# Application Note No. 4



# Testing DS1 Services

## 1. Introduction

This application note summarizes DS1 service testing procedures at the Digital Signal Cross-Connect, or DSX, and line repeaters (for repeatered T1-carrier). Related application notes cover DSX applications and[1] CSU/DSU applications.[2]

Testing DS1 services can be broken into measuring line performance and path performance. Line performance parameters are signal characteristics such as pulse amplitude and bit rate. Path performance parameters are bit integrity characteristics such as bit error rate (BER) and errored seconds (ES). Path performance cannot be determined until line perfomance is verified. The following sections discuss testing at the central office, remote terminals, and at line repeaters.

## 2. Testing at the Central Office

Of particular concern when connecting and setting up test sets is the timing source. If the test is to simply monitor signals at the DSX monitor jacks, the test set receiver derives its clock from the incoming signal and no special timing settings are needed. On the other hand, if signals are injected into DSX Line IN jacks, it is necessary to set the clock source for the test set transmitter. Most test sets have at least three settings: Internal; Loop Timing (from receive, or main, input); and Reference Input. Some test sets have a fourth setting, External, which is used when the timing is derived from a separate interface connector.

The Internal setting is used when the test set internal oscillator provides the clock to the test set's transmitted signal. This would be the situation when the test set is connected to a loop-timed interface. This includes asynchronous digital lines, such as repeatered T1-carrier span lines, that are connected at the other end to an active interface set for loop timing. See Fig. 1(a).

The Loop Timing setting in the test set is used when the test set is to derive its transmit clock from the received input. This is the case when the interface being tested is timed from an internal source or an external source, such as a Building Integrated Timing Supply (BITS). Similarly, if the interface at the far end of a line being tested provides the clock for its transmitted signal, then the test set at the near end must be set for loop timing. See Fig. 1(b).

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[1] See Application Note No. 2, *DSX Applications in Small Central Offices*.
[2] See Application Note No. 3, *CSU/DSU Applications in DS1 Rate Service*.

