COPPER CABLING TROUBLESHOOTING HANDBOOK

FLUKE networks

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INTRODUCTION

“Certification” is the process of comparing the transmission performance of an installed cabling system to a standard using a defined method of measuring the performance. Certification of the cabling system demonstrates component quality and installation workmanship. It is typically a requirement to obtain the cabling manufacturer’s warranty. Certification demands that the cabling links yield a “Passing” result. Technicians must diagnose the failing links and after a corrective action has been implemented they must retest to ensure the link meets the required transmission performance. The total time to certify an installation does not only include making the certification measurements but also documentation and troubleshooting.

Today’s cabling installation professionals must therefore know how to troubleshoot and diagnose high-performance cabling systems.

Why the need for advanced diagnostics?

As newer high-performance cabling systems have been developed and deployed, every aspect of the installation demands a higher level of skill and more attention to detail. New test parameters have been added. The links must be tested using one of two link models, the Permanent Link or the Channel and the links are tested and evaluated over a greater frequency range and with more data points. The components with which these links are constructed need to deliver better performance and the quality of the workmanship during installation must rise accordingly.

Due to the increased complexity of these cabling systems, determining the cause of failure and quickly restoring suitable performance has become a challenging task. This handbook guides you through the troubleshooting of advanced structured cabling systems using the Fluke Networks DSX-600 CableAnalyzer™ so you can increase your productivity and deliver better value to your organization.

Troubleshooting basics

Most common causes of failures in twisted pair cabling:

1. Installation errors: failure to make proper connections while maintaining the wire pairs and the twist rate in each pair (always keep the "original twist" in each wire pair as much as practical)
2. Connectors that do not meet the required transmission quality
3. Incorrect tester set up
4. Defects or damage in the installed cable
5. Bad patch cords*

* Patch cords rate high on the list when we are discussing operating networks. Certification is often executed using the Permanent Link Model since the actual patch cords used by the operating network are not yet installed or available.

Before you begin testing, you should verify the basics:

- Has the correct test standard been selected? The certification test is executed as an automated test or an “Autotest”. The test standard you select for an autotest determines the link model (Permanent Link or Channel), the test parameters to be measured and the frequency range over which the tests are executed and the Pass/Fail criteria for each test.
- Has the correct link model been selected?
- Are you using the appropriate test adapter with a plug that matches the jack in the telecommunication outlet (TO) or the patch panel?
- Has the test reference been set in the last 30 days? It is recommended to set the reference on a regular basis and at a time that is easy to remember. (Such as at the beginning of each testing session)
- Are you using the most current version of the tester software?
- Is the NVP set correctly for the cable under test? NVP plays a role when the tester reports length or distance to a defect
- Is the tester within its operating temperature range and in calibration?

Remember that your Fluke Networks DSX-600 CableAnalyzer™ is a very accurate instrument that measures small noise disturbances in cables. These instruments are calibrated in the factory before shipping and this calibration should be verified every 12 months in an authorized Service Center. If the tester has been stored in a colder or warmer place than the one in which you are working (i.e. overnight in a vehicle), allow the unit to warm up to its steady-state operating temperature before setting a reference or executing any measurements. This may take 10 to 15 minutes or more depending on the temperature differential.

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Link models

To obtain meaningful results, it is essential to select the appropriate autotest and link model.

Permanent Link

The Permanent Link performance is defined in such a way that after adding good patch cords to a passing link, the channel performance is automatically met. By good patch cords, we mean patch cords that pass the same class or category rating as the link or a higher level of performance.

For this reason, it is recommended that new cabling installations are certified using the Permanent Link model and test standard. Patch cords and equipment cords may be changed many times during the life of the permanent link.

The maximum allowed length of the Permanent Link is 90 meters. This link is most often used by installers to prove the fixed portion of the cabling system (excluding user cords) meets the requirements of ANSI/TIA/EIA-568 or ISO/IEC 11801. The cabling vendor offering the warranty will require this. If you see an installer making these measurements using Channel adapters, you may wish to stop them and ask why they are not making Permanent Link measurements.

The Permanent Link shown in figure 1 includes an optional Consolidation Point. Other Permanent Link models may have a second patch panel instead of the TO which is typically seen in a Data Center. The Permanent Link measurement includes the RJ45 plug at the end of the test lead, but does not include the cable portion of the test lead or connection to the test equipment (see figure 1). In the case of the DSX Permanent Link adapters, the RJ45 plug is guaranteed to meet the NEXT, FEXT and Return Loss requirements of the earlier mentioned standards. The cable portion of the test lead is removed from the measurement using calibration constants stored in the adapter.

