Supplemental Deployment Information for HDSL, HDSL2, and HDSL4 (HDSLx)

Document Number: 61221HDSLL1-10C
May 2005

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Revision History

Revision	Date	Description of Changes
A	April 2001	Initial release
B	December 2002	Add expanded deployment measurements; add HDSL4 details
C	May 2005	Enhance HDSL4 details

Conventions

The following typographical conventions are used in this document:

This font indicates a cross-reference link. First-time references to tables and figures are shown in **this font**.

This font indicates screen menus, fields, and parameters.

THIS FONT indicates keyboard keys (ENTER, ESC, ALT). Keys that are to be pressed simultaneously are shown with a plus sign (ALT+X indicates that the ALT key and X key should be pressed at the same time).

This font indicates references to other documentation and is also used for emphasis.

`This font` indicates on-screen messages and prompts.

`This font` indicates text to be typed exactly as shown.

This font indicates silkscreen labels or other system label items.

This font is used for strong emphasis.

NOTE

Notes inform the user of additional but essential information or features.

CAUTION

Cautions inform the user of potential damage, malfunction, or disruption to equipment, software, or environment.

WARNING

Warnings inform the user of potential bodily pain, injury, or death.

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ADTRAN offers training courses on our products. These courses include overviews on product features and functions while covering applications of ADTRAN's product lines. ADTRAN provides a variety of training options, including customized training and courses taught at our facilities or at customer sites. For more information about training, please contact us.

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GENERAL

Digital Subscriber Line (DSL) technologies are being deployed at an astounding rate. While many circuits are successfully installed and turned-up with minimal effort, others seem to be prone to problems from the start. Since the copper loop plant is the physical transmission medium for these DSL circuits, its transmission properties have a profound effect on how well these circuits perform.

The primary objective of the Supplemental Deployment Information for HDSLx document is to assist our ADTRAN customers in understanding the requirements for testing the Outside Plant (OSP) pairs, either for pre-qualification of a loop for new service or troubleshooting an existing circuit that has failed while in service. This document is intended to address most common loop deployment issues but may be periodically updated as necessary to include additional field test experience or technology advancements.

Testing copper pairs for “plain old telephone service” (POTS) is common practice in telephone companies. Performing the traditional POTS cable acceptance tests is considered adequate for voice-band grade services but does little to address an HDSL, HDSL2, or HDSL4 (HDSLx) circuit operating at higher frequencies. However, these tests are an essential part of testing for DSL circuit deployment.

The value of the POTS testing is to determine if there is a need to proceed with further testing of the pair. That is, if a copper pair cannot support POTS service, it should *not* be used for DSL service. The first step, then, in qualifying a local loop for DSL service is to make sure it meets all of the requirements for POTS Voice-Band service.

The transmission of analog voiceband signals is very tolerant to many of the impairments that are normally encountered in the OSP environment. On the contrary, DSL signals are less forgiving due to the higher frequencies involved. Hence, there is a need to supplement the POTS testing with higher frequency tests to uncover loop anomalies that will affect DSL services but which are invisible to voiceband testing.

This document presents information necessary to test the copper loop and determine its transmission qualities (both low and high frequency), enabling deployment of DSL services with a higher degree of confidence and success.

Scope and Purpose

The purpose of this document is to address the test parameters for cable pair testing by technicians in the field. The assumption is made that all of the pre-deployment engineering for the circuit is complete, and for HDSL and HDSL2, that the loop meets the Carrier Serving Area

(CSA) requirements, at least on paper. For more information, refer to "CSA Guidelines and Bridged Taps" on page 18.

NOTE

HDSL4 can operate on loops that exceed the CSA requirements. ADTRAN offers an excellent computer-aided loop design tool, *DSL Assistant*, to help in this process. For more information, refer to "DSL Assistant" on page 21 for details.

As previously indicated, this document will focus on both the low and high frequency tests required to help determine the suitability of a cable pair for DSL service. Although the majority of the information is applicable to any DSL service (including 2B1Q ISDN, Total Reach® ISDN and DDS, SHDSL, or ADSL), this document will focus specifically on HDSL, HDSL2, and HDSL4 technologies and the parameters that are unique to each of these.

This document will first present a section on low frequency testing, which should be familiar to most readers and easily performed with commonly available test equipment. This will be followed by a section on high frequency/wideband testing, and finally, a section containing miscellaneous suggestions and tips learned from field experience.

It is *not* the intent of ADTRAN to require that all of these tests be performed on every pair being considered for HDSLx service. The intent *is* to enhance the understanding of the factors that affect HDSL service quality. The overall testing strategy that will meet local HDSL circuit requirements is ultimately the responsibility of the entity installing the HDSLx service.

As indicated, HDSL loop qualification consists of the following procedures:

- "Voice-Band Testing" on page 2
- "Wideband Loop Loss Testing" on page 13

VOICE-BAND TESTING

The first step in qualifying a local loop for DSL service is to ensure that the loop meets the basic requirements normally expected of the copper plant.

Testing the copper cable plant includes the following procedures:

- "Cable Preparation" on page 3
- "Foreign DC Voltage" on page 3
- "Power Influence" on page 4
- "Insulation Resistance" on page 5
- "Loop Resistance/Resistive Balance" on page 6
- "Capacitive Length" on page 8
- "Longitudinal Balance" on page 9
- "Circuit Noise" on page 10
- "Installation Site Grounding" on page 11

Cable Preparation

The tests described in this section will determine the low frequency performance of the cable pair. However, since the final objective is to qualify the loop for DSL service, some additional preparation must be performed:

- The loop must meet the requirements for the amount of bridged tap present, per CSA guidelines. These guidelines are included for reference in "CSA Guidelines and Bridged Taps" on page 18.
- All load coils must be removed from the pair. This includes load coils that may be present on the bridged taps as well.
- All other line conditioning equipment (such as line buildout capacitors, bridge lifters, etc.) must be removed.
- It is good practice to run a TDR (Time Domain Reflectometer) test on the pair just to make sure that none of the above items (that may not have been shown on cable records) remain on the pair. Moreover, TDRs can locate major or minor cabling problems including sheath faults, broken conductors, water damage, loose connectors, crimps, cuts, shorted conductors, and a variety of other fault conditions as well as their location along the cable.
- Ensure proper cable and site bonding and grounding per standard operating practices.

Foreign DC Voltage

Foreign (or stray) DC voltage on a pair usually comes from either a "hard" cross (or short) to another conductor in the cable, or from a high resistance leakage path to other conductors due to water in the cable. The presence of any DC voltage indicates possible damage to the copper facility, as DC can only come from the Central Office battery. It is highly advisable to pursue the location of the foreign voltage source and eliminate the cause; however, the DSL transceivers can compensate for a certain amount of foreign DC voltage on the pair, so it is not necessary to have a totally "clean" circuit.

The accuracy of measurements for foreign DC voltage depends on the impedance of the voltmeter/test set. It is imperative that these measurements be made with a high impedance voltmeter (preferably digital) as lower impedance analog meters tend to load the circuit excessively and will not allow the technician to get an accurate measurement (**Figure 1**).

Foreign DC Voltage Measurement Objective: $\leq$**3 VDC**

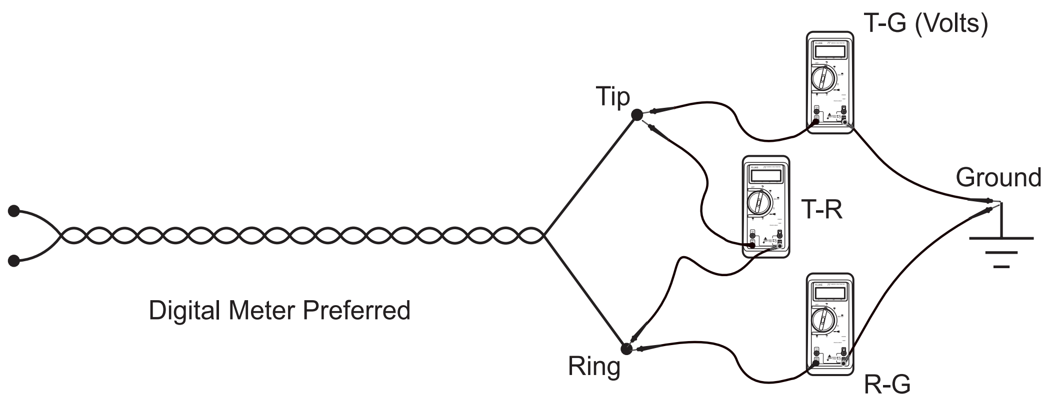


Figure 1. Foreign DC Voltage Measurement

Power Influence

Power influence (PI) is stray, steady-state AC voltage on the pair, and its source is direct induction from the local power utility lines in close proximity to the telephone cable. It is commonly thought that “close proximity” to the telephone cable means on the same pole line or buried on the same side of the road as the power line. In fact, power line induction can come from power lines hundreds or thousands of feet away from the telephone cable.

A common misconception is that the cable shield is used to reduce the power influence on the pairs. In reality, the shield is only about 3% effective at “insulating” the cable pairs from the 60 Hz magnetic fields that induce voltage on the pairs. Therefore, the only way to reduce excessive PI on a cable is to address the issue in conjunction with the local power utility to reduce the magnetic fields radiating from their power lines.

Although the cable shield does little to actually shield the cable core at 60 Hz and low harmonics, it is still essential as a return path for low frequency longitudinal currents on the cable pairs. The shield must be bonded and grounded regularly so these currents are drained to earth. **Figure 2** illustrates the PI test connections.

A certain level of PI can be tolerated by the DSL transceivers, so the accepted industry standards for PI are applicable for DSL circuits as well.

Power Influence Measurement Objective:	**≤80 dBrnC =**	**Acceptable**
	80-90 dBrnC =	**Marginal**
	≥90 dBrnC =	**Unacceptable**

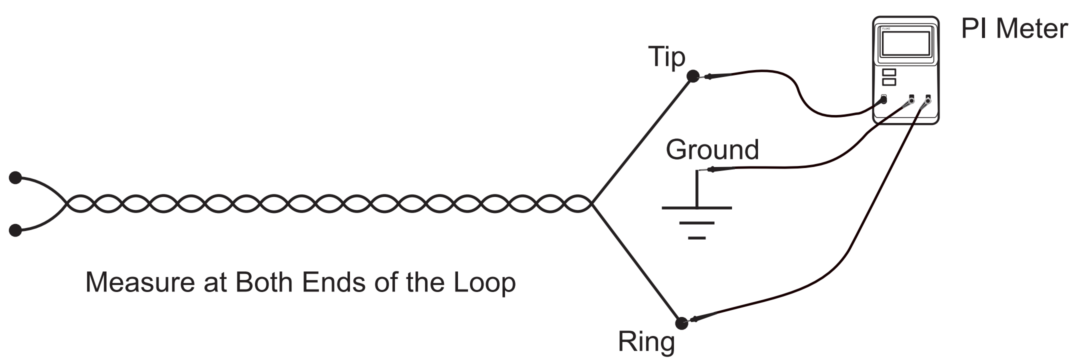


Figure 2. Power Influence Measurement

In addition to the predominant 60 Hz magnetic fields, power utility lines can also radiate higher frequency harmonics as well. These harmonics manifest themselves as noise on the cable pairs. Fortunately, the cable shield becomes increasingly more effective at higher frequencies. Although the cable shield is only 3% effective at 60 Hz, its effectiveness rises to around 50% at 540 Hz (the 9th harmonic of 60 Hz) and 80% at 1020 Hz. In order for the shield to be effective at all, it is absolutely essential that it is properly bonded and grounded. For more information, refer to local operating company practices for specifics.

Insulation Resistance

Insulation resistance is a measure of the DC isolation between a given conductor and other conductors in the cable and also the cable shield. When a cable is new, the insulation resistance is on the order of magnitude of billions of ohms. However, as the cable ages and is exposed to the elements (water is the worst offender) the insulation resistance deteriorates. The majority of cables in the OSP environment will have insulation resistance measurements well in excess of hundreds of megohms. This is easily achieved and completely acceptable for DSL service. Experience has shown that cable can degrade to the point that the insulation resistance is on the order of tens of megohms. Most often, these tend to be very old paper/ pulp-insulated cables. Therefore, to better ensure reliable DSL service, we recommend that a cable support an insulation resistance of at least 3.5 MΩ between conductors, as well as between conductor to ground (**Figure 3**). Ideally, insulation resistance tests should be made at voltages comparable to the loop technology being deployed. HDSLx circuits utilize span powering voltages of up to 190 VDC, so insulation resistance tests should be made at this voltage or perhaps slightly higher (such as 250 VDC). At a bare minimum, measure the insulation resistance with an ohmmeter that is designed to measure leakage and outputs at least 70 VDC.

