DSP-PCI-6S
DSP-SPOOL

Patch Cord and Cable Spool Test Interface Adapters

Users Manual

November 2002, Rev. 1 3/03

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Fluke Networks
PO Box 777
Everett, WA 98206-0777
USA

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DSP-PCI-6S
DSP-SPOOL
Patch Cord and Cable Spool Test Interface Adapters

Introduction

The DSP-PCI-6S Patch Cord Test Adapters and DSP-SPOOL Cable Spool Interface Adapters let you use a DSP-4000 Series test tool to test patch cords, cable spools, and cable segments in accordance with the following standards:

- The DSP-PCI-6S adapters test Category 6 patch cords and cable in accordance with the TIA/EIA-568-B.2-1 Category 6 and IEC 61935-2 standards. These adapters, which meet backwards-compatibility requirements, also test Category 5 and 5e patch cords according to TIA/EIA and IEC standards.
- The DSP-SPOOL adapter tests spools of Category 5, 5e, and 6 cable for NEXT and return loss. With two DSP-SPOOL adapters, you can test 100 m samples of Category 5, 5e, and 6 cable in accordance with the standards mentioned above.

Notes

Test standards are subject to amendments. Contact the Telecommunications Industry Association (TIA) for detailed information on standards. Contact Fluke Networks for general information on standards and for DSP software updates that may result from changes to standards.

The Cat 5 standards in TIA/EIA-568-A and ISO/IEC-11801-2000 are considered obsolete and have been replaced by the Cat 5e requirements in TIA/EIA-568-B and the Cat 5/Class D requirements in ISO/IEC-11801-2002, respectively.

The patch cord adapters feature special test jacks selected specifically for testing Cat 6 patch cords as specified in TIA/EIA-568-B.2-1.

Unpacking

The DSP-PCI-6S Patch Cord Interface Adapter Set comes with the following:

- One DSP-PCI-M6 patch cord test adapter for the main DSP-4x00 unit
- One DSP-PCI-R6 patch cord test adapter for the remote DSP-4x00 unit
- DSP-PCI/DSP-SPOOL Test Interface Adapters CD-ROM
- Test specification database (on CD-ROM)

The DSP-SPOOL Cable Spool Interface Adapter comes with the following:

- One DSP-SPOOL cable spool interface adapter
- DSP-PCI/DSP-SPOOL Test Interface Adapters CD-ROM
- Test specification database (on CD-ROM)

If anything is missing or damaged, contact Fluke Networks immediately.

Contacting Fluke Networks

Visit the Fluke Networks website at **www.flukenetworks.com**. Send email to **support@flukenetworks.com**.

For operating assistance in the USA, call 1-800-283-5853.

To order accessories or get the location of the nearest Fluke Networks distributor or service center, call:

- USA: 1-888-99-FLUKE (1-888-993-5853)
- Canada: 1-800-363-5853
- Europe: +44 1923 281 300
- Beijing: 86 (10) 6512-3435
- Japan: +81-3-3434-0181
- Singapore: +65-6738-5655
- Anywhere in the world: +1-425-446-4519

Visit our website for the latest list of phone numbers.

Getting LinkWare Software

LinkWare™ Cable Test Management Software lets you install the DSP-4x00 test specification database in your DSP units and upload test results to a PC for analysis and archiving. LinkWare has replaced the CableManager™ software that may have been included with your DSP tester. You may download LinkWare at no charge from the Fluke Networks website.

DSP-4x00 Software Requirements

To use the DSP-PCI or DSP-SPOOL adapters you may need to update the software in your main and remote DSP units. You will also need to install the DSP-PCI/DSP-SPOOL test specification database in the main and remote units.

DSP-4x00 Software Version Requirements

The DSP-4x00 must have at least the following software versions:

- DSP-4000: version 3.9 or higher
- DSP-4100: version 4.9 or higher
- DSP-4300: version 1.9 or higher

To determine the software versions in your main and remote units, do the following:

1. Connect the main and remote units together with the calibration module.
2. Turn on the remote unit; then turn on the main unit and look at the version information on the startup display.

   You can also view this information by selecting Version Information from the SPECIAL FUNCTIONS menu.

The latest software versions are available at no charge on the Fluke Networks web site. Use LinkWare software to load new software into the DSP-4x00. See the online help in LinkWare for instructions.

Installing the DSP-4x00 Test Specification Database

The special patch cord database supplied on the CD must be installed in the DSP-4x00 main and remote units to test patch cords or cable spools. You can also download the database from the Fluke Networks website. The database is subject to change in response to changes in approved TIA and IEC standards. Check the Fluke Networks website regularly for updates.

To see if a DSP-4x00 main unit has the special test specification database, look for patch cord limits in Setup. To check a remote unit, note the version number of the patch cord database in a main unit; then use the steps given in the previous section to check the database version in the remote unit.

If the special test specification database has not been loaded into your DSP-4x00 main and remote units, load this database as follows:

Notes

The DSP-4x00 test specification database is subject to updates. Updated versions will be available on the Fluke Networks website.

The database used with the DSP-PCI-6S and DSP-SPOOL adapters includes limits for testing patch cords, cable spools, 100 m cable segments, and many common types of copper and fiber cable installations. To access limits not included in the patch cord database, reinstall the most recent test specification database in the main and remote units. The most recent database is included in the most recent DSP software update, which is available on the Fluke Networks website.

If you have your DSP-4x00 serviced at a Fluke Networks service center, you will need to reload the test specification database.

To install the test specification database used with the DSP-PCI-6S and DSP-SPOOL test adapters, do the following:

1. Download the database from the Fluke Networks website, or put the CD with the database into your CD drive.
2. Connect a PC that has LinkWare software to the DSP-4x00 main unit with the serial interface cable. Turn on the DSP-4x00 main unit.
3. Choose **Utilities**, **DSP Utilities**, **Software Update** from the LinkWare menu.
4. In the **Files of Type** box, select **Specification DB** (*.sdb).
5. Locate and select the .sdb file. The file's name is "PatchCord_vxxxy.sdb" where "xxxy" is the version.
6. Click **Open** (or double-click the selected file name).
7. After downloading the standard database in the DSP-4x00 main unit, connect the DSP-4x00 remote unit to the PC with the serial interface cable. Turn on the DSP-4x00 remote unit.
8. Repeat steps 3 through 6 to download the .sdb file to the remote unit.
9. After the special test database has been downloaded into the DSP-4x00 remote unit, connect the DSP-4x00 main unit to the DSP-4x00 remote unit with the self calibration module.
10. Turn the rotary switch to SPECIAL FUNCTIONS, select **Self Calibration**; then press ENTER. Follow the instructions to perform the self calibration.

About Performance Tests for the Adapters

When you receive the test adapters, you should test and characterize their performance. Later, the performance test results can help you determine when the adapters' jacks or sockets need replacing or verify that the adapters are working properly. See Appendix A: "Testing the Adapters' Performance" for performance test procedures.

Pre-Qualifying Patch Cord Materials

You should always test cable and connectors before using the materials to build patch cords. If you are a cabling contractor, you should test cable spools before the cable is installed. Cable from different manufacturers can have significant differences in NEXT and return loss performance.

Pre-Qualifying Cable

You can use Fluke Networks DSP-SPOOL Spool Test Adapters, the main unit DSP-PCI-M6 Patch Cord Test Adapter, or a regular Category 6 channel adapter to test cable. The cable spool adapter accepts stripped wire ends, while the patch cord and channel adapters require you to terminate the cable with an RJ45 plug. You can use one or two adapters to test cable, as follows:

Testing with one adapter: You can use both models of test adapters or a channel adapter to test cable without terminating the far end of the cable. Using one adapter is convenient, since one end of the cable is often buried in the spool. To test cable with a DSP-PCI or channel adapter, you must terminate the cable with an RJ45 plug. This offers an additional convenience if you are making patch cords: the first connector is already in place after you test the spool.

When you test with one adapter, the cable spool tests evaluate the following:

- Pair-to-pair NEXT
- Power sum NEXT
- Return loss

The cable spool test specifications assume that propagation delay and delay skew requirements are met by the cable's design; therefore, test limits for these measurements are not required. By default, the tester shows PASS for tests that have no limits.

The length test is not assigned a PASS/FAIL result for the following reasons:

- Manufacturers closely control the length of spooled cable, so evaluating the length is not necessary.
- Tolerance, which you may require for length measurements, is not defined in any cabling standard.
- There is always a ±10 % tolerance associated with length measurements due to NVP, which is not precisely known in most cases.

Notes

When testing with one adapter, NEXT loss and return loss are measured in one direction only. Performance deficiencies far into the cable may not be detected, depending on the round-trip insertion loss. When you test cable spools from only one end, you assume that the performance near the beginning of the spool represents the performance throughout the spool.

While you can use a DSP-PCI main unit adapter to test cable spools, the DSP-PCI remote unit adapter is not suitable for testing spools.

Testing with Two Spool Test Adapters: Using two DSP-SPOOL adapters and a cable spool test standard, you can test cable up to 100 m for the following parameters:

- Insertion loss (attenuation)
- Pair-to-pair NEXT (both directions)
- Power sum NEXT (both directions)
- Pair-to-pair ELFEXT
- Power sum ELFEXT
- Return loss (both directions)
- Propagation delay
- Delay skew
- DC resistance

Unwinding 20 m of Cable Before Testing

Before testing spooled cable, you may want to unwind approximately 20 m of cable for the following reasons:

- Winding-to-winding coupling on the spool may increase NEXT. This form of alien crosstalk should not occur in properly-installed cabling.
- RL properties of cable often improve when the cable is straightened, as it will be when installed.
- Any additional undesirable side effects of spooling are reduced to low levels when the distance to the disturbance exceeds 20 m.

Unwinding may not be necessary unless the cable tends to fail when completely spooled or you want the test results to show larger margins.

Caution

Connecting wires larger than AWG 24 (0.0201 in or 0.511 mm diameter), such as AWG 22 or AWG 23, to the cable spool adapter can damage the sockets, making them unsuitable for AWG 24 wires.

The tables in Appendix C show key TIA/EIA and ISO/IEC performance requirements for cable.

Testing Cable Longer than 20 m with a Spool Test Adapter

To test a cable spool or segment greater than 20 long with a DSP-SPOOL adapter, do the following:

1. Unwind approximately 20 m of cable from the spool if necessary. See "Unwinding 20 m of Cable Before Testing" for details.
2. Strip off enough of the cable jacket so you can fan out the wire pairs to plug them into the spool test adapter. Then strip off 10 mm (3/16 in) of the insulation from each wire. Untwist the wire pairs as little as possible.
3. Attach a spool test adapter to a DSP-4x00 main unit. Connect the cable to the adapter as shown in Figure 1.
4. Select an appropriate cable spool test standard, then run an Autotest.

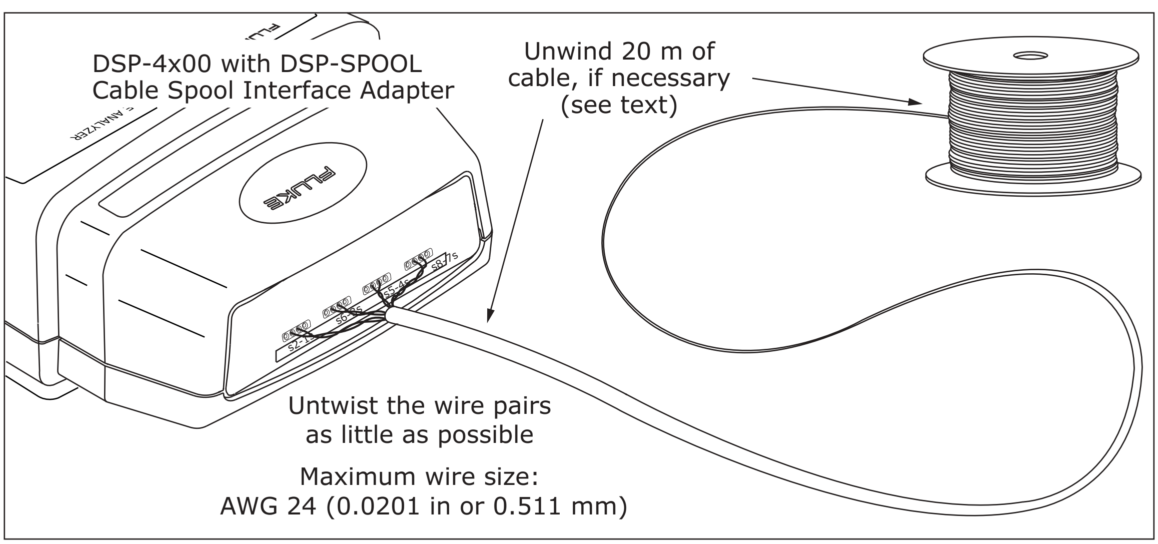

Figure 1. Testing Cable Spools with the Cable Spool Interface Adapter

Testing 100 m Cable Sections with Two Spool Test Adapters

1. Cut off a section of cable 100 m long.
2. Strip off enough of the cable jacket on each end so you can fan out the wire pairs to plug them into the spool test adapters. Then strip off 10 mm (3/16 in) of the insulation from each wire on each end. Untwist the wire pairs as little as possible.
3. Attach spool test adapters to main and remote DSP-4x00 units. Connect the cable ends to the spool test adapters.
4. Select an appropriate cable spool test standard, then run an Autotest.

Testing Cable Longer than 20 m with a Patch Cord or Channel Test Adapter

To test a cable spool or segment longer than 20 m with a DSP-PCI-M6 main unit adapter or a channel test adapter, do the following:

1. Unwind approximately 20 m of cable from the spool if necessary. See “Unwinding 20 m of Cable Before Testing” for details.
2. Terminate the cable with an RJ45 plug.
3. Attach a DSP-PCI-M6 main unit adapter or channel adapter to a DSP-4x00 main unit. Connect the cable to the adapter
4. Select an appropriate cable spool test standard, then run an Autotest.

