T1 Installation and Maintenance

INTRODUCTION

T1 also known as Digital Signal level 1(DS1) is a digital technology that was created during the 1960s to carry voice and data services. The original focus of the technology was to carry traffic between telephone offices, but it did not take long before it was offered as a standard service to customers. Over the years, it has grown to be the workhorse of the industry world and is also the key building block for higher services like T3 and Synchronous Optical Networks or SONET.

In the present day T1 span lines are taxed to the extreme by new data service offerings such as Video, IP, IPTV, VOIP, and increased 3rd Generation services from wireless providers. These service offerings require tremendous amounts of bandwidth, quality of service (QOS) and reliable networks; they can be crippled by lags in the network or intermittent problems. In the past, faulty DS1 circuits functioned adequately just carrying voice customers, these circuits however cannot perform well with today's data customer's bandwidth demands. Now more than ever quick installation, proper testing and maintenance of DS1 signals are essential.

The focus of this white paper is modern installation and maintenance testing of DS1 signals. Topics include a brief DS1 overview, detailed out-of-service tests to be performed, loop-testing, mis-optioned line coding testing and monitoring of in-service signals. Proper errors and measurements results analysis is also discussed.

Whether an experienced technician or not, the material in this document will enable more efficient installation and maintenance of DS1 signals.

1.544Mbps Hi-Cap Digital Service

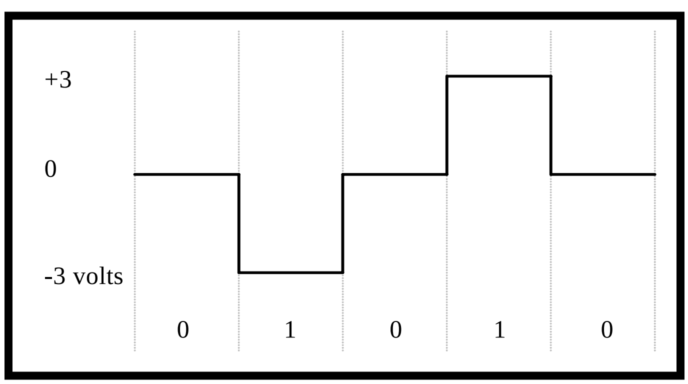
Written by
Anu Schramm

►DS1 OVERVIEW

A DS1 is a 1.544 Mbps digital signal. There are up to 24 individual digital channels or DS0s (Digital Signal Level Zero) that are multiplexed together creating a single signal that is transported via copper pairs or further multiplexed into larger bandwidth signals, such as DS3 or Optical Carrier levels (OC-N). The 24 individual DS0s have line rates of up to 64kps, and are multiplexed by using fixed timeslots which carry 8000 bits per second of information. To keep the individual channels aligned framing overhead is added. Framing can vary, predominantly D4/SF or ESF are used.

Framing	D4	ESF
Number of Frames	12	24
Loop codes	In-band	Out-of-band
Application	Primarily voice	Voice, video and data
Benefits	Works with older equipment	• In-service monitoring (CRC) • Performance Report Messaging (PRM) • Increased alarms

Once the signal is framed, line coding is added to prepare the signal to be transported on a copper medium. Alternate Mark Inversion or AMI is a bi-polar coding scheme that makes a digital one or mark a positive or negative three volts. Zeros or spaces are represented by zero volts. The ones must alternate between the positive and negative voltage. Bi-Polar coding offers advantages that include:



- Lowering the frequency so the signal can travel further on a copper medium.
- +3/-3 volts help balance the voltage of the signal and allow simplex current to be placed on the line to power the repeaters and network interface units.
- Built-in error detection called BPVs. If the ones do not alternate in polarity AMI is violated, and the error is called a BPV, these errors can be detected while customer traffic is on the circuit.

