

HDSLx Installation and Maintenance

INTRODUCTION

In the 1960's, T1 service emerged, offering dedicated bandwidth to corporate customers. Although it allowed for the transmission of multiple voice channels over two twisted pairs, installing and maintaining a DS1 circuit was cumbersome and costly. This fact along with an aging copper plant drove the development of High bit rate Digital Subscriber Line or HDSLx. Several variations of HDSLx which include HDSL, HDSL2 and HDSL4 have quickly become the providers' first choice in deploying DS1 service to customers. Manufacturers claim easy installation easy installs, but what do you do if service cannot be established. The reality is that installation and maintenance is not as simple as promised. So, why is it that we consider them a plug and play solution? The truth lies in the prequalification and verification of the copper plant. This cannot just be done from circuit records, technicians must be aware of recommended guidelines.

If we continue to turn up HDSLx circuits without qualifying the plant and verifying the service, we can only expect these headaches to continue. Could you imagine building a home, without knowing what the soil conditions are on the lot you are about to build? If we run the proper tests during circuit turn up, we will easily identify any problems on the loop, prior to installing the cards and handing the service over to the customer. With a strong foundation, good understanding of the span characteristics and the right tools, technicians will be able to get the HDSLx circuits up and running in no time.

This application note will provide an overview of the HDSLx technologies with a focus on the various problems that are encountered in the field, isolation techniques and recommended repair guidelines. It is the first step in installing and maintaining quality service.

HDSLx

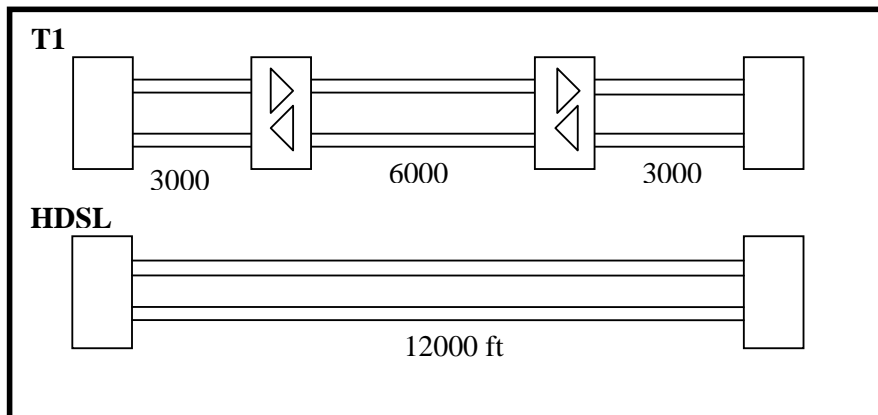
HDSL
HDSL2
HDSL4

Authors

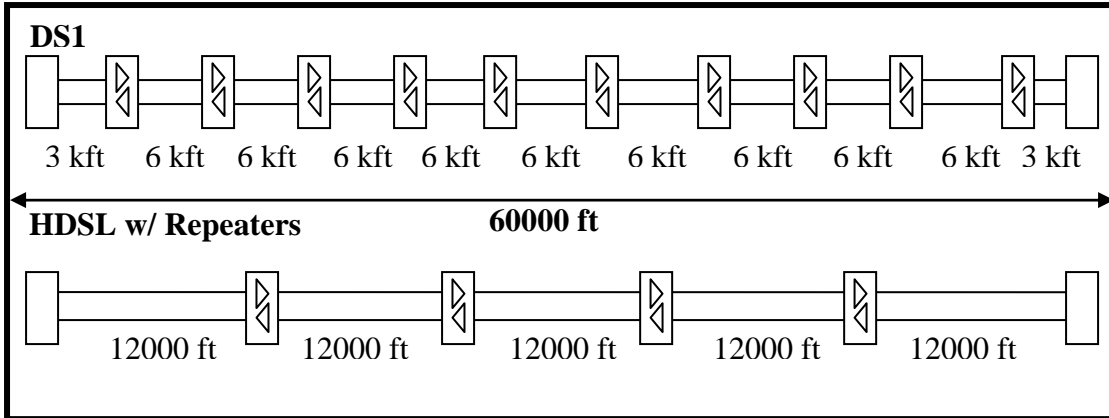
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► **HDSLx OVERVIEW**