Pre-Qualifying Plugs

To get a general idea of how plugs will affect patch cord performance, test a sample of the plugs terminated with 100 Ω resistors. Figure 2 shows this configuration. This test is strongly recommended for Cat 6 plugs, as the Cat 6 NEXT pass/fail limits have little margin for poor performance.

Refer to the TIA/EIA-568-B.2-1 or IEC 60603-7 standard for additional information on test plug requirements.

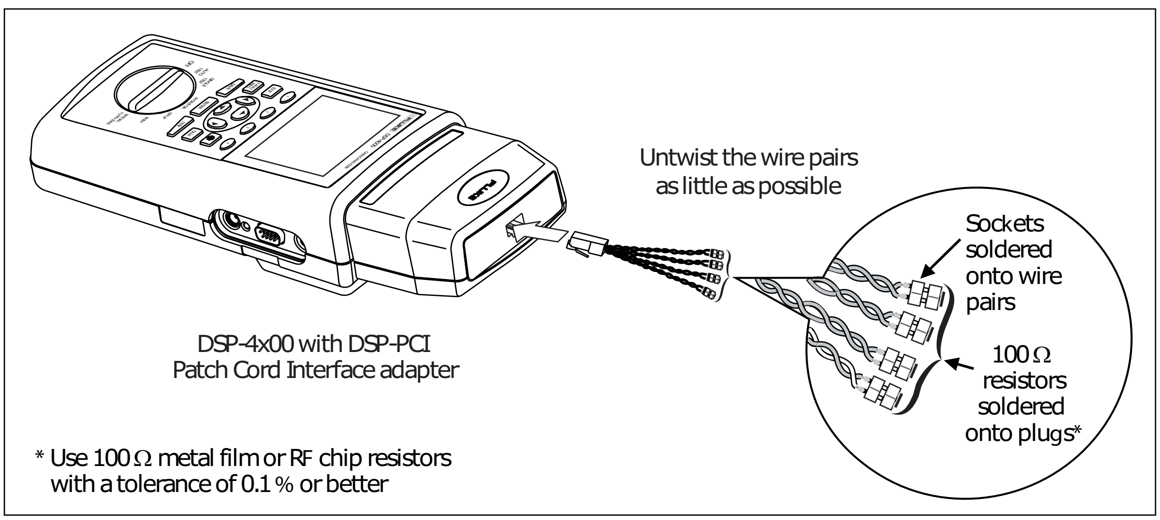

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Figure 2. Pre-qualifying RJ45 Plugs

Testing Patch Cords

Patch cord tests evaluate the following:

- Wire map
- NEXT
- Return loss

The patch cord test specifications assume that insertion loss (attenuation) requirements are met by the patch cord's design; therefore, test limits for this measurement are not required. For the same reason, limits for other electrical parameters, such as propagation delay, delay skew, and dc resistance are not included in the patch cord test limits. By default, the tester shows PASS for tests that have no limits.

The length test is not assigned a PASS/FAIL result for the following reasons:

- Patch cord length is easily observed.
- Patch cord test limits change little with length. NEXT limits vary only slightly with length, and return loss limits are independent of length.
- Tolerance, which you may require for length measurements, is not defined in any cabling standard.
- There is always a ±10 % tolerance associated with length measurements due to NVP, which is not precisely known in most cases.

Note

NEXT loss and return loss are measured in one direction only, as required by the patch cord test standard. For standard patch cords up to 5 m this method is adequate and can detect performance problems at the remote connection. For longer patch cords, you can repeat the test with the patch cord reversed.

The DSP-4x00 test database for patch cords is derived from current TIA/EIA-568-B.2-1 and ISO/IEC-11801-2002 standards. Requirements in international standards, defined by ISO/IEC-11801, vary little (up to fractions of a dB) from the TIA standards. Tables 9 and 10 in Appendix C show key TIA/EIA and ISO/IEC performance requirements for patch cords.

Caution

The jack's lifetime may be reduced substantially when mated with plugs that have been inadequately crimped.

If the NEXT and return loss margins appear unusually high (greater than 5 dB), the main and remote adapters may have been reversed. Switching the adapters between the main and remote units can cause the results to appear up to 10 dB better than they actually are. Keep your DSP-4x00 software current, as future versions may be able to warn you about reversed adapters.

To test patch cords, proceed as follows:

1. Attach the DSP-PCI adapter for the main unit to the main DSP-4x00 unit. Attach the DSP-PCI adapter for the remote unit to the remote DSP-4x00 unit.
2. Select an appropriate patch cord test standard from the DSP-4x00's SETUP menu.
3. Connect a patch cord to be tested between the main and remote units, as shown in Figure 3.
4. Run an Autotest on the patch cord.
5. If the patch cord fails NEXT or return loss, see "Troubleshooting NEXT Failures" on page 10 or "Troubleshooting Return Loss Failures" on page 12 for information on determining the cause of the failure.
6. Press SAVE to save the test results, if desired.

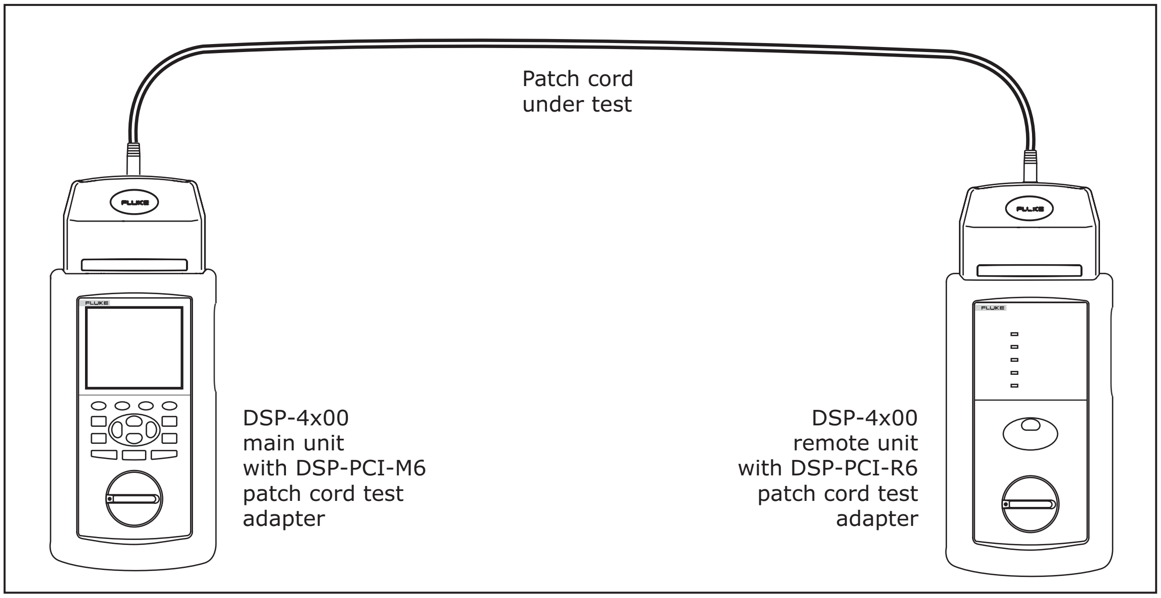

Figure 3. Patch Cord Test Configuration

Mechanical Stress Tests for Patch Cords

Every patch cord design should be evaluated for changes in performance–particularly return loss performance–under mechanical stress. Refer to the TIA/EIA or ISO/IEC standards for details on stress tests.

Since it is not practical to perform the stress tests on every patch cord produced, you can test samples of production patch cords to ensure quality. The sample size depends on the desired quality level. Alternately, you can use the stress tests to determine the possible shift in performance, then apply the shift to worst-case margins to ensure that patch cords meet specifications under worst-case conditions. You can apply the shift as you test, or you can use LinkWare software to upload test results to a PC; then evaluate the results on the PC.

Troubleshooting NEXT Failures

Most NEXT failures are caused by connectors, where the twist in the wire pairs is interrupted. You can use the DSP-4x00's HDTDX test to determine which plug is causing a patch cord to fail. Then you can re-terminate that end of the cord so it will pass the performance tests.

Identifying Bad Connectors on Patch Cords

When a patch cord fails the NEXT test, you can determine which connector is bad as follows:

1. Run an Autotest to get the HDTDX plot. If the HDTDX plot is not available when you press FAULT INFO after the Autotest, run the HDTDX Single Test.
2. Find the pair with the highest reflection percentage in the list of HDTDX results, and note whether the reflection is at the near-end or the far-end connector.

   You may also see the reflections for each pair on the HDTDX plot, though reading the exact reflection percentage is more difficult. To see the plot with better resolution, use LinkWare software.
3. Use Table 1 or 2 to convert the HDTDX percentages to NEXT values for Cat 5, 5e, and 6 patch cords. Use Table 1 for Cat 6 patch cord test selections. Use Table 2 for Cat 5 and 5e patch cord test selections.

Example of Troubleshooting a NEXT Failure

The following example shows how to use HDTDX results to identify which connector caused a patch cord to fail the NEXT test. The example also shows how to determine the NEXT value for a connector, which is a localized source of NEXT.

Figure 4 shows an example of HDTDX results for a Cat 6 patch cord that failed the NEXT portion of an Autotest. The highest peak is 45 % at 11 ft, which corresponds to the far-end connector.

Note

The HDTDX amplitude associated with the vertical scale on the HDTDX plot depends on the test standard you selected on the DSP-4x00.

For this Cat 6 example, we find 45 % in Table 1 by first finding “40 %” in the left column; then following the row over to “+5 %”. The NEXT value for the connector is 49.0 dB at 100 MHz. This is below the 54 dB limit specified for Cat 6 connectors, which means the connection is bad. According to the table, a good Cat 6 connection will give a maximum of about 35 % reflection on the HDTDX plot.

Remember that a bad connection may be due to a bad connector or poor workmanship. For example, a connection made with a good connector may fail the NEXT test because the wire pairs are untwisted too far back from the connector.

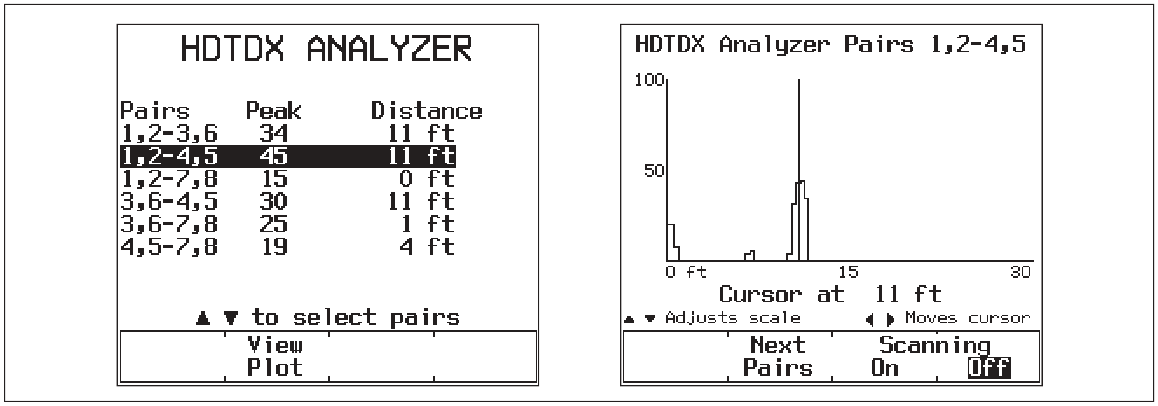

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Figure 4. Example of HDTDX Test Results

The highest accuracy of the HDTDX response is at the main DSP-4x00 unit. The accuracy of the response farther away from the main unit declines as a result of imperfect correction for attenuation and loss of bandwidth, as well as other disturbing effects that are always present in twisted pair cabling (such as reflected FEXT). For the most accurate measurement of a particular connector's HDTDX response, test the cable with the connector of interest plugged into the main DSP-4x00 unit.

If the HDTDX response from connectors at one end start creeping closer to the limit or begin to fail more frequently, you should suspect a problem with the jack in the patch cord adapter at that end. In this case, reverse a patch cord with a marginal or failing connector and test it again. Then compare the results from the two test directions. If the marginal or failing response does not switch between the main and remote adapters, you may need to replace the test jacks in the adapters.

For additional examples and further discussion of using HDTDX results to analyze patch cord performance, see Appendix B.

Table 1. Local NEXT (in dB at 100 MHz) for HDTDX Percentages for Cat 6 (per TIA/EIA-568-B.2-1) and Cat 6 (per ISO/IEC-11801) Patch Cord Test Selections

HDTDX	+0 %	+1 %	+2 %	+3 %	+4 %	+5 %	+6 %	+7 %	+8 %	+9 %
0 %	72.4	71.8	71.3	70.8	70.3	69.8	69.2	68.7	68.2	67.7
10 %	67.2	66.6	66.1	65.6	65.1	64.6	64.0	63.5	63.0	62.5
20 %	62.0	61.4	60.9	60.4	59.9	59.4	58.8	58.3	57.8	57.3
30 %	56.8	56.2	55.7	55.2	54.7	54.2*	53.6*	53.1	52.6	52.1
40 %	51.6	51.0	50.5	50.0	49.5	49.0	48.4	47.9	47.4	46.9
50 %	46.4	45.8	45.3	44.8	44.3	43.8	43.2	42.7	42.2	41.7
60 %	41.2	40.6	40.1	39.6	39.1	38.6	38.0	37.5	37.0	36.5
70 %	36.0	35.4	34.9	34.4	33.9	33.4	32.8	32.3	31.8	31.3
80 %	30.8	30.2	29.7	29.2	28.7	28.2	27.6	27.1	26.6	26.1
90 %	25.6	25.0	24.5	24.0	23.5	23.0	22.4	21.9	21.4	20.9
100 %	20.4									

* Approximate limit for Cat 6 connectors.