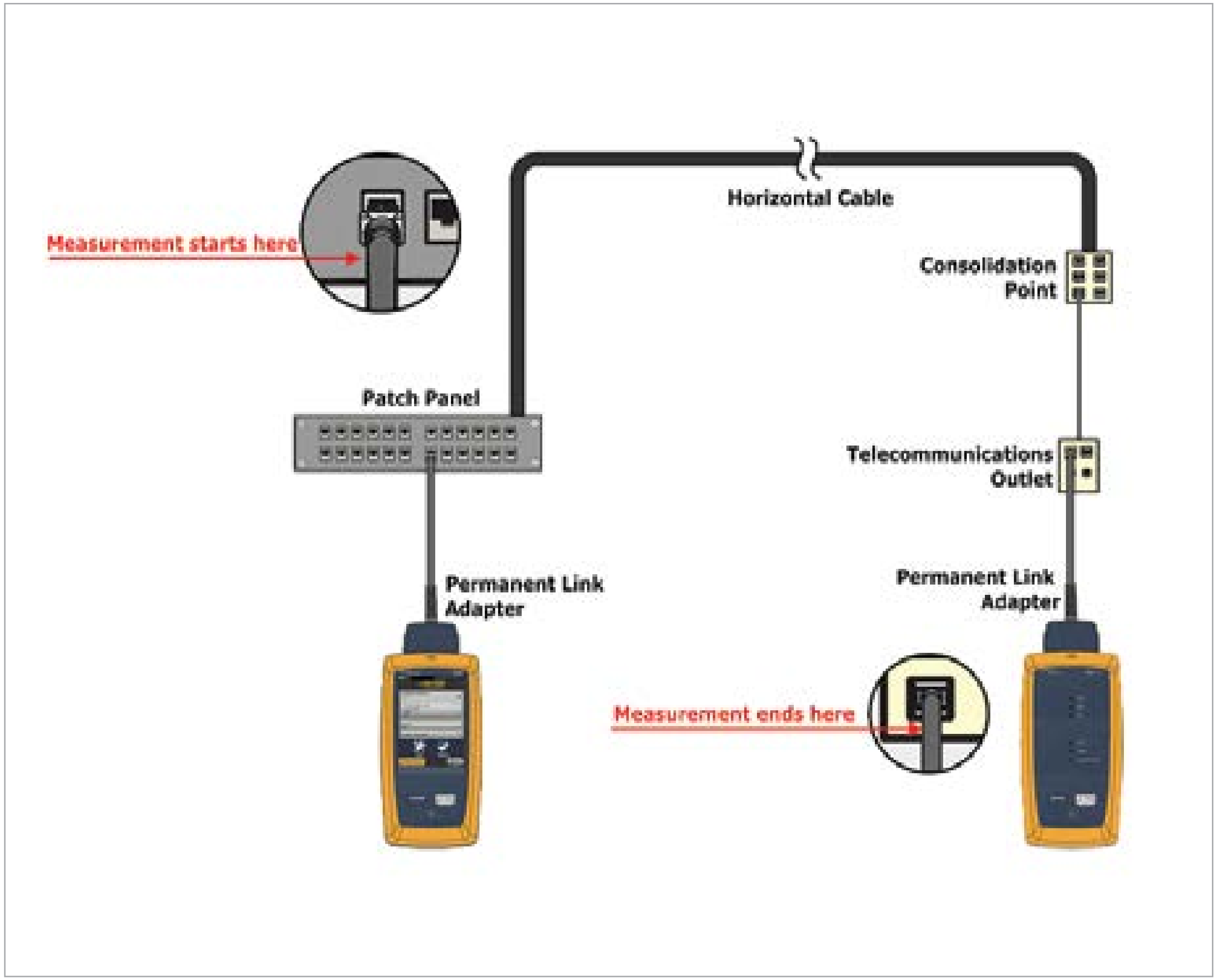


Figure 1

Another Permanent Link configuration that's being seen more often nowadays is the Modified Permanent Link. This is not recognized in TIA or ISO/IEC, but is supported in ANSI/BICSI-004. The Modified Permanent Link is used to asses a horizontal link that results in a direct connection to equipment like a PoE (Power over Ethernet) Wireless Access point or CCTV camera. To assess this type of link the TIA Permanent Link test limit must be used. The main tester must be connected via a Permanent Link adapter to the patch panel. A Channel adapter on the remote unit at the remote end must be used to connect the RJ45 plug of the direct connection.

Channel

Channel measurements are typically performed when restoring a service or to verify the existing cabling for application support. The maximum length allowed for a Channel is 100 meters. It is uncommon to perform Channel tests at the conclusion of a new installation, since the patch cords that belong to each link are rarely available at that time. Correct Channel measurements must cancel the effects of the mated connection in the tester's channel adapters as seen in figure 2, which also shows the optional consolidation point we saw in the Permanent Link. The same Data Center and Direct equipment links also exist for the Channel.