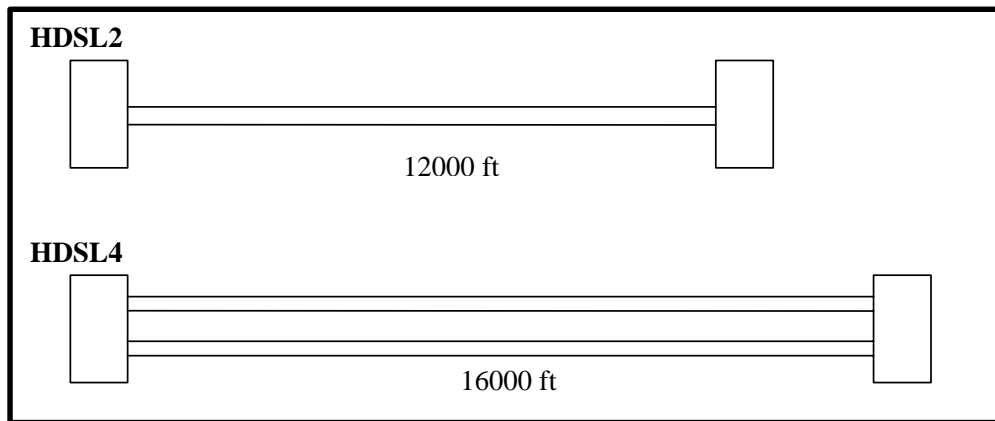
The original HDSL service emerged in the late 90's and was also called "repeaterless" DS1 service. The technology had the intent to deliver a DS1 signal with "fiber-like" quality over copper and borrowed concepts from Basic Rate ISDN or BRI. HDSL can reach a customer 12000 feet away across two non-loaded copper loops by changing the encoding scheme, terminating cards and also by simultaneously transmitting one-half of the DS1 signal across each of the loops. Resulting in 12 channels or DS0s on loop 1 and 12 DS0s on loop 2 resulting in a 784 kbps signal on each loop. The reason for changing both the coding and splitting the DS1 into two separate signals was to lower the center frequency of the signal. Traditional DS1s run at 1.544 Mbps and have a center frequency of 772 kHz while each loop of an HDSL span passes 768 kbps at a center frequency of 196 kHz.



When HDSL became more prevalent in the industry, repeaters or doublers were introduced to extend distances, making HDSL no longer a repeaterless technology. Today, it is possible to add up to four line repeaters making it possible for HDSL to reach customers up to 60000 feet away. To reach this distance a DS1 requires 10 line repeaters thus HDSL allows service with less electronics or points of failure.



Equipment vendors were looking at ways to provide DS1 payload over a single copper loop without sacrificing distance or quality. HDSL2 or HDSL 2-wire was designed to meet these requirements. Benefits of HDSL2 include passing a DS1 signal across a single non-loaded copper loop, reaching a distance of 12000 ft with no repeaters. This technology utilized newer coding techniques to retain the lower frequency but is able to simultaneously transmit and received the entire DS1 payload across one pair. However, with the emergence of all other xDSL technologies in the local loop, new problems were arising due to overlapping frequencies. Spectral compatibility issues were becoming a big concern and even though HDSL and HDSL2 were spectrally compatible, once a repeater was introduced all compatibility was lost.



More recently HDSL4 has emerged and reverts back to the two loop or 4-wire concept. As with traditional HDSL, two non-loaded loops are required and spectral compatibility is achieved. Another advantage of HDSL4 is the ability to extend the distance to 16000ft without repeaters and by adding two repeaters a maximum reach of 47000 feet is gained.

The emergence of HDSLx has changed T1 installs forever. Initially, HDSL was installed on sub-par physical paths with less repeaters and little or no

provisioning. Although HDSLx offers cost savings to traditional T1 installs through less equipment, it is not an excuse for not ensuring a clean loop. When the service does not work, it easily takes two to three times longer to isolate and repair problems. There is no doubt that HDSLx is a great service, but it must be clearly understood that just like DS1, HDSLx is not a plug and play service. The loop must be provisioned and the service must be tested before turned over for customer traffic. Relying on the measurements provided by the HDSLx cards to identify problems is not enough, and is not a replacement for skilled technicians who truly understand modern copper impairments and issues.