Table 2. Local NEXT (in dB at 100 MHz) for HDTDX Percentages for Cat 5 (per ISO/IEC-11801) and Cat 5e (per TIA/EIA-568-B) Patch Cord Test Selections

HDTDX	+0 %	+1 %	+2 %	+3 %	+4 %	+5 %	+6 %	+7 %	+8 %	+9 %
0 %	60.9	60.3	59.8	59.3	58.8	58.3	57.7	57.2	56.7	56.2
10 %	55.7	55.1	54.6	54.1	53.6	53.1	52.5	52.0	51.5	51.0
20 %	50.5	49.9	49.4	48.9	48.4	47.9	47.3	46.8	46.3	45.8
30 %	45.3	44.7	44.2	43.7	43.2[1]	42.7[1]	42.1	41.6	41.1	40.6
40 %	40.1[2]	39.5[2]	39.0	38.5	38.0	37.5	36.9	36.4	35.9	35.4
50 %	34.9	34.3	33.8	33.3	32.8	32.3	31.7	31.2	30.7	30.2
60 %	29.7	29.1	28.6	28.1	27.6	27.1	26.5	26.0	25.5	25.0
70 %	24.5	23.9	23.4	22.9	22.4	21.9	21.3	20.8	20.3	19.8
80 %	19.3	18.7	18.2	17.7	17.2	16.7	16.1	15.6	15.1	14.6
90 %	14.1	13.5	13.0	12.5	12.0	11.5	10.9	10.4	9.9	9.4
100 %	8.9									

1. Approximate limit for Cat 5e connectors.
2. Approximate limit for Cat 5 connectors.

Troubleshooting Return Loss Failures

Most return loss failures are caused by impedance mismatches in cable. Cable frequently does not meet the rather strict requirements for mean characteristic impedance of patch cords (100 Ω ±5 Ω). Connectors on Cat 5e patch cords rarely cause return loss failures, though poor workmanship could result in a return loss failure if too much cable is untwisted at the connector. Cat 6 patch cords are more sensitive to poor workmanship than Cat 5 or 5e results.

Among the sources of characteristic impedance mismatches are

- Imperfections within the twisted pair cable resulting from variations in the manufacturing process or poor installation practices.
- Mismatched cable in a link.
- Mismatches between cable and connecting hardware
- Mismatches between the cable impedance and the source or termination (load) impedance.

To determine the cause of a return loss failure in a patch cord, proceed as follows:

Note

The accuracy of the HDTDR response is limited by the accuracy of the reference 100 Ω resistor used for calibrating the DSP-4x00. While the HDTDR response can be used to determine possible causes of return loss failures, it should not be the only determining factor. You should also use the return loss frequency response when diagnosing return loss failures, as described in Appendix B.

1. Run an Autotest or the HDTDR Single Test to get the HDTDR plot.
2. Analyze the return loss results as follows:

   (a) When troubleshooting return loss failures, always consider the return loss frequency response together with the HDTDR plot. Reflections on the HDTDR plot by themselves are often too small to indicate the exact problem.

   In general:

   - RL failures at high frequencies tend to be caused by connectors.
   - RL failures at low frequencies (below 50 MHz) tend to be caused by characteristic impedance mismatches in the cable.

   Look at the return loss frequency response for places where the response comes close to the limit; then note the frequency of the smallest margin to determine if the return loss failure is likely caused by connectors or cable.

   (b) Look for HDTDR response amplitudes that exceed 3 %. These are typically found at the ends of the patch cord. You will probably need to use the DSP-4x00's -25 % to +25 % HDTDR scale. To use this scale, press **4X** on the main unit. Use to determine the reflection values at points of interest.

   For higher resolution on the HDTDR plot, use the Quick Plot feature in LinkWare to upload the plot to a PC.

   Note

   The DSP-4x00 remote unit causes a large reflection at the remote end of the patch cord. To see the remote end clearly, terminate the patch cord with a jack terminated with 100 Ω resistors, instead of a remote patch cord test adapter. See "Examples of Return Loss Failures" on in Appendix B for additional information. You may also reverse the patch cord and run the HDTDR test again to see the connector's response more clearly.

   Note whether reflection is unipolar (Figure 5), symmetrical (Figure 6), or asymmetrical (Figure 7). Unipolar and asymmetrical pulses can indicate the sources of return loss problems. You can use symmetrical reflections to determine the return loss of a localized RL problem, which is typically caused by a connection. See the sections below for details.

See Appendix B for examples of return loss troubleshooting procedures.

Interpreting Unipolar Reflections

If the HTDR response shows a unipolar reflection, as in the left side of Figure 5, look down the cable for another reflection with matching amplitude but opposite phase, as in the right side of Figure 5. The two reflections usually indicate the beginning and the end of a characteristic impedance mismatch in the cabling.

Every 1 % of reflection coefficient corresponds to a characteristic impedance mismatch of approximately 2 Ω; however, this relationship is only an indicator of the impedance change. The absolute accuracy of this value is limited by the low levels of the reflected signals. Table 3 shows the relationship between HDTDR reflections and impedance mismatch values.

The reflections in Figure 5 are 9 %, and the mismatch starts with a positive pulse. This means the cable's characteristic impedance is about 19.8 Ω more than the 100 Ω expected by the tester. This may be caused by a 120 Ω cable used by mistake.

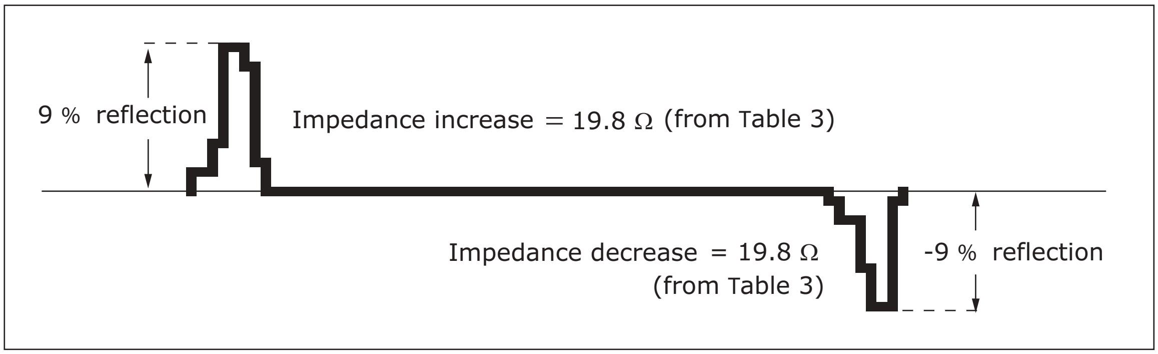

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Figure 5. Unipolar HDTDR Reflections Indicating a Characteristic Impedance Mismatch

Interpreting Symmetrical Reflections

Symmetrical reflections (Figure 6) represent impedance changes caused by connectors. To determine the approximate return loss of a connector, use the cursor on the HDTDR plot to measure the reflection coefficient at a peak on the reflection; then find the corresponding return loss value in Table 3.

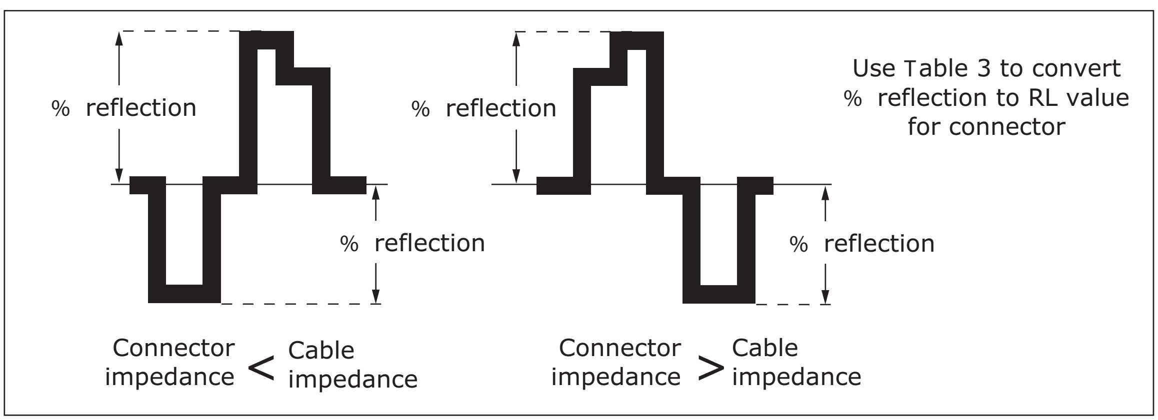

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Figure 6. Symmetrical HDTDR Reflections Caused by Connectors

Table 3. HDTDR Reflection vs. Approximate Return Loss and Characteristic Impedance Mismatch

HDTDR Amplitude (%)	Symmetrical Reflection Approximate Return Loss from Localized Connector Reflection (dB)	Unipolar Reflection Approximate Characteristic Impedance Mismatch Between Cable Segments (Ω)
0	Infinite	0
1	40.0	2.0
2	34.0	4.1
3	30.5	6.2
4	28.0	8.3
5	26.0	10.5
6	24.4	12.8
7	23.1	15.1
8	21.9	17.4
9	20.9	19.8
10	20	22.2

Interpreting Asymmetrical Reflections

Asymmetrical reflections (Figure 7) are generally caused by a connector's return loss combined with a characteristic impedance mismatch of the cable. The difference in magnitude between the smaller and larger peaks represents the impedance mismatch of the cable.

The reflection in Figure 7 has a 6 % positive pulse, but only a -3 % negative pulse. The extra 3 % reflection on the positive pulse represents the cable's impedance mismatch. From Table 3, 3 % reflection corresponds to about 6.2 Ω, which represents the cable's impedance mismatch.

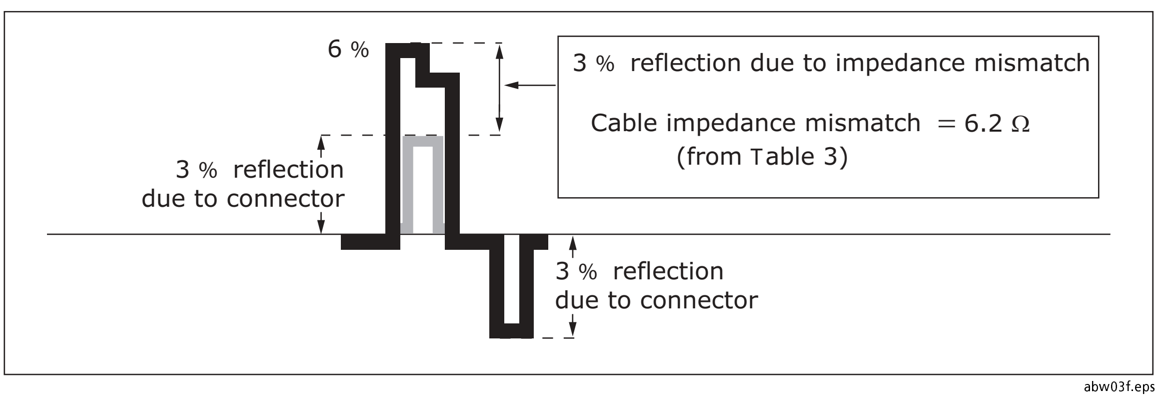

Figure 7. Determining Characteristic Impedance Mismatch from an Asymmetrical HDTDR Reflection

Replacing the Adapters' Cable Connectors

The RJ45 test jacks in the DSP-PCI adapters and the sockets in the DSP-SPOOL adapters are typically good for 5000 insertions when used continuously. When used non-continuously, the lifetime may be reduced to 750 insertions. After 750 insertions, the gold plating that prevents oxidation on the contacts may be worn away; however, continuous use wipes off the oxidation and extends the life of the contacts.

Caution

The jack's lifetime may be reduced substantially when mated with plugs that have been inadequately crimped.

When to Replace Test Jacks or Sockets

You should replace the test jacks in the DSP-PCI adapters or the sockets in DSP-SPOOL adapters when any of the following occur:

- Margins for patch cord or cable spool tests begin to shrink.
- Patch cord or cable spool tests, particularly wire map or return loss tests, begin to produce intermittent and/or inconsistent results.
- The jacks or sockets have been used for more than 5000 insertions.
- The tests described in Appendix A: "Testing the Adapters' Performance" fail or the results are noticeably different from those observed when the adapters were new.

Replacing the RJ45 Jacks in the DSP-PCI Adapters

Note

To ensure reliable operation, replace the entire DSP-PCI patch cord adapter after the RJ45 jack has been replaced 10 times.

Caution

The DSP-PCI adapters contain static-sensitive devices. When replacing the RJ45 jack, follow guidelines for preventing electrostatic discharge (ESD).

1. Before taking the adapter cases apart, note how the latch-end of the adapters are assembled. Figure 8 shows some details of the latch assembly.
2. Take the adapter cases apart by removing the four screws from the back of the cases. Note how the end plates fit into the channels in the top and bottom covers.
3. Remove the circuit boards from the cases.
4. Pull the RJ45 jacks off the circuit boards (Figure 9), being careful not to stress the boards.
5. Align the new RJ45 jacks on the connectors on the circuit boards. Note in Figure 9 how the insulation displacement connectors in the jacks slide into the connectors on the circuit boards.
6. Place the boards on a hard, flat surface; then push the RJ45 jacks onto the connectors on the boards. If firm pressure does not push the jack onto the connectors, realign the jack on the connectors before trying again.
7. Reassemble the adapters.
8. Test the adapters using a performance test from Appendix A.