Insulation Resistance Measurement Objective: ≥3.5 MΩ (T-R, T-G, R-G)

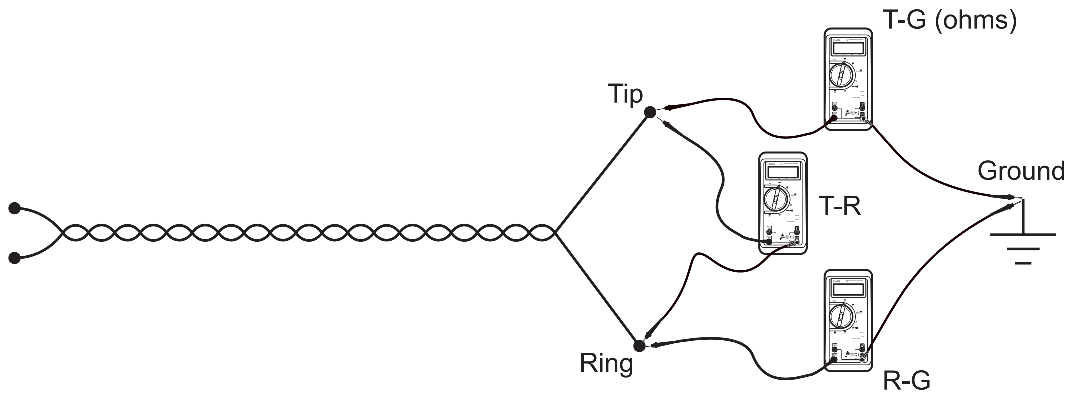


Figure 3. Insulation Resistance Measurement

CAUTION

When insulation resistance values fall into the 100 kΩ range, the Ground Fault Interrupter (GFI) in the span-powering circuitry in the HTU-C begins to activate, as it cannot differentiate between the degraded insulation resistance leakage and a cable technician getting a shock. This can result in a service outage due to the span power shutting down.

Loop Resistance/Resistive Balance

The DC loop resistance of a pair is the resistance measured between the tip and ring conductors with the far end of the pair shorted (**Figure 4**). Therefore, loop resistance is the sum of the resistances of the individual tip and ring conductors in series.

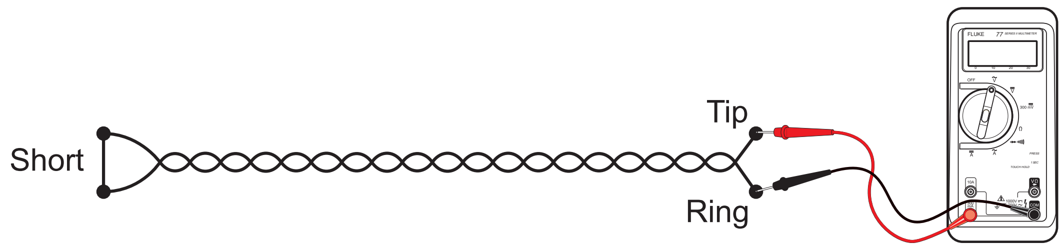


Figure 4. Loop Resistance Measurement

With HDSL4, loop resistance is a parameter that is different on the first span (between the CO and repeater) and subsequent spans (between two repeaters or between repeater and the customer).

The loop resistance measurement can be used to approximate the length of a loop and can therefore be used as a simple initial test to determine if a particular loop is a candidate for HDSLx technology. **Table 1** lists maximum target resistance values for the different HDSLx technologies. Target values are shown because resistances will vary due to temperature and wire gauge changes. When resistance measurements exceed the values in Table 1, exercise caution when deploying HDSLx circuits.

For accurate loop qualification, wideband attenuation characteristics must also be considered. For attenuation guidelines, refer to "Wideband Loop Loss Testing" on page 13.

Table 1. Maximum Target Loop Resistance per Segment

	HDSL	HDSL2	HDSL4
Loop Resistance* in ohms	751	751	1000 (1st segment) 920 (subsequent segments)

* Resistance values in this table are based on 70°F temperature and 26 AWG cable.

Note that for HDSL4, the maximum length of the first segment (closest to the CO) is longer than segments downstream of the first repeater. For HDSL4 circuits with multiple repeaters, the loop segments must meet the resistance budget guidelines described in "HDSL4 Span Powering Considerations" on page 37.

Resistive balance is a measure of the resistance of each of the conductors by themselves and is measured by grounding both conductors at the far end and then comparing tip-to-ground and ring-to-ground measurements (**Figure 5**).

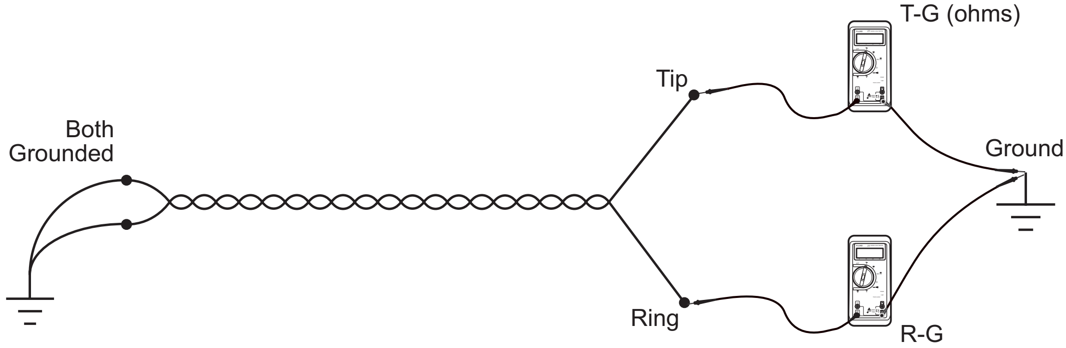


Figure 5. Resistive Balance Measurement

Theoretically, the tip and ring conductors should be of equal value (because they are the same gauge, same temperature, same length, same number of splices, etc.) and their resistance should be equal to half of the total loop resistance measurement. In practice, however, the two conductors may exhibit unequal resistances - the most probable reason being a high-resistance splice in the conductor that has the highest resistance measurement. The total loop resistance should measure within ± 2% of the theoretical value for the section under test, as derived from sequential cable markings or OSP cable records. The resistive balance of the individual conductors should be ± 5 ohms or 1% of the loop resistance, whichever is the lesser of the two.

Resistive Balance Measurement Objective: **±5 Ω, or 1% of Tip/Ring difference, whichever is less**

Capacitive Length

Telephone cables are manufactured to exacting specifications and tight tolerances to maintain their desired transmission properties. Knowing the makeup of the pair (sections, gauge, temperature, etc.), a technician can accurately determine the length of a cable from the loop resistance measurement determined above. Similarly, the capacitance of the pair can be used to find the length of the pair. Normally called an “open meter,” this commonly available test set can be calibrated to the cable type being measured and give a display of the length of the pair as determined from the capacitance seen between tip, ring, and ground (**Figure 6**). Comparing the capacitive length of the pair to its resistive length provides valuable diagnostic information to determine if there is a section of water in the cable, split pairs, or unknown bridged tap (or length beyond the customer) still present.

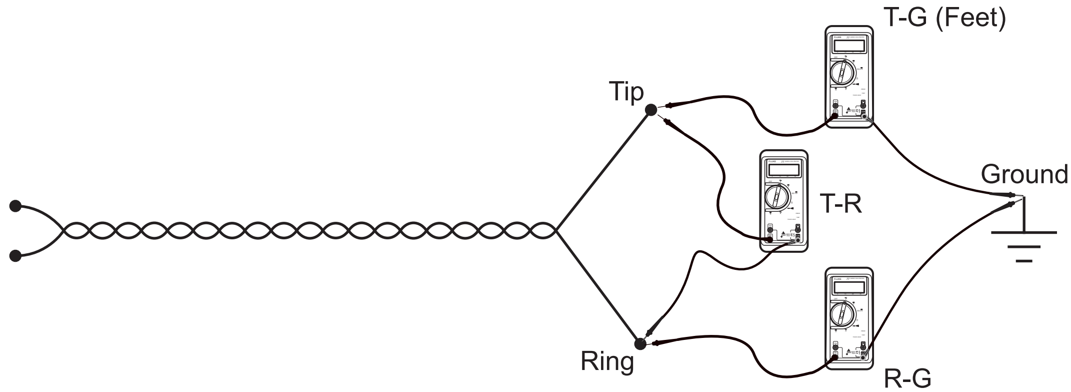


Figure 6. Capacitive Length Measurement

It would be difficult to impose hard specifications on the parameters mentioned above. However, the following are some general guidelines that may help when troubleshooting discrepancies between resistive and capacitive length readings:

- The tip and ring conductors should be the same capacitive length, within ± 2%.
- A difference of up to 6% between the resistive and capacitive lengths of a pair should not be cause for concern, but a capacitive length of 10% or more than the resistive length would indicate an excessive bridged tap, water, or at least a problem worth investigating. A capacitive length reading less than the resistive length reading may indicate the presence of a split-pair in the section.
- The resistance of the copper conductors in the pair varies with the gauge of the conductor (e.g., 26 AWG has more resistance per kft than 19 AWG), and this needs to be taken into account when totaling up the loop resistance if different gauge sections are involved. Conversely, the capacitance of the pair is tightly controlled by the manufacturer at 0.083 µF/mi (15.72 nF/kft), no matter what type of cable or gauge is involved. Therefore, a capacitive length measurement cannot differentiate whether there are multiple gauge changes in the section, but resistance measurements can vary widely depending on the presence of gauge changes and their lengths.

Longitudinal Balance

The longitudinal balance of a cable pair is a measurement of how similar the electrical characteristics of the tip conductor are to those of the ring conductor (**Figure 7**). The degree of how well the tip and ring conductors are electrically matched translates directly into how well the pair is able to "self-shield" itself from the effects of noise and interference present in the environment around the pair (both internal and external to the cable). A pair with a high (good) longitudinal balance reading converts very little external noise into noise across tip and ring, therefore allowing the DSL bit-stream to run error free. On the other hand, a pair with a low longitudinal balance reading is a very effective antenna and couples every undesirable signal around it into the DSL circuit, which can result in bit errors and loss of sync in severe cases. The specifications for longitudinal balance in the audio frequency range are well established in the industry.

Longitudinal Balance Measurement Objective: **≥60 dB = Acceptable**
50-60 dB = Marginal
<50 = Unacceptable

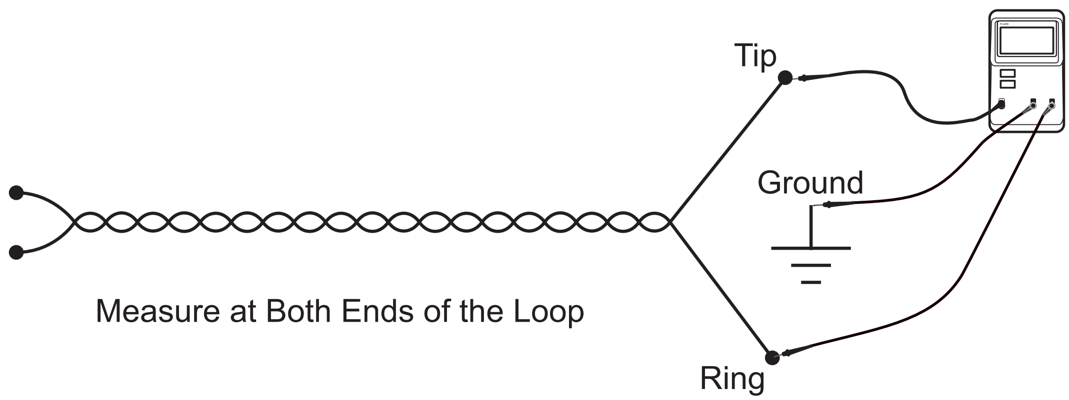


Figure 7. Longitudinal Balance Measurement

The objective values are based on low-frequency measurements on the pair (either calculated from power influence and circuit noise values or by instrumentation that externally "drives" the pair with a low-frequency excitation signal). Test equipment is becoming available which will make longitudinal balance measurements at HDSL frequencies as well. Because variations in cable transmission properties are much more pronounced at higher frequencies, the longitudinal balance measurements will tend to be somewhat lower than the above stated values. A more realistic number for longitudinal balance at 196 kHz is given in the objective:

Longitudinal Balance Measurement Objective (at 196 kHz): >40 dB

Circuit Noise

Circuit noise is the amount of noise power that is measured between tip and ring on a cable pair. In this section we are dealing with the noise power as measured through a C-message weighting filter. A C-message weighting filter roughly simulates the 300-3000 Hz voice frequency passband. Even though the frequency range in which we are taking the measurements is well below the operating passband of the DSL circuit, these noise measurements (**Figure 8**) are still useful for the following reasons:

- The most significant source of the noise measured in the C-message band is the power utility grid. This noise can come from multiple sources (such as defective power factor correction capacitors, improperly loaded transformers, arcing switches, etc.). All of these sources can generate noise at harmonic frequencies many multiples higher than the 60 Hz fundamental frequency. Although most of the noise energy is contained below 3 kHz, the potential for interference over wider bandwidths exists as well. Time spent mitigating these noise sources will also result in higher-quality POTS service in the same cable as well.

NOTE

The importance of proper cable shield bonding and grounding cannot be overemphasized when it comes to controlling noise in a cable.

