checking system components using the equipment and methods described. Once isolated, replacement or repairs can be effected. ■