Cabling Certification

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INTRODUCTION

Cable certification is an important component of a network infrastructure qualification and is often one of the least understood aspects of the qualification process. Cable certification serves as proof that the local area network cabling infrastructure was installed according to industry standards and, more importantly, the certification provides objective evidence that the cable performs as intended in a network infrastructure environment.

In many cases, vendors test all the cables and provide the customer with the testing results. These results are reports provided with the testing suite used by the cable installers. How do you know what needs to be tested? How can you independently verify the cabling results? Why should you want to verify the testing results? This paper provides a cable testing primer specifically geared toward organizations governed by Food and Drug Administration (FDA) regulations.

Why Certify the Cabling?

Most current-day enterprise and laboratory systems are network-centric applications, which implies that the line between the application and the network has been blurred. The network is now an integral part of the application that supports all transactions with other peers or servers. These types of applications are prevalent in many Good Manufacturing, Laboratory, and Clinical Practice (GXP) environments and are utilized to generate and store GXP data, which is in turn used to manufacture, test, and support medical device claims. For this reason, the FDA has, in recent years, insisted that all computing infrastructure, including cabling, be qualified and placed under change control.

Cabling certifications achieve several objectives. First, the certification process ensures that cabling, regardless of cable type, has been installed properly and performs as expected. There are many things that can affect the performance of a cable. For example, if a cable is kinked in the ceiling or is pulled too hard during installation, then the cable will not be able to handle the rated transmission and will result in slower data transfer rates or in network errors. Again, installing cables too close to a source of electromagnetic radiation, such as near a high voltage power line, or a florescent light fixture, may render the cable useless or may interfere with data transmissions.

The second reason to certify a cable is that cable manufacturers usually stipulate cable certifications before they will honor their cable warranty. Lastly, cable certification serves as the objective evidence that the cables have been tested, perform as expected, and are not a source of errors in a network infrastructure Installation Qualification (IQ) and Operational Qualification (OQ).

Cable Types

There are several types of cables that are used to interconnect the network infrastructure. These can be classified as either copper or fiber. Both of these types of cables are manufactured to meet or exceed the specifications set forth by the Telecommunications Industry Association (TIA) and the Electronic Industries Alliance (EIA) in the TIA-EIA 568 B standard. The standard provides the specifications for manufacturing materials, installation, and performance characteristics for data cables.

Copper Cable

Copper is most commonly used to interconnect a workstation or a server to a hub or a switch; copper can also be used for interconnection between switches if the switches are within 100 meters (300 feet) of each other. Currently, there are four copper cable categories rated to handle network data traffic: Category 5 (Cat 5), Category 5 Enhanced (Cat 5e), and Category 6 (Cat 6), with Category 7 still in the specification phase.

All of the cables are similar in that each cable is comprised of eight shielded copper strands. The main difference between the cabling categories is the number of twists in each of the strands per inch of cable. Each strand is paired up with another strand for a total of four pairs. Each pair of strands is twisted around the other three pairs of strands to form a braid. Furthermore, each cable is rated to handle different transmission frequencies. For example Cat 5 and Cat 5e are rated to handle transmissions of 100 MHz, while Cat

6 is rated to handle transmissions of 250 MHz.

When cables are tested, a signal is passed through the cable that covers the entire rated spectrum. For example, when testing a Cat 5 cable, the signals passed through it cover a frequency range of 1 to 100 MHz, and for Cat 6, the signals cover a range from 1 to 250 MHz. The signals are transmitted through each of the eight strands of the cable and are measured at the opposite end to determine signal loss, distance, and cable shorts. The worst-case measurement at a given frequency must fall within the given TIA 568 B specification.

Each of the cable categories undergoes the same set of tests with different specifications for each of the testing parameters. The following list indicates the testing parameters required for cable certification:

- Wire Map
- Length
- Insertion Loss
- NEXT
- PSNEXT
- ELFEXT
- PSELFEXT
- Return Loss
- Propagation Delay
- Delay Skew
- ACR (Not required, but is often reported)

Note: These testing parameters apply to Categories 5, 5e, and 6. Category 7 specifications are currently under development.

A brief description of each of the TIA-EIA 568 B testing parameters follows. For more information and for parameter calculations, review the TIA-EIA 568 B standard.