- Another source of C-message noise comes from within the pair itself. If there are oxidized splices somewhere along the pair, they can generate noise when sealing current is supplied. Again, this noise is typically confined to frequencies well below the operating band of DSL circuits, and it would probably be filtered out by the DSL transceivers. However, oxidized splices have also been known to “go open” at some point in the future, and an open splice will affect a DSL circuit. If noisy splices can be located and repaired, the reliability of the DSL circuit can only go up and the repeat trouble reports should decrease.

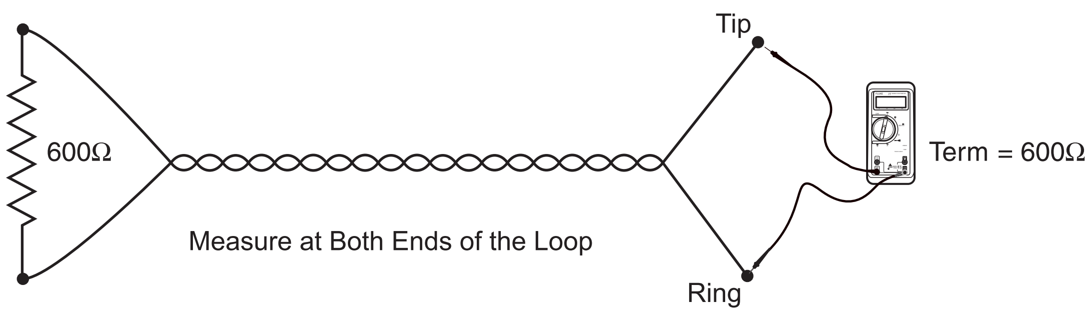


Figure 8. Circuit Noise Measurement

Circuit Noise Measurement Objective:	**≤20 dBrnC =**	**Acceptable**
	20-30 dBrnC =	**Marginal**
	>30 dBrnC =	**Unacceptable**

In the newest HDSL2 and HDSL4 modules, ADTRAN provides a Bad Splice Detection feature which is designed to detect anomalies caused by oxidation, etc. For more information on this feature, refer to the Installation and Maintenance Practice for these modules.

Installation Site Grounding

Field experience has shown that proper circuit pack grounding is not only necessary for safety, but it is absolutely essential for reliable DSL circuit operation. Proper grounds are required not only at the Central Office circuit pack but also in the field at the repeater cases and the customer premises (**Figure 9**).

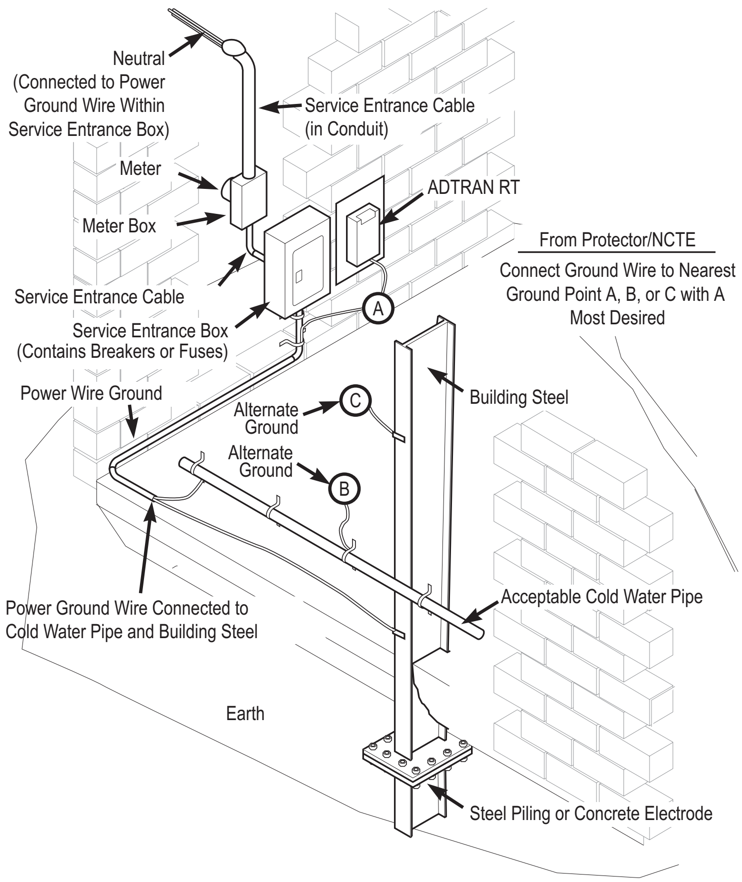


Figure 9. Installation Site Grounding

Grounding impacts DSL circuits in the following ways:

- Each DSL circuit pack (CO unit, range extenders, and customer unit) has built-in surge protectors to protect the product from high-voltage transients (such as lightning, power line crosses, etc.) coming in on the tip and ring conductors which could otherwise cause catastrophic failure of the hardware. These surge protectors drain the incoming surge away from the circuit pack by shunting it to the frame ground connection, which needs to be connected to a low-impedance ground point. Without a good path to ground, the surge protection is rendered useless. At the very least, the circuit pack will be damaged, but in a worst-case scenario the surge may cause sufficient damage to the board to cause a fire.
- Current DSL circuit packs use high-speed digital processing and switch mode power supplies, both of which by nature are electrically noisy. Design and compliance engineers take great care in ensuring the circuitry is both shielded from itself and from other outside noise sources (either ingress or radiation). All of this shielding is highly dependent on having a low-impedance ground connection to the circuit pack. If that ground is not

present, erratic, unreliable behavior of the DSL circuit has been observed ranging from unexplained errors to circuits “going to sleep.” Many chronic problems have been resolved by employing proper grounding techniques.

- Another item related to grounding is that of making sure that the frame ground pin of the circuit module is actually connected to ground when it is installed in the housing. This may seem obvious, but not all housing vendors bring their frame ground out on the same pins. Check the housing documentation and the circuit pack Installation and Maintenance practices against each other for compatibility with respect to grounding.

Two aspects need to be considered when grounding HDSL equipment. Ultimately the ground connection terminates at a ground rod or building steel, which provides the “connection” to the earth. It is desirable to keep the resistance of this interface to the earth as low as possible, preferably less than 25 ohms. Depending on local soil conditions, this may present a challenge; however, there are several vendors that provide chemical treatment systems and other installation strategies that can lower the ground resistance to an acceptable level.

The other aspect of ground installation that is often overlooked is the resistance of the wiring (and connections) between the ground lug of the HDSL shelf and the ground rod. A low resistance between them is essential to avoid hazardous potential differences during a large surge such as a lightning strike. For example, it is not uncommon to experience a lightning surge of 2000 amps, which must be drained to ground. If even 1 ohm of resistance is in the path between the HDSL shelf and the ground rod, it will result in a 2000-volt potential difference between the ground rod and the shelf. Therefore, Underwriter's Laboratories (UL) recommends a maximum of 100 milliohms of resistance between the frame ground lug of the shelf and the earth ground connection (e.g., ground rod, building steel, AC service entrance equipment, master ground bar). This will ensure equipotential bonding of all equipment during a surge condition, minimizing equipment damage and maximizing personnel safety and circuit reliability. Fortunately, this grounding requirement is readily achievable by proper selection and sizing of the ground wiring conductors.

Earth Ground Resistance Measurement Objective: ≤**25** Ω

Frame Ground Wiring Resistance Objective: ≤**100 m**Ω

References

Additional information on site grounding can be found in the standards shown the following references:

- TIA/EIA-607, Commercial Building Grounding and Bonding Requirements for Telecommunication
- National Electrical Code, Article 800
- Electrical Protection of Telecommunications Outside Plant (Revision of T1.316-1997) – T1.PP.316-2002
- Electrical Protection Applied to Telecommunications Network Plant at Entrances to Customer Structures or Buildings, T1.318-2000

NOTE

A T400/T200 Test Access Card is extremely useful in troubleshooting housing and grounding problems. (ADTRAN P/N 1244065L2 or equivalent)

WIDEBAND LOOP LOSS TESTING

This section describes testing methods to determine the suitability of a loop for HDSL, HDSL2 and HDSL4 technologies. The performance of all digital subscriber loop (DSL) technology is based upon the ratio of the received signal power to the received noise power. This signal to noise ratio (SNR) ultimately determines the success or failure of the HDSLx technology on the candidate loop. The loop loss is generally characterized by one of three parameters, loop attenuation, insertion loss or pulse attenuation. As each of the HDSLx technologies transmits its known power level, it is the loop loss which dictates how much power will reach the receiver input and thus determines the signal portion of the signal to noise ratio. The noise at the receiver is a combination of background (white) noise, crosstalk noise and impulse noise. These noise signals compete, in an adverse manner, with the received signal when the receiver attempts to recreate the original transmitted information. These noise signals make up the noise portion of the signal to noise ratio. The subsequent sections describe both loop loss, noise measurements and our recommended guidelines for loop qualification.

Topics detailed in this section include the following:

Loop Attenuation

The proper design method and performance criteria for loop qualification is loop attenuation. The loop attenuation parameter is the loop loss, weighted according to the HDSLx transmit power spectral density (PSD). This means that the loop loss at frequencies which carry more transmit power are weighted more in the calculation than frequencies which have little or no transmitted power. As a result of the weighting in calculation of loop attenuation, this single parameter is the most accurate method for determining the amount of signal that will be received at the far end of the loop.

Figure 10 provides a comparison of various DSL PSD signals.

Worksheets for Loop Attenuation calculations for HDSLx are provided in "Calculating Loop Qualification" on page 23.

Table 2 provides the HDSL2 and HDSL4 loop attenuation values for various lengths of 26 AWG PIC cable at 70°F. The HDSL2 and HDSL4 loop attenuation values are different for the same loop because the transmit spectra and symbol rate are different. Even for the same technology (HDSL2, HDSL4), the loop attenuation is different between the CO side and the remote side of the loop. This is the case whenever the transmit PSD is asymmetric between the CO and remote side of the loop.