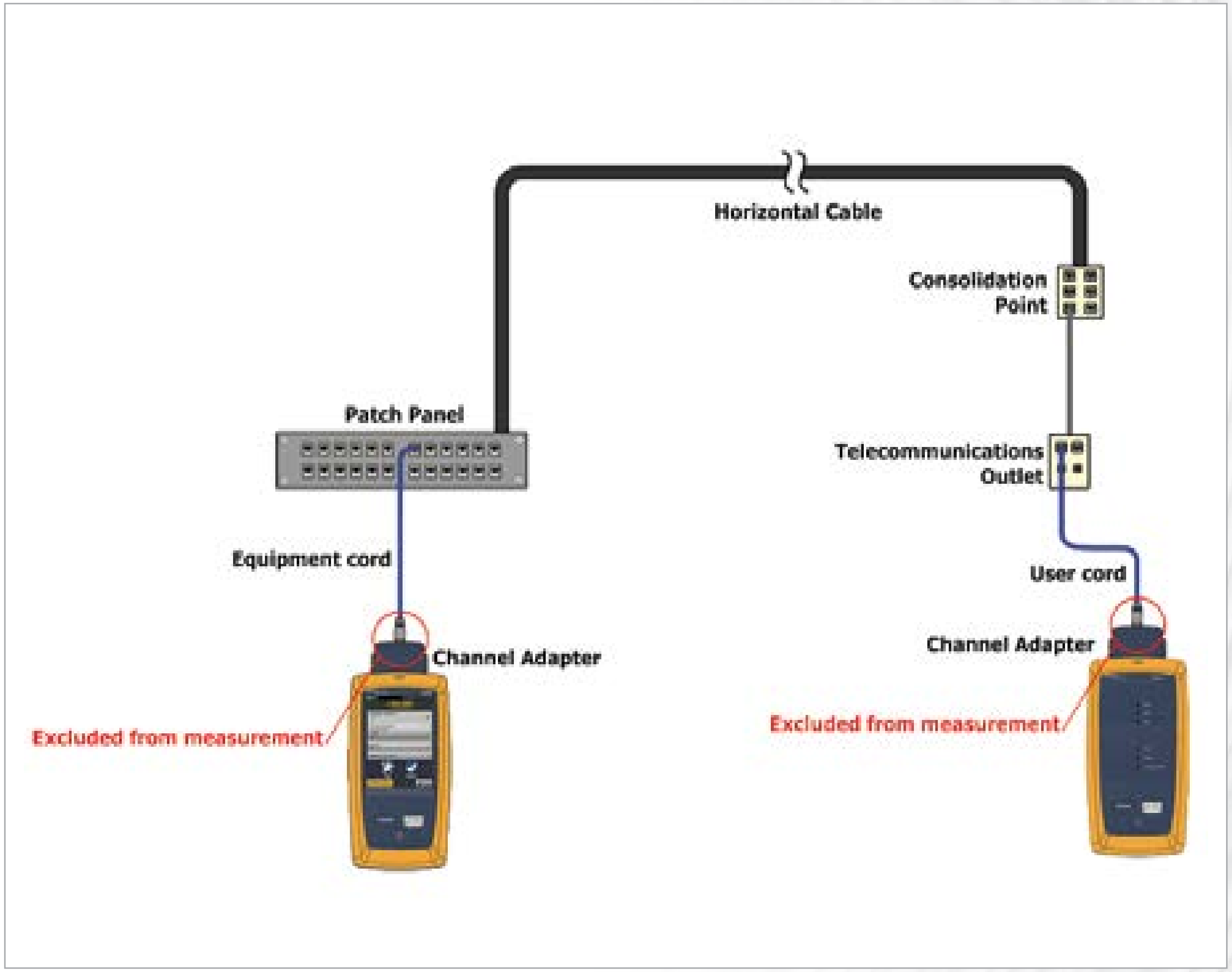


Figure 2

The automated DSX-600 diagnostics

When an Autotest fails or delivers a “marginal” pass result, the DSX-600 can use its diagnostic capabilities to find the cause of the marginal failures.

First, let us review what a marginal test is. The margin of a test is the difference between the measured value and the applicable Pass/Fail limit value. The margin is positive when the test passes, negative when the measurement fails and zero when the measured value is equal to the limit value. A greater margin indicates that the result is further away from the limit line. A larger positive margin therefore indicates a better test result. A very small margin means that the test result is close to the limit value. A test result is called marginal when its margin is less than the accuracy specification of the instrument for the test parameter.
For example, in figure 3, the Return Loss accuracy is ±1.79 dB @ 22.5 MHz and the worst case margin of a link at 22.5MHz was 0.4 dB. This Return Loss result at 22.5 MHz is considered very close to the limit and is called a marginal test

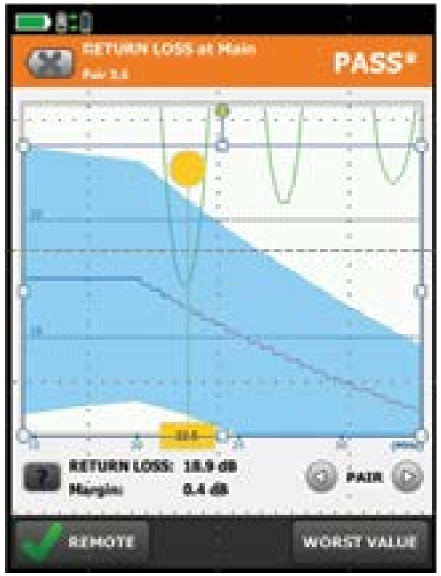


Figure 3. Shows result for worst pair where the screen has been zoomed to show the result in more detail. For this TIA Cat 5e Permanent. Link Return Loss accuracy is ±1.79 dB @ 22.5 MHz. The margin was 0.4 dB so the result has fallen within the accuracy band and therefore is marked PASS