Fig. 1(a)
Test Set Internal Timing Connections

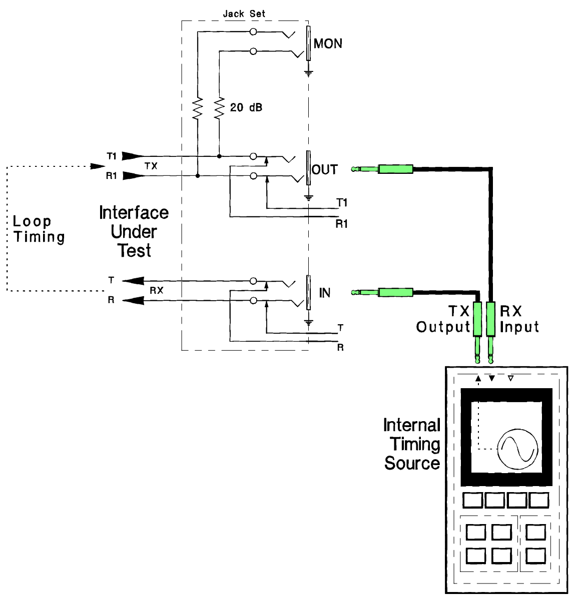



Fig. 1(b)
Test Set Loop Timing Connections

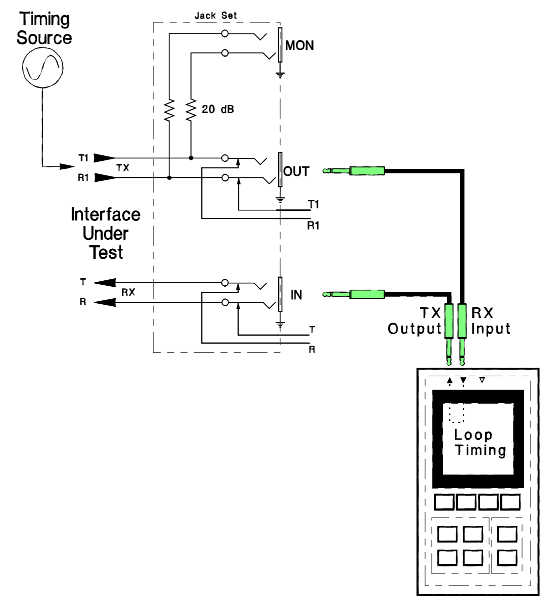
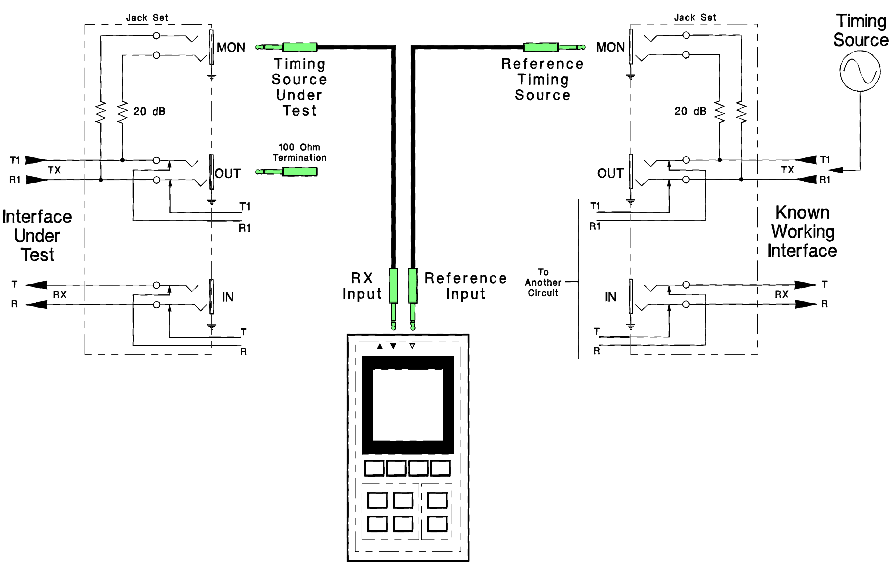



Fig. 1(c)
Test Set Reference Input Timing Connections




The Reference Input setting allows the test set to derive its transmit clock from a source other than its internal oscillator or received input. The Reference Input is handy to test for bit and frame slips on centrally timed systems by comparing a reference (central timing source) to the test set received input from a MON jack. A typical connection is shown in Fig. 1(c). The test set receiver should be set to “Monitor” mode whenever it is plugged into a MON jack. The 100 ohm termination plugged into the Line OUT jack of the interface under test is necessary only if the interface is not crossconnected to another interface that provides a termination. Alternately, the test set receive input can be connected to the Line OUT jack and set to "Terminate." The Line IN connection is intrusive whereas the MON connection is non-intrusive.

When the test set receiver is set to Monitor or Terminate, the Reference Input in most test sets also is set to Monitor or Terminate, respectively. Therefore, if the test set receiver input is connected to the Line OUT jack and set for Terminate, and the reference input is connected to the MON jack of the timing reference, the reference input will be -20 dB with respect to the receiver input. This is not a problem if the reference input is able to use the lower signal level (check the manual to be sure).

As mentioned earlier, both line and path parameters are required to be measured. Line performance parameters usually are measured at the DSX. The most important and easily measured parameters are summarized in Table 1. Other parameters, not listed in Table 1, include jitter, pulse shape and spectral power in a specific bandwidth. These normally are not measured with common field test equipment, so they are not discussed further. The facility (or line) side of CO Repeaters do not meet DSX requirements but still can be measured with all modern test sets. Specific tests at CO repeaters are covered later.

Table 1
Common Line Performance Parameters Measured at the DSX

| **Parameter** | **Requirements** | **Nominal Value** |
|---|---|---|
| Line Rate[3] | 1,543,950 to 1,544,050 b/s[4] | 1,544,000 b/s |
| Pulse Amplitude | ± 2.4 to 3.6 v-p | ± 3.0 v-p |
| Pulse Imbalance | 200 mv | 0 mv |
| Power Level | -1.0 to +1.0 dBdsx | 0.0 dBdsx |

Fig. 2 shows two DSX jack sets, one connected to a digital switching system (Jack Set A) and the other connected to a repeatered T1-carrier span line (Jack Set B). Also shown are several test access points with numbered call-outs. These test access points may be used alone or in various combinations depending on the type of test to be performed. Several test combinations and procedures are described in this section.

In most situations it is only necessary to set the test set receiver framing and line code to "Auto" and the transmitter framing and line code to "As Input." This way, the test set will automatically detect the frame structure and line code and set the transmitter accordingly. However, this may not work on interfaces that have failed or are sending an all-ones pattern (Alarm Indication Signal, AIS). If this is the case, it is necessary to manually set the test set frame structure. D3/D4 framing is used primarily with digital trunk interfaces in end offices. Extended Superframe (ESF) is used primarily with digital lines that serve special circuits. Similarly, the AMI line code is used with digital trunk interfaces while the B8ZS line code is commonly used with digital lines serving special circuits.