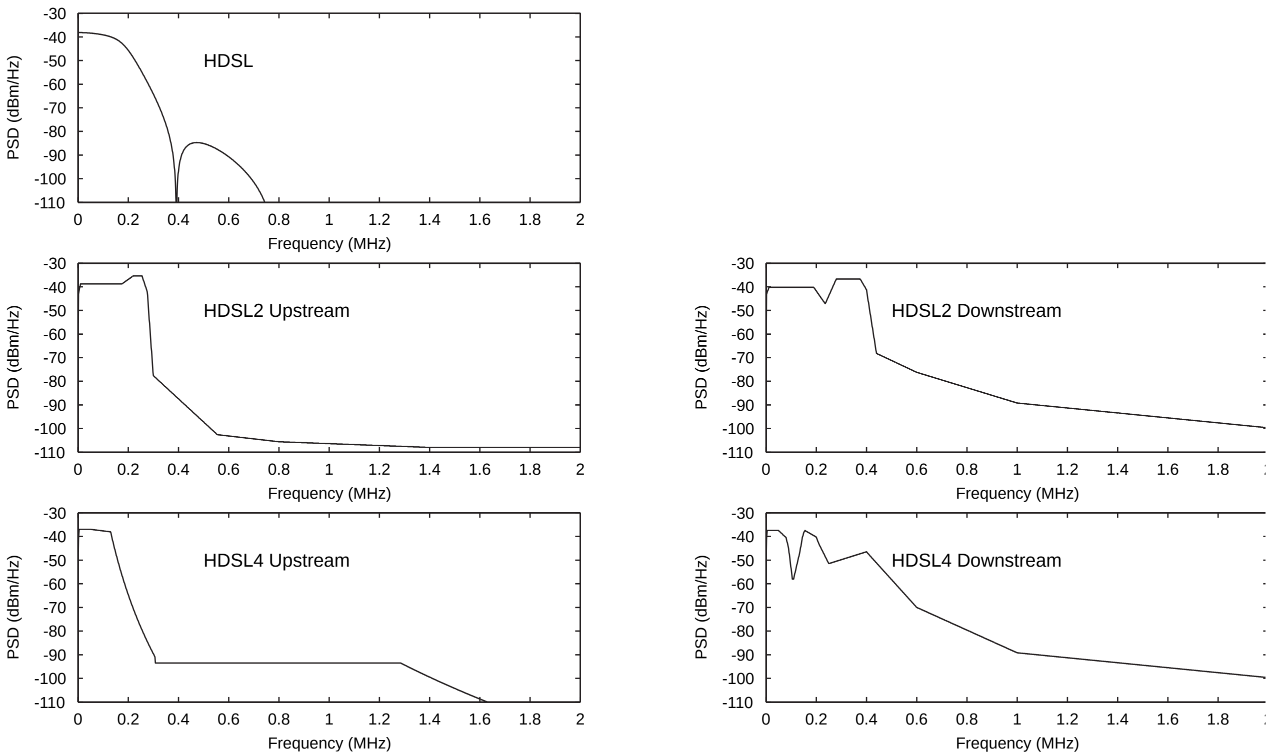


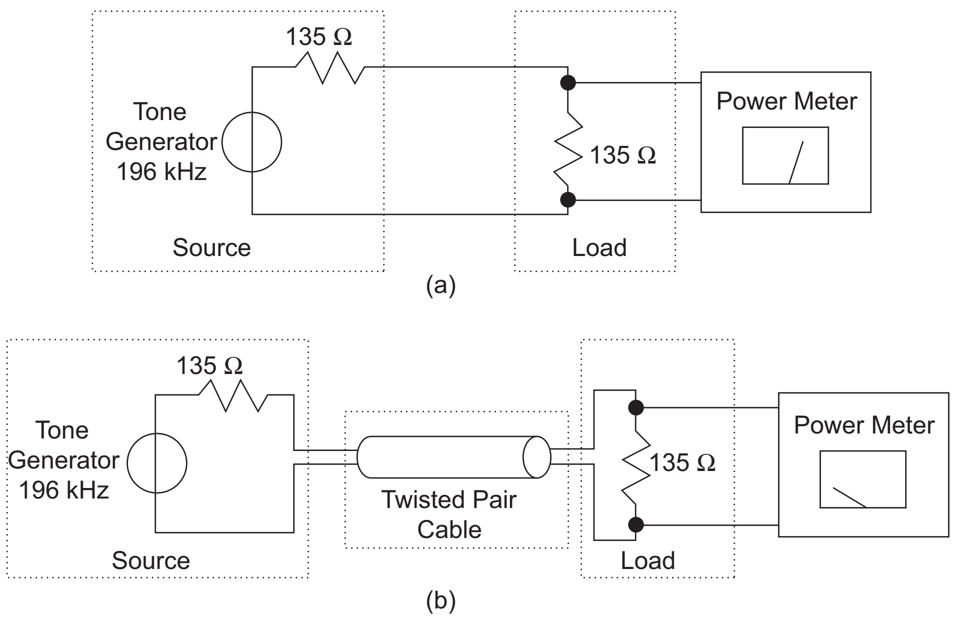
Figure 10. Power Spectral Density

Table 2. HDSL2 and HDSL4 Loop Attenuation for Various Lengths of 26 AWG Cable

No. 26 AWG Length (kft)	Loop Attenuation at H2TU-C	Loop Attenuation at H2TU-R	Loop Attenuation at H4TU-C	Loop Attenuation at H4TU-R
8	26.84	28.53	22.69	24.69
9	30.20	32.01	25.54	27.66
10	33.56	35.48	28.39	30.61
11	36.92	38.93	31.23	33.56
12	40.28	42.38	34.08	36.50

Insertion Loss

Insertion loss is the difference in power (in dB) at a given frequency that is caused by the loop. Consider a test where the power of a single tone is measured without a loop present. Then the test is repeated with the loop under test "inserted" between the source and the power meter (**Figure 11**). The insertion loss is the ratio of the power with and without the loop inserted.



Injecting a tone at a given frequency;
(a) measure power across load with no loop, then (b) measure power across load with loop inserted. Insertion loss is the difference (in dB) between two measurements.

Figure 11. Physical Interpretation of Insertion Loss

Historically, loop loss has been equated to insertion loss. This mindset originated with AMI-T1 signaling where the peak of the transmitted spectrum is 772 kHz. The practice for T1 installations generally included grooming of the pairs by removing bridge taps from the loop. With all bridge taps removed, the simple insertion loss at the peak of the spectrum is a very good measure of the signal content at the receiver. Because the AMI-T1 transmit spectrum is the same upstream and downstream, the single-frequency insertion loss is equally valid, independent of direction. The single-frequency insertion loss criteria continued its use with ISDN (at 40 kHz). The low transmit frequency of ISDN results in relative immunity to crosstalk noise and bridge taps so the insertion loss practice continued to be successful. The practice of using insertion loss (at 196 kHz) for loop qualification has continued throughout recent history for 2B1Q HDSL. Due to its ease of measurement, insertion loss is commonly used to characterize the loss of a loop and is usually taken at the Nyquist frequency (½ baud rate). The result is a crude estimate of the overall attenuation effect of the loop.

The problem with insertion loss at a single frequency, as a loop qualification criteria, is that the loop loss curve is extremely frequency dependent with bridged taps on the circuit. **Figure 12** shows the insertion loss as a function of frequency for several loops with various bridge tap topologies. All of the loops provide 6 dB performance margin measured at the CO side of an HDSL4 loop.

The insertion loss at 196 kHz varies by over 10 dB, but the loss at frequencies below 130 kHz all behave similarly.

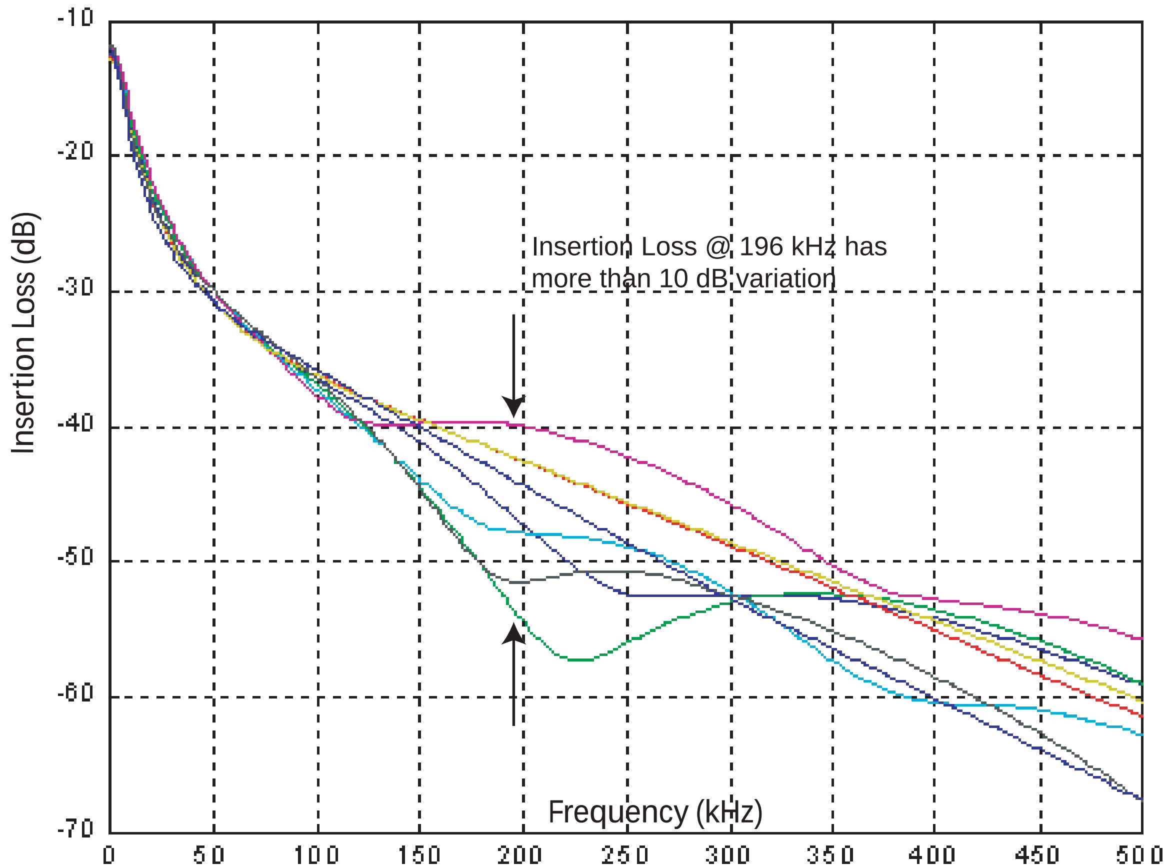
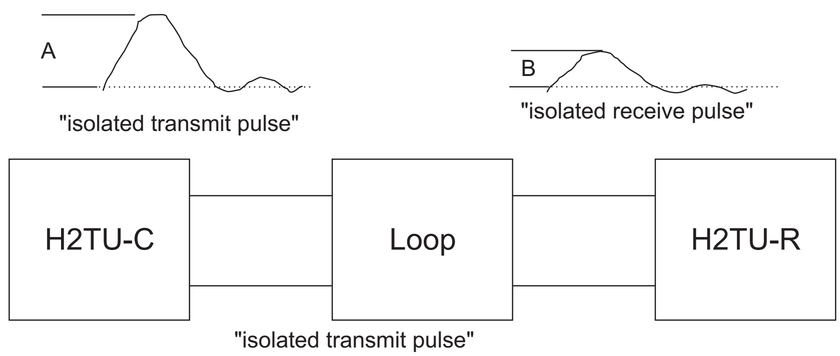


Figure 12. Insertion Loss of Various Loops Having a 6 dB Margin

The single frequency insertion loss becomes even less valuable when 1) the transmit spectra are substantially different in the upstream and downstream direction or 2) when they have significant power at much different frequencies than that for which insertion loss is evaluated. Both HDSL2 and HDSL4 are such technologies. HDSL2 transmits a significant amount of power between 275 and 400 kHz in the downstream direction. HDSL4 has very little power beyond 140 kHz in the upstream direction. Therefore, insertion loss at 196 kHz is **not** a valuable measure of the expected received signal power for either of these technologies.

Pulse Attenuation

The pulse attenuation description of loop loss is illustrated in **Figure 13** below. Pulse attenuation is the attenuation of the peak amplitude of a single transmitted pulse through the loop (in dB). The pulse attenuation parameter is extremely useful; however, it is difficult to measure directly with test equipment. ADTRAN HDSLx equipment uses analog and digital gain stages to determine the attenuation of an operational loop and reports this attenuation on the Status screen (see **Figure 14**).



Pulse Attenuation = $20 \log_{10} (A/B)$

Figure 13. Pulse Attenuation Diagram

```
Shelf: 1   Slot:  15          Total Access System                12/24/04 09:29
Unacknowledged Alarms: CRITICAL MAJOR            INFO
                     Circuit ID:
                          Detailed HDSL2 and T1 Status

                              HDSL2 RECEIVER DATA
                                H2TU-C    H2TU-R

                               --------  --------
          MARGIN(CUR/MIN/MAX): 17/17/17  17/17/17
               ATTEN(CUR/MAX):   30/31     32/32
                     ES 15MIN:   000       000
                    SES 15MIN:   000       000
                    UAS 15MIN:   000       000

                             T1 RECEIVER DATA
                        DSX-1                DS1
                       -------             -------
           FRAMING:      ESF                 ESF
         LINE CODE:     B8ZS                B8ZS
         ES-P/ES-L:    000/000             000/000       1. Zero Registers
       SES-P/SES-L:    000/000             000/000       2. Restart Min/Max
       UAS-P/UAS-L:    000/000             000/000
            ALARMS:      RED                NONE            Selection:
```

Figure 14. HDSL2 Detailed Status Screen

CSA Guidelines and Bridged Taps

The presence of a bridged tap on a cable pair will affect the performance of any DSL circuit, primarily due to the reflections caused by the bridged tap of the DSL signal at both the bridge point as well as from the end of the bridged tap. These (unwanted) reflections tend to interfere with the desired signal on the pair and can cause errors on the loop. The HDSL transceiver and signal processing circuitry are designed to be able to tolerate a certain amount of these signal reflections, which simply appear as "noise" on the desired signal. However, if a bridged tap is present that exceeds the guidelines provided in this section, it is highly likely that errors will be encountered on the loop, necessitating removal of the bridged tap altogether or, at the very least, reducing its length to bring it within recommended specifications.

Field experience has also shown that the location of the bridged tap has a direct bearing on how seriously it impacts the performance of the circuit. In general, the closer the bridged tap is to an HDSLx transceiver (such as a CO unit, repeater, or remote unit), the more degrading the effect will be.

The following sections outline the general bridged tap requirements for HDSL, HDSL2, and HDSL4.

HDSL/HDSL2 Bridged Tap Guidelines

The ADTRAN HDSL/HDSL2 systems provide DS1-based services over loops designed to comply with Carrier Service Area (CSA) guidelines. CSA deployment guidelines are provided as follows:

1. All loops are nonloaded only.
2. For loops with No. 26 AWG cable, the maximum loop length including bridged tap lengths is 9 kft.
3. For loops with No. 24 AWG cable, the maximum loop length including bridged tap lengths is 12 kft.
4. Any single bridged tap is limited to 2 kft.
5. Total bridged tap length is limited to 2.5 kft.
6. The total length of multigauge cable containing 26 AWG cable must not exceed:

   $12 - \{(3*L_{26})/(9-L_{BTAP})\}$ (in kft)

   where:

   L_{26} = Total length of No. 26 AWG cable excluding bridged taps (in kft)

   and,

   L_{BTAP}= Total length of all bridged taps (in kft)

NOTE

Bridged tap requirements are the same on both sides of a repeater.

The chart shown in **Figure 15** summarizes these deployment criteria.

