White Paper

The "Permanent Link" in Field Certification – Reasons, Advantages, Testing Challenges

In the telecommunications industry, new advances bring new challenges, as is the case with evolving TIA standards. In March 2001, the Telecommunications Industry Association (TIA) approved version B of the main standards document that describes the design, installation and performance requirements for telecommunications cabling systems for commercial buildings (ANSI/TIA/EIA-568-B). Field test requirements changed significantly as the TIA adopted a new link configuration – the Permanent Link – to be used to verify the performance of the installed twisted-pair cabling links in the field. (The Permanent Link configuration was adopted earlier in the international standards ISO 11801 and other regional derivative standards documents.) This article revisits why the Permanent Link concept has been adopted, highlights its benefits to installers and end-users, and examines its impact on the operations and performance requirements of field test equipment.

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Channel, Basic Link and Permanent Link defined

Channel

TIA and ISO standards define the Channel as the completed cabling link over which the active network equipment must communicate. This end-to-end link includes the equipment patch cords to connect the active network devices in the telecommunications or equipment room, the cords to connect the network devices in the office or work areas, and the patch cords in an optional cross-connect patch panel.

Ultimately, a network's operation relies on the performance of the Channel – this complete end-to-end link. The installation contractor for the cabling system seldom, if ever, takes responsibility for the completed Channel with all of its equipment cords and patch cables. Some percentage of the installed links may have been planned for future expansion and may not be completed into Channels any time soon. Equipment cords and patch cables are generally installed after the "permanent" cabling installation has been completed and tested, and they may be exchanged many times throughout the life of the network cabling system. Therefore, it is mandatory to have a means to certify that the fixed cabling infrastructure meets a performance level that lets the user add good patch cords and equipment cords later on. This is why the latest industry standards define performance criteria for the fixed cabling infrastructure, which corresponds to the cabling to be completed by the installation contractors.

Basic Link

Initially, TIA standards adopted the Basic Link configuration for field-test purposes, while ISO standards adopted the Permanent Link. The Basic Link configuration consists of a maximum of 90 meters (295 ft) of uninterrupted solid-copper twisted-pair cable with a termination connection on each end and a patch cord to connect the field tester. The maximum length for each of the tester patch cables is 2 meters. The performance limits for testing the Basic Link were based on this configuration and included the allowable contributions made by the two tester patch cables. The Basic Link model is now obsolete and should no longer be used to certify cabling in compliance with the standards.

Permanent Link

Current standards define the Permanent Link test model to verify the performance of the fixed portion of the installed cabling. The Permanent Link test configuration expands on the previous, Basic Link goal to achieve a dual goal:

1. Define a test configuration that characterizes the permanently installed, fixed portion of the cabling as accurately as possible
2. Provide the assurance that a passing link installed in the building infrastructure can reliably be configured into a passing Channel by adding good patch cords

In order to achieve both goals, the Permanent Link configuration allows that the contributions made by the tester patch cables (test adapters) must be fully excluded from all measurement results. The second goal is achieved by using a plug at the end of the test adapter that meets precise performance specifications. (Later sections in this article will discuss these requirements in more detail.)