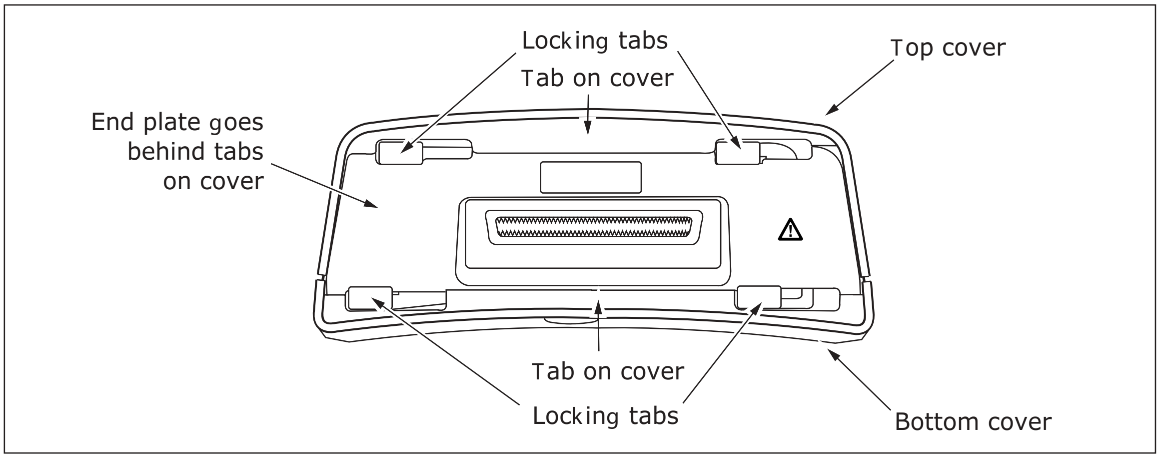

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Figure 8. Latch Assembly Details

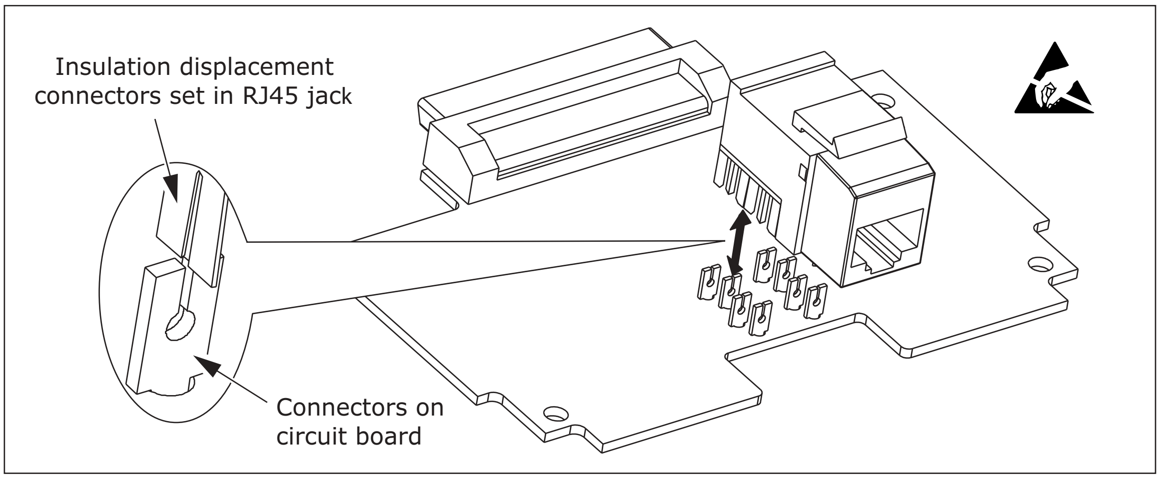

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Figure 9. Replacing the RJ45 Jack

Replacing the Sockets in the DSP-SPOOL Adapter

Caution

The DSP-SPOOL adapters contain static-sensitive devices. When replacing the sockets, follow guidelines for preventing electrostatic discharge (ESD).

1. Before taking the adapter case apart, note how the latch-end of the adapters are assembled. Figure 8 shows some details of the latch assembly.
2. Take the adapter case apart by removing the two screws from the back of the case. Note how the end plates fit into the channel in the top and bottom covers.
3. Remove the circuit board from the case.
4. Pull off the sections of sockets from the socket connector strip on the edge of the circuit board; then replace them with new socket sections.
5. Reassemble the adapter.
6. Test the adapter as described under "DSP-PCI and DSP-SPOOL Performance Tests Using the Adapter Test Standard" on page 25.

Replacement Parts

Table 4 shows the replacement parts available for the DSP-PCI Patch Cord Interface Adapters and DSP-SPOOL Cable Spool Interface Adapter. The parts are available from Fluke Networks, unless otherwise specified.

Table 4. Replacement Parts

Description	Fluke Networks Part Number
Single RJ45 test jack for DSP-PCI adapter	2041476*
Kit of 10 RJ45 test jacks for DSP-PCI adapters	2061277*
Socket set for DSP-SPOOL adapter	2002241
Cat 6 patch cord interface adapter for main unit	2043873
Cat 6 patch cord interface adapter for remote unit	2048847
Replacement connection pin for DSP-PCI adapter circuit board	2058656
DSP-PCI/DSP-SPOOL Test Interface Adapters CD-ROM (includes Users Manual and test specification database)	2044803

* You may also purchase a set of two RJ45 test jacks from the following supplier:

Superior Modular Products
33 Superior Way
Swannanoa, NC 28778, USA
Telephone: 1-828-298-2260 or 1-800-880-7674
World Wide Web: www.superiormod.com

Superior Modular part number for set of two RJ45 test jacks: PCTAC6K N488001 (for Fluke Networks DSP-PCI-6S)

Specifications

DSP-4x00 Measurement Accuracy

The DSP-4x00 test tool is guaranteed to meet the Level III accuracy requirements at Cat 6 permanent link and channel pass/fail limits. Refer to the *DSP-4000 Series Users Manual* for details.

Patch Cord Test Configuration Measurement Accuracy

The charts in Figure 10 show NEXT and return loss measurement accuracies for the patch cord test configuration. The results were computed using the methods defined in standards applicable to field tester requirements. The accuracies shown reflect the accuracy of the measurement circuitry, excluding variability caused by the adapters' connectors.

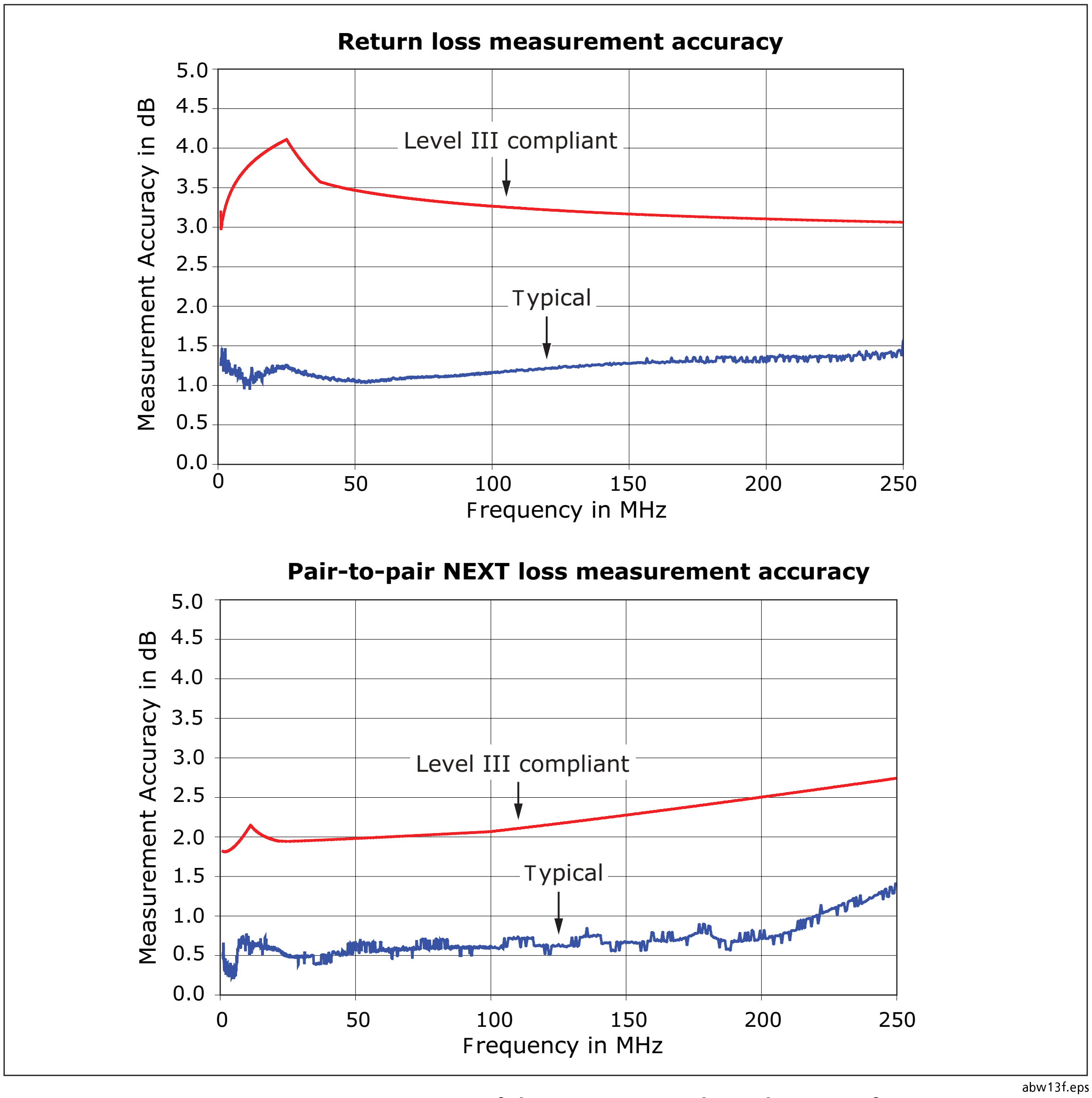

Figure 10. Measurement Accuracy of the DSP-4x00 Patch Cord Test Configuration

Appendix A
Testing the Adapters' Performance

Introduction

This appendix provides performance test procedures for the DSP-PCI-6S and DSP-SPOOL adapters. You can use the results from these tests for the following:

- **Acceptance testing**

  The performance tests let you verify the adapters' performance when acceptance testing is required for quality assurance.

- **Determining when the RJ45 jacks or the sockets need replacing, or the adapters are otherwise damaged**

  Category 6 patch cord test limits are very tight. You may see many failures and, consequently, may wonder if the test adapters are working properly. The RJ45 jacks in the DSP-PCI-6S adapters and the sockets in the DSP-SPOOL adapters wear out with use. Worn jacks or sockets or other damage to the adapters can cause tests to fail. The performance tests help you determine when the jacks or sockets need replacing or the adapters need service center repair.

- **Verifying the adapters' performance**

  The performance tests let you verify the adapters' performance after you replace the RJ45 jacks or the sockets in the adapters or anytime the adapters' performance seems questionable.

  While it is not possible to fully evaluate the adapters' performance in the field, the tests suggested in this section provide enough data for you to characterize the adapters and determine if they are working properly.

Choosing a Performance Test

You may choose to run one or more of the following performance tests, depending on your situation:

- For the DSP-PCI adapters:
  - ◊ Compare the test results from a reference patch cord to previous results from the same patch cord. Fluke Networks recommends this method, as it is the most practical for most people.
  - ◊ If you do not have a reference patch cord and its previous test results, or if the reference patch cord test failed and you want to further evaluate the adapters' performance, run the NEXT and return loss performance tests.
  - ◊ Run consistency tests to reveal performance differences between the main and remote adapters and help you determine if just one adapter in the pair is causing tests to fail.
- For DSP-PCI and DSP-SPOOL adapters, the test specification database includes test standards for the adapters. These tests require an RJ45 plug or twisted pairs terminated with 100 Ω 0.1 % RF chip resistors, as shown in Figures 13 and 14. If you have the terminated plug or twisted pairs, these tests are the easiest to run and provide the best evaluation of the adapters' performance

DSP-PCI Performance Test Using a Reference Patch Cord

When you first receive your adapters, you should test a patch cord and save the cord and test results for future reference. You may use the patch cord and its results later to determine if the adapters' RJ45 jacks need replacing or to verify the adapters' performance.

Note

If you did not perform this test when you first received your adapters, or you do not have access to a reference patch cord and its original test results, you can use other tests to evaluate the adapters' performance. See "DSP-PCI NEXT and Return Loss Performance Tests" on page 23 or "DSP-PCI and DSP-SPOOL Performance Tests Using the Adapter Test Standards" on page 25 for details.

To test the adapters when you first receive them, do the following:

1. Attach the main and remote adapters to main and remote DSP-4x00 units.
2. Select an appropriate patch cord test standard in SETUP.
3. Run an Autotest on some patch cords to find one that passes. A PASS* result is adequate.
4. Save the test results from a compliant patch cord and mark the patch cord ends with "main" and "remote" as it was connected during the test. Store the reference patch cord for later use.

Notes

To help ensure consistent return loss measurements from the reference patch cord, do not mechanically stress the cord. Patch cord properties can change when the cord is bent or twisted.

When you test the reference patch cord later, use the same main and remote DSP units as were used for the initial test. The serial numbers of the units are saved with the test results.

To test the same adapters later, do the following:

1. Connect the reference patch cord between the same main and remote units used for the original test. Be sure the marked ends of the patch cord go to the correct units.
2. Run an Autotest; then save the results.
3. Compare the results with the reference patch cord's previous results. The difference between the old and new NEXT and RL results should be less than 0.5 dB near the PASS/FAIL limits.