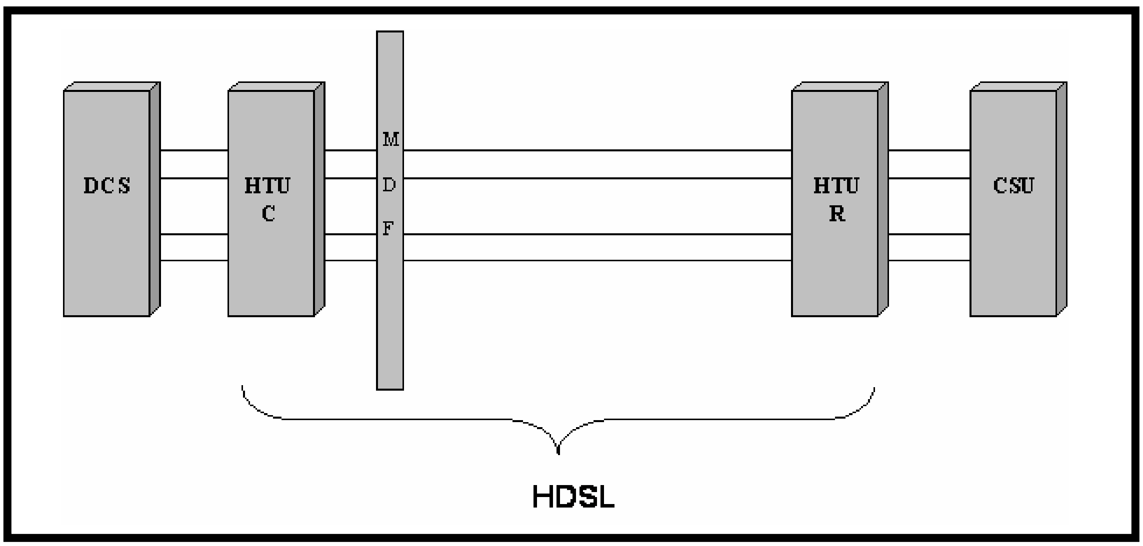
With DS1s there are ones density requirements that must be met to ensure enough pulses are present on the line. Without sufficient pulses the network equipment can lose timing and drift, causing errors and possible network outages. The rule for ones density states 12.5% of the traffic on the line must be ones with no more than 15 consecutive zeros. This rule can be limiting to data traffic which has the potential to send many zeros and violate the rule.

DS1 signals need sufficient pulses to maintain timing!

The newer form of coding is AMI with Bipolar with 8 zero Substitution or simply B8ZS. When optioned, this method that manipulates zeros so that the ones density requirement can be met. It is important to understand that B8ZS is only invoked when there are 8 zeros in a row.

►HDSL

Traditional DS1s are slowly being replaced with High Bit Rate Digital Subscriber Lines or simply HDSL. The throughput or service is still a DS1, but it utilizes newer technology to allow the service to work on the aging cable plant. This allows it to maximize the performance without costly replacement of copper cable. For more information on HDSL technology please refer to the TESSCO Application Note titled HDSL Installation and Maintenance.



►Installation Testing

Installation Testing is not only the first step in turning-up a new circuit; it also provides important benchmark information for future testing. Out-of-Service testing requires test traffic to be placed on the line. Observing the results of the test can give valuable information beyond simply a pass or fail result.

1. The first step in testing is to verify the metallic infrastructure prior to stress testing. Things that should be checked are:
   - Cable pairs are pre-qualified
   - Proper current and voltage
   - All jumpers and connections, and cross connects are installed and verified
   - Terminating equipment installed
   - Correct line coding and framing provisioning of the circuit.

2. The second step of installation testing is to place simulated traffic on the circuit. This is called a Bit-Error Rate Test (BERT). A BERT test is used to analyze the entire 1.544Mbps data stream and is truly a bit-by-bit comparison and analysis.

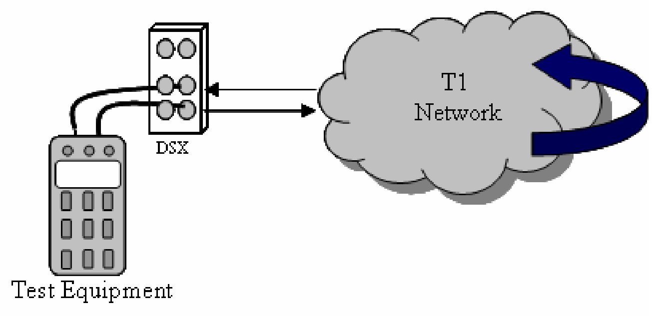
Run Multiple Patterns!

All ONES
3 in 24
All Zeros (B8ZS)
T1 DALY

There are many test patterns available on test equipment. There is not a single pattern that can efficiently test an entire DS1. Multiple patterns must be used to properly stress test the circuit and provide an accurate picture of network performance.

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 15 zeros in a row Should be sent “unframed” Tests timing recovery for AMI
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)

BERT tests can either be conducted with one or two test sets. If only one test set is available a BERT can be accomplished by testing to a loop. Either a hardloop or software loop is acceptable.



- A hardloop is a physical loop created by wire, either a loopback plug, bantams, or RJ-48X can create this hardloop.
- Software loops are commands from test equipment that causes Network Interface units (NIU) or Customer Service Units (CSU) to automatically send traffic back towards the sender. Details of software loops will be discussed later.