➤ Wire Map
The wire map tests each of the eight strands to ensure they terminate correctly at each end of the cable. This test ensures that, for example, the strand in position one at one end of the cable is the same strand in position one at the other end of the cable. A cable analyzer is attached to each end of the cable. Then, the analyzer sends a signal down each of the strands in order and verifies that the signal at the other end of the strand has been received and that the strand was terminated in the correct order. Additionally, the wire map test verifies that there are no breaks or shorts in the cable. Breaks or shorts in the cable may occur when the cable is defective or when it is pulled too hard during installation.

➤ Length
The length test consists of two parameters: electrical length and total cable length. Since the cable is comprised of eight strands of twisted wire, it is important to make sure that the strands are of the same length. Sending a signal through the cable and determining how quickly the signal travels through the cable determines the length of the strands. This is known as the Nominal Velocity Propagation, or NVP, and is reported as a percentage of the speed of light. The second length component is the total length of the entire cable. Copper cabling cannot exceed 300 feet when used in an Ethernet network. If the cable exceeds 300 feet, the network will experience errors; fiber optic cabling should be used for lengths greater than 300 feet.

➤ Insertion Loss
Insertion loss is also known as attenuation, which is the loss of signal as it travels across the length of the cable. Insertion loss is a result of signal absorption by the insulation, the signal radiation, and the resistance of the actual wire. Testing is accomplished by sending a signal across each of the strands on each of the rated frequencies (i.e., 1-100 MHz for Categories 5 and 5e and 1-250 MHz for Category 6) and then by measuring the resulting signal at the other end of the cable.

➤ NEXT
NEXT is the acronym for Near End Crosstalk and it occurs when the signal from one strand is picked up by another strand. The twists in the cable strands are designed to minimize the signal crossover known as crosstalk. Crosstalk usually increases as the frequency increases and for this reason Category 5 cables (rated for 1-100 MHz) cannot handle the traffic of Category 6 cables (rated for 1-250 MHz).

➤ ACR
ACR is the attenuation to crosstalk ratio and it is used to determine the signal to noise ratio in a cable. It is the calculated difference between the insertion loss and the near end crosstalk (NEXT). Specifically, it is the measurement of the signal strength at the opposite side of the cable that survives the insertion loss at the other end relative to the crosstalk.

➤ PSNEXT
PSNEXT is the Power Sum Near End Crosstalk and just as the name implies, it is the mathematical power sum calculation and not a direct measurement. PSNEXT is the summation of the individual

NEXT effects experienced on each pair of strands created by the other three pairs.

- ELFEXT
  ELFEXT is the Equal Level Far End Crosstalk and it is a measurement of the crosstalk at the other end of the cable. Since Far End Crosstalk (FEXT) is influenced by the length of the cable and the insertion loss experienced as a result of the cable length, the measurement is not useful, and therefore, must be corrected to normalize the measurement. ELFEXT is the corrected normalized value and it is calculated by measuring the FEXT and subtracting the insertion loss.
- PSELFEXT
  PSELFEXT is the Power Sum of the Equal Level Far End Crosstalk. This value is also a mathematical power sum calculation of the ELFEXT and it is not a direct measurement. PSELFEXT is the summation of the individual ELFEXT effects experienced by each pair of wire strands as a result of the other three pairs.
- Return Loss
  Return Loss is the measurement of reflected energy from a transmitted signal caused by impedance mismatches at all locations along the cable. As the signal travels down the cable, a portion of the signal may be reflected back to the source. Return loss is typically measured in decibels; larger decibel numbers mean lower amounts of energy reflected back to the source. Discontinuities may be caused by connectors, improper installation, handling of the cable, or manufacturer defect. It is important the reflected signal is minimized as much as possible because the reflected energy reduces the power of the transmitted signal.
- Propagation Delay Skew
  Propagation Delay Skew is the difference between the signal propagation delays among the different wire pairs. A particular signal may be divided among different wire pairs in the cables and differences in the propagation delay may cause the signal to arrive at its destination at different times. Network interface cards are designed to tolerate slight variations in delay, but large variations will make the reassembly of the signal impossible.
- Propagation Delay
  Propagation Delay is the time required for the signal to travel from one end of the cable to the other. This measurement is reported in nanoseconds.

Fiber Optic Cable

Fiber is most often used to interconnect wiring closets or for specialized applications, whereas copper is most often used for workstations or servers. Fiber is also used to enhance performance over short distances as well; sometimes the load may be too intensive for copper to handle in a timely and efficient manner. Fiber cables are usually constructed of 50/125μm or 62.5/125μm multimode optical fibers. Fiber is comprised of twenty-four strands and is not subject to many of the issues faced by copper cabling.