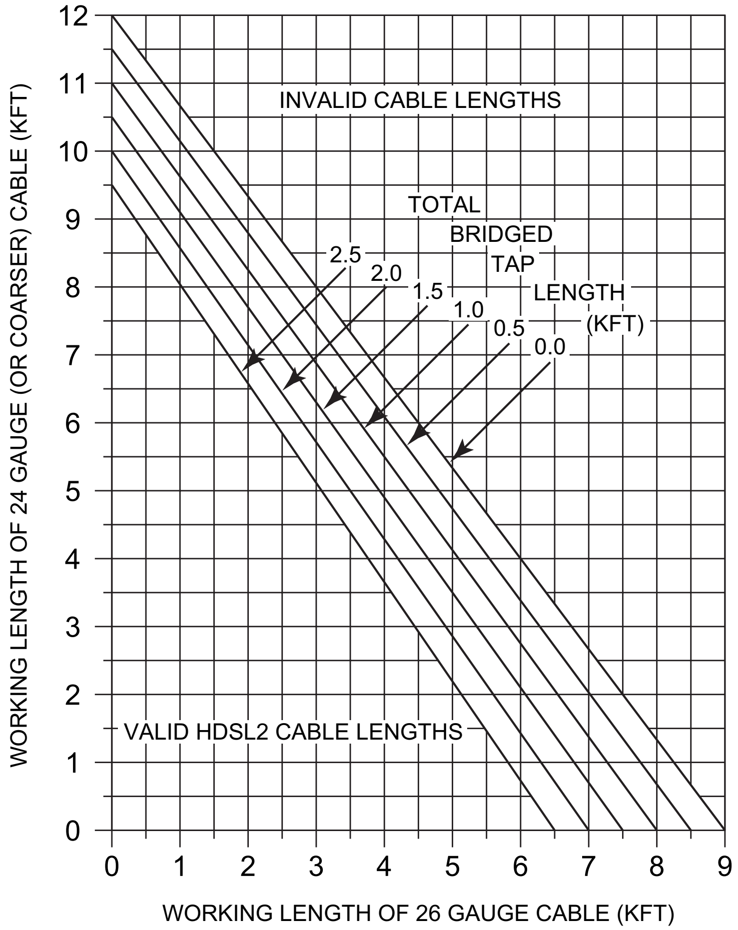


Figure 15. HDSL/HDSL2 Deployment Guidelines

HDSL4 Bridged Tap Guidelines

The ADTRAN HDSL4 system provides DS1-based services over loops designed to comply with the guidelines given below.

Since HDSL4 is designed to operate on loops that exceed the CSA guidelines, the bridged tap requirements are slightly different than those for HDSL/HDSL2.

HDSL4 bridged tap requirements are different for the first segment (i.e., between the H4TU-C and first H4R or H4TU-R) and for subsequent segments (i.e., between repeaters, and between the last repeater and the H4TU-R).

First Segment

The guidelines provided below apply to the first segment in the circuit:

- between the H4TU-C and H4R, or
- an HDSL4 circuit with no H4R.

Guidelines for First Segment:

1. All loops are nonloaded only.
2. For loops with No. 26 AWG cable, the maximum loop length including bridged tap lengths is 12 kft.
3. For loops with No. 24 AWG cable, the maximum loop length including bridged tap lengths is 16 kft.
4. Any single bridged tap is limited to 2 kft.
5. Total bridged tap length is limited to 2.5 kft.
6. The total length of multigauge cable containing No. 26 AWG cable must not exceed:

   $16 - \{(4 * L_{26})/(12 - L_{BTAP})\}$ (in kft)

   where:

   L_{26} = Total length of No. 26 AWG cable excluding bridged taps (in kft)

   and,

   L_{BTAP}= Total length of all bridged taps (in kft)

Second/Third Segment

The guidelines listed below apply to the second (and subsequent) segments of the circuit:

- between the H4Rs
- between the last H4R and the H4TU-R).

Guidelines for Second/Third Segment:

1. All loops are nonloaded only.
2. For loops with No. 26 AWG cable, the maximum loop length including bridged tap lengths is 11 kft.
3. For loops with No. 24 AWG cable, the maximum loop length including bridged tap lengths is 15 kft.
4. Any single bridged tap is limited to 2 kft.
5. Total bridged tap length is limited to 2.5 kft.
6. The total length of multigauge cable containing No. 26 AWG cable must not exceed:

   $15 - \{(4 * L_{26})/(11 - L_{BTAP})\}$(in kft)

   where:

   L_{26} = Total length of No. 26 AWG cable excluding bridged taps (in kft)

   and,

   L_{BTAP} = Total length of all bridged taps (in kft)

DSL Assistant

The ADTRAN DSL Assistant application is a design tool intended for planning and design groups to calculate insertion loss, resistance designs, and loop reach for various digital subscriber line technologies. This application can be used to graphically build and display elements of the DSL loop (see **Figure 16**).

Features

DSL Assistant supports the following ADTRAN DSL Technologies:

- HDSL/HDSL2/HDSL4
- ISDN, Total Reach ISDN
- Total Reach DDS
- IDSL
- 4-wire DDS with secondary and non-secondary channel rates

Additionally, DSL Assistant can assist with the following tasks:

- Creates work prints
- Supports CSA standard loops for HDSL, HDSL2 and ISDN
- Supports ANSI and ETSI calculations
- Supports insertion loss and loop attenuation calculations
- Accounts for length and location of bridged taps
- Accounts for temperature variances
- Accounts for cable gauge changes
- Accounts for HDSL4 resistance design rules

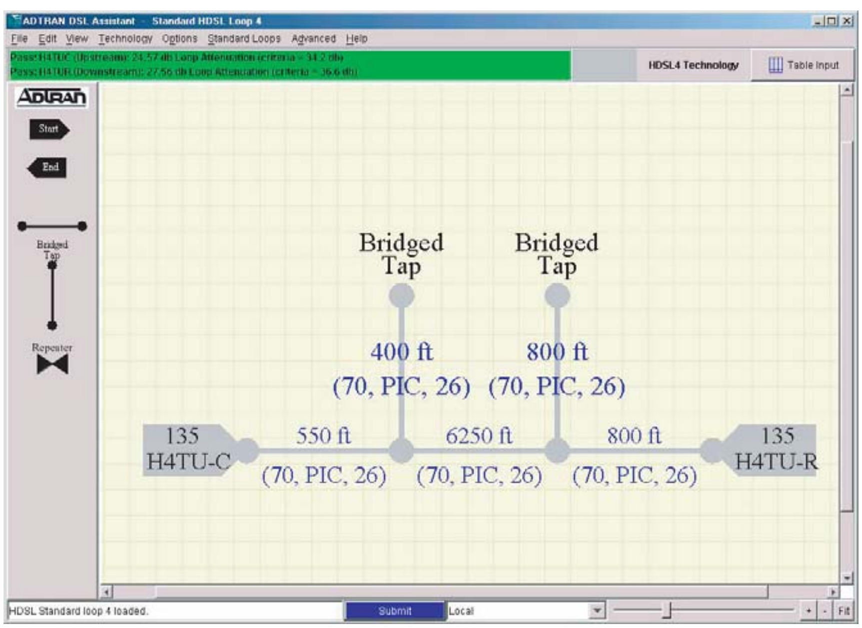


Figure 16. DSL Assistant Example Screen

How To Order DSL Assistant

To order DSL Assistant by phone, please call 1-800-9ADTRAN and select the “Operator” option. Ask for the Literature Department and request the following:

Table 3. DSL Assistant Ordering Guide

Part Number	Description
1221902L4	DSL ASSISTANT (SBC and general LEC)
1221902L1	VERIZON, DSL ASSISTANT
1221902L6	BELLSOUTH, DSL ASSISTANT

To order by e-mail, send a message to literature.request@adtran.com.

Calculating Loop Qualification

To provide robust HDSLx service, qualifying the loops for attenuation, noise, and circuit resistance is required. This section will provide the parameters and worksheets to ensure the loop meets the recommended criteria for service.

During the initial design process, ADTRAN recommends the use of its DSL Assistant loop design application to determine whether the loop attenuation of the proposed circuit is within the limits allowed for robust HDSLx performance.

The performance of an HDSLx circuit primarily depends on attenuation (a function of reach) and the noise environment. Noise is in large part a function of crosstalk from other technologies in the cable bundle.

The HDSL2 technology has a commonly advertised reach equivalent to 9 kilofeet of 26 AWG cable, while HDSL4 has a commonly advertised reach of 12 kilofeet of 26 AWG cable in the first segment and 11 kilofeet of 26 AWG cable in subsequent segments. These distances assume a less-than-worst case noise environment. For robust HDSLx service, the recommended distances are modified to the 26 AWG equivalent of 8,350 feet for HDSL2 and 11.1/10.5 kilofeet for HDSL4.

Topics within this section include the following:

HDSL 2B1Q Loop Qualification

Historically, the allowable insertion loss at 196 kHz for HDSL has been 35 dB. For robust 2B1Q HDSL performance, the recommended max insertion loss at 196 kHz is 32.5 dB.

HDSL2 Loop Qualification

The recommended maximum loop attenuation for HDSL2 (measured at the H2TU-C) is 28 dB. This equates to a straight 26 AWG loop length of 8350 ft. **Table 4** provides the insertion loss at several frequencies for an 8350 ft. 26 AWG loop.

Table 4. Insertion Loss of 8350 Feet of 26 AWG for HDSL2

Frequency (kHz)	Insertion Loss dB
50	23.7
80	26.5
130	29.5
196	32.5
250	35.1
300	37.4
350	39.6

HDSL4 Loop Qualification, First Segment

The recommended maximum loop attenuation for HDSL4 is 31.2 dB measured at the CO side of the loop or 33.6 dB measured at the H4TU-R. This equates to a straight 26 AWG loop length of 11.1 kft. **Table 5** provides insertion loss at several frequencies for an 11.1 kft, 26 AWG loop.

Table 5. Insertion Loss of 11.1 kft of 26 AWG for HDSL4

Frequency (kHz)	Insertion Loss dB
50	31.5
80	35.3
130	39.1
196	43.0

HDSL4 Loop Qualification, With Repeaters

The loop attenuation for the second and subsequent segments of a repeatered HDSL4 loop should not exceed 29.8 dB. This equates to a straight 26 AWG loop length of 10.5 kft. **Table 6** provides the insertion loss at several frequencies for a 10.5 kft, 26 AWG loop. The insertion loss at 196 kHz is not listed in the table because the repeaters only transmit frequencies below 140 kHz.

Table 6. Insertion Loss of 10.5 kft 26 AWG at Various HDSL4

Frequency (kHz)	Insertion Loss dB
50	29.9
80	33.4
130	37.1
196	N/A

Simplified Field Technician Loop Qualification Methods

Field technicians can take a few insertion loss measurements at various frequencies and make a reasonable assessment of the loop for HDSLx deployment. The frequencies that the insertion loss measurements must be taken differ for each HDSLx technology. ADTRAN has worked with test set manufacturers to automate a procedure to directly determine a derived measurement of loop attenuation. This is the best method to determine the loop qualification in the field.

Field Loop Qualification for HDSL2

For loop attenuation capable wideband test equipment, the maximum allowable loop attenuation is provided in the **Table 7**.

Table 7. HDSL2 Maximum Loop Attenuation

Location of Measurement	Recommended Max Loop Attenuation (dB)
H2TU-C	28.0
H2TU-R	29.7

HDSL2 transmits the downstream signal to 400 kHz while the upstream signal is limited to about 280 kHz. This asymmetric property of HDSL2 requires multiple insertion loss measurements from 50 kHz to 350 kHz. If the test equipment can measure insertion loss at selected frequencies then the technician may be able to use a subset of HDSL2 related frequencies to evaluate the loop.

H2TU-C Qualification Worksheets

Table 8 provides a worksheet for computation of total loss at the H2TU-C.

For each of the five measured insertion loss values, compute the difference between the maximum loss and the measured loss (max minus measured). If all five of the differences are positive, then the loop meets the performance criteria. If any one of the four difference values is negative (measured loss is more than maximum loss), then the sum of the five differences must be at least +3dB. If neither of these criteria is satisfied, then the loop may not provide robust HDSL2 deployment.

Table 8. H2TU-C Qualification Worksheet

Frequency (kHz)	Maximum Loss (dB)	Measured Loss (dB)	Delta Loss (dB) (Max minus Meas)
50	23.7	_______ dB	_______ dB
80	26.5	_______ dB	_______ dB
130	29.5	_______ dB	_______ dB
196	32.5	_______ dB	_______ dB
250	35.1	_______ dB	_______ dB
		* Sum Delta Loss =	_______ dB

* If any single frequency insertion loss exceeds the maximum loss (delta loss < 0), then the sum of the five delta loss values must be > 3.0 dB.

H2TU-R Qualification

Table 9 provides a worksheet for computation of total loss at the H2TU-R.

Table 9. H2TU-R Qualification Worksheet

Frequency (kHz)	Maximum Loss (dB)	Measured Loss (dB)	Delta Loss (dB) (Max minus Meas)
50	23.7	_______ dB	_______ dB
130	29.5	_______ dB	_______ dB
196	32.5	_______ dB	_______ dB
200	37.4	_______ dB	_______ dB
350	39.6	_______ dB	_______ dB
		* Sum Delta Loss =	_______ dB

* If any single frequency insertion loss exceeds the maximum loss (delta loss < 0), then the sum of the five delta loss values must be > 3.0 dB.

The loop performance at the H2TU-C is essential in the above tests as it is more likely that the central office side of the loop will experience significant inband crosstalk.

Field Loop Qualification for HDSL4

For loop attenuation capable wideband test equipment, the maximum allowable loop attenuation is provided in the **Table 10** below.

