Bend Radius Under Tensile Load

Installation practices can degrade performance of UTP cable.

BY GREGORY A. BRAMHAM

It has long been suspected that common installation practices are a contributing factor to network cabling performance. Now a collaborative effort among cable manufacturers, testing equipment manufacturers, installation process engineers, and industry consultants has initiated a study to determine just what the contributing installation factors may be.

The structured cabling industry is experiencing several new technologies, including the highly publicized introduction of proposed augmented category 6 (category 6A) unshielded twisted pair (UTP) cables, operating at frequencies up to 500 MHz to support 10 gigabit Ethernet over a 100 m channel. At these higher frequencies, category 6A cables require improvements in several performance parameters to meet specifications for 10 gigabit Ethernet applications. This stretches the limits of cable design, which may make them more sensitive to the effects of mishandling during installation.

This study was conducted to examine how bend radius under load impacts the performance of category 6A cables and to establish a practical minimum bend radius under load that accommodates the full range of today's communication cables.

Test Methodology

Minimum bend radius for 4-pair UTP communications cables is the minimum radius around which the cable can bend without altering the geometry

Steps	Variable (Diameter)	Description	Rationale
1	Baseline Test	40 m unrolled on the floor, loosely and as straight as possible with no applied tension.	Used with in-house testing specs as a baseline for analyzing final results.
2	Cable Tray Edge	Cable tray edge is approximately the same diameter as the category 6A cable itself.	Technicians have been known to use cable tray edge as a guide for pulling the cable into the pathway.
3	1-Inch Rod	Provides a bend radius less than twice the diameter of category 6A cable.	Technicians have used whatever is the most convenient tool to guide cables, including a broomstick or one-inch rod.
4	2-Inch Rod	Provides a bend radius smaller than four times the diameter of category 6A cable.	A 2-inch rod is commonly used because its radius is four times the diameter of category 5e and category 6 cables (as specified in ANSI/TIA/EIA-568B.2).
5	3-Inch Rod	Provides a bend radius four times the diameter of category 6A cables.	If the "four times diameter" rule is truly sufficient, the 3-inch rod should show no degradation of failure of testing parameters.
6	4.25-Inch Rod	Provides a bend radius six times the diameter of category 6A cable.	The 568B-2.10 draft standard had a placeholder of 8X the cable diameter, and the test needed to cover all radii.
7	5.75-Inch Rod	Provides a bend radius eight times the diameter of category 6A cable.	The 568B-2.10 draft standard had a placeholder of 8X the cable diameter, and the test needed to cover all radii.
8	2-Inch Roller	Provides a bend radius smaller than four times the diameter of category 6A cable.	Tests using rollers (dynamic) versus rods (static) were performed to determine if reduced friction plays a role in how the bend radius affects performance.
9	3-Inch Roller	Provides a bend radius four times the diameter of category 6A cable.	Tests using rollers (dynamic) versus rods (static) were performed to determine if reduced friction plays a role in how the bend radius affects performance.

TABLE 1: Test variables using 40 m cable lengths from five cabling manufacturers

of the cable to the extent that its electrical performance is adversely affected. At the higher operating frequencies of category 6A cables, variations in the geometry of the cable can have an even greater effect. While bend radius is a concern for cables at rest, it is even more of a concern for cables during installation because tensile force places more stress on the cable.

In this study, five different manufacturer's category 6A cables were subjected to various bend radii during installation using current and accepted methods. While cabling standards for category 6A cable are not yet finalized, this cable type was chosen because it represents the latest technology from cable manufacturers, and it currently has the largest diameter among 4-pair UTP cables (up to 0.354 inches).

It was essential that this study establish a minimum bend radius under load that accommodates all categories of 4-pair UTP cable. Minimum bend radius has a direct correlation to the diameter of a cable—the larger the cable, the larger the minimum bend radius. In other words, if a minimum bend radius under load does not impact the performance of the larger category 6A cable, it will not impact smaller diameter cables such as category 5e and category 6 UTP.

Test Setup

In this study, cable performance tests were performed on all four pairs of each manufacturer's cable without the use of connectors or patch cords, which would introduce additional variables. Testing was conducted using leading test equipment with appropriate lab adapters and advanced software that enabled testing only the cable and isolating the impact of bend radius under load by eliminating any variability introduced by operator error or termination. To obtain accurate results, all performance testing was conducted by technicians with specific knowledge and expertise in the use of the test equipment.