With fiber, there are only two parameters to test: attenuation (insertion loss) and length. Attenuation is the same for fiber as it is for copper in that it is the measurement of signal loss of each fiber strand from one end of the fiber link to the other. The length parameter is considerably larger than copper in that the maximum length of the cable cannot exceed 2000 meters, otherwise network errors will begin to occur.

Data Analysis

Once the testing certification has been completed, the vendor should provide you with the testing results. The testing results are reported as a series of graphs and numbers. The report shows the technicians name, test date, analyzer's serial number, cable ID, parameters used to test, and finally, the testing results. Each of the parameters is tested across the entire frequency spectrum for each of the wire pairs; the worst value for a given frequency is reported. That is to say, the wire pair with the worst parameter result is the value taken for the entire cable.

The report will display the limit and the actual value for the given frequency. Since the values of the testing parameter vary with respect to the frequency, both the result and the corresponding limit will change as the frequency changes. For this reason, it is impossible to set one specification for each parameter for each cable. This is where the TIA-EIA 568 B calculations are helpful.

TIA-EIA 568 B provides the calculations necessary to derive the specification for each of the parameters for a given frequency. These values may be useful to compute when the report does not provide the TIA-EIA 568 B limits or, as a second check, to ensure that the analyzer is working properly. The reader is referred to the TIA-EIA 568 B standard for further detail. The values for each of the testing parameters are reported from both ends of the cable.

Most testing reports present the testing result as the actual value, but in some cases the result may be reported as the margin. The margin is the difference between the result and the limit. This may cause some confusion, so it is important to understand how the value is being presented. When reviewing the testing results, the reviewer must check

Figure 1

Relationship between Test Values and TIA-EIA Limits

Test Value	Relationship	Specification Limit
Insertion Loss (Attenuation)	≤	TIA-EIA Limit
PSNEXT	≥	TIA-EIA Limit
Return Loss	≥	TIA-EIA Limit
PSELFEXT	≥	TIA-EIA Limit
NEXT	≥	TIA-EIA Limit
ELFEXT	≥	TIA-EIA Limit
Propagation Delay	≤	TIA-EIA Limit
Delay Skew	≤	TIA-EIA Limit
Length	≤	TIA-EIA Limit
Wire Map	Pass/Fail	

that the values for both the remote and the far end are within specifications. (*See Figure 1.*)

When certifying a large number of cables, a statistical sampling approach may be more appropriate. Statistical techniques may be employed to avoid 100% inspection and to provide a high enough confidence in the work performed.

What to Expect from a Cabling Vendor

Vendors have the same responsibilities as any technician performing a GXP test. The technician must be trained to perform the cable certification and should be able to provide documented evidence of on-the-job-training or a manufacturer's certification upon request. Additionally, vendors are responsible for having a training program and for keeping accurate training records. When performing a network infrastructure qualification, the training records should be included in the protocol or the location of the training record should be recorded. Since the turnover rate of the cabling technicians may be high, it is recommended that the training records be kept with the protocol or with the Human Resources Department.

Vendors must also ensure that their cable testing equipment is within calibration. Cable tester manufacturers recommend that cable testers be returned for calibration at least once a year to ensure the equipment is operating correctly. Once calibrated by the manufacturer or by an authorized third party, a calibration certificate is issued.

Vendors must ensure that only calibrated analyzers are used for certifying data cables in a GXP environment. Testing equipment can be configured to test a cable in what TIA-EIA refers to as a "channel" or a "permanent link" configuration. Depending on the configuration used, testing equipment may need to have more than one component, each requiring a calibration certificate. For example, a test instrument may use the main analyzer for one end of the cable, a remote analyzer for the other end of the cable, and a special cable that is used to attach the main analyzer to the cable jack being tested. The vendor must provide the calibration certificate for each component of the test equipment. As with training, the vendor is responsible for having a calibration program and for maintaining accurate calibration documentation.

Finally, the vendor is responsible for providing the actual test results. Most of the reports used as client deliverables are generic reports provided by the testing suite used. The vendor must provide written documentation that the cabling installation was performed as specified by the customer's statement of work. In many cases, vendors will test against the manufacturer's specifications and not the TIA-EIA 568 B standard because they must provide the manufacturer proof of proper installation to honor the stated warranty. Most often, the manufacturer's cable specifications will meet or exceed the TIA-EIA 568 B standard. However, there are some instances in which the manufacturer's specification may fall slightly outside the TIA-EAI 568 B standard. For this reason, the client must ensure that the testing is performed against the TIA-EIA 568 B standard in addition to what the cable manufacturer requires to ensure its warranty.