If the old and new results are more than 0.5 dB apart near the PASS/FAIL limits, the RJ45 jacks may need replacing. See "Replacing the Adapters' Cable Connectors" on page 16 for details.

DSP-PCI NEXT and Return Loss Performance Tests

If you did not previously test a reference patch cord and save the results and the cord as described under "DSP-PCI Performance Test Using a Reference Patch Cord" on page 22, you may use NEXT and return loss tests to test the DSP-PCI adapters. You may also use these tests to further evaluate the adapters' performance if they fail the reference patch cord test.

NEXT Performance Test

To test the adapters' NEXT performance, do the following:

1. Attach the main and remote adapters to main and remote DSP-4x00 units.
2. Select an appropriate patch cord test standard in SETUP.
3. If you do not already have a reference patch cord, run the Autotest on some Cat 6 patch cords to find one that passes. A PASS* result is adequate.
4. Use LinkWare software's Quick Plot function to view the HDTDX plot from the compliant Cat 6 patch cord.
5. Verify that the HDTDX responses for the main and remote adapter connectors are 36 % or less. Figure 11 shows examples of passing and failing test adapters.

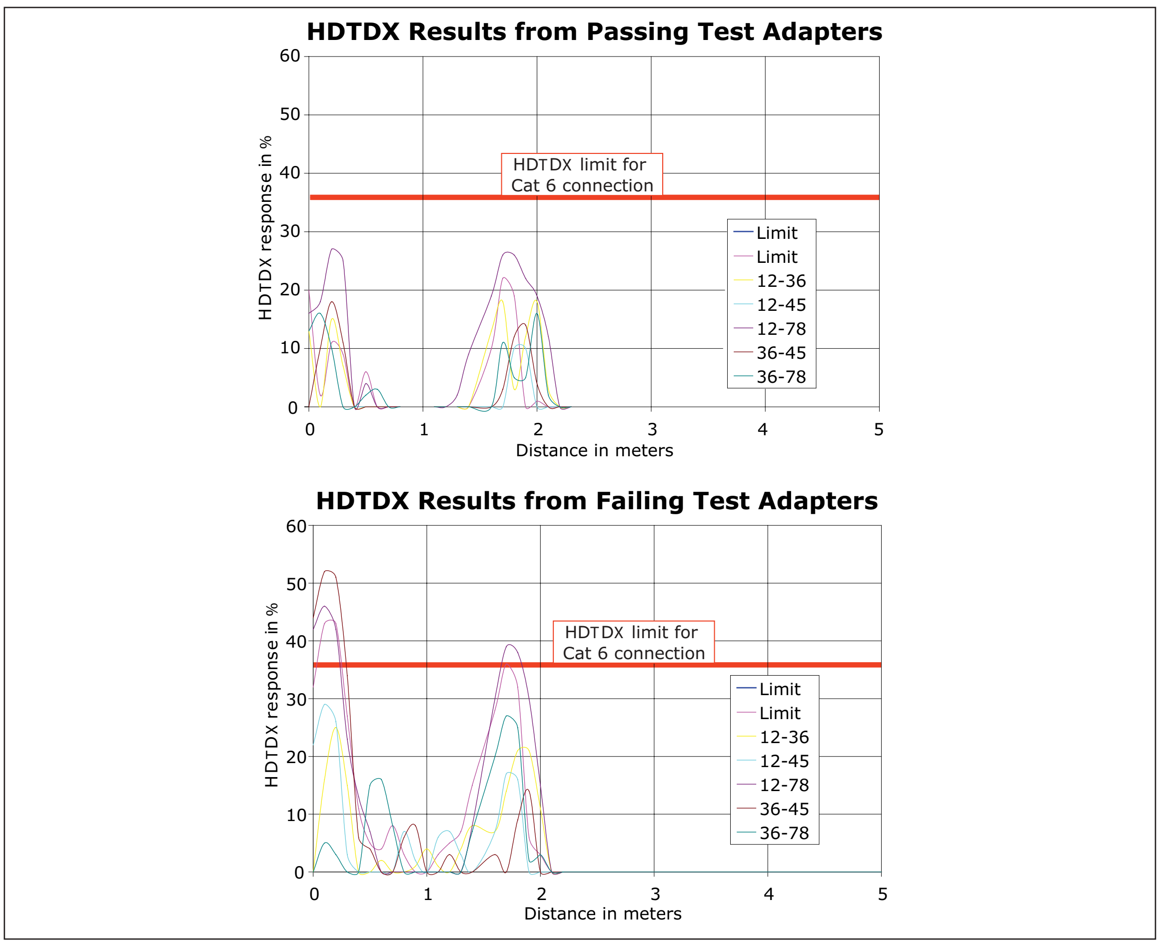

Figure 11. Examples of HDTDX Results for Passing and Failing DSP-PCI Adapters

Return Loss Performance Test

Testing the adapters' return loss performance involves two HDTDR tests: one for the main unit adapter and one for the remote unit adapter.

To test the main unit adapter, do the following:

1. Attach the main and remote adapters to main and remote DSP-4x00 units.
2. Select an appropriate patch cord test standard in SETUP.
3. If you do not already have a reference patch cord, run the Autotest on some Cat 6 patch cords to find one that passes. A PASS* result is adequate.
4. Use LinkWare software's Quick Plot function to view the HDTDR plot from the compliant Cat 6 patch cord.
5. Verify that the HDTDR responses for the main adapter connector are 6 % or less. Figure 12 shows an example of a passing main adapter.

Note that the remote reflections exceed the 6 % reflection coefficient limit. This is normal because the remote DSP-4x00 unit acts like an open circuit when the tester measures the HDTDR response. A separate test is necessary for testing the remote adapter's return loss performance.

Note

While the return loss test for the main adapter is easy to run, the test for the remote adapter is somewhat more involved. Typically, adapters that meet NEXT performance requirements will also meet return loss requirements; therefore, it is not necessary to test the remote adapter's return loss performance unless you suspect that the remote adapter has a return loss problem. Contact Fluke Networks technical support if you suspect a return loss problem with the remote adapter.

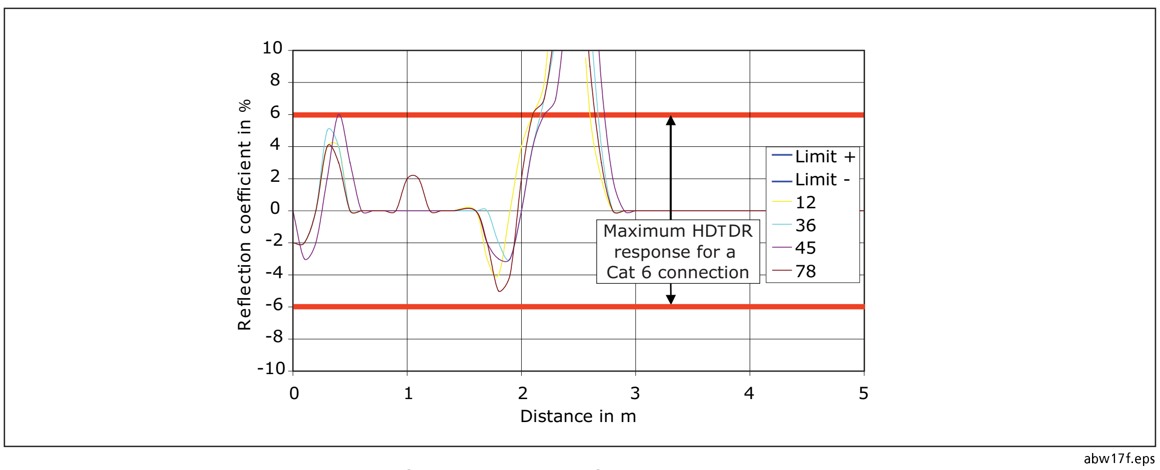

Figure 12. Example of HDTDR Results for a Passing Main DSP-PCI Adapter

DSP-PCI and DSP-SPOOL Performance Tests Using the Adapter Test Standards

You can use the performance tests described in this section for acceptance testing or to help you determine when the DSP-PCI adapters' jacks or the DSP-SPOOL adapter's sockets need replacing. These tests use the adapter test standard included with the patch cord and spool test specification database.

For the DSP-PCI adapters, these tests provide the best evaluation of the adapters' performance; however, if you do not have the terminated plug described below, you may use the reference patch cord test described on page 22 to test DSP-PCI adapters.

The tests for a DSP-PCI require a terminated Cat 6 plug to be connected to the adapter. The tests for a DSP-SPOOL adapter require four terminated sockets to be connected to the adapter. Figures 13 and 14 show how to terminate the adapters for these performance tests. Use 100 Ω metal film or RF chip resistors with a tolerance of 0.1 % or better.

To test the performance of the patch cord or spool test adapters, proceed as follows:

1. Attach a patch cord test adapter or spool test adapter to the main unit. Connect the Cat 6 test plug or terminated wires to the adapter, as shown in Figure 13 or 14.
2. In SETUP, select the appropriate test standard:
   - For a DSP-PCI main or remote adapter, select "DSP-PCI-M6 Adapter Test" or "DSP-PCI-R6 Adapter Test", respectively.
   - For a DSP-SPOOL adapter, select "DSP-SPOOL Adapter Test".
3. Run an Autotest. If the test fails, the jacks or sockets may need replacing or the adapter may be defective.
4. Save the results for future reference or to compare to previous results, if desired.
5. If you are testing a set of DSP-PCI adapters, attach the other adapter to the main DSP unit; then repeat steps 2, 3, and 4.

Note that because the floor of the return loss measurements is 40 dB (limited by the true value of the 100 Ω resistors) the return loss performance of the remote adapter cannot be verified with a high level of confidence.

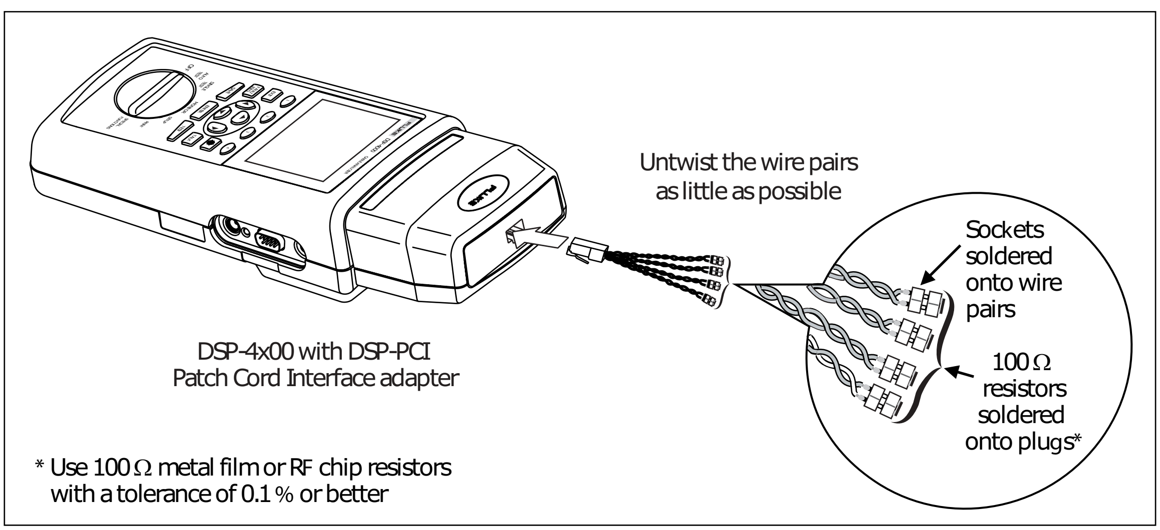

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Figure 13. Terminating the DSP-PCI Adapter for the Adapter Test

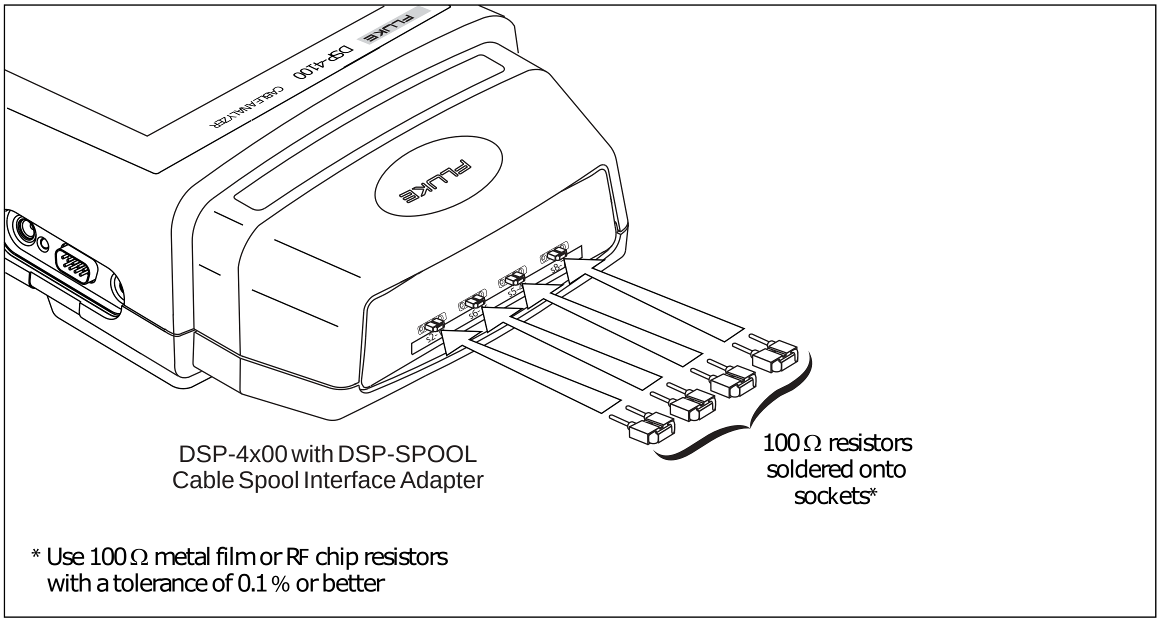

Figure 14. Terminating the DSP-SPOOL Adapter for the Adapter Test

Note

For the terminating sockets you may cut socket pairs apart from the replacement sockets provided with the DSP-SPOOL adapter. Sockets are also available from Fluke Networks. See "Replacement Parts" on page 18 for the part number.