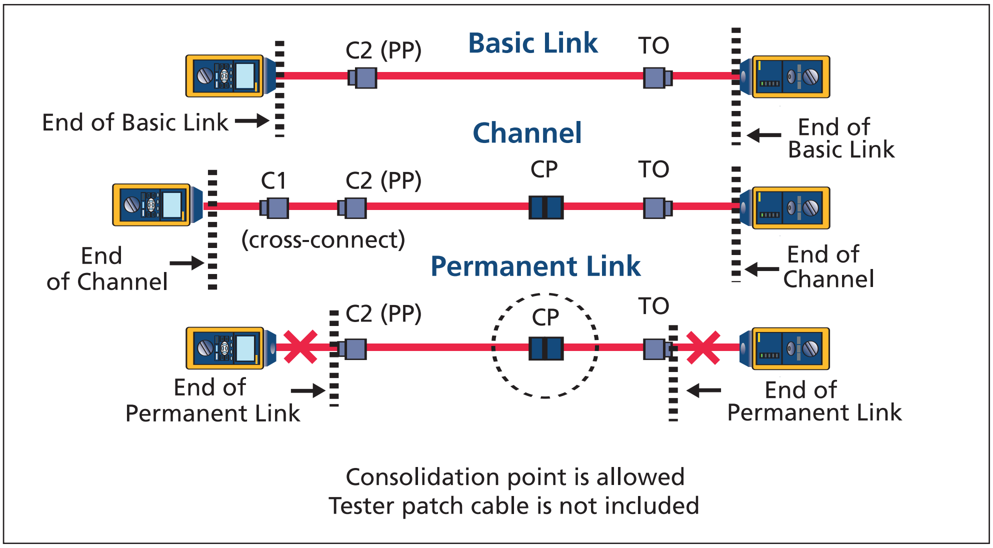


Figure 1: The different link models for testing.

Figure 1 shows the configuration relationship between the Channel, the Basic Link as it was defined, and the Permanent Link. At first glance, the difference between the Permanent Link and Basic Link test configurations may seem trivial. However, the advent of new test parameters (primarily Return Loss) higher performance requirements (Cat 5e and Cat 6), and the need to verify connecting hardware interoperability all rendered the Basic Link test model inadequate. Performance specifications for the Basic Link are no longer specified in TIA/EIA-568-B. In addition, the Basic Link test configuration never incorporated the consolidation point, which is often used in open office cabling systems or in “zone wiring” and is considered an element of the fixed wiring plant. The Permanent Link model incorporates the consolidation point.

Critical performance parameters

A number of performance parameters must be evaluated in order to certify that a link meets TIA or ISO transmission standards. In Table 1, the left column lists the parameters that are measured directly; the right column lists the parameters computed from these directly measured parameters. Because the accuracy of the computed parameters depends on the accuracy with which the test parameters in the left column are measured, these directly measured parameters are the focus of this article. Two of them – Near-End Crosstalk (NEXT) and Return Loss (RL) – are critical to assure that the field tester measures the Permanent Link accurately and in full compliance with the latest industry standards. While the other test parameters in column 1 are important, especially the insertion loss measurement, they do not pose a significant challenge for the test equipment to produce accurate results.

Measured Test Parameter	Computed Test Parameter
Wiremap	
Propagation Delay	Length, Delay Skew
Insertion Loss (IL)	
Near-End Crosstalk (NEXT)	Power Sum Near-End Crosstalk (PSNEXT) Attenuation to Crosstalk Ratio (ACR) Power Sum ACR (PSACR)
Far-End Crosstalk (FEXT)	Equal Sevel Far-End Crosstalk (ELFEXT) Power Sum Equal Level Far-End Crosstalk (PSELFEXT)
Return Loss (RL)	

Table 1: Link Certification Test Parameters

Wiremap

Obviously, wire pairs must be correctly connected in order to provide signal continuity and verify any other transmission requirements. This test is not affected by the transition from Basic Link to Permanent Link.

Propagation Delay (length)

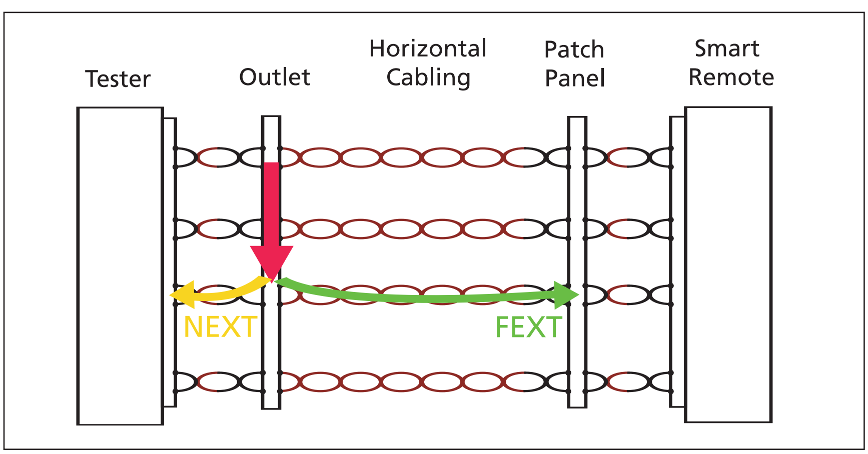
Length is derived from the propagation delay measurement – that is, the time required for the signal to travel the length of the link. Length (distance) is calculated from this time measurement by multiplying time and speed. The Nominal Velocity of Propagation (NVP) value of the cable characterizes the speed with which the electrical signals travel along the cabling. The speed of the signal is constant for a given cable construction. In order to deliver the length of the Permanent Link itself, the propagation delay of the test adapter cables must be characterized and applied as a constant correction factor to obtain the true Permanent Link measurements.