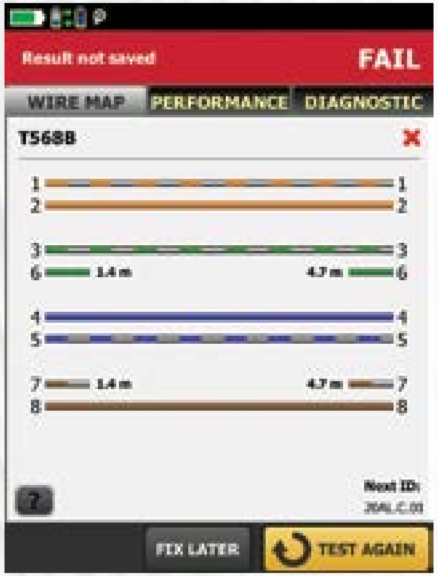


Figure 4. Shows a wire map failure on wires 6 and 7. Both are open at 1.4 m from the near end and 4.7 m from the far end, suggesting the cable has been severed or not connected at the same points. Inspect the link at these points to identify the issue

result. A marginal PASS is indicated by PASS. In this situation, the tester can be set up to perform HDTDR and HDTDX tests showing diagnostics information to help identify and point out what may have caused this marginal result. This information provides the opportunity to quickly locate the problem, correct it, and deliver a link with good performance. For more information, see the section that discusses HDTDR and HDTDX diagnostics.

If the cabling link fails to pass the wire map test—the test which verifies that all 8 wires connect the right pins at either end of the cable—the tester halts and presents a window saying 'Warning Bad Wire Map". If you press OK, then the wire map diagram is shown with the option to turn 'SCAN ON' which may help find intermittent connection, or 'FIX LATER' which enables you to save the results then go to then next link to be tested. Alternatively, you can 'CONTINUE' which continues the test with the bad wire map, this may allow you to find other issues to help you troubleshoot the problem in the link. Figure 4 shows such a wire map failure. The DSX-600 main unit is always assumed at the left hand side of these screens, i.e. the near end. The wire map diagram shows Wire 6 of pair 3/6 and Wire

7 of pair 7/8, both are open at 1.4 Meters at the near end and 4.7 Meters from the far end. The software halts and asks the operator whether or not to continue the test. It often makes more sense to tackle the wire map error before continuing the test. The open wire causes the results for some test parameters to fail. In this case we continued and the DSX shows a FAIL. At this point we could inspect the link at 1.4M from the near end to discover the cause of the failure. We could also select the DIAGNOSTICS tab which enables us to see the results of the HDTDR or HDTDX results.

Shield integrity test

Wire Map testers use DC Resistance measurements to ensure the shield is correctly terminated and presented in a cabling system. In Data Centers, where the shield is typically grounded at both ends, any wire map tester will report the shield as connected, even if one of the ends is not. That's because the shield test is a simple DC Resistance measurement. If the shield is open, it will find the remote unit using the building ground (earth) or the shields of other cables. See figure 5. This can result in a false PASS and poor Alien Crosstalk performance.