Table 10. HDSL4 Maximum Loop Attenuation

HDSL4 Loop Side	Recommended Max Loop Attenuation (dB)
H4TU-C	31.3
H4TU-R or H4RU-R (first segment)	33.6
H4RU-C or H4TU-R (repeater segment)	29.8

HDSL4 technology transmits the majority of its signal in the downstream below 200 kHz while the upstream signal is limited to about 140 kHz. This asymmetric property of HDSL4 requires multiple insertion loss measurements from 50 kHz to 196 kHz. If the test equipment can measure insertion loss at selected frequencies then the technician may be able to use a subset of HDSL4 related frequencies to evaluate the loop.

For each of the three (four) measured insertion loss values, compute the difference between the maximum loss and the measured loss (max - measured). If all four of the differences are positive, then the loop meets the performance criteria. If any one of the three (four) difference values is negative (measured loss is more than maximum loss), then the sum of the four differences must be at least +3dB. If neither of these criteria is satisfied, then the loop is suspect and may not provide robust HDSL4 deployment.

HDSL4 Non-repeater and first segment qualification

Table 11 provides a worksheet for computation of total loss of a non-repeatered HDSL4 loop or the first segment of a repeatered HDSL4 circuit.

Table 11. Non-Repeatered HDSL4 Worksheet

Frequency (kHz)	Maximum Loss (dB)	Measured Loss (dB)	Delta Loss (dB)(Max-Meas)
50	31.5	_______ dB	_______ dB
80	35.3	_______ dB	_______ dB
130	39.1	_______ dB	_______ dB
196	43.0	_______ dB	_______ dB
		* Sum Delta Loss =	_______ dB

* If any single frequency insertion loss exceeds the maximum loss (delta loss < 0), then the sum of the four delta loss values must be > 3.0 dB.

HDSL4 Repeater segment qualification

Table 12 provides a worksheet for computation of total loss of the subsequent segments of a repeatered HDSL4 loop.

Table 12. Repeatered HDSL4 Worksheet

Frequency (kHz)	Maximum Loss (dB)	Measured Loss (dB)	Delta Loss (dB)(Max-Meas)
50	29.9	_______ dB	_______ dB
80	33.5	_______ dB	_______ dB
130	37.1	_______ dB	_______ dB
		* Sum Delta Loss =	_______ dB

* If any single frequency insertion loss exceeds the maximum loss (delta loss < 0), then the sum of the three delta loss values must be > 1.0 dB.

EXAMPLE - Field Loop Qualification

Consider a 26 AWG loop whose length is 9500' with a 700' bridge tap at the H4TU-R end of the loop. **Figure 17** shows the insertion loss characteristics of the loop and, for reference, the insertion loss characteristics of a straight 11.3 kft 26 AWG loop. During the design process using DSL Assistant the loop should be OK to deploy HDSL4. The field technician pre-qualifying the loop would collect the insertion loss values and enter them into **Table 13**.

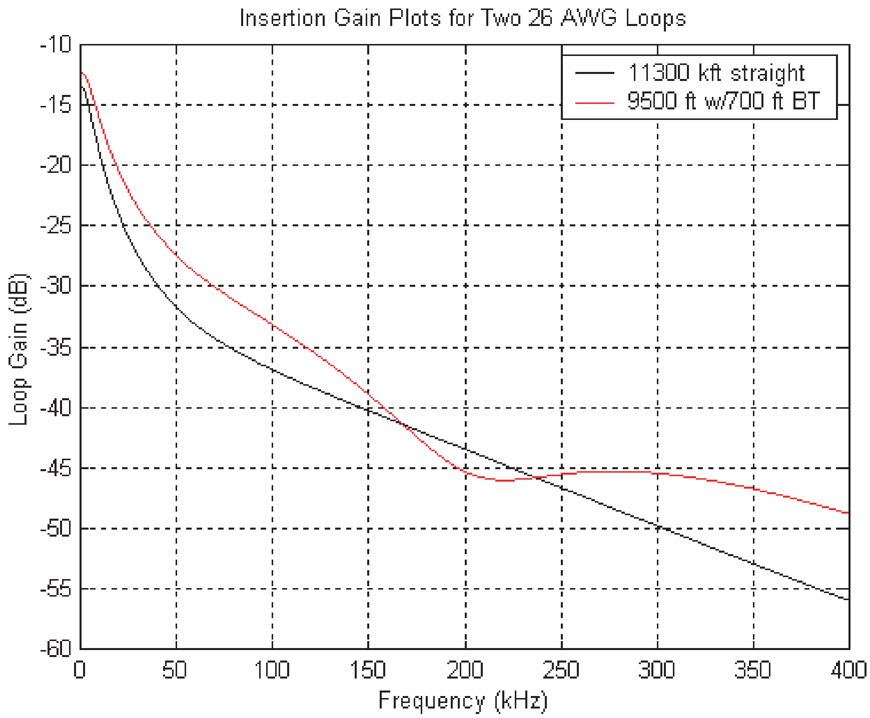


Figure 17. Insertion Loss Measurements for Example

Table 13. 9500 Foot Loop of 26 AWG Cable, 700 Foot Bridged Tap

Frequency (kHz)	Maximum Loss (dB)	Measured Loss (dB)	Delta Loss (dB)(Max-Meas)
50	31.5	27.5 dB	4.0 dB
80	35.3	31.1 dB	4.2 dB
130	39.1	36.4 dB	2.7 dB
196	43.0	45.0 dB	-2.0 dB
		* Sum Delta Loss =	8.9 dB

* If any single frequency insertion loss exceeds the maximum loss (delta loss < 0), then the sum of the four delta loss values must be > 3.0 dB.

For this example, the insertion loss at 196 kHz exceeds the maximum loss for this one frequency; however, the lower three frequencies have much less loss that maximum resulting in the delta loss of 8.9 dB passing the 3 dB criteria (8.9).

Wideband Noise

The wideband noise measurement is an extension of the C-message circuit noise measurement described previously. As discussed, the C-message filter is designed to measure noise in the bandwidth of approximately 300-3000 Hz. These measurements are useful because they can identify noise sources that can have an indirect impact on the DSL circuit. However, for DSL, we also need to take noise measurements within the HDSLx passband. This will determine if the ambient noise, which can have a direct impact on the HDSL signal, is at an acceptable level. These measurements require a wider bandwidth filter than the C-message filter.

HDSL2 and HDSL4 technologies are both asymmetric and wideband, so the measurement procedures for wideband noise differ from that for 2B1Q HDSL. Because legacy test set equipment is limited to 50 kb filters, it is not recommend for HDSLx noise testing. Proper qualification for HDSLx noise environments requires multiple filter measurements using three IEEE specified filters.

- E-filter with a bandwidth of 50 kHz
- F-filter with a bandwidth of 245 kHz
- G-filter with a bandwidth of approximately 1MHz.

Excessive noise levels indicate high frequency noise from several possible sources. The most prevalent source would be crosstalk from another DSL service in the same binder group (as a result of poor longitudinal balance on one or more pairs in the cable) or a short length of split pairs with the offending circuit. These are examples of cable impairments that would not affect the POTS circuits, but they can be potential problem sources for DSL circuits.

The measurement objectives for wideband noise are provided in the following subsections.

NOTE

Noise measurements must be taken at *both* ends of the loop (CO and customer premise) and compared with their respective pass/fail criteria.

2B1Q HDSL Wideband Noise Guidelines

The table below provides a pass/fail noise power criteria for HDSL. The –43 dBm F-Filter measurement may be exceeded if ADSL, HDSL2 or HDSL4 is in the same binder. An additional noise power measurement through the G-filter setting will provide a good indication that one of these higher bandwidth services exists in the binder. If the G-filter power level is within 1 dB of the F-filter power level then the majority of the noise is in the HDSL band. In this case, the maximum F-filter noise power should not be exceeded. If on the other hand, the G-filter noise power is 3 dBm greater than the F-filter power then 3 dB more F-filter noise is acceptable at the CO. The noise measure should be made at both ends of the loop and the worst case determining the pass/fail criteria.

Table 14. 2B1Q HDSL Wideband Noise Pass/Fail Criteria

Filter Type	Maximum Noise (dBm)	Measured Noise (dBm)	Delta Noise (dBm) (Measured minus Max)
E	–54	_______ dB	_______ dB
F	–43	_______ dB	_______ dB
		*Sum Delta Noise (CO) =	_______ dB

* If either noise measurement exceeds the maximum noise (delta noise > 0), then the sum of the two delta noise values must be < –1.25 dBm.

HDSL2 Wideband Noise Guidelines

The table below provides a pass/fail noise power criteria for HDSL2. The –38 dBm F-Filter measurement may be exceeded if ADSL is in the same binder. An additional noise power measurement through the G-filter setting will provide a good indication that one of these higher bandwidth services exists in the binder. If the G-filter power level is within 1 dB of the F-filter power level then the majority of the noise is in the HDSL band. In this case, the maximum F-filter noise power should not be exceeded. If on the other hand, the G-filter noise power is more than 4 dBm greater than the F-filter power then 1 dB more F-filter noise is acceptable at the CO. The noise measure should be made at both ends of the loop and each end must satisfy its pass/fail criteria.

Table 15. HDSL2 CO-Side Wideband Noise Pass/Fail Criteria

Filter Type	Maximum Noise (dBm)	Measured Noise (dBm)	Delta Noise (dBm) (Measured minus Max)
E	–55	_______ dB	_______ dB
F	–38	_______ dB	_______ dB
		*Sum Delta Noise (CO) =	_______ dB

* If either noise measurement exceeds the maximum noise (delta noise > 0), then the sum of the two delta noise values must be < –1.25 dBm.

Table 16. HDSL2 REMOTE-Side Wideband Noise Pass/Fail Criteria

Filter Type	Maximum Noise (dBm)	Measured Noise (dBm)	Delta Noise (dBm) (Measured minus Max)
E	–53	_______ dBm	_______ dBm
F	–38	_______ dBm	_______ dBm
G	–36	_______ dBm	_______ dBm
		*Sum Delta Noise (CO) =	_______ dBm

* If either noise measurement exceeds the maximum noise (delta noise > 0), then the sum of the two delta noise values must be < –1.25 dBm.

HDSL4 Wideband Noise Guidelines

The table below provides a pass/fail noise power criteria for HDSL4. The –43 dBm F-Filter measurement may be exceeded if ADSL, HDSL2 or HDSL4 is in the same binder. An additional noise power measurement through the G-filter setting will provide a good indication that one of these higher bandwidth services exists in the binder. If the G-filter power level is within 1 dB of the F-filter power level then the majority of the noise is in the HDSL band. In this case, the maximum F-filter noise power should not be exceeded. If on the other hand, the G-filter noise power is 3 dBm greater than the F-filter power then 1 dB more F-filter noise is acceptable at the CO. The noise measure should be made at both ends of the loop and each end must satisfy its pass/fail criteria.

Table 17. HDSL4 CO-Side Wideband Noise Pass/Fail Criteria

Filter Type	Maximum Noise (dBm)	Measured Noise (dBm)	Delta Noise (dBm) (Measured minus Max)
E	–54	_______ dBm	_______ dBm
F	–43	_______ dBm	_______ dBm
		*Sum Delta Noise (CO) =	_______ dBm

* If either noise measurement exceeds the maximum noise (delta noise > 0), then the sum of the two delta noise values must be < –1.25 dBm.

Table 18. HDSL4 REMOTE-Side Wideband Noise Pass/Fail Criteria

Filter Type	Maximum Noise (dBm)	Measured Noise (dBm)	Delta Noise (dBm) (Measured minus Max)
E	–53	_______ dBm	_______ dBm
F	–44	_______ dBm	_______ dBm
		*Sum Delta Noise (CO) =	_______ dBm

* If either noise measurement exceeds the maximum noise (delta noise > 0), then the sum of the two delta noise values must be < –1.25 dBm.

NOTE

For the middle segments (between repeaters) the wideband noise test criteria should match Table 17 because the H4TU-C sees the same signal as both ends of the repeater section.

Metallic Impulse Noise

Impulse noise on a pair is a critical parameter to measure. If there are impulse noise hits of sufficient magnitude, they will cause bit errors on the HDSL loops. Impulse noise can originate from within the cable itself or externally to it, as illustrated in the examples below:

- Sources within the cable - Rotary dial phones, ring trips (POTS line going off-hook during a ringing cycle), start of ringing cycle, relay contact closures on signaling circuits, central office noise.
- Sources external to the cable - Lightning, power system switching events, maintenance activity on cable pairs or MDF, heavy motors starting/stopping.

As mentioned, HDSLx circuit errors occur any time there is an impulse noise hit of sufficient magnitude occurring on the pair. This fact must be taken into account when trying to determine if impulse noise is a problem on a particular cable pair. For example, many impulse noise sources exhibit “time-of-day” activity patterns. Therefore, the pair should be monitored long enough to get a true indication if impulse noise is going to be a problem. Otherwise, there is the danger of testing the pair during one of its quiet periods and being misled. Field experience and numerous impulse noise studies have clearly shown that impulse noise events are highest (in amplitude and occurrence rate) during the normal daytime busy hours (weekday mid-morning and mid-afternoon), so impulse noise tests should be performed at those times.