DSP-PCI Consistency Tests

Consistency tests show the performance differences between the main and remote adapters. Variations between the adapters may greatly affect patch cord tests when the properties of the near end and far end patch cord plugs are substantially different, which is often the case. Consistency tests help you determine if one DSP-PCI adapter in a set is causing patch cord tests to fail.

To run the consistency tests, proceed as follows:

1. Attach the main and remote adapters to main and remote DSP-4x00 units.
2. Connect a known-good, representative patch cord between the main and remote units. Mark one end of the cord so you can record which test results corresponds to each patch cord position.
3. Select an appropriate patch cord test standard in SETUP.
4. Run an Autotest; then note the margins for NEXT and return loss tests. If desired, save the test results for future reference.
5. Reverse the patch cord, then repeat step 4.
6. Compare the NEXT and return loss margins from the two test directions.

Differences between NEXT and return loss results for the forward and reverse directions are typically in the order of 1 dB when the patch cord performance is near the PASS/FAIL limit. Differences are higher when the patch cord performance is better.

Generally, comparing the NEXT and return loss margins as described above is adequate for determining measurement consistency. For more detailed analysis, compare the NEXT, return loss, HDTDR, and HDTDX plots for each test direction. Use LinkWare software to upload the NEXT, return loss, and HDTDR plot data to a PC. To upload HDTDX plot data, run the HDTDX Single Test; then use the **Detailed Test Data** function in LinkWare to upload the plot data to a PC. Figures 15 and 16 show examples of these comparisons. To overlay the plots as shown, use LinkWare to save the data as a .csv file; then use a spreadsheet application to create a plot that includes both sets of CSV data.

Figure 15 shows typical NEXT and HDTDX results for the three most critical wire pairs: 36-45, 12-36, and 36-78. Note that the patch cord used for this example is fully compliant. The HDTDX responses of the connection at the main and remote test adapters are slightly different, which causes the slight differences between the NEXT frequency responses.

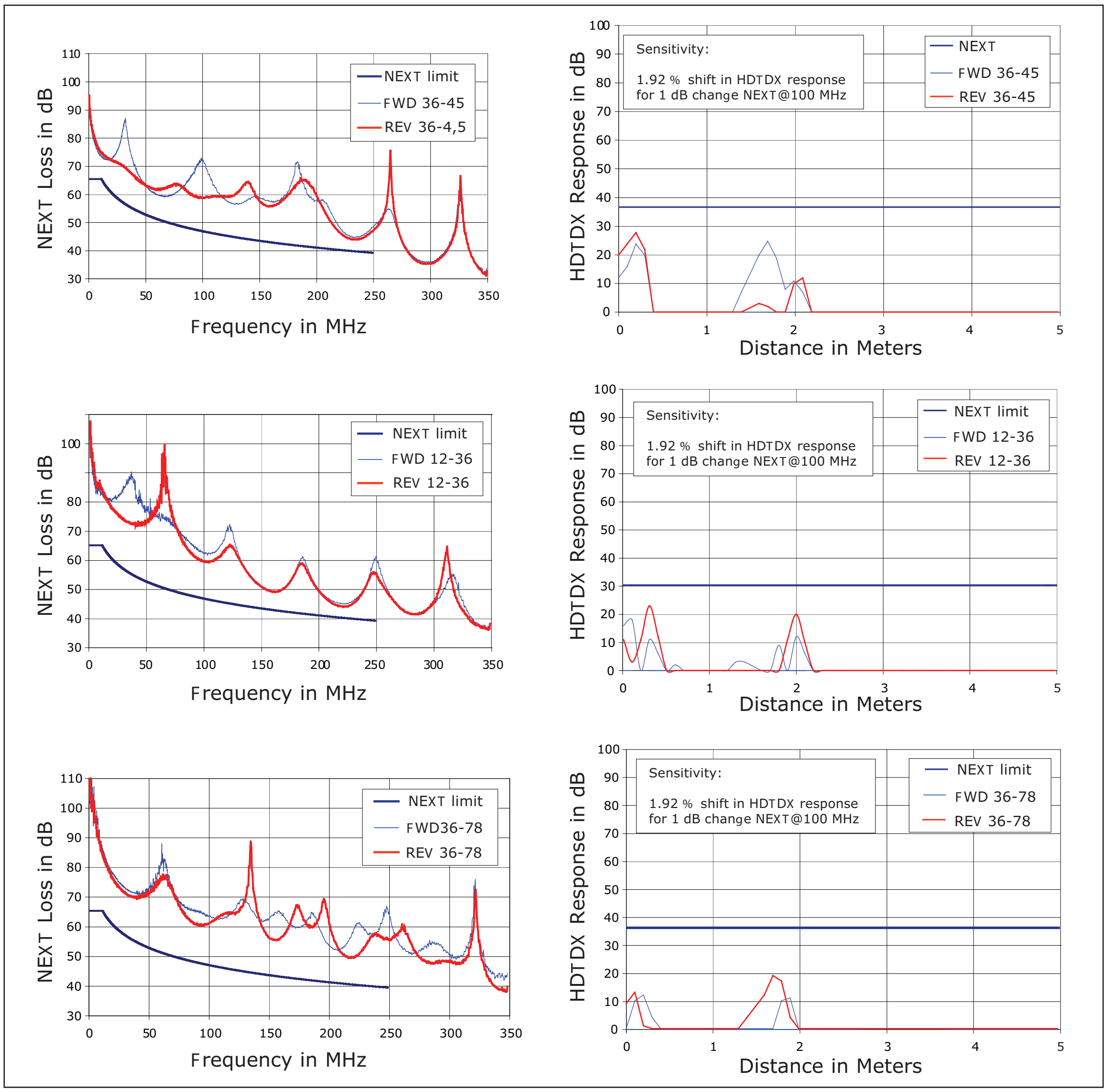

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Figure 15. Examples of NEXT and HDTDX Consistency Test Results for a Compliant 1.5 m Cat 6 Patch Cord

Figure 16 shows examples of the return loss consistency test results for the 36 and 45 wire pairs. The patch cord shows excellent performance. The large reflection at the far end of the HDTDR response is always present and results from the open circuit created by the remote adapter during HDTDR measurements.

Note that for NEXT and return loss the variations between results from the two test directions are greater when the measured performance is much better than the test limit. This occurs because the results are closer to the DSP-4x00 measurement floor and are therefore more affected by measurement disturbances.

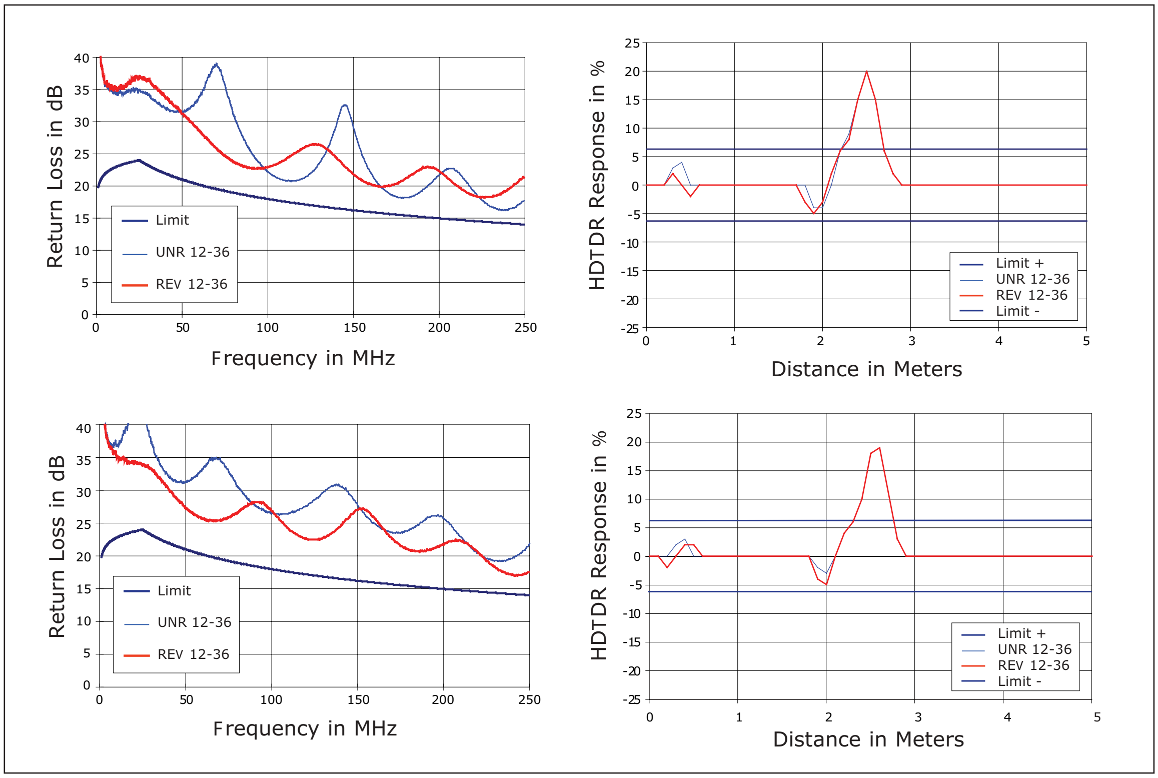


Figure 16. Examples of RL and HDTDR Consistency Test Results for a Compliant 1.5 m Cat 6 Patch Cord

Appendix B
Troubleshooting Examples and Theory

Introduction

This appendix provides additional examples and theory for using HDTDX or return loss results to troubleshoot patch cords that fail the NEXT or return loss test.

Note

The plots shown for these examples were created with a spreadsheet application.

Examples of NEXT Failures

The following examples apply the analysis techniques described in "Troubleshooting NEXT Failures" on page 10 to test results from a Cat 5e and Cat 6 patch cord.

Figure 17 shows the NEXT frequency response and the HDTDX response from a 2 m, Cat 5e patch cord. The frequency response shows that the patch cord passed; however, the HDTDX shows that the 36-45 and 12-36 pairs at the remote end exceed the response limit for a Cat 5e connector. (The response limit of 35 % comes from Table 2 on page 12. The limit for Cat 5e connectors is shaded in the table.) This does not cause the patch cord to fail because the performance of the wire pairs is quite good.

Notice on the HDTDX response that the 36-45 wire pair produces minimal reflections along the cable portion of the patch cord, but produces the largest reflections of all the wire pairs at the connectors. This is common because wire pairs with the poorest NEXT in the cable (the pairs with the lowest twist rates–typically blue and brown) are commonly matched up with the connector pins that exhibit the best mated NEXT performance (typically 12-78).

In most cases, the 36-45 wire pair shows almost no reflections at all along the cable. If the frequency response fails and the connectors look ok in the HDTDX response, but the 36-45 pair shows reflections above 0 %, the cable is marginal.