Insertion Loss

In earlier versions of the standards, this parameter was called "attenuation." Insertion Loss is a linear function of cable length; doubling the length also doubles the Insertion Loss. The field test tool should be able to apply a near-perfect correction for the loss contributed by adapter cables with well-known and constant length. This parameter will not cause any difficulty in measuring the Permanent Link configuration.

Crosstalk

Two sets of parameters measure the crosstalk performance of a link: Near-End Crosstalk (NEXT) and Far-End Crosstalk (FEXT). NEXT and FEXT occur simultaneously. NEXT is the crosstalk signal that "returns" on the affected wire pair to the transmitter side. The FEXT component of the crosstalk on the affected wire pair travels in the same direction as the transmitted signal to the far end of the link (see figure 2). The NEXT pair-to-pair measurements are performed between all of the pair combinations and from both ends of the link-under-test. The same rule applies to FEXT pair-to-pair measurements. NEXT and FEXT measurements pose challenging requirements to ensure full compliance with the goal statements for certification of the Permanent Link.



Figue 2: NEXT and FEXT

Return Loss

All current test standards require that Return Loss be measured and tested. Return Loss is a measure of the reflected energy – the echo signal – on each wire pair of a link. Return Loss is an important transmission characteristic when the cabling must be able to transmit in full duplex mode on each wire-pair. Gigabit Ethernet or 1000BASE-T uses full duplex transmission over all wire pairs simultaneously. So will the proposed 10Gigabit Ethernet or 10GBASE-T. All current standards (TIA Cat 5e, ISO Class D 1999, and later), TIA Cat 6 and ISO Class E) certify the cabling link for full duplex transmissions.

The signal reflection, or echo, is caused by changes in impedance along the cabling link. Any change in impedance along the wire pair causes a reflection of some amount of signal energy back in the direction of the transmitter. Return Loss represents the total signal echo on a wire pair. As a noise source, Return Loss is measured to assure the size of the reflected signal energy will not jeopardize the reliability of the transmission.

Impedance changes or impedance anomalies occur for several reasons:

- Imperfections within a twisted-pair cable (characterized by the structural Return Loss value of the cable itself)
- Mismatches between cables of different construction (solid core copper for the horizontal run versus the stranded construction of patch cables and equipment cords) and, potentially, different models and brands
- Mismatches between cable and connecting hardware
- Untwisting of wire pairs at the connector termination, which has a significant impact on Return Loss performance
- Separating the wire pairs. The impedance of a wire pair in the cable is affected by the proximity of the other wire pairs and metallic conductors such as shields
- Tight wraps of cable bundles. Bundles should be wrapped with devices that do not exert too much force on the cables within. Simple visual inspection can foretell problems, especially when physical deformation can be observed and the geometry of the original cable design is disturbed
- Sharp bends in the cable; these bends also disturb the original geometry of the cable design and the way in which the pairs are arranged in the cable

Patch cords have a significant influence on the Return Loss characteristics of a link.

Test adapter performance to meet Permanent Link test standards

Both crosstalk (NEXT) and Return Loss are challenging parameters under the new Permanent Link test standards.

NEXT and Return Loss have one characteristic in common: the closer the disturbance occurs to the end of the link from which the measurement is performed, the greater the influence of that disturbance on the measurement. A Return Loss example most simply illustrates this point. Assume we test a link with a poor quality connection at the consolidation point (CP). The wire pairs have been untwisted at the termination, and the connector itself creates a significant impedance change. The CP represents the worst contributor to Return Loss in the link-under-test. The CP is located 60 meters (approx. 200 feet) from the telecommunication room (TR) and 12 meters (40 feet) from the outlet in the work area. When we test the Return Loss from the TR, the stimulus signal travels 60 m to the CP and is attenuated in its travel. The impedance anomaly around the CP creates a 6% reflection that must travel back 60 m to the tester to be measured while the reflected signal also undergoes attenuation. When the tester measures the Return Loss from the other direction, the test stimulus signal travels 12 m to the CP. The reflected signal is again 6%, but this time the signal arriving at the problem point is approximately five times stronger (it traveled ⅕th of the distance). This reflected signal is now five times larger and must only travel 12 m (again ⅕th of the distance) to be measured by the tester. The reflected signal (measured as Return Loss) caused at the CP is now 25 times stronger compared to the Return Loss signal from this same CP when the link was measured from the end in the Telecommunication Room. Expressed in decibels, the Return Loss value measured closer to the problem point is 28 dB worse.