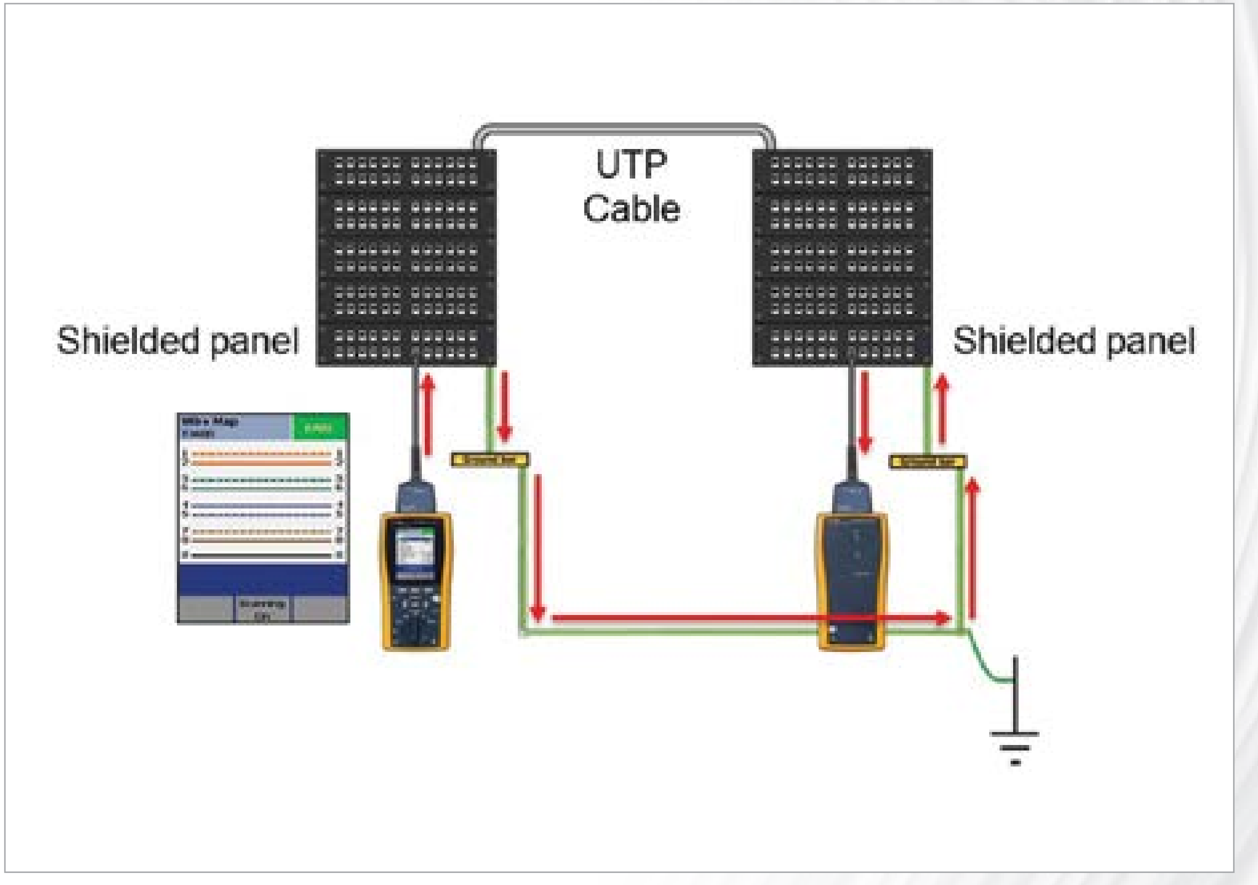


Figure 5. Alternate electrical paths, such as through the building ground (earth) can cause some testers incorrectly report the shield is properly connected

Using TDR techniques, the DSX-600 can prevent false passes when checking shield continuity in a data center with common grounds.

See figure 6. (S = Shield).

The automated link diagnostics save time and costs over trial and error techniques that usually include the re-terminating of wiring and/or replacing of connecting hardware in several locations in order to get a failing link to pass. The section on advanced troubleshooting techniques will show you how you can obtain and interpret the underlying diagnostic information generated by the tester's analysis algorithms. To find out more about these diagnostic capabilities let's have a look at the HDTDR and HDTDX capabilities of the DSX-600.

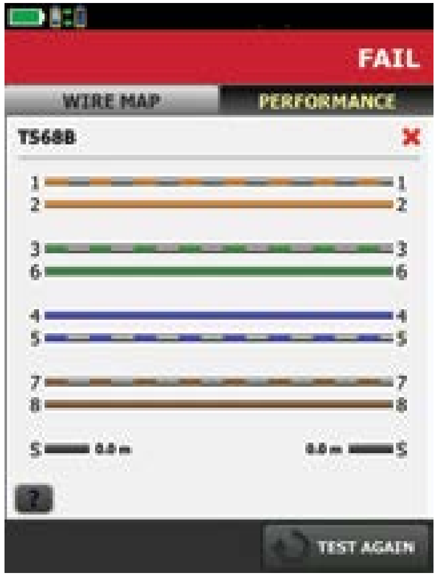


Figure 6. The DSX-600 CableAnalyzer can make Shield integrity measurements using TDR techniques that can prevent false shield test passes

Advanced troubleshooting diagnostics

The DSX-600 diagnostics discussed above represent a distillation of a more complex analysis of the test results data. In this section we will go into more detail about the diagnostic analysis of link failures. Knowledge of the advanced diagnostics techniques may help you to distinguish cases in which the automated diagnostics fall short. The basis of the tester's ability to report the distance to a location along the link-under-test where crosstalk is excessive or where Return Loss is excessive, is the conversion of the test results data collected in the frequency domain to the time domain. The DSX-600 executes this conversion using unique and patented digital signal processing techniques. The data in the time domain is in turn converted to a profile of the measured disturbance along the length of the link.

The two parameters that provide the time domain information are HDTDX (High Definition Time Domain Crosstalk) and HDTDR (High Definition Time Domain Reflectometry). As the name indicates, the HDTDX parameter shows the profile of crosstalk happening along the link-under-test while HDTDR shows signal reflections along the link. Impedance changes cause signal reflections that contribute to the measured Return Loss value. If these reflections become too big and the total amount of energy reflected exceeds the maximum amount allowed, the Return Loss test fails.

Figure 7. Return loss failure with worst pair 7/8 reporting -2.0 dB margin @ 4.9 MHz

Figure 8. HTDR showing Return loss issues along the whole cable

HDTDR diagnostics

In figure 7, we see a Return Loss failure at the remote end, so how do we go about identifying the problem? First we identify the worst pair for return loss. In this example the worst pair is pair 7/8. The worst pair result is 19 dB - that's -2.0 dB Margin at 4.9 MHz. But if we examine the graph in more detail, we see that all the failures are below 50 MHz. This often suggests a cable issue.

Now let's run the HDTDR diagnostics, the results of which are shown in figure 8. First let's find and view the worst pair which was pair 7,8. Now let's pinch and zoom on the vertical axis to see the 1% horizontal grid lines in greater detail. Events should not exceed 0.8% so we have drawn red lines on the diagram to make it easier to see which and how many events pass the 0.8% lines. No more than four events maximum should pass over the red lines. In the case we have many along the whole length of the cable going in the positive and negative direction. This would suggest we have a cable issue as we have many reflective events all along the cable. This would mean we would have to replace the cable.