Let's think back to our building a house example. The process is simple:

- Select an approved site
- Build footers and foundation
- Build frame
- Add siding
- Then comes the roof!!!

Could we imagine building a home, and without ensuring the foundation and frame was built properly, we started putting up the siding and our roof? So why would we do this for our HDSLx circuit? First we must verify that our site and foundation, or in this case our copper plant is "sturdy" enough to carry traffic, isn't cracked or broken, and is on solid soil, so it will not sink or slide away.

Comparison Chart

	HDSL	HDSL2	HDSL4
Payload	<i>DS1 @ 1.544Mbps</i>	<i>DS1 @ 1.544Mbps</i>	<i>DS1 @ 1.544Mbps</i>
No. of Pairs	<i>2</i>	<i>1</i>	<i>2</i>
Line Coding	<i>2B1Q</i>	<i>TC-PAM w/ Spectral Shaping</i>	<i>TC-PAM w/ Spectral Shaping</i>
Bit Rate	<i>784kbps / pair</i>	<i>1552kbps</i>	<i>784kbps / pair</i>
Loop Length	<i>12000ft</i>	<i>12000ft</i>	<i>16000ft</i>
Max Reach	<i>60000ft (4 repeaters)</i>	<i>12,000 ft (repeaters rarely used)</i>	<i>47000ft (2 repeaters)</i>
Loop Resistance	<i>900 Ω</i>	<i>800 Ω</i>	<i>1150 Ω</i>
Noise Margin	<i>≥6dB</i>	<i>≥5dB</i>	<i>≥6dB</i>
Transmit Power	<i>+13.5dBm</i>	<i>+16.8dBm +16.5dBm</i>	<i>+14.1dBm</i>
Spectral Compatibility	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>
Spectral Compatibility with repeaters	<i>No</i>	<i>No</i>	<i>Yes</i>

► **PRE-QUALIFICATION**

In our earlier analogy, prior to building our home, we must verify we have a solid foundation. Same goes for our HDSLx circuit. We must provision the copper loop(s) to ensure all requirements for service are met.

Smart coils were designed to allow ADSL traffic to pass, so that a second pair would not be required to service customers on long POTS loops. They will not allow HDSLx traffic to pass and must be removed.

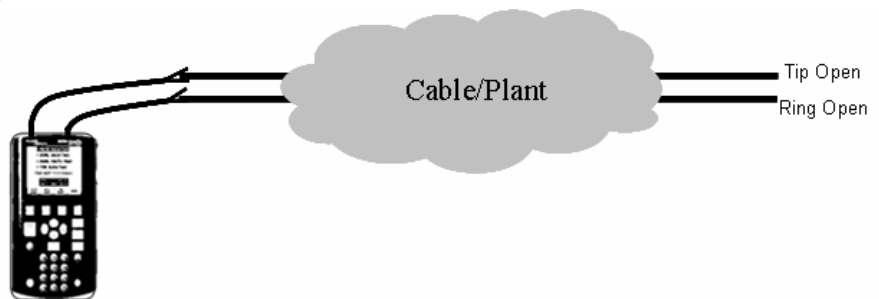
Remove “ALL” load coils

Load coils work as low pass filters, cutting off high frequency signals (over 3.1 kHz). They are used on POTS loops that extended out past 18000 feet to counter balance the natural capacitance build inductance being added to the span over long distances. Load coils will not allow HDSLx (or any high frequency signal) to pass therefore they must be removed prior to install. There are numerous tools on the market to assist in identification, location and counting of load points. Some common tools include a basic load coil counter, Time Domain Reflectometer (TDR), or an integrated test solution.

Measuring Loop Length

To accurately assess the travel distance of the copper wire is not as easy as it sounds. As stated earlier, HDSL and HDSL2 allow for a loop length of 12000 feet and HDSL4 for 16000 feet. All three HDSLx technologies look at the “total” amount of copper. Ensuring the circuit meets loop length requirements is the extremely important in ensuring we have a quality signal. The most accurate method of checking loop length is with a capacitance or opens meter.

Bridged-Taps add to total length of you loop! For example: If you have a single 1,000 Bridged-Tap, then HDSL will only go 11,000 ft.