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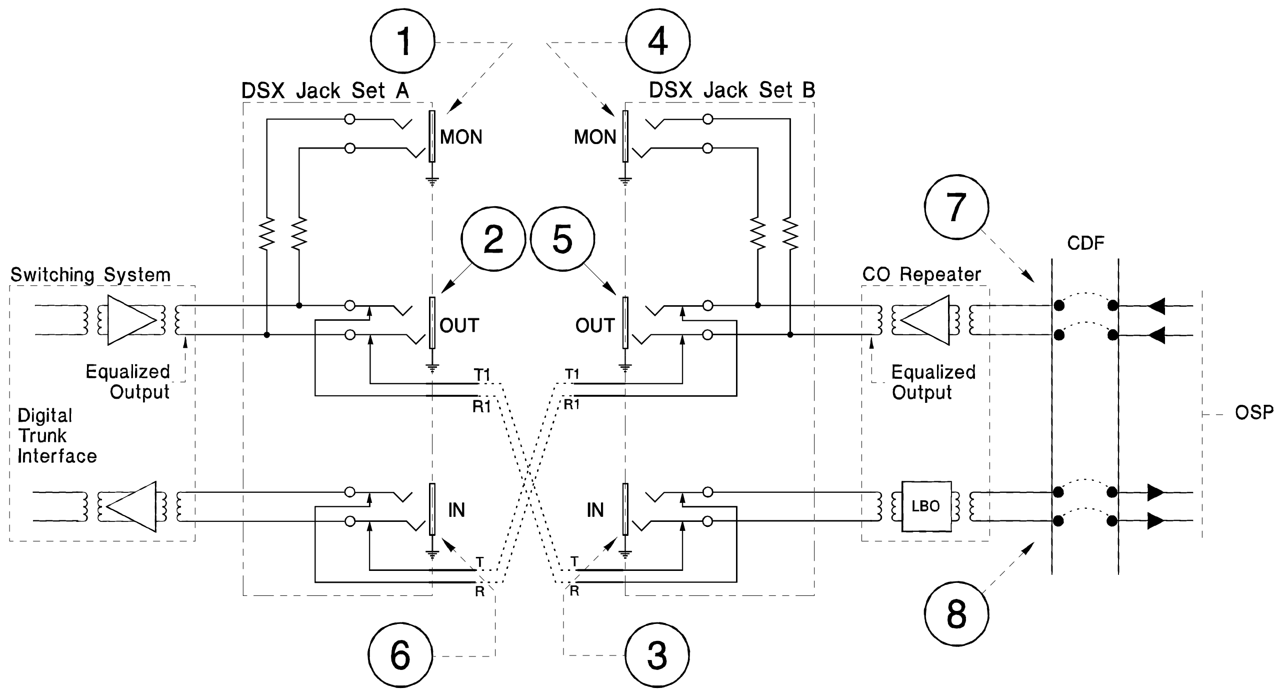
[3] Many test sets measure bit rate in terms of frequency, Hz, instead of b/s.
[4] Equipment built prior to about 1979 has a tolerance of ± 200 b/s.

However, most modern end office switching systems support also ESF with B8ZS, so it may be necessary to determine the proper settings from the office records before connecting the test set.

Fig. 2
Central Office Test Connections




① Purpose: Monitor the signal output from the digital interface
Intrusive: No
Transmitter: Not connected if the only purpose is to monitor the signal
Transmitter timing source: Not applicable
Receiver: Connected and set to Monitor mode
Received Level: -20 dBdsx (translated to 0 dBdsx in Monitor mode)
Remarks: None

② Purpose: Test the signal output from the digital interface
Intrusive: Yes
Transmitter: Not connected if only purpose is to measure signal (see remarks)
Transmitter timing source: Not applicable
Receiver: Connected and set to Terminate mode
Received Level: -1.0 to +1.0 dBdsx
Remarks: Use in conjunction with ⑥ to loopback signal (see ②/⑥). Use with ③ to have test set pass the signal through to the CO repeater (see ②/③).

③ Purpose: Inject a signal into the CO repeater to emulate the signal output from a digital interface or to loop-up or loop-down a CSU at the far end
Intrusive: Yes

Transmitter:  Connected and payload set to QRW
Transmitter timing source:  Internal or Reference input
Receiver:  Not connected if the only purpose is to inject a signal (see remarks)
Received Level:  Not applicable
Remarks:  Use in conjunction with ⑤ to loopback the signal to the CO repeater (see ③/⑤). If the Line IN jack used with this test is jumpered to a corresponding Line OUT jack with an active digital interface, a 100 ohm terminating resistor should be inserted into the Line OUT jack.  Use with ② to have test set pass a signal from the digital interface through to the CO repeater (see ②/③).