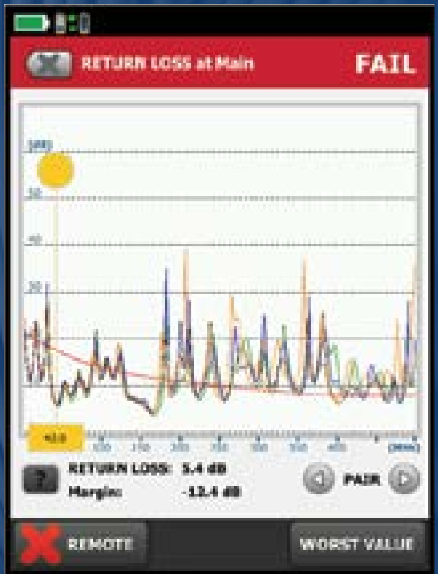


Figure 9. Return Loss failures on all pairs at the low frequencies

Figure 10. The HTDR analysis shows Return Loss at the beginning of the cable for all four pairs, usually a characteristic of water in the cable

In figure 9, we see another Return Loss failure, but this time from the main unit or near end. If we examine the graph we find that all four pairs fail and the failures are especially bad at the lower frequencies. The worst Return Loss for all four pairs is at 5.4 dB with a really bad margin of -12.4 dB at 42MHz. This often suggests water in the cable.

So let's make a HDTDR diagnostic measurement on this link to see if it can tell us where the water is. We can see the results in figure 10. The results show most of the Return Loss is happening within the first six meters of the cable. The first event where the water begins is normally in the region of 6% to 15%. In this case, we would have to replace the cable and solve the reason for the water getting in it.

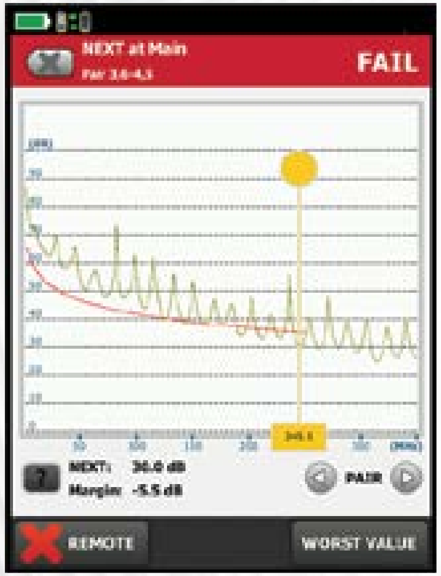


Figure 11. NEXT worst pair shows a NEXT failure of -5.5 dB margin @ 245.5MHz on Pair 3,6 -4,5.

Figure 12. HDTDX showing connectors at the start and middle of the link

HDTDX diagnostics

In figure 11, we see a NEXT (near end crosstalk) failure. Once again we identify the worst case pair. In this case is 3,6-4,5. If we examine the NEXT graph we see the worst case NEXT is 30.0 dB with -5.5 dB margin at 245.5 MHz. So let's do the HDTDX diagnostic test and view the worst pair 3,6-4,5 and seen in figure 12.

On analyzing the HDTDX trace we see two pulses, one at the beginning 0.0 meters, one in the middle at 6.0 meters and the end of the cable is at 11 meters, this showing us the connectors in the link. Connectors should ideally be no worse than 30% on links less than 15 m (50 ft.). We have drawn a horizontal line on the HDTDX graph at

30% so it's easier to see where 30% has been exceeded. The first connection clearly exceeds 30%. The pulse in the middle of the graph also exceeds 30%, so clearly shows another connector in the middle of the link at 6.0 meters. This is not ideal! In addition, we see some aberrations between the first and second pulse. This indicates NEXT along the cable, maybe the cable has been damaged. Events in the cable should ideally not exceed 10%. If they do, there should be no more than four of them. Any which way, it looks like we should recommend replacing this whole link to eradicate the middle connector and maybe improve the NEXT because of the potentially damaged cable.

In the next example, shown in figure 13, we see another NEXT failure. Once again we look for the worst case NEXT margin failure pair. In this example it's pair 3,6-4,5. Typically it's always 3,6-4,5 that exhibits the worst case NEXT, by the nature of the construction of the cable.

Figure 13. Next failure at -6.0 dB Margin @ 267.0 MHz on Pair 3,6 -4,5

Figure 14. HDTDX shows crosstalk all along the cable

This time we have a NEXT of 28.9 dB with a margin of -6.0 dB at 267.0 MHz. So to find out where this is happening along the cable, we need to run the HDTDX diagnostic test. We see the results for this on figure 14. Again we view the worst pair 3, 6-4,5 and we see the far end connector far exceeds the ideal of 30%, it's nearly 60%. So, we could re-terminate the connector which may allow the link to pass. However, if we further analyze the HDTDX trace, we also see that there are many aberrations along the cable that exceed our ideal 10%. So the likely recommendation would be to change the cable which would also mean remaking the far-end termination. This should now result in a NEXT PASS.

Causes of cabling faults

For each of the required TIA and ISO structured cabling measurements, you will find troubleshooting tips to help quickly pinpoint the cause of failures when they occur. In some instances, you will find suggested reasons why the measurement does not fail in cases you would expect to see a failure.