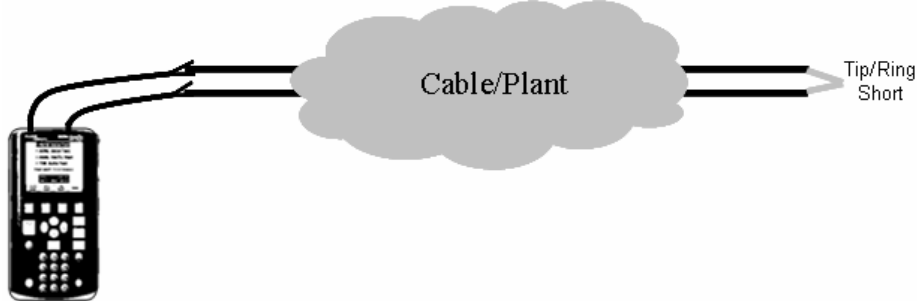
A capacitance measurement is done by connecting a meter to one end while the far end remains open. When making a capacitance measurement, readings may be altered by AC faults. Due to this, you should short the pair and compare it to a resistance measurement.

Compare capacitance to resistance

A common misperception is that only a resistance measurement is sufficient to check for loop length. A resistance measurement reads the amount of voltage passed through a span, which is essentially a DC test which can miss bridged-taps.

Take BOTH capacitance and resistance readings!

Loop resistance is measured across tip and ring with a short at the far end. Readings must be within the limits provided by the equipment manufacturers.



A loop resistance reading is easily translated to a distance reading and many testers will do the conversion for you. The chart below also provides a guideline on how to convert resistance to distance. This is not an exact measurement and everything from temperature, gauge and type of cable must be considered.

AWG	Ohms/1000 ft
22	16.8
24	27.3
26	43.6

The next step in measuring loop length is to compare the two readings, capacitance versus resistance. These two readings should be fairly close, if they differ, then there is a good chance that a Bridged-Tap or other fault is present on the span.

DC Faults

DC faults include shorts, opens, and grounds. These are the main type of faults that technicians are trained to find. Normally, the fault either completely deters the signal from passing or is seen as alarms or excessive errors. There are numerous methods and testing solutions for troubleshooting DC faults, but the key is to be familiar with your test equipment, cable and above all how to interpret readings and measurements. The industry is full of great test gear, but this is only a tool and the knowledge to use that tool must not be overlooked.

For example, our previous capacitance and resistance readings will assist in identifying any possible faults on the span. If the capacitance reading is shorter than expected this could imply a cut or open in the cable. This can be verified by doing a loop resistance measurement. If the cable is actually cut, the loop resistance reading across tip and ring will be $\geq 3.5\text{M}\Omega$.

Resistance should also be measured across tip, ring and ground with the far end open. This measurement is crucial in identifying shorts and grounds on a pair. Results for all services should result in a minimum resistance reading of $3.5\text{M}\Omega$. Less resistance between tip and ring indicates the presence of a short. Less resistance between tip and ground or ring and ground indicates the presence of a ground or a split.

To ensure resistive balance or DC Balance of the pair, create a short between tip and ground and another between ring and ground and measure resistance

HDSL requires balanced pairs!

respectively. The resistance reading between tip to ground and ring to ground should be within $\pm 5\Omega$. If this is not the case, then there is a ground or other resistive fault on either tip or ring. This fault must be found and fixed.

There are no short cuts here and whether you have a basic kick-meter or a multi-function tester such as a Dynatel 965DSP, Fluke Networks CopperPro or JDSU HST-3000c you must be able to efficiently clear the span. Through our experience we have found that over 60% of all spans are not pre-qualified and when the service due date has been missed and the customer is upset, it is too late to qualify the network.

TDR Trace Examples

Short
(Downward Spike)

Open/Load
(Upward Spike)

Bridged Tap
(Combination of Up/Downward)

AC Faults

AC type faults are typically described as frequency specific faults because they affect signal quality by increasing loss across the frequency spectrum, which, in turn, causes bit errors. Examples of AC type faults are bridged taps, wet sections and frequency interference. Bridged taps are sections of cable that extend off the main cable route. Depending on their location, length and termination, bridged taps cause loss to the HDSLx signal.