Testing can be performed in one of two configurations, the channel configuration and the permanent link configuration. The vendor is responsible for providing the client with a written report stating the cable used, testing method used, analyzer calibration, and the testing specifications.

As with any GXP validation, it is always prudent to review the training and calibration records prior to starting the cable testing. This will avoid retests, delays, and deviations during testing. If a cable does not meet the specifications, it is often due to the termination of the cable at the data jacks.

Your Responsibility

In a GXP environment, documentation is always the key to having a successful system and passing an audit. The easiest way of documenting the cabling infrastructure is through a floor plan that documents the network wiring closet location and the location of each of the network drops. Each of the network drops should be clearly marked on the floor plan with a unique identification label at the workstation termination point. The termination point or network jack label must have enough information to determine the location of the other end of the cable. This may include a code for the site, wiring closet, network patch panel, and network port as part of the unique identifier. Naming conventions may vary in different organizations, but the code should provide enough information to identify the patch panel port in the wiring closet.

A second piece of useful documentation is a cabling results database. The database can be as simple as a centralized file for all the cabling results, or as sophisticated as an electronic document management system. Regardless of what method is used, the cabling results for any network cable must be readily available for inspection. This is particularly important if the cabling data is used to support multiple network validations. Cabling certification supporting multiple networks can then be referenced in a centralized location.

Finally, the vendor should be provided with a statement of work. The statement of work must address the following items:

- Proof of training for technician performing tests; analyzer components must be within calibration at the time of testing.
- Cabling that fails the testing parameters set forth in the TIA-EIA 568 B must be fixed or reinstalled and retested.
- Cable type to be installed must be specified.
- All testing must adhere to the TIA-EAI 568 B standard.
- The vendor must provide a summary of the testing results and testing configuration (i.e.: “channel” or “permanent link” testing configurations).
- Cable installation must meet the city or state building codes and standards.

CONCLUSION

The certification of a cable is a simple, clear-cut process that is analogous to many of the GXP testing activities already performed as part of normal operations in an FDA regulated environment. Cabling is an integral component of the network infrastructure, but is often overlooked. Cabling certification ensures that the cabling was properly installed according to the design specifications outlined in the TIA-EIA 568 B standard and that all cabling functions within those parameters. ❑

REFERENCES

1. “*Commercial Building Telecommunications Cabling Standard TIA/EIA-568-B,*” TIA/EIA Standard, (May) 2001.
2. FDA. General Principles of Software Validation; Final Guidance for Industry and FDA Staff
3. FDA. *Guidance for Industry Part 11, Electronic Records; Electronic Signatures - Scope and Application*
4. Fields, T., “Establishing a Sound IT Infrastructure in a GXP Environment,*” Journal of Validation Technology,* Vol 9, No. 3, 2003, pp. 229-234.
5. Haudahl, J. S., *Network Analysis and Trouble Shooting*. Addison-Wesley: Upper Saddle River, 2000, pp 357.
6. Hay, D. C., Requirements *Analysis: From Business Views to Architecture*. Prentice Hall PTR: Upper Saddle River, NJ, 2003, pp xxxvi, 458.
7. McCabe, J. D., *Network, Analysis, Architecture, and Design*, Elsevier Science (USA): San Francisco, 2003, pp 501.
8. Neal, C., “Prerequisites for Successful Validation*” Journal of Validation Technology*, Vol 9, No. 3, (May) 2003, pp. 240-245.
9. Tracy, D. S. and Nash, R. A. “A Validation Approach for Laboratory Information Management Systems.” *Journal of Validation Technology*, Vol 9, No. 1, (November) 2002, pp. 6-14.

Article Acronym Listing

ACR	Attenuation to Crosstalk (ratio)
EIA	Electronic Industries Alliance
ELFEXT	Equal Level Far End Crosstalk
FDA	Food and Drug Administration
FEXT	Far End Crosstalk
GXP	Good Manufacturing, Laboratory, and Clinical Practice
IQ	Installation Qualification
MHz	Megahertz
NEXT	Near End Crosstalk
NVP	Nominal Velocity Propagation
OQ	Operational Qualification
PSELFEXT	Power Sum of the Equal Level Far End Crosstalk
PSNEXT	Power Sum Near End Crosstalk
TIA	Telecommunications Industry Association