The test adapters are obviously very close to the measurement end of the link, which gives them a strong influence on the outcome. As mentioned earlier, this is also the case for the patch cords and equipment cords during normal network operation. The goal in adopting the Permanent Link model is to get an accurate measure of the performance of the installed link by itself (excluding any contribution from the test adapters), which is why special adapters and test techniques must be applied.

NEXT and FEXT measurements

1. **Exclude the test adapter contribution**

   The test adapter must not contribute any NEXT or FEXT disturbance to the measurements if the first goal of the Permanent Link measurement method is to be met. Fluke Networks has accomplished this goal with two complementary methods: (1) using high-performance cabling in the test adapter and (2) applying time-domain algorithms that allow the tester to identify the crosstalk – small as it may be – generated in the adapter cable and exclude this crosstalk from the final measurement value. Fluke Networks testers use extensive digital signal processing (DSP) power to provide time domain data. The results of this unique time domain capability can be seen in the diagnostics that locate sources of crosstalk along the link (HDTDX or high-definition crosstalk analysis).

2. **Interoperability**

   Interoperability is the second important goal of the Permanent Link test model. Interoperability ensures that completing the Channel with compliant patch cords creates a Channel that meets the desired performance level. The performance of the connections at the end of the Permanent Link has a significant impact on the NEXT, FEXT and Return Loss performance of the Channel. The Permanent Link test model therefore includes the connections formed between the terminating plug of the tester adapter and the link-under-test in the measurements of NEXT, FEXT and Return Loss. See figure 1 Permanent Link. The C2 and TO connections are part of the link-under-test). The Link NEXT outcome is very sensitive to the performance of the mated connection at the end of the Permanent Link. This observation demands that the plug at the end of the test adapter is a reference plug for the test standard to be applied for the link-under-test (for instance TIA Cat 6). The measurement with a well-defined plug ensures that the jack at the end of the Permanent Link provides interoperability with plugs of compliant patch cords. The test requirements for the Cat 6 Permanent Link explicitly state:

   > *Permanent Link adapter plugs shall meet the NEXT loss requirements specified in table E.3 for all pair combinations when measured in accordance with annex E*. Source: TIA-568-B.2-1 – Appendix B Test Instruments (Normative, required for Accuracy Level III), Paragraph B.1.2.1 Permanent Link adapter modular plug NEXT Loss. Table E.3 is entitled: Category 6 de-embedded test plug NEXT Loss ranges.

   Using standard commercial patch cords as test adapters cannot guarantee this requirement is satisfied. Even when standards-compliant components are used, the mated connection between plug and jack can vary as much as 3 dB. Fluke Networks has developed a unique and removable test plug (DSP-PM06) that meets the “center” definition for Cat 6 modular plugs as defined in Table E.3 of the referenced TIA document. The performance of these test plugs falls within a narrow window in the center of the range defined by the standards, making them suitable for laboratory applications. The narrow range of these PM06 plugs also assures excellent repeatability for link measurements.

The Return Loss measurement

The quality and Return Loss performance of the tester adapter cables have a significant impact on the accuracy and validity of the Return Loss test of the link. As mentioned, anomalies near the end of the link from which the test is executed have an overwhelming impact on the measurement results. The adapter cables are the closest element to the tester input port.