A BERT can also be conducted between two test sets creating an end-to-end or head-to-head test. This provides an advantage over loop test because direction of faults can be located quickly, isolating whether the problem is in either the transmit or receive direction.

3. The third step of installation testing to analyze the results.

- Bit Errors--Each bit which passes through the test set and is compared to a know pattern, any discrepancies are noted as a bit error. Bit Errors can only be observed with test patterns, not live or random traffic.

- BPV—If pulses on the line do not alternate between positive and negative it is called a BPV. BPVs can be detected on live or test traffic. BPVs are indicators of local copper faults. Some equipment can fix BPV errors, making a BPV test better suited for localized testing not end-to-end.

- CRC—Cyclic Redundancy Check is used only in ESF framing. It is a method of observing each ESF frame for errors. It is calculated regardless if the traffic is customer data or test traffic. It is important to note that CRC errors are not one to one with a bit error.

- Frame Errors-A frame error occurs when the framing overhead bit is errored. This result is calculated on all framed DS1 signals.

- Frequency—A DS1 is 1.544 Mbps +/- 50 per ANSI T1.102, this is an important measurement to make on new DS1s. It will first provide a baseline to compare to after an outage. Frequency also can be an indicator of how well a timing source is functioning. If there is no primary clocking device on a circuit, the DS1 will drift and the frequency will not be 1.544 Mbps.

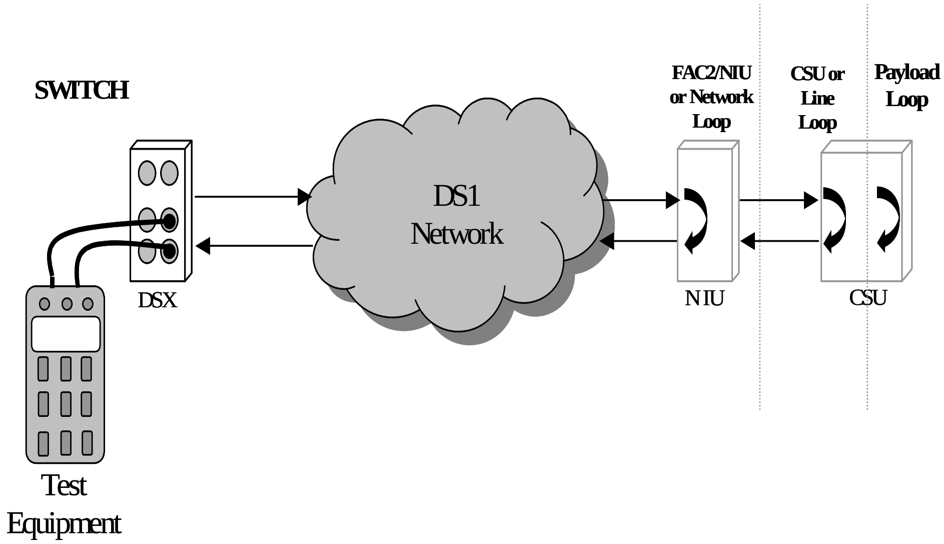
- Signal Level—An often neglected measurement that can provide valuable information as well as an important benchmark. Signal Level is the measurement of signal voltage at a particular location and it is given in either Volts peak-to-peak or dBdsx. If the signal level is low it is possible that the DS1 will terminate prematurely. In order to ensure a proper reading of signal level the All Ones pattern should be used, since it will put maximum power on the line.

Signal level should be measured on all newly installed DS1 with the “All Ones” pattern. This is a higher frequency than other patters and will show the maximum amount of loss.

- Timing Slip—A timing slip measurement is a comparison of two DS1 signals, the measurement can be conducted on in-service or out-of-service DS1 signals. The purpose of a timing slip measurement is to check the timing on a particular DS1. By comparing a DS1 to a reference DS1 one can gauge whether the test DS1 is quicker or slower than the reference signal. Problems with timing slips are indicative of multiple clocks on a circuit.

►Loop Testing

Loop testing is another category of testing that can be conducted on newly installed DS1s or out-of-service DS1 signals. The focus of this testing is to verify the proper function of line equipment such an NIU, CSU and intelligent repeaters. As well as verifying segments of a DS1 circuit by testing to these devices.



The general premise of loop testing is to remotely test, isolate and sectionalize a circuit.

1. The first step is to send a particular sequence of ones and zeros that network elements recognize and respond to be either looping-up to looping-down, essentially a soft-loop. An NIU, CSU or intelligent repeater each has a unique code that it is programmed to respond to, allowing a tester to be specific about which device to loop-up or loop-down. By looping-up the equipment automatically sends incoming information back to the sender.