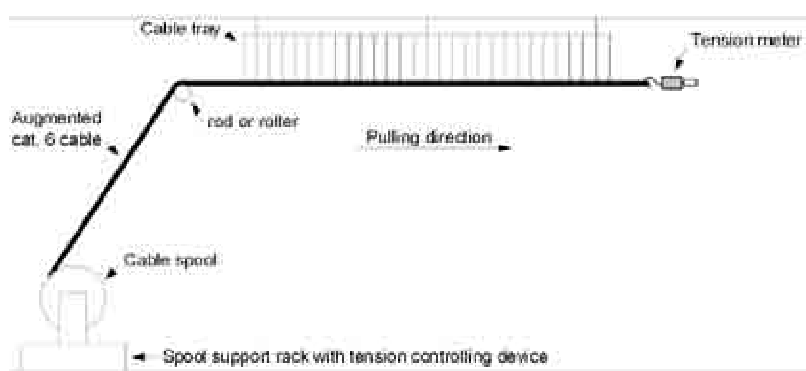

FIGURE 1: Test setup

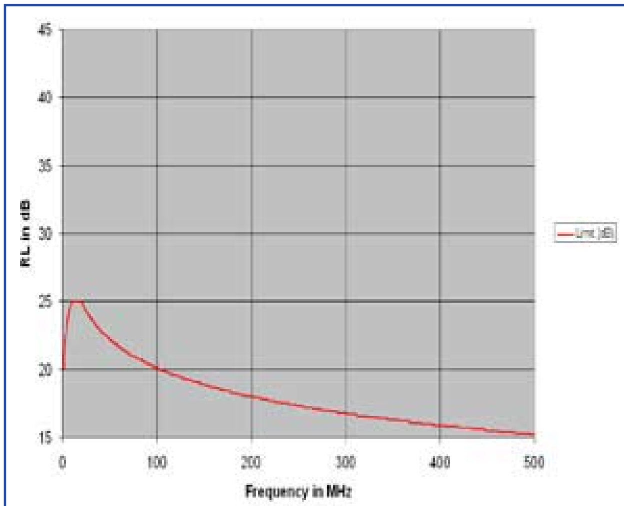

FIGURE 2: Current return loss limit for category 6A cable

The cables used for each variable in this study were 40 m (130 ft) in length, which represents an average horizontal cable run in premise installations. To provide a baseline for analyzing final results, a 40 m sample under no tensile load was tested from each reel prior to installation. To subject the cables to different bend radii using current and accepted installation methods, 40 m lengths of each manufacturer's category 6A cable were pulled into the pathway over various sized rods and rollers. Following installation using each rod and roller size (see variables in Table 1), the four pairs were tested for insertion loss, crosstalk, return loss, propagation delay and delay skew parameters for frequencies up to 500 MHz as defined by the IEEE 802.3an 10-GBASE-T standard and proposed TIA draft addendum 10 of the ANSI/TIA/EIA-568-B.2 standard.

It was important to recreate a typical installation setup used by technicians in the field on a daily basis (see Figure 1). Conducted at a room temperature of 70° F (20° C), setup included a cable spool supported by a spool support rack with a tension-controlling device. To maintain constant control of tension on each cable, cables were pulled into the cable tray manually, one at a time, using a straight path with no obstacles. During installation, pulling was monitored with the tension meter to prevent exceeding a pulling tension of 25 lbf,

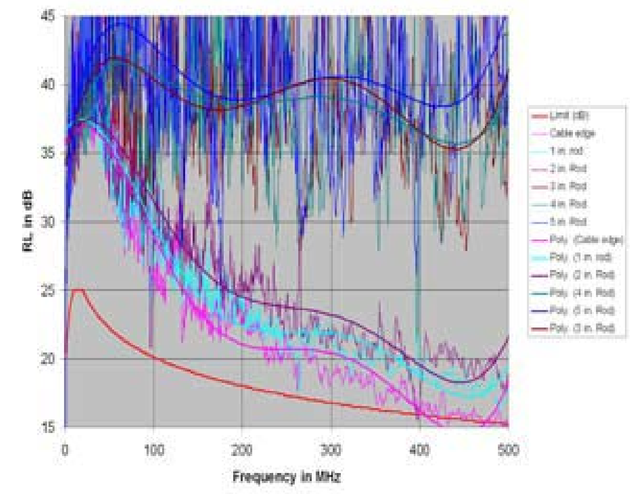

FIGURE 3: Return loss results using static rods
***Note: The polynomial curve provides a trendline for analyzing this fluctuating large data set.**