Wiremap

Wiremap test result	Possible cause of result
Open	Wires broken by stress at connections
	Cables routed to wrong connection
	Wire is not punched down properly and does not make contact in the IDC
	Damaged connector
	Cuts or breaks in cable
	Wires connected to wrong pins at connector or punch block
	Application-specific cable (e.g. Ethernet using 1,2/3,6 only)
Short	Improper connector termination
	Damaged connector
	Conductive material stuck between pins at a connection
	Damage to cable
	Application specific cable (e.g. factory automation)
Reversed pair	Wires connected to wrong pins at connector or punch block
Crossed pair	Wires connected to wrong pins at connector or punch block
	Mix of 568A and 568B wiring standards (1,2 and 3,6 crossed)
	Crossover cables used (1,2 and 3,6 crossed)
Split pair	Wires connected to wrong pins at connector or punch block

Length

Test result	Possible cause of result
Length exceeds limits	Cable is too long—check for coiled service loops and remove in this case
	NVP (nominal Velocity of Propogation) is set incorrectly
Length reported is shorter than known length	Intermediate break in the cable
	NVP is set incorrectly
One or more pairs significantly shorter	Damage to cable
	Bad connection

Delay/Skew

Test result	Possible cause of result
Exceeds limits	Cable is too long—Propagation Delay
	Cable uses different insulation materials on different pairs—Delay Skew

Insertion Loss (Attenuation)

Test result	Possible cause of result
Exceeds limits	Excessive length
	Non-twisted or poor quality patch cables
	High impedance connections—use time domain techniques to troubleshoot
	Inappropriate cable category—e.g. Cat 3 in a Cat 5e applications
	Incorrect autotest selected for cabling under test

NEXT and PSNEXT

Test result	Possible cause of result
FAIL or PASS*	Poor twisting at connection points
	Poorly matched plug and jack (Category 6/Class E applications)
	Incorrect link adapter (Cat 5 adapter for Cat 6 links)
	Poor quality patch cords
	Bad connectors
	Bad cable
	Split pairs
	Inappropriate use of couplers
	Excessive compression caused by plastic cable ties
	Excessive noise source adjacent to measurement
Unexpected PASS	Knots or kinks do not always cause NEXT failures, especially on good cable and far removed from the ends of the link
	Incorrect autotest selected (e.g. "Bad" Cat 6 link tested to Cat 5 limits)
	"Fails" at low frequency on NEXT graph but passes overall. When using the ISO/IEC standards, the so called 4dB rule states all NEXT results measured while insertion loss <4dB cannot fail

Return Loss

Test result	Possible cause of result
FAIL or PASS*	Poor twisting at connection points
	Poorly matched plug and jack (Category 6/Class E applications)
	Incorrect link adapter (Cat 5 adapter for Cat 6 links)
	Poor quality patch cords
	Bad connectors
	Bad cable
	Split pairs
	Inappropriate use of couplers
	Excessive compression caused by plastic cable ties
	Excessive noise source adjacent to measurement
Unexpected PASS	Knots or kinks do not always cause NEXT failures, especially on good cable and far removed from the ends of the link
	Incorrect autotest selected (e.g. “Bad” Cat 6 link tested to Cat 5 limits)
	“Fails” at low frequency on NEXT graph but passes overall. When using the ISO/IEC standards, the so called 4dB rule states all NEXT results measured while insertion loss <4dB cannot fail

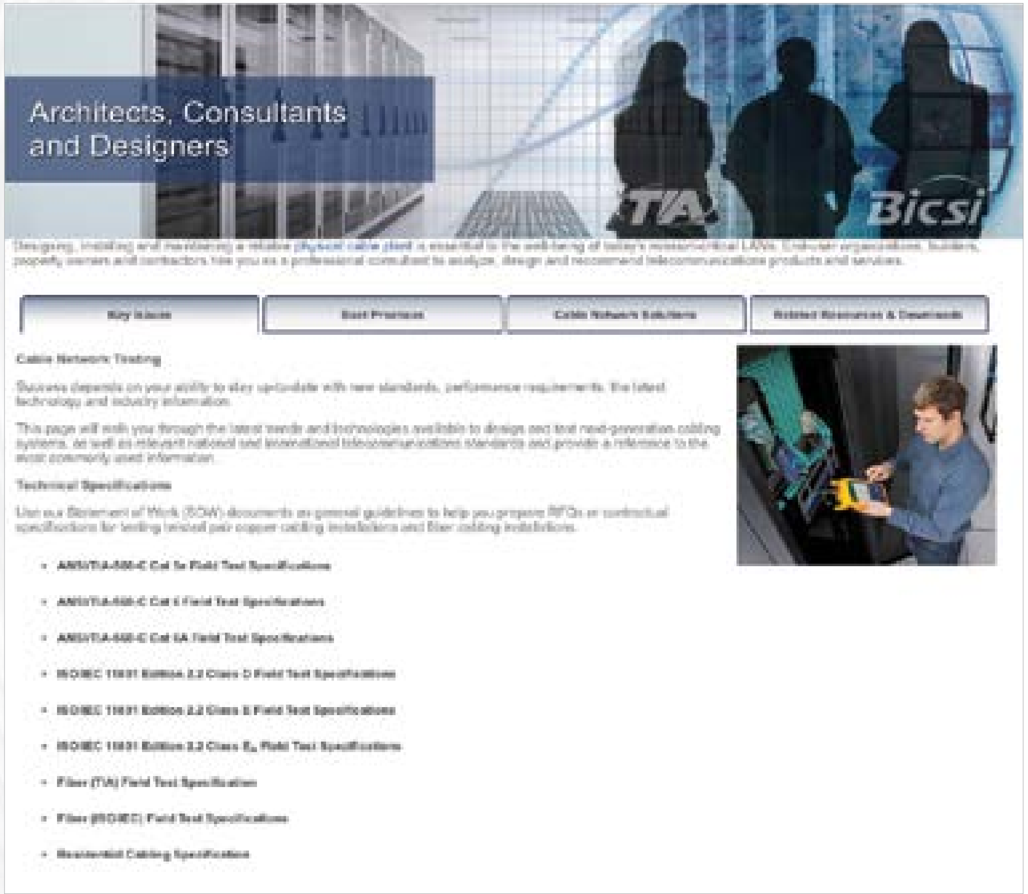
ACR-F and PS ACR-F (older names: ELFEXT and PSELFEXT)