HDSLx allows for some bridged taps on the span. These limitations are based on CSA requirements. The total length of all taps must be less than 2500 ft, with no single tap exceeding 2000 ft in length. In addition, no taps are allowed within 100 feet of any equipment (C.O., repeaters, CPE). It is highly recommended that you ignore all these requirements, and completely remove all bridged taps.

Bridged Taps
Although HDSLx allows for bridged taps, you will see that they are a main cause of trouble on spans. To save yourself time, locate and remove all bridged taps regardless if they meet specs or not. Bridged-Taps may cause intermittent drop-outs!

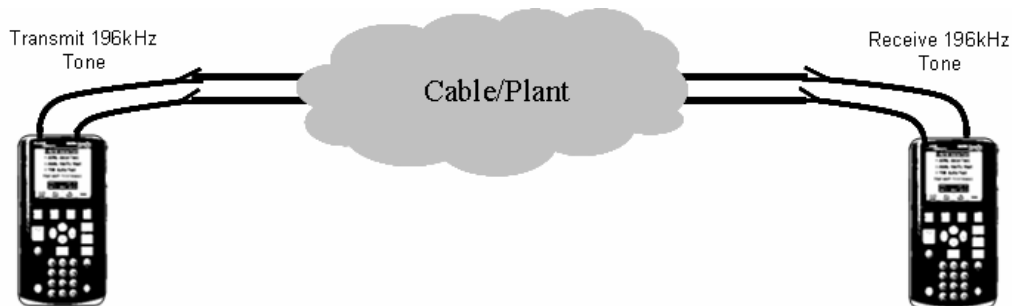
Water in the cable has a similar effect on the signal as bridged taps, causing loss at specific frequencies and errors to customer traffic. Water may also result in pairs going open, so even if the water doesn't seem to be affecting the service currently, it is important to identify and remove.

When comparing the capacitance and resistance readings done earlier, if the length given by the capacitance meter is greater than that of the resistance meter, there is a good chance that a bridged tap or a wet section is present on the span. Bridged taps and wet sections that may be present on the span add inductance to the circuit. This inductance will be measured by the capacitance meter and be included as additional loop length. For example, if the capacitance reading is 12000 ft and the resistance meter gives a reading of 10000 feet, we can assume that there is approximately 2000 feet of bridged taps on the span. To verify the presence of a wet section or a bridged tap a TDR may be used.

A Time Domain Reflectometer (TDR) is a great tool to be used to identify and locate physical layer faults. A TDR transmits pulses onto tip and ring and monitors the reflections that come back. These reflections are caused by faults, which are changes in the impedance of a span. The TDR can confirm the type of fault by analyzing the shape of the energy reflection and the location of the fault by comparing the time the pulse was sent to the time the reflection was received. Since TDR pulses are AC signals, the TDR is extremely accurate at finding AC faults such as bridged taps, wet sections, splits, and load coils, but will also identify DC faults such as shorts and opens.

Tone Test

A loss measurement should also be done on the loop to try and identify how the span will react to HDSL frequencies as well as assist in identifying any AC type faults. A signal will attenuate as it travels along the copper. This attenuation increases with distance. The higher frequencies will have higher attenuation than lower frequencies. Perform a tone test at 196 kHz end-to-end is a quick check to verify spans AC performance. For HDSL and HDSL2 loss should be $\leq 35\text{dB}$ and for HDSL4 (due to longer loop) should be $\leq 46\text{dB}$.



► DEALING WITH NOISY CIRCUITS

Noisy circuits are quite common in the outside plant, and one of the biggest problems to find outside plant technicians. Identifying the source of the noise trouble is an even bigger headache, especially if its impulse noise that isn't always present on the span.

The degree of how well tip and ring are electrically matched translates directly into how well the pair can shield itself from noise and interference. A pair that is not well balanced is open to undesirable signals that convert to noise on the pair and degrade the HDSLx signal, resulting in bit errors and even loss of sync. Proper grounding and bonding also help to alleviate these problems. Grounding will be discussed later.

Splits cause unbalanced pairs as well as inhibits the designed twist of the wire

Noise is often caused by oxidized or bad splices. Since a bad splice tends to eventually go open it must be identified and fixed prior to service going down. Another cause for noise may be a split pair. A split pair is a wiring mistake made when a wire of one pair is incorrectly spliced to another wire of an adjacent pair. Splits are often connected by reconnecting the pair further down the line. When a split occurs, the impedance of the pair changes and the twist control is destroyed. With no twist, the pair works like an antenna picking up excess crosstalk, which, in turn, results in a noisy line. Both bad splices and split pairs create an unbalanced circuit. Spans that are not properly balanced will have constant noise problems. To identify noise on a span, both noise and balance measurements must be taken.