④ Purpose:  Monitor the signal output from the CO repeater
Intrusive:  No
Transmitter:  Not connected if the only purpose is to monitor the signal
Transmitter timing source:  Not applicable
Receiver:  Connected and set to Monitor mode
Received Level:  -20 dBdsx (translated to 0 dBdsx in Monitor mode)
Remarks:  None

⑤ Purpose:  Test the signal output from the CO repeater
Intrusive:  Yes
Transmitter:  Not connected if the only purpose is to test the signal (see remarks)
Transmitter timing source:  Not applicable
Receiver:  Connected and set to Terminate mode
Received Level:  -1.0 to +1.0 dBdsx
Remarks:  Use in conjunction with ③ to loopback the signal to the line (see ③/⑤).  Use with ⑥ to pass the signal through to the digital interface (see ⑤/⑥).

⑥ Purpose:  Inject a signal into the digital interface to emulate the signal output from the CO repeater
Intrusive:  Yes
Transmitter:  Connected and payload set to framed all-ones
Transmitter timing source:  Internal or Reference input
Receiver:  Not connected if the only purpose is to inject a signal (see remarks)
Received Level:  Not applicable
Remarks:  Use in conjunction with ② to loopback the signal to the digital interface (see ②/⑥).  Use with ⑤ to pass the signal from the CO repeater through to the digital interface (see ⑤/⑥).

⑦ Purpose:  Test the signal incoming from the line (facility) to the CO repeater
Intrusive:  No
Transmitter:  Not connected
Transmitter timing source:  Not applicable
Receiver:  Connected and set to Bridging mode
Received Level:  -23 to 0 dBdsx, depending on the loss to the first line repeater

Remarks: Use with ⑧ to loopback the CO repeater signal on the line side of the CO repeater (see ⑦/⑧).

⑧ Purpose: Test the signal outgoing to the line (facility) from the CO repeater
Intrusive: No
Transmitter: Not connected
Transmitter timing source: Not applicable
Receiver: Connected and set to Bridging mode
Received Level: -23 to 0 dBdsx, depending on the LBO in the CO repeater
Remarks: Use with ⑦ to loopback the CO repeater signal on the line side of the CO repeater (see ⑦/⑧).

②/③ Purpose: Test signal output from the digital interface while passing the signal through to the CO repeater
Intrusive: Only when connections are being made; otherwise, the test set and connections are transparent
Transmitter: Connected to Line IN jack at ③ and set payload to “As Input”
Transmitter timing source: Loop timing
Receiver: Connected to Line OUT jack at ②
Received Level: -1.0 to +1.0 dBdsx
Remarks: None

②/⑥ Purpose: Loopback the digital interface
Intrusive: Yes
Transmitter: Connected to Line IN jack at ⑥ and set payload to “As Input”
Transmitter timing source: Loop timing (if interface is internally timed)
Receiver: Connected to Line OUT jack at ②
Received Level: -1.0 to +1.0 dBdsx
Remarks: None

③/⑤ Purpose: Loopback the CO repeater
Intrusive: Yes
Transmitter: Connected to Line IN jack at ③ and set payload to “QRW”
Transmitter timing source: Internal
Receiver: Connected to Line OUT jack at ⑤
Received Level: -1.0 to +1.0 dBdsx
Remarks: None

⑤/⑥ Purpose: Test signal output from the CO repeater while passing the signal through to the digital interface
Intrusive: Only when connections are being made; otherwise, the test set and connections are transparent
Transmitter: Connected to Line IN jack at ⑥ and set payload to “As Input”
Transmitter timing source: Loop timing
Receiver: Connected to Line OUT jack at ⑤