Test Result	Possible Cause of Result
FAIL or PASS*	General rule: troubleshoot NEXT problems first. This normally corrects any ACR-F (ELFEXT) problems
	Service loops with many tightly coiled windings

Resistance

Test Result	Possible Cause of Result
FAIL or PASS*	Excessive cable length
	Poor connection due to oxidized contacts
	Poor connection due to marginally attached conductors
	Thinner gauge cable
	Incorrect patch cord type

Architects, consultants and designers pages



Consult the Fluke Networks web page for product information as well as updates in standards or white papers on best practices.

Go to www.flukenetworks.com/expertise/role/Architects-Consultants-Designers

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CONCLUSION

Cabling installation is a multi-step process. Components such as racks, patch panels, outlets and cable are delivered to the job site. The final product is “assembled” on site. It is a prudent practice to certify the cabling system after installation to ensure that all installed links meet their expected level of performance. The testing phase will very likely deliver some failing or marginally passing results. In order to deliver a high quality cabling system, the defects that cause the failures and marginal passes must be uncovered and corrected.

The Fluke Networks certification test tools have always provided unique and powerful diagnostics assistance to installation technicians. By knowing the nature of typical faults, and how the tester’s diagnostics report them, you can significantly reduce the time to correct an anomaly, an installation error or a defective component. Personnel responsible for the networks operation can also benefit from the diagnostic capabilities of a certification test tool; with the tester’s assistance they can limit the duration of network downtime and restore service quickly.

Familiarize yourself with the capabilities of your test tool, a modest investment that pays for itself many times over.

For the latest information on cable testing standards, news, and issues, visit Fluke Networks:

Web site: www.FlukeNetworks.com

Blog: www.flukenetworks.com/blog/cabling-chronicles

Enroll in a local Fluke Networks CCTT (Certified Cable Technician Training): www.flukenetworks.com/content/certified-cabling-test-technician-training-program.

CableAnalyzer comparison guide

The DSX-600 provides essential Cat 6A and Class EA Copper Certification featuring ten second test times and advanced user interface. Manage jobs and testers from any smart device over Wi-Fi with LinkWare™ Live. Features legendary Fluke Networks reliability backed by worldwide support.

Feature	DSX-600 CableAnalyzer™	DSX-5000 CableAnalyzer™	DSX-8000 CableAnalyzer™
Description	Essential Cat 6A and Class EA copper tester	Cat 6A and Class FA copper tester	Fastest, most accurate Cat 8 and Class I/II copper cable tester
Cat 3 – Cat 6A/Class EA	✓	✓	✓
Cat 6A/Class FA	✓	✓	✓
Cat 8/Class I/II	✓	X	✓
Maximum frequency	500 MHz	1000 MHz	2000 MHz
Autotest time	10 sec Class EA /Cat 6A 9 sec Class E/Cat 6	10 sec Class EA /Cat 6A 9 sec Class E/Cat 6	16 sec Cat 8 / Class I/II 8 sec Class EA/Cat 6A 7 sec Class E/Cat 6
Shield integrity test	✓	✓	✓
Permanent link adapter	Optional	✓	✓
Advanced fault info troubleshooting	X	✓	✓
PoE resistance unbalance	X	✓	✓
Integrated alien crosstalk capability	X	✓	✓
Coax adapters	Optional	Optional	Optional
M12 adapters	Optional	Optional	Optional
Patch cord adapters	X	Optional	Optional
Fiber—OLTS, OTDR and inspection	X	Optional	Optional

Ensure the fiber-based network goes up and stays up!

For additional resources to help you establish Fiber Testing Best Practices Visit: **www.flukenetworks.com/FBPPG**

For additional resources to help you establish Copper Testing Best Practices Visit: **www.flukenetworks.com/CBPPG**

Fluke Networks
P.O. Box 777, Everett, WA
USA 98206-0777

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