To identify how similar the electrical characteristics of tip are to that of ring a longitudinal balance reading must be done. A longitudinal balance measurement is taken with the C-message filter and readings should be $\geq 60\text{dBmC}$. This measurement must be done at both ends of the span, and the worst reading should be taken as accurate. Since this measurement is taken using the C-message filter, it is taken over the low frequencies. To ensure the pair is balanced for HDSLx service, longitudinal balance measurement at 196 kHz frequency should also be done. The result should be $>40\text{dB}$.

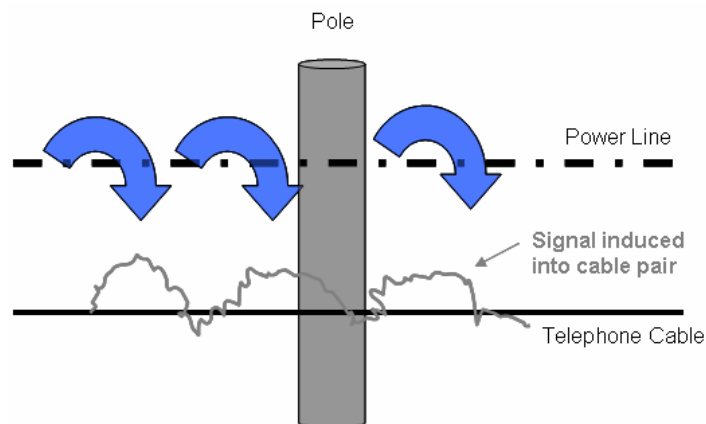
Circuit Noise is the amount of noise across tip and ring and is also measured with the C-message filter across the voice band. An acceptable noise reading should be $\leq 20\text{dBmC}$.

Since HDSLx runs frequencies out of the scope of a C-message filter, a wideband noise measurement should be taken using the F-filter at both ends of the span. F-filter was designed to be an accurate representation of the HDSL frequency band. This reading ensures there are no higher frequency noise problems. Noise readings for HDSL should be $< -45\text{dBm}$, for HDSL2 should be $< -47\text{dBm}$, and for HDSL4 should be $< -54\text{dBm}$. Excessive f-filter noise levels indicate high frequency noise from various sources, including crosstalk as a result of poor balance caused by split pairs.

Power Influence

HDSLx traffic can be affect by AC power lines in close proximity. It is a property of the “Right Hand Rule” of physics. A simplified version states that any time an electrical signal passes through a power line; a magnetic field is created which can induce that current into a nearby cable. If the shield is correctly maintained (bonded, grounded) it should prevent a large amount of the magnetic field from reaching the pairs inside. However, sometimes even the shield can’t cancel out the entire effect of power influence.

Power influence by itself may not be a problem. However, power influence typically amplifies any existing cable noise, including metallic noise.



Foreign DC Voltage

Although HDSLx equipment can compensate for some foreign voltage on the loop, it is important to identify the root of this voltage. Most manufacturers say DC voltage on the span should not exceed 3VDC across tip, ring and ground. Meeting this parameter may be difficult depending on route, age and condition of the cable. The realistic parameter here is “less is better”, the goal should be 3 VDC. The source of foreign DC voltage is usually battery that is leaking on to the pair due to a cross. Verify that your pair is clean and identify and remove the source of any foreign DC voltage on the span. Similar to noise and power influence, grounding and bonding is extremely important and we have found this to cause more problems than many will admit.

Power Influence

AC voltage on the span is usually caused by Power Influence, which will in many cases be the cause for noise trouble.

Measurements should be:

- $\leq 80dBrnC$ = acceptable
- $>80 < 90dBrnC$ = marginal
- $\geq 90dBrnC$ = unacceptable

If pair is balanced and still has noise problems, then the noise may be caused by defective power factor correction capacitors, improperly loaded

The HDSLx CO unit provides DC voltage on the span for powering purposes. When repeaters are present, the CO unit provides up to -190VDC with a simplex current between 10 to 150mA. These numbers vary depending on the load of the circuit.