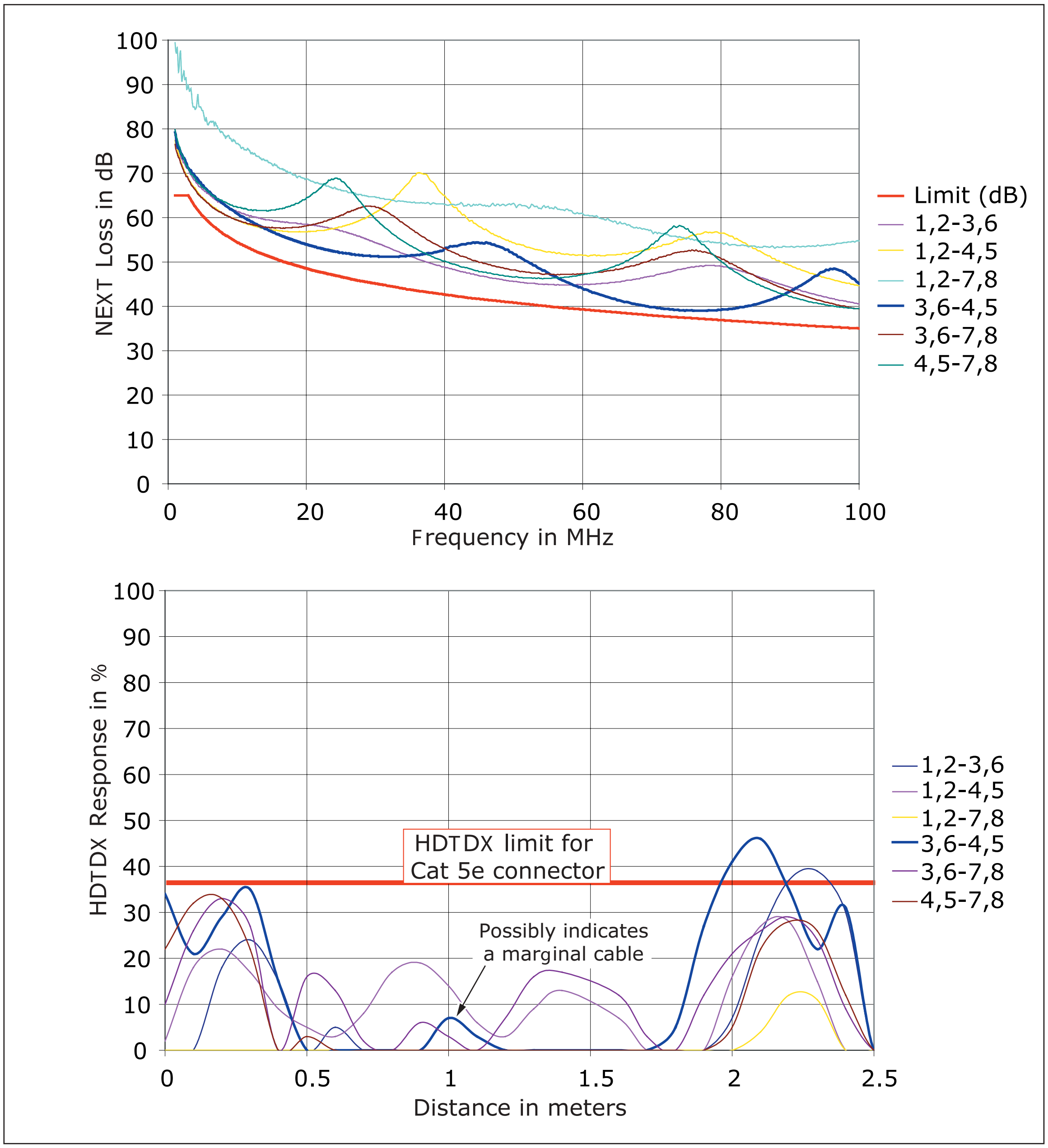
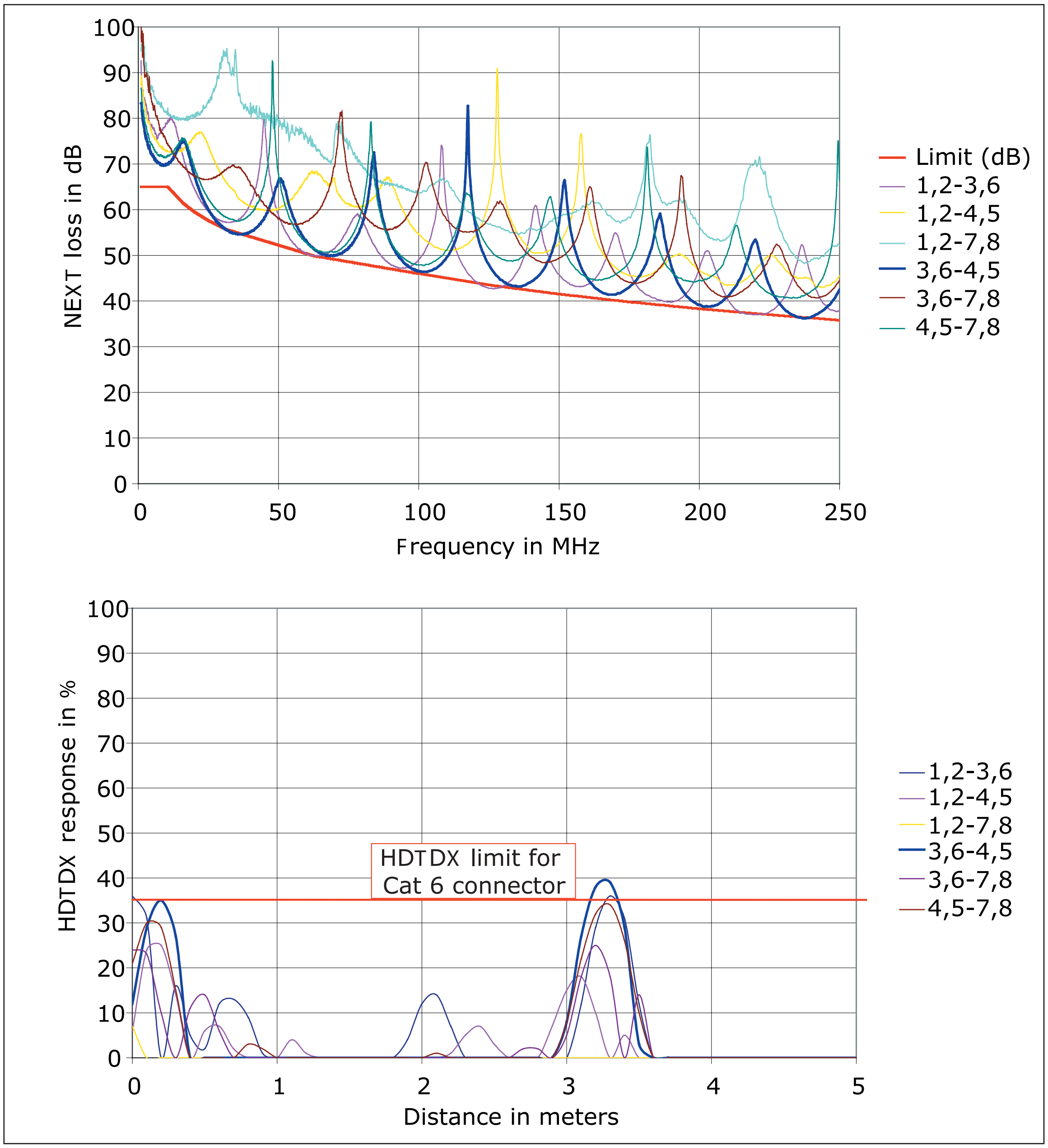


Figure 17. Examples of a NEXT and HDTDX Responses of a 2 m, Cat 5e Patch Cord

Figure 18 shows typical NEXT and HDTDX responses for a Cat 6 patch cord. The frequency response shows marginal performance. The HDTDX response shows that the connector limits the patch cord's performance. In fact, the mated performance of the remote connector exceeds the response limit. Since the excess reflection is only about 5 dB, you must consider the uncertainty discussed earlier regarding the accuracy of the remote patch cord test adapter. To check this, you could reverse the patch cord and test again. If the 5 dB of excess reflection still appears at the remote unit, you would attribute the higher HDTDX response to the properties of the test jack in the remote adapter. (If more patch cords begin to show this response, it may be time to replace the test jacks.)



abw22f.eps

Figure 18. Examples of NEXT and HDTDX Responses of a 3 m, Cat 6 Patch Cord

Examples of Return Loss Failures

The examples in this section apply the troubleshooting techniques described in "Troubleshooting Return Loss Failures" on page 12 to the HDTDR results from a Cat 5e and a Cat 6 patch cord.

Note the following characteristics of the frequency response in Figure 19 (top):

- The 36 wire pair exhibits the poorest return loss. This often results from the spacing of the 36 wire pair in the RJ45 connector.
- The worst-case margin occurs near 25 MHz. This is common in 2 m patch cords because the peaks at 1/4 of the wavelength at 25 MHz occur at approximately 2 m (depending on the cable NVP). This suggests that a characteristic impedance mismatch in the cable is limiting the patch cord's return loss performance.

The graph at the bottom of Figure 19 shows the corresponding HDTDR response. Following are some features of interest:

- There is a large reflection at the remote end— a common feature on HDTDR plots. This is caused by the DSP-4x00, which measures length at the same time it generates HDTDR information. To measure length, the DSP-4x00 leaves the remote termination open. The resulting pulse masks the HDTDR responses at the remote end of the cable. To get more informative results for the remote end, substitute a test jack terminated with 100 Ω resistors for the remote unit. You may also reverse the patch cord and run the HDTDR test again to see the connector from the near end.

Note

Substituting a test jack terminated with 100 Ω resistors for the remote unit makes the wire map test unusable.

- The 36 wire pair shows an undershoot of 2 % and an overshoot of 6 % at the near end.
  - ◊ The smallest absolute value is 2 %. This suggests, per Table 3 on page 15, that the connector's return loss is approximately 34 dB at 100 MHz. Note that this value is approximate, and the only conclusion regarding the connector is that it does not seriously impact the patch cord's performance. Since the undershoot occurs first, the connector's equivalent characteristic impedance is below 100 Ω.
  - ◊ The difference between the undershoot and overshoot is 4 %. Since every 1 % corresponds to an impedance shift of approximately 2 Ω, this suggests that the mean characteristic impedance of the cable portion of the patch cord is approximately 108 Ω (the net change is positive, so the mean characteristic impedance is higher than 100 Ω).

The cable appears to be bad because it appears to exceed the ±5 Ω limit for patch cords. Since this method provides only approximate results, you should also look at the frequency response for confirmation. The frequency response at the top of Figure 19 shows that the smallest margin occurs at a low frequency, which indicates that the cable portion of the cord is limiting the return loss.

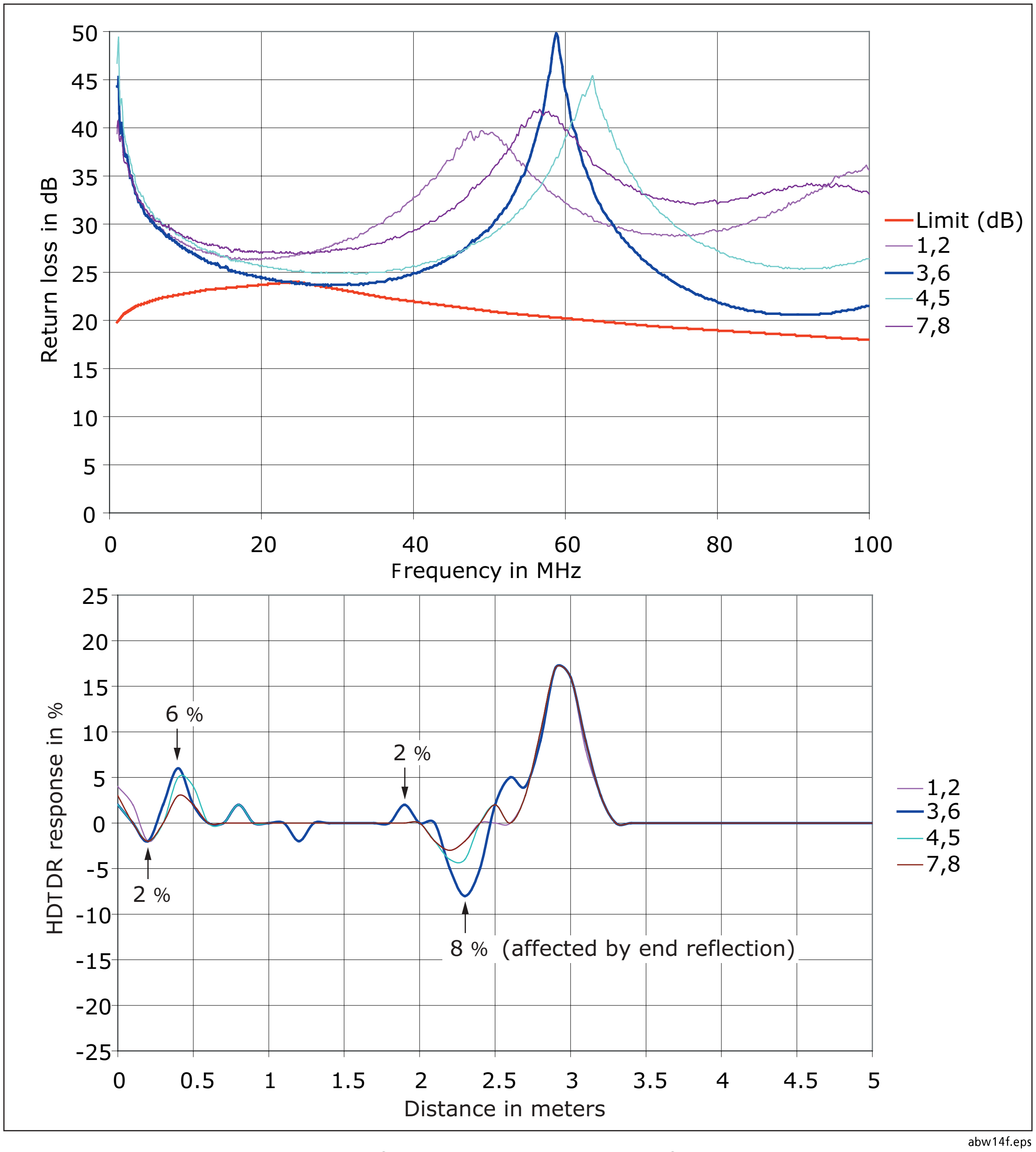


Figure 19. Examples of RL and HDTDR Responses of a Cat 5e Patch Cord

The HDTDR response at the bottom of Figure 20 suggests that the connectors limit the return loss performance of this patch cord. In this case, the mean characteristic impedance appears good because the HDTDR response at both ends appears rather symmetrical. Additionally, the frequency response at the top of Figure 20 shows that the smallest margin occurs at a high frequency, which again indicates that the connectors are causing the problem. The second, 3 % bump on the HDTDR response is suspicious, and may indicate a shift in mean characteristic impedance over that portion of the cable. However, the bump is a localized phenomenon and does not cause the cable to fail.