Recommended Impulse Noise Testing

Copper pair testing for impulse noise levels for HDSLx applications consists of multiple tests over several minutes. The procedure is as follows:

1. Determine the peak impulse detection threshold using the E-filter setting.

   The threshold should begin at least 13 dB above the measured average wideband noise level through the E-filter.

2. Run the test for a period of 5 minutes.
3. If no counts are recorded, then lower the threshold by 2 dB and rerun the test.
4. At any time during impulse testing, if counts are incrementing more than 1 in 10 seconds, stop the test, raise the threshold by 1 dB and restart for another 5 minute test period.
5. After determining the lowest E-filter impulse noise threshold which results in fewer than 3 hits in 5 minutes, a second set of impulse noise tests are made with an F-filter setting.

   Table 19 provides the E-filter thresholds and the corresponding maximum recommended F-filter threshold requirement for the various HDSLx technologies.

Should the maximum E-filter impulse threshold be exceeded, then the loop should be considered to have too much low frequency impulse noise unless the loop attenuation is substantially below the maximum recommended for the technology.

Table 19. HDSLx Impulse Noise Threshold Requirements

Technology	Measured E-Filter Threshold	Maximum F-Filter Threshold Requirement
HDSL	–29 dBm ≥ threshold ≥ –31 dBm	–25 dBm
	–32 dBm ≥ threshold ≥ –34 dBm	–24 dBm
	≤ –35 dBm	–23 dBm
HDSL2	–39 dBm	–28 dBm
	≤ –40 dBm	–25 dBm
HDSL4	–36 dBm	–28 dBm
	≤ –37 dBm	–25 dBm

In some cases, maximum allowable crosstalk noise could cause some of these impulse noise thresholds to be exceeded. If the thresholds listed in the table are lower than 15 dB above the average wideband noise in the same filter band, then it is likely that the measured threshold will exceed the recommendation. Should this occur, it would be expected that the noise margin will be < 6 dB on a loop that is near the maximum allowable loop attenuation.

Longitudinal Impulse Noise

Longitudinal impulse noise is similar to metallic impulse noise, except instead of taking the measurement between tip and ring, the measurement is made between the pair and ground (tip and ring are shorted together during the test). This is a measure of the amount of impulse noise that is impinging on the pair from the “outside,” with respect to ground. This can give an indication of how noisy the environment is in which the pair is operating. In more common terms, this test may be known as an “Impulse Noise to Ground” test. The test procedure and measurement objective are given below.

Measurements should be made on the individual pair with both the HTU-C and HTU-R disconnected from the pair (**Figure 18**). Tip and ring of the pair should be tied together and wired to the “TIP” input of the measuring test set. The “RING” input of the test set should be tied to local ground through a 0.1 μF capacitor (100 VDC minimum rating).

The longitudinal impulse noise should be read through an F-filter on the test set.

Longitudinal Impulse Noise Measurement Objective: ≤ +7 dBmF (135 Ω)

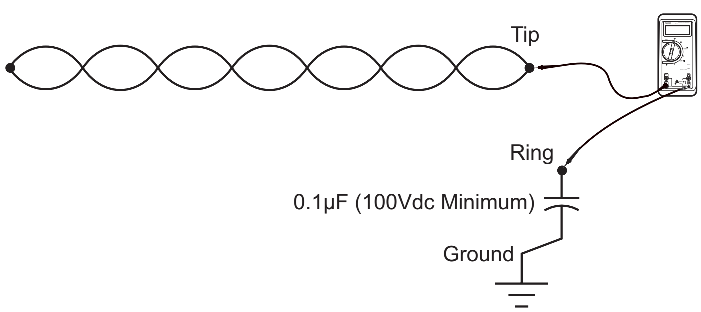


Figure 18. Longitudinal Impulse Noise Measurement

ADDITIONAL FACTORS TO CONSIDER

This section discusses some of the specific practical issues that have been learned through field experience.

Topics detailed in this section include:

- "Protector Modules" on page 35
- "Splices" on page 36

Protector Modules

Several instances have been encountered in the field where multiple surge protectors were either intentionally or inadvertently installed on the HDSL circuit at the customer premises. These circuits were plagued with chronic problems until all of the protectors (except the building entrance protector) were removed.

Surge protectors fall under two different categories defined by their function in the circuit. The two categories and their functions are defined below:

- Primary protectors - Primary protectors are the familiar 5-pin plug-in modules used in central offices and customer premises building entrance terminals. Their function is to protect the telephone company cable by clamping large, high energy surges (i.e., lightning) to ground before they can reach a voltage level that will damage the cable. They have a relatively high firing voltage (300-450 V), react relatively slowly, and can handle a tremendous amount of surge current.
- Secondary protectors - Secondary protectors are used to protect electronic equipment. In the case of this discussion, secondary protection is incorporated on the HDSL circuit cards. Secondary protection is characterized by lower firing voltages (around 270 V) and faster response times, which are critical parameters for the protection of electronic circuitry.

A typical installation includes both a primary and a secondary protector. The primary protector is the 5-pin module supplied by the telephone company, and the secondary protector is built on to the HDSL circuit pack. Secondary protectors typically have lower firing voltages and faster response times. They protect the HDSLx equipment against small surges from far-away strikes. For more direct lightning surges with larger surge currents, the primary protectors engage and protect the equipment.

In any event, it is unnecessary to install an additional primary or secondary protector on the circuit. In fact, it has been observed that this can actually degrade the performance of the HDSL circuit, presumably due to the extra stray capacitance of the additional protectors right "on top" of the HDSL transceiver. As indicated earlier, the secondary protection that protects the HDSL circuit card from incoming surges is incorporated on the card itself, thereby making this a "fixed" parameter. However, a wide variety of primary protectors are currently in use by the telcos, including carbon, gas tube, and solid state. HDSL technology is fairly tolerant to the type or construction of the primary protectors, but a few points are worth mentioning:

- The older-style protectors that actually have "heat coils" in them should be avoided, as the inductance of the coils will adversely affect the HDSL signal.
- The protectors should have a rated firing voltage of at least 270 VDC. This higher voltage is needed to accommodate the span powering voltage and still give enough "headroom" so that small voltage spikes and induced AC voltages on the pair can superimpose on the span

powering voltage and not cause the protector to fire (consequently causing errors or temporary circuit shut-down).

- Carbon and gas-tube protectors inherently have less capacitance than solid state protectors. On a very long marginal circuit, the added capacitance of the solid state protectors could possibly cause the circuit to run errors. Generally, it would not be good engineering practice to "push" a circuit out to these limits anyway, so this condition is usually not a concern. The trade-off is that carbon and gas-tube protectors have much slower response times than the solid state protectors, so solid state protectors tend to predominate in spite of the small capacitance increase.
- The firing voltage of protectors tends to degrade after being hit with numerous surges (i.e., a protector with a firing voltage of 270 VDC, when new, might start firing at 230 VDC after repeated surge hits). Therefore, it is possible for an HDSL circuit to run fine for years and then start to become problematic due to degraded protectors. For such circuits, replacing the protectors with new ones will clear the problem.

Splices

Data transmission transceivers (especially echo-cancelled technologies) are subject to performance degradation and errors in the presence of bad splices. In some cases, the bad splice leads to an open circuit or high impedance that can easily be measured with an ohmmeter. In other cases, the bad splice is more difficult to detect. A splice may be benign for a period of time, allowing a circuit to function appropriately for portions of the day. However, over time the splice will oxidize and incur small, rapid changes in impedance. This inconsistency makes the problem difficult to locate. Additionally, an impedance change that is large enough to cause a transmission problem may still be small enough to remain undetected by test equipment utilized on the copper pairs.

In some cases, re-seating a module will introduce a current surge that will temporarily "clean" the splice connection, but over time the splice will degrade again.

ADTRAN has developed a bad splice detection feature for the HDSL2 and HDSL4 technologies which will detect problematic splice connections. Refer to the latest Installation and Maintenance Practices for the HDSL2 and HDSL4 equipment for more information.

HDSL4 SPAN POWERING CONSIDERATIONS

Topics included in this section include the following:

Like all HDSLx systems, HDSL4 incorporates span powering of the remote unit and any intermediate repeaters used in the system. However, since the reach of HDSL4 is significantly greater than that of previous technologies, we need to be concerned with the resistance design of the circuit to ensure that the voltage drop on the loop is not excessive and that there is still enough voltage at the end of the loop to power the H4TU-R.

As an HDSL4 circuit is designed, it is necessary to ensure that both the dB loss criteria and the resistance criteria are simultaneously satisfied. The ADTRAN DSL Assistant circuit design application can be a valuable tool during this process as it allows users to graphically assemble various circuit designs and check them to ensure their successful deployment. For more information, refer to "DSL Assistant" on page 21

Resistance Considerations

As indicated in the overview earlier, the longer loop lengths involved with HDSL4 require that the resistance of the loop be taken into account when designing a circuit. As loop lengths increase, so does the loop resistance, and hence the voltage drop on the loop. The objective is to make sure that there is enough voltage at the end of the loop to power the H4TU-R (or a third repeater, if a locally powered H4TU-R is being used).

For circuit designs requiring no repeaters (i.e., only one span terminating in an H4TU-R) or a single repeater and a remote, it is unlikely that there will be any powering problems on typical CSA-type loops. However, when the H4TU-C is used to power two repeaters and a remote unit, there may be a significant voltage drop on the first span leaving the H4TU-C. This drop in voltage must be considered when designing the circuit to minimize the losses. The following subsection will describe this process in detail.

Resistance Design Guidelines for HDSL4 Circuits with Two Repeaters

Each of the three segments associated with span powering two HDSL4 repeaters and an HDSL4 remote must satisfy the recommended loop attenuation requirements in addition to the DC resistance budgets.

In general, 22 and 19 AWG segments will be restricted by their loop attenuation only, while the DC resistance will restrict the reach for 26 and 24 AWG segments in order to maintain module powering requirements. When designing a dual HDSL4 repeater loop, all loops must meet the maximum loop resistance requirements; but to maximize total reach, the segment from the CO to the repeater should have lower DC resistance than the other segments.

Single HDSL4 repeater spans must also meet the loop attenuation qualification guidelines but do not require any additional restriction due to DC resistance.

The segment resistance ($\Omega_{segment}$) is determined using the equation provided below:

$\Omega_{segment} = L_{26} * \Omega_{26} + L_{24} * \Omega_{24} + L_{22} * \Omega_{22} + L_{19} * \Omega_{19}$

where:

$L_{\#}$ is the length of # AWG cable (kft, excluding bridged taps)

and,

$\Omega_{\#}$ is the DC resistance of # AWG cable

Table 20 lists single pair cable DC resistance values to be used in the equation above.

Table 20. Single Pair Cable DC Resistance Values

	Resistance (ohms/kft)			
AWG	**70°F**	**90°F[1]**	**120°F**	**140°F[2]**
19	16.465	17.183	18.261	18.979
22	33.006	34.446	36.606	38.046
24	52.498	54.789	58.225	60.516
26	83.475	87.117	92.581	96.223

1. Interpolated between 70°F and 120°F data
2. Extrapolated from 70°F and 120°F data

Repeatered HDSL4 can be deployed on all unloaded resistance design loops (up to 1500 Ω). Dual repeater deployment (on loops of 1500-2000 Ω and 2000-2800 Ω) loops must be qualified. Once the resistance of each segment is confirmed, refer to **Figure 19** to decide if the H4TU-C is capable of span powering two H4Rs and one H4TU-R.

Follow these steps to utilize the graph in Figure 19:

1. Find the line on the graph that represents the known third segment resistance. These are the lines running diagonally across the graph labeled 300-1100 ohms. This line represents the upper limit for two H4Rs plus H4TU-R span powering.
2. Find the first segment resistance on the vertical axis.
3. Find the second segment resistance on the horizontal axis.
4. Find the instance where the two points from steps 2 and 3 meet on the graph.
5. The point found in step 4 must be below the upper limit line defined by the third segment measurement (step 1). If the intersection where these two points is above this line, the H4TU-C *cannot* span power two H4Rs and the H4TU-R.

NOTE

These measurements represent only one of the two HDSL4 pairs.