► GROUNDING PROBLEMS

Proper grounds are required not only for safety reasons but also for quality service. This does not just include the cable plant, but should also be checked at facilities and electronics including at the CO circuit pack, remotes, repeaters/doublers and at the customer location. Many times there is not a clearly identified or easily accessible ground when installing the remote card (HRU, HTU-R...), so it is simply skipped. This is a major mistake and can cause intermittent drop-outs, errors or even complete equipment failure. The lesson here is simple: if it can be grounded...ground it.

Don't forget to ground the remote chasis (HTU-R, HRU...)

When you are unsure about a solid ground, take the time to test it. To avoid noisy circuits and failures due to voltage surges, it is desirable to keep the connection to ground as low as possible, preferably less than 25Ω. The resistance of the wiring between the ground lug of the HDSL shelf and the ground rod should be less than 100mΩ.

► **VERIFYING THE SERVICE**

Very often technicians confuse a loss reading with service verification. Although a loss measurement is a great way to quickly check the spans AC performance, this by no means verifies the service. Most AC faults affect a specific frequency, which will affect service quality. If the fault affects a frequency other than 196 kHz, the trouble will go unnoticed until handed over to the customer. Therefore, measuring at one frequency is not enough to ensure quality across the entire frequency spectrum.

Run Multiple Patterns!
All ONES
3 in 24
All Zeros (B8ZS)
T1 DALY

The most accurate way to verify proper performance of a span is to run an end-to-end BER Test (BERT). A Bit Error Rate test is performed end to end, using a digital signal that simulates customer traffic. Since type of traffic the end user will be passing through the circuit is not known, the most accurate way to verify the span is to run

multiple BERT patterns that will thoroughly stress the circuit. Running the following patterns will help in identify any problems that are service related.

Pattern	Description	Stresses/Comments
All ONES	A pattern of repeating ones.	Maximum power
3 in 24	A pattern with long strings of zeros	12.5% ones density and 15 zeros
QRSS	Quasi-Random Signal Source	Simulates live traffic
T1 DALY	Modified 55Octet Hex Pattern	Extremely stressful simulation of live traffic.
55 OCTET	55 Octet Hex Pattern	Extremely stressful simulation of live traffic Can cause network alarms
All ZEROS	A pattern of repeating zeros/spaces	Tests for B8ZS encoded equipment. Will not run on AMI!
1:7	One 1 and Seven 0s	Timing recovery for B8ZS (unframed) B8ZS test (framed)

So, now you are saying to yourself “these are DS1 patterns, I’m turning up HDSLx”. Well, that is true, but what we are handing off to the customer is a DS1 circuit. And by testing the span in the exact way the customer will use it, you ensure that problems are identified before hand-off. As a result, the customer will experience consistent, high quality performance. For more information on DS1 testing please consult our *DS1 Testing and Installation* whitepaper.

► CONCLUSION

HDSL requires proper testing in order to perform properly. It is a reliable technology, but only as good as the cable it traverses. We realize that there is increased expectations and limited manpower, but the alternative is missed due dates, intermittent drop-outs and inadequate DS1 service. Yes, manufacturers of HDSLx line equipment are now incorporating in service monitoring as well as basic testing capabilities. This is useful in troubleshooting problems after the service is installed, but these tests do not properly test the copper cable or provided a pre-assessment of the plant.

Customers of the DS1 service are also installing advanced data services like cellular 3rd Generation data and video conference systems. These technologies will not tolerate marginal services and many believe that they simply will not work across HDSLx. This has not been validated, but our experience is that many HDSLx lines are currently operational but not functioning properly. This means that you are not delivering quality service due to inadequate qualification. It is highly recommended that you run all the tests discussed in this application note. This way we can minimize the amount of time needed for an HDSL turn-up.

It is extremely important to fully understand HDSLx as well as AC and DC copper concepts. Educating technicians on the newer technologies and testing concepts will ensure better results, quality turn-ups and fewer kickbacks. Test equipment should also be a concern and there is a wide variety of quality products available that can address the tests discussed in this application note.

Isn't it time to give HDSLx the attention required to ensure a quality DS1 service?

For further information on other technologies please consult the TESSCO library of white papers.

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