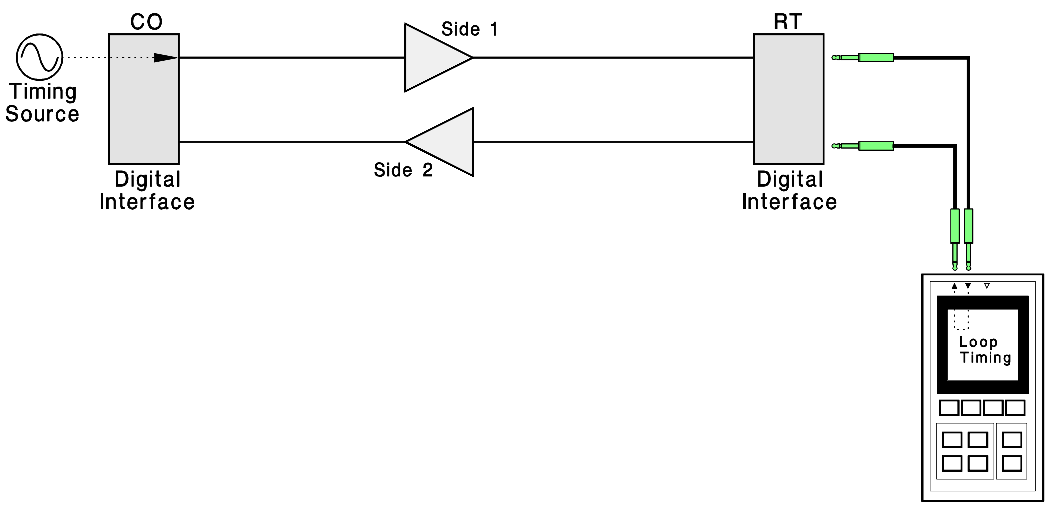
Received Level: -1.0 to +1.0 dBdsx
Remarks: None

⑦/⑧ Purpose: Loopback the CO repeater on the line side of the CO repeater
Intrusive: Yes
Transmitter: Connected to CO repeater input at ⑦ on the CDF
Transmitter timing source: Loop timing if at the CO or Internal if at a remote terminal
Receiver: Connected to CO repeater at ⑧ on the CDF and set to Terminate
Received Level: -23 to 0 dBdsx, depending on the LBO in the CO repeater
Remarks: The CO repeater must be isolated from the outside plant cable pairs by removing the jumpers or pulling the protectors out to the detent position.

## 3. Testing at Remote Terminals

While the previous discussion focused on tests and measurements at the DSX and CO repeaters in the central office, similar configurations and procedures can be used at remote terminals, such as digital loop carrier (DLC) remote terminals and remote switching terminals (RST), with minor, but important, changes.

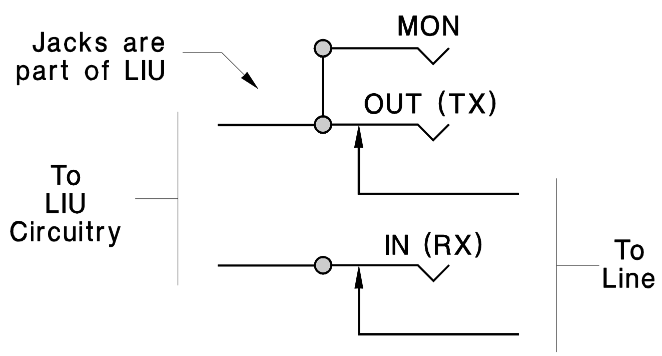
Fig. 3
Test Set Loop Timing at a Remote Terminal




When signals are injected into a line from the remote end, the test set transmitter timing normally is derived from the central office end. In this case, the test set is set for loop timing as shown in Fig. 3. If no test jacks are available, the test set can be connected by alligator clips. If it is only necessary to monitor the signal at active equipment, then a bridging connection is necessary. Set the test set receiver to “Bridging” mode. If the test set is to terminate the line, set the test set receiver to “Terminate” mode. The Bridging and Terminate modes have no effect on the test set transmitter, which is always in the terminated mode.

The line interface unit in the remote terminal equipment may have a monitor jack. However, in some equipment this jack may be connected directly to the output port rather than through isolation resistors as with the DSX. See Fig. 4. Non-isolated monitor jacks will give incorrect levels when the test set is connected and set to the “Monitor” mode. Also, in this situation the Monitor mode may load the interface and cause the circuit to malfunction. In the “Bridging” mode, the levels should be correct and the loading effects will be negligible.

Fig. 4
Monitor Jack Without Isolation Resistors
in the Line Interface Unit




Timing may be derived from another working line, if available, by using the test set Reference Input. If the line being tested at the remote end also is connected to a test set at the central office, one end or the other must be the timing source. The central office end usually is the normal timing source, so the remote end is set for loop timing and the central office end for internal (or master) timing.

## *4. Testing at Line Repeaters*

This section discusses testing at a repeatered T1-carrier line repeater. These tests require access to the backplane wiring in the repeater housing unless a line repeater extender (Alcatel p/n 621261) is available.

For purposes of the following, the upstream side of the line repeater is the side that supplies power to the line repeater. The downstream side is the side that loops power from the upstream side. Generally, the upstream side is the central office and the downstream side is the remote terminal or customer location