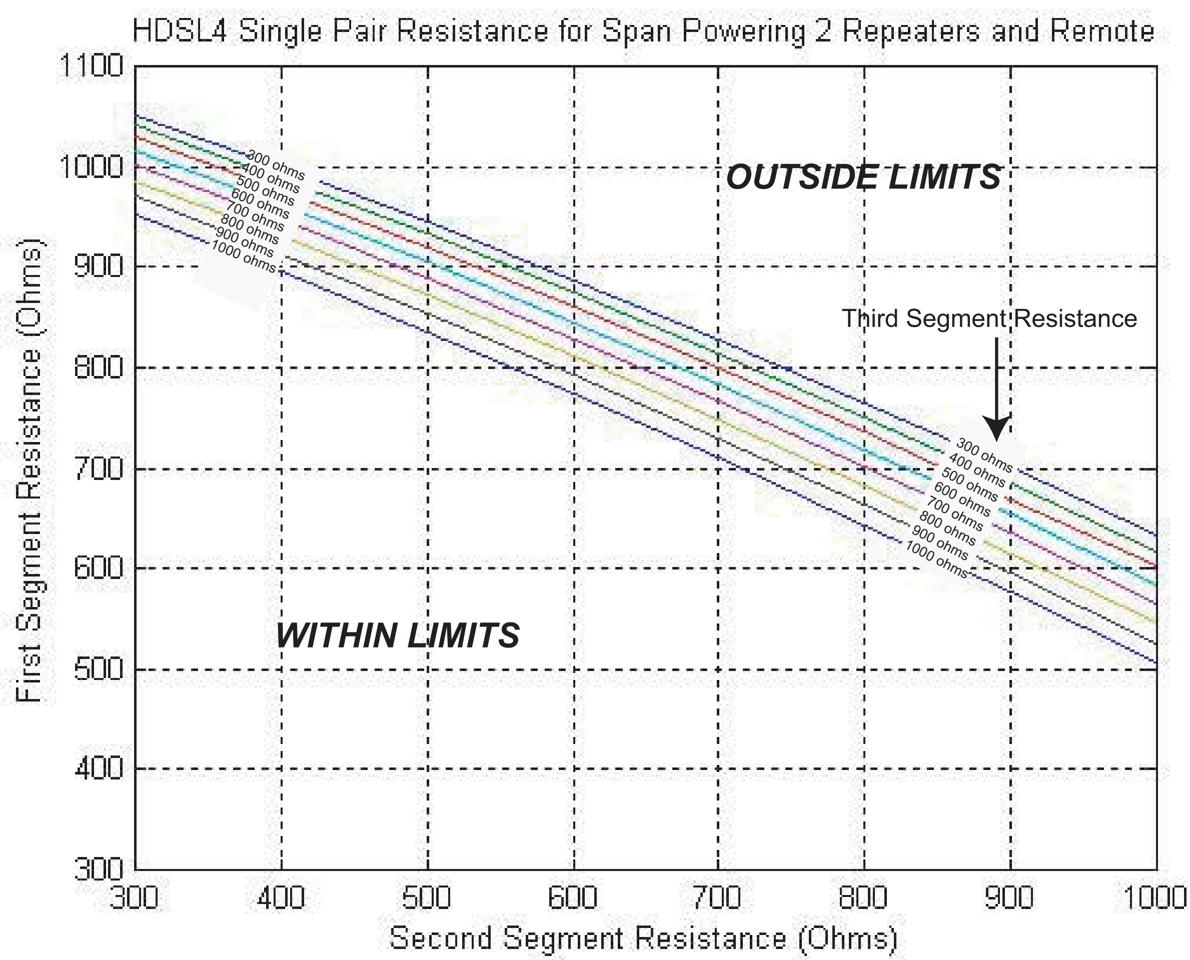


Figure 19. Resistance Budget Span Powering Two Repeaters

Resistance Budget Example

An example problem is illustrated in **Figure 20**. For this example, begin with three known measurements:

- 600 ohm first segment resistance
- 700 ohm second segment resistance
- 900 ohm third segment resistance

Refer to the graph, follow these steps to solve the example problem:

a. Find the 900 ohm third segment resistance line on the graph. This line is depicted in bold in Figure 20. This line is the upper span power limit.

b. Find the 600 ohm first segment resistance point on the vertical axis.

c. Find the 700 ohm second segment resistance point on the horizontal axis.

d. Find the instance on the graph where the points from step b and step c meet.

If this point is below the bold line defined in the step a, then a circuit with these parameters *is* capable of span powering two H4Rs and one H4TU-R.

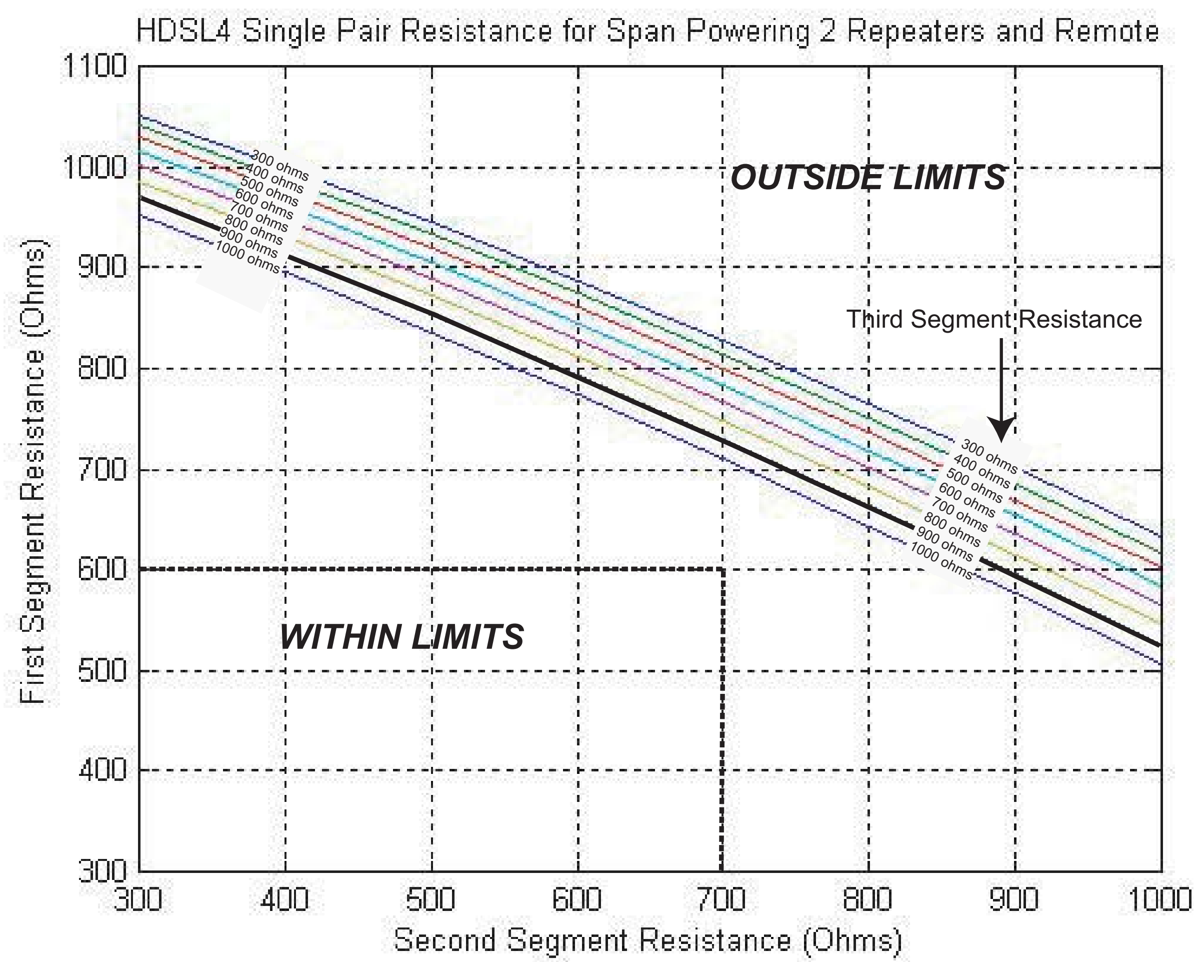


Figure 20. Resistance Budget, Span Powering Two Repeaters (Example)

Resistance Design Guidelines for HDSL4 Circuits with Three Repeaters

NOTE

An ADTRAN HDSL4 circuit can power three elements *only*. If three repeaters are utilized in the circuit, a locally powered H4TU-R must be utilized.

NOTE

HDSL4 circuits utilizing three repeaters have different resistance budget requirements. These requirements are provided separate from the two-repeater support calculations. (DSL Assistant, versions 3.4 and prior, has no provision for three-repeater circuits.)

Under unusual circumstances, there may be extremely long loops for which three repeaters will be required. The standards-based –190 VDC power supply can not span power all three repeaters plus a span-powered remote. In this long-reach application, the DC resistances of the individual segments between the Central Office and the third repeater must be within limits similar to those described on the previous page.

The DC resistance graph for the three-repeater circuit (with locally powered remote) is shown in **Figure 21**.

The procedure for utilizing this graph is identical to that described for “Resistance Design Guidelines for HDSL4 Circuits with Two Repeaters” on page 37.

The greatest overall reach can be achieved by shortening the first segment, which reduces first segment resistance, thus allowing the subsequent segments to span further.

The loop attenuation requirements for all of the segments beyond the first repeater are identical since the modulation on those loops is identical.

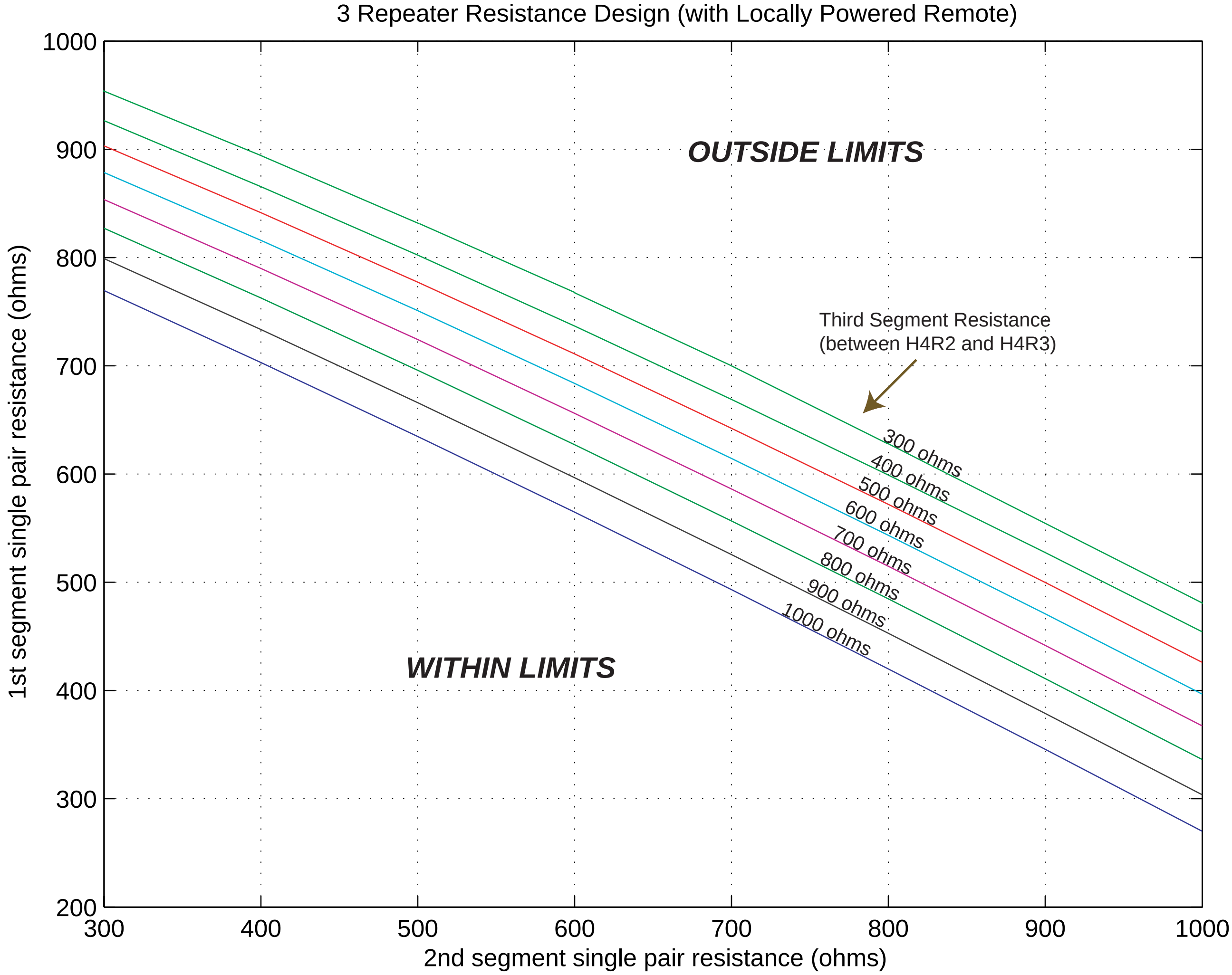


Figure 21. Resistance Budget, Span Powering Three Repeaters

Appendix A
Contact Information

WARRANTY AND CUSTOMER SERVICE

ADTRAN will replace or repair this product within the warranty period if it does not meet its published specifications or fails while in service. Warranty information can be found at www.adtran.com/warranty.

Refer to the following subsections for sales, support, Customer and Product Service (CAPS) requests, or further information.

ADTRAN Sales

Pricing/Availability:

800-827-0807

ADTRAN Technical Support

Pre-Sales Applications/Post-Sales Technical Assistance:

800-726-8663

Standard hours: Monday - Friday, 7 a.m. - 7 p.m. CST
Emergency hours: 7 days/week, 24 hours/day

ADTRAN Repair/CAPS

Return for Repair/Upgrade:

(256) 963-8722

Repair and Return Address

Contact CAPS prior to returning equipment to ADTRAN.

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