2. Secondly, a single tester can test the line by sending patterns (BERT) and observing results and/or verifying the proper response by the line equipment. Results such as Bit Errors, BPVs, CRC, Frame Errors should be analyzed. Even though all circuits have occasional errors, the goal is to send multiple patterns for several minutes each without errors.

3. Lastly, it is important when conducting loop testing to disconnect the loop by sending a loop-down code and resuming sending and receiving traffic. To verify the loop has been taken down, Bit Errors should be sent and not received back.

There are two types of loopcodes, in-band and out-of band. In-band loopcodes are sent in the payload of a DS1. An out-of-band loopcode is sent in the datalink overhead area of the ESF frame.

Loop Type	Looping Method	Common Loop Codes
Manual	Loop plug, Patch cord, Manual equipment loop	N/A
NIU/Smart Jack	Manually, Loop Code	In-Band: Facility 1, 2 or 3 *FAC2/NIU (Up: 11000/Down: 11100) Out-of-Band: ESF Network
CSU	Manually, Loop Code	In-Band: CSU *(Up: 10000/ Down: 100) Out-of-Band: ESF Line and ESF Payload
Intelligent Repeaters	Manually, Loop Code	Vary by vendor (Typically 16 bits long)

►AMI/B8ZS Mis-Option

A common problem on DS1 signals is mis-optioned line coding. This situation occurs when one portion of a DS1 network is optioned for AMI line coding and another portion or piece of equipment is optioned for B8ZS line coding. This mismatch of line coding produces errors on the line and corrupts customer data. Since B8ZS places intentional errors (ones) on the line for ones density requirements if equipment is not optioned to recognize the errors as actual ones and will corrupt the original data. This mismatch can show itself as BPV, CRC or Frame Errors. To test for a mis-optioned line code two test set and testers are desirable.

1. The first step is to conduct an end-to-end test using an All-Zeros pattern. The long strings of zeros will cause B8ZS equipment to place intentional BPVs on the line triggering the AMI encoded equipment to see errors.

2. The second step is to conduct an end-to-end test using the All-Ones pattern. This pattern will not cause intentional BPVs to be placed on the line by B8ZS equipment since there are no strings of zeros. This will allow the equipment to synchronize and result in a clean BERT test.

By observing a BERT that fails on All-Zeros and passes on All-Ones the testers can be sure that there is mis-optioned line coding on the circuit. The final step is to test both ways to narrow the direction of the fault and to move test equipment to isolate the area of the fault.

►In Service Monitoring

When an operational DS1 begins to have errors or is experiencing intermittent problems the first step to troubleshooting the circuit is to monitor it. This is an often neglected step in troubleshooting a faulty circuit. There is a tremendous amount of information that can be gained while monitoring the DS1. This also serves as a way to reduce down-time of the circuit by allowing customer traffic to pass. It is also important not to rush when monitoring a signal; many intermittent problems may be missed in a short monitor.

Monitoring of a circuit requires one test set. Depending if the test set has one or two receivers the tester may view the status of one side of the signal at a time or both simultaneously. Access to a circuit may be at a DSX patch-panel, test port on line equipment or at the copper punch down block.

While monitoring a signal valuable results are available. The following is a list of possible results, alarms and messages that can be gained during an in-services test:

- CRCs (ESF only)
- Frame Errors
- BPV—Check local copper connections such as wire-wraps at a DSX
- Timing Slips—Check if any equipment has internal timing set
- Frequency—Check accuracy of timing source
- Signal Level—low levels can cause errors as well as intermittent alarms
- Also alarm conditions may be gathered while in a monitor test. Red or Loss of Signal, Yellow and AIS conditions can point to direction of fault and which faults are present on the line.
- If the DS1 is framed with ESF Framing, then Performance Report Messages (PRMs) may be available to analyze. Theses PRMs are sent in the Facilities Datalink and send status messages through the overhead. PRMs must be enabled within the equipment to be viewed.

It is important to note that Bit Errors are not available while monitoring customer traffic. Since pattern sync only occurs with test patterns.

One very common problem on existing DS1 signals is intermittent problems. These issues are often hard to catch and are a source of frustration. What are possible causes of intermittent problems?

- Bad connections
- Equipment failure
- Power problems
- Timing Problems
- Interference on the line

►CONCLUSION

In today's increasingly demanding data networks it is imperative to provide quick installation and maintain trouble-free DS1 signals. Without complete understanding of how to install, test and properly maintain these networks, advanced services cannot function properly. It is imperative that service providers do their very best to educate their employees as well as provide tools and test equipment to ensure high quality service.

This document provided an understanding of the DS1 technology as well as in-depth analysis of testing. For further information on other technologies please consult the TESSCO library of white papers.