This effect of patch cables on the Return Loss measurement is the most significant reason to adopt the Permanent Link model for testing the installed cabling links. This model prescribes that any contribution made by the tester patch cables be excluded in order to obtain the true performance of the link-under-test. The Permanent Link interface adapter itself must have very good Return Loss characteristics. The following three conditions describe “very good Return Loss” characteristics for test adapters:

(1) Impedance (differential): very close to 100 Ohm

(2) Very good Return Loss performance

(3) Stability: Stable impedance characteristic over time (after coiling and uncoiling to pack the tester)

Commercial patch cords may start out with reasonably good Return Loss performance, but they do not meet the longer-term stability requirement expressed in item 3. The Return Loss performance of any twisted-pair patch cord continuously degrades due to handling, coiling, storing and uncoiling. No treatment can recover this degradation in performance; it is a one-way slope. The accuracy of the Return Loss measurement is in serious jeopardy when the patch cable "through" which the tester evaluates the Return Loss performance of the fixed installation is itself a major source of significant reflections. A patch cord does not give any physical warning signs that the Return Loss has deteriorated beyond acceptable limits to provide accurate link measurements.

As part of the earlier development work at Fluke Networks, engineers evaluated many commercially available stranded patch cables against the three criteria stated above. Most of the cables evaluated were Cat 7 or Class F patch cords with individually shielded wire-pair construction referred to as PiMF (pair in metal foil) or SSTP (shielded screened twisted pair) cable.

The samples were wound on a drum approximately 6 inches in diameter, then unwound and rewound a number of times. The cable Return Loss was measured after 50, 100 and 200 winding operations. Figure 3 shows the Return Loss deterioration of one of the better performing commercial cable samples. As the figure illustrates, the Return Loss of this sample when subjected to 200 windings dropped 10 dB, rendering it no longer suitable to meet the accuracy requirements for Level III Return Loss tests. (Accuracy Level III expresses the tester and adapter requirements to meet the accuracy performance for Cat 5e and Cat 6 links).

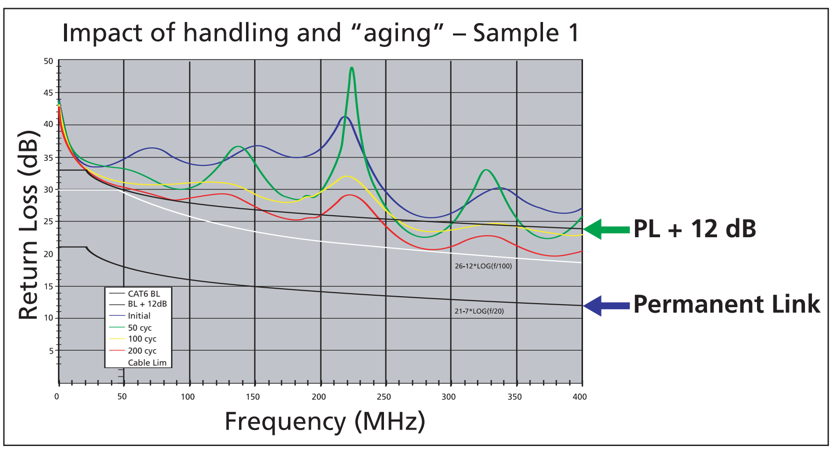


Figure 3: The different link models for testing.

To solve these demanding tester accuracy requirements, Fluke Networks developed a proprietary cable for use in the Permanent Link adapters. A second-generation cable is now available. These proprietary cables exhibit high Return Loss performance in addition to superior NEXT and FEXT characteristics. These cables will also show some minor deterioration over time. The beauty of the connector to accommodate the removable test plug (DSP-PM06) is that a calibration artifact can be connected in the place of the PM06. This allows the contractor's technician to execute a simple calibration procedure that restores the Return Loss measurement capability of the tester and adapter to "new." The calibration artifact (DSP-PLCAL) is available from Fluke Networks; the test procedure is supported in LinkWare™, the test results management software package provided with every Fluke Networks certification tester. Fluke Networks recommends the adapters be calibrated approximately every six months.

Conclusion

The advantage of the Permanent Link test model is it assures the fixed cabling infrastructure meets its intended transmission performance level and interoperability with other standards – compliant components is achieved. One of the major benefits of certifying a cabling installation this way is the ability to exchange or replace patch and equipment cords without having to certify the Channel for compliance. This holds true as long as the patch cords are tested to meet the appropriate performance level. (Testing patch cords will be the subject of a future article in this series).

At the same time, the Permanent Link test model creates new challenges to obtain accurate and valid test results. Fluke Networks provides flexible, easy-to-use Network SuperVision™ Solutions that assure new insight and the highest accuracy in Permanent Link testing performance. We anticipate evolving requirements and design our solutions to stay on top of industry standards so that our users do, too.

NETWORKSUPERVISION

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