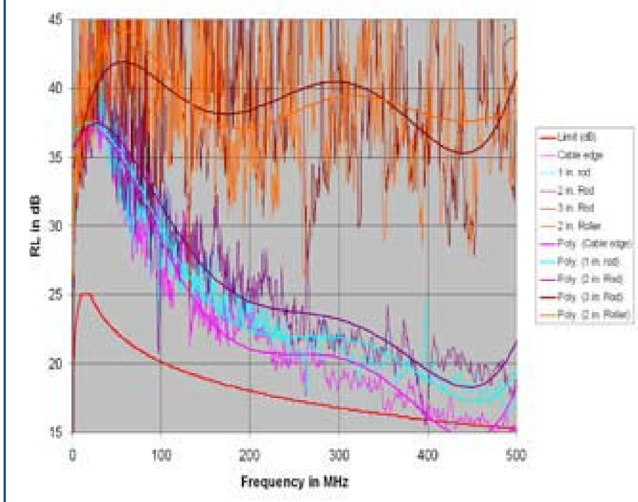

FIGURE 4: Return loss results using static rods and 2-inch roller
***Note: The polynomial curve provides a trendline for analyzing this fluctuating large data set.**

which is the standard specified limit. While tensile pressure often exceeds the 25 lbf limit in the field, this study kept all factors within industry specifications. Throughout the installation, a series of digital cameras were utilized for visual validation and photographic verification.

Test Results

While testing was performed for all critical performance parameters, the results showed that bend radius under tensile load only significantly affected the return loss parameter. While insertion loss, crosstalk, propagation delay, and delay skew performance parameters can be marginally influenced by bend radius, these parameters are primarily impacted by the construction of the cable and the effects of introducing connectors and patch cords, which were eliminated from this study. In fact, the test results showed that several of the category 6A cables exhibited very high performance for these parameters, which demonstrates that manufacturers have managed to design and develop high quality category 6A cables.

On the other hand, return loss was significantly affected in this study. Calculated in decibels (dB), return loss is the ratio of the power of the outgoing signal to the power of the signal reflected back. The larger the value when expressed in positive dB, the less the signal is reflected. In a full duplex system, any signal reflected back interferes with the signal moving in the opposite direction.

Figure 2 represents the maximum return loss parameters for category 6A cable operating up to 500 MHz as currently specified in the proposed TIA draft addendum 10 of the ANSI/TIA/EIA-568-B.2 standard. To meet the draft standard, a category 6A cable must not exceed the return loss specification over the entire frequency range.

Figures 3 and 4 show the return loss results for the worst-case scenario. The graphs show the limits per the draft standard and test results of pair 4-5 from a single manufacturer for each event. The polynomial lines are used to show the trend of the data line results. Starting at frequencies below 100 MHz, the 3-inch, 4-inch and 5-inch diameter rods demonstrated a significant increase in return loss performance than the cable tray edge, 1-inch rod and 2-inch rod. At frequencies above 300 MHz, the differences were much more dramatic with the 3-inch, 4-inch and 5-inch rods providing 15 to 25 dB better return loss. In fact the use of the cable tray edge caused the most degradation of return loss, resulting in performance failures between 400 and 500 MHz.

To determine if reduced friction plays a role, testing was also conducted using 2-inch and 3-inch diameter rollers. As shown in Figure 4, the 2-inch roller exhibited significantly better return loss performance than a 2-inch static rod, and similar performance results to the 3-inch static rod. This demonstrates that the reduced friction provided by the roller did in fact play a role in how the size of the bend radius under load affected the cable performance.

While all cables demonstrated a relationship between bend radius under tensile load and performance, cabling standards are always based upon the worst-case scenario—this is the only method for determining a recommended bend radius that will support all cables. It is important to mention that the intent of this study was not to evaluate the actual performance of the channel or the impact of bend radius while cables are at rest. The intent was to exclusively determine the impact of bend radius during installation. Therefore, the results are evaluated based on the effect of the rod or roller used to install the cable, regardless of meeting the limits set by the draft standard.

Conclusion

Once network cable is purchased, it will be subjected to various stresses on the job site. For example, cables can be kinked or handled in ways that might damage the cable, resulting in degraded cable performance. Many installation practices in use today are outdated, do not address mishandling issues, and are not adequate for today's advanced cables. The results of this study showed that excessive bend radius under load significantly affected the return loss parameter for category 6A cables, clearly demonstrating that installation practices do in fact impact UTP performance. With the introduction of category 6A cable, it is more important than ever that training thoroughly address installation practices.

Based upon the results of this study, the use of a minimum bend radius under load of 1.5 inches using a static 3-inch diameter rod or 1 inch using a 2-inch diameter roller will contribute to the protection of the data transmission integrity through the cable. Because this study is based on the latest technology, the largest diameter cable, and the worst-case scenario, this minimum bend radius under load is a practical recommendation that will accommodate the full range of today's UTP communications cables and help maximize the cabling system performance. ■

Gregory A. Bramham

Greg Bramham is vice president of Beast Cabling Systems, Inc, in Arlington, VA. For more information, contact Greg at gbramham@beastcablingsystems.com.