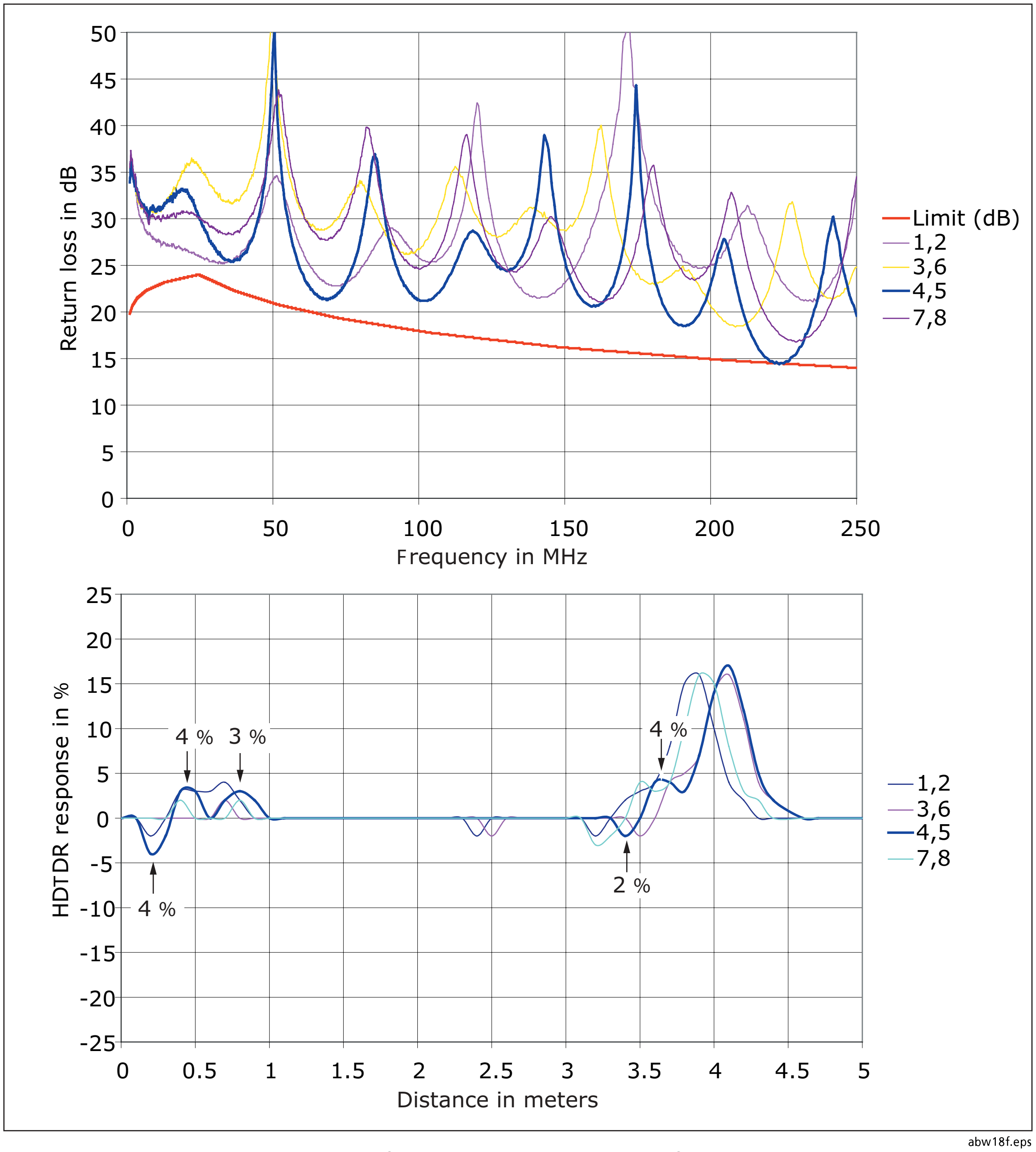


Figure 20. Examples of RL and HDTDR Responses of a Cat 6 Patch Cord

Appendix C
Cable and Patch Cord Performance Requirements

Introduction

The tables in this appendix show TIA/EIA and ISO/IEC performance requirements at selected frequencies for Cat 5, 5e, and 6 cable and patch cords. These numbers are used in the DSP test specification database.

Note

ISO/IEC performance requirements vary slightly (up to fractions of a dB) from TIA/EIA requirements, as shown in the following tables.

Table 5. Cat 5e Cable Performance Requirements per TIA/EIA-568-B

Frequency (MHz)	Insertion Loss [1, 2] (dB)	Insertion Loss [1, 3] (dB)	NEXT PP [4] (dB)	NEXT PS [4] (dB)	ELFEXT PP [1] (dB)	ELFEXT PS [1] (dB)	Return Loss [2, 4] (dB)	Return Loss [3, 4] (dB)
1	2.0	2.4	65.3	62.3	63.8	60.8	20.0	20.0
4	4.1	4.9	56.3	53.3	51.8	48.8	23.0	23.0
8	5.8	6.9	51.8	48.8	45.7	42.7	24.5	24.5
10	6.5	7.8	50.3	47.3	43.8	40.8	25.0	25.0
16	8.2	9.9	47.2	44.2	39.7	36.7	25.0	25.0
20	9.3	11.1	45.8	42.8	37.8	34.8	25.0	25.0
25	10.4	12.5	44.3	41.3	35.8	32.8	24.3	24.2
31.25	11.7	14.1	42.9	39.9	33.9	30.9	23.6	23.3
62.5	17.0	20.4	38.4	35.4	27.9	24.9	21.5	20.7
100	22.0	26.4	35.3	32.3	23.8	20.8	20.1	19.0

1. Measurement only for 100 m cable segment testing.
2. Requirements are for solid conductor cable.
3. Requirements are for stranded conductor cable.
4. Requirements start at 8 MHz for a 300 m spool test and at 4 MHz for a 500 m spool test (not specified in standards).

Table 6. Cat 6 Cable Performance Requirements per TIA/EIA-568-B.2-1

Frequency (MHz)	Insertion Loss [1, 2] (dB)	Insertion Loss [1, 3] (dB)	NEXT PP [4] (dB)	NEXT PS [4] (dB)	ELFEXT PP [1] (dB)	ELFEXT PS [1] (dB)	Return Loss [2, 4] (dB)	Return Loss [3, 4] (dB)
1	2.0	2.4	74.3	72.3	67.8	64.8	20.0	20.0
4	3.8	4.5	65.3	63.3	55.8	52.8	23.0	23.0
8	5.3	6.4	60.8	58.8	49.7	46.7	25.0	24.5
10	6.0	7.1	59.3	57.3	47.8	44.8	25.0	25.0
16	7.6	9.1	56.2	54.2	43.7	40.7	25.0	25.0
20	8.5	10.2	54.8	52.8	41.8	38.8	23.6	25.0
25	9.5	11.4	53.3	51.3	39.8	36.8	21.5	24.2
31.25	10.7	12.8	51.9	49.9	37.9	34.9	20.1	23.3
62.5	15.4	18.5	47.4	45.4	31.9	28.9	19.4	20.7
100	19.8	23.8	44.3	42.3	27.8	24.8	18.8	19.0
125	22.4	26.8	42.8	40.8	25.9	22.9	18.4	18.2
200	29.0	34.8	39.8	37.8	21.8	18.8	18.0	16.4
250	32.8	39.4	38.3	36.3	19.8	16.8	17.3	15.6

1. Measurement only for 100 m cable segment testing.
2. Requirements are for solid conductor cable.
3. Requirements are for stranded conductor cable.
4. Requirements start at 8 MHz for a 300 m spool test and at 4 MHz for a 500 m spool test (not specified in standards).

Table 7. Cat 5 Cable Requirements per ISO/IEC-11801-2002

Frequency (MHz)	Insertion Loss [1, 2] (dB)	Insertion Loss [1, 3] (dB)	NEXT PP [4] (dB)	NEXT PS [4] (dB)	ELFEXT PP [1] (dB)	ELFEXT PS [1] (dB)	Return Loss [2, 4, 5] (dB)	Return Loss [3, 4, 5] (dB)
1	2.1	3.2	65.3	62.3	63.8	60.8	20.0	20.0
4	4.0	6.0	56.3	53.3	51.8	48.8	23.0	23.0
10	6.3	9.5	50.3	47.3	43.8	40.8	25.0	25.0
16	8.0	12.1	47.2	44.2	39.7	36.7	25.0	25.0
20	9.0	13.6	45.8	42.8	37.8	34.8	25.0	25.0
31.25	11.4	17.1	42.9	39.9	33.9	30.9	23.6	23.3
62.5	16.5	24.8	38.4	35.4	27.9	24.9	21.5	20.8
100	21.3	32.0	35.3	32.3	23.8	20.8	20.1	19.0

1. Measurement only for 100 m cable segment testing.
2. Requirements are for solid conductor cable.
3. Requirements are for stranded conductor cable.
4. Requirements start at 8 MHz for a 300 m spool test and at 4 MHz for a 500 m spool test (not specified in standards).
5. Requirements start at 4 MHz for all tests. The requirements between 1 MHz and 4 MHz are covered by a 100 Ω ± 5 Ω mean impedance requirement. The spool test disregards this, since requirements are equivalent except for possibly shielded cable types.

Table 8. Cat 6 Cable Performance Requirements per ISO/IEC-11801-2002

Frequency (MHz)	Insertion Loss [1, 2] (dB)	Insertion Loss [1, 3] (dB)	NEXT PP [4] (dB)	NEXT PS [4] (dB)	ELFEXT PP [1] (dB)	ELFEXT PS [1] (dB)	Return Loss [2, 4, 5] (dB)	Return Loss [3, 4, 5] (dB)
1	2.1	3.1	74.3	72.3	67.8	64.8	20.0	20.0
4	3.8	5.7	65.3	63.3	55.8	52.8	23.0	23.0
10	6.0	9.0	59.3	57.3	47.8	44.8	25.0	25.0
16	7.6	11.4	56.2	54.2	43.7	40.7	25.0	25.0
20	8.5	12.8	54.8	52.8	41.8	38.8	25.0	25.0
31.25	10.7	16.1	51.9	49.9	37.9	34.9	23.6	23.3
62.5	15.5	23.2	47.4	45.4	31.9	28.9	21.5	20.8
100	19.9	29.9	44.3	42.3	27.8	24.8	20.1	19.0
125	22.5	33.7	42.8	40.8	25.9	22.9	19.4	18.2
155.52	25.3	38.0	41.4	39.4	24.0	21.0	18.8	17.4
175	27.1	40.6	40.7	38.7	22.9	19.9	18.4	16.9
200	29.1	43.7	39.8	37.8	21.8	18.8	18.0	16.4
250	33.0	49.5	38.3	36.3	19.8	16.8	17.3	15.6

1. Measurement only for 100 m cable segment testing.
2. Requirements are for solid conductor cable.
3. Requirements are for stranded conductor cable.
4. Requirements start at 8 MHz for a 300 m spool test and at 4 MHz for a 500 m spool test (not specified in standards).
5. Requirements start at 4 MHz for all tests. The requirements between 1 MHz and 4 MHz are covered by a 100 Ω ± 5 Ω mean impedance requirement. The spool test disregards this, since requirements are equivalent except for possibly shielded cable types.

Table 9. Cat 5e and Cat 6 Patch Cord Performance Requirements per TIA/EIA-568-B and TIA/EIA-568-B.2-1

Frequency (MHz)	NEXT Loss Category 5e (dB)					NEXT Loss Category 6 (dB)					Return Loss (dB)	
											Cat 5e	Cat 6
Length (m)	**1**	**2**	**5**	**10**	**20**	**1**	**2**	**5**	**10**	**20**	**all**	**all**
1	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	19.8	19.8
4	59.1	62.3	61.5	60.4	59.1	65.0	65.0	65.0	65.0	65.0	21.6	21.6
8	53.5	56.4	55.6	54.6	53.5	65.0	65.0	65.0	64.8	63.1	22.5	22.5
10	51.7	54.5	53.7	52.8	51.7	65.0	65.0	64.5	62.9	61.3	22.8	22.8
16	48.0	50.4	49.7	48.9	48.0	62.6	62.0	60.5	59.0	57.5	23.4	23.4
20	46.3	48.5	47.9	47.1	46.3	60.7	60.1	58.6	57.2	55.8	23.7	23.7
25	44.6	46.7	46.0	45.3	44.6	58.8	58.1	56.8	55.4	54.1	24.0	24.0
31.25	42.9	44.8	44.2	43.5	42.9	56.9	56.2	54.9	53.6	52.3	23.0	23.0
62.5	37.8	38.9	38.5	38.1	37.8	51.0	50.4	49.2	48.1	47.2	20.0	20.0
100	34.5	35.1	34.8	34.6	34.5	47.0	46.4	45.3	44.4	43.8	18.0	18.0
125						45.1	44.5	43.5	42.7	42.3		17.0
200						41.1	40.6	39.8	39.3	39.0		15.0
250						39.2	38.8	38.1	37.6	37.6		14.0

Table 10. Cat 5 and Cat 6 Patch Cord Performance Requirements per ISO/IEC-11801-2002

Frequency (MHz)	NEXT Loss Category 5 (dB)					NEXT Loss Category 6 (dB)					Return Loss (dB)	
											Cat 5	Cat 6
Length (m)	**1**	**2**	**5**	**10**	**20**	**1**	**2**	**5**	**10**	**20**	**all**	**all**
1	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	19.8	19.8
4	62.5	62.1	61.1	59.9	58.5	65.0	65.0	65.0	65.0	65.0	21.6	21.6
10	54.7	54.3	53.4	52.5	51.4	65.0	65.0	63.9	62.3	60.7	22.8	22.8
16	50.7	50.3	49.5	48.7	47.8	62.4	61.6	60.0	58.5	57.1	23.4	23.4
20	48.8	48.4	47.7	46.9	46.1	60.5	59.7	58.2	56.7	55.4	23.7	23.7
31.25	45.0	44.7	44.0	43.3	42.8	56.7	56.0	54.5	53.1	52.0	23.1	23.1
62.5	39.1	38.9	38.4	38.0	37.8	50.8	50.1	48.8	47.7	47.0	20.0	20.0
100	35.2	35.0	34.7	34.5	34.6	46.8	46.2	45.0	44.2	43.7	18.0	18.0
125						44.9	44.3	43.3	42.5	42.2		17.0
155.52						43.1	42.5	41.5	40.9	40.7		16.1
175						42.1	41.5	40.6	40.1	39.9		15.6
200						41.0	40.5	39.6	39.1	39.1		15.0
250						39.1	38.6	37.9	37.6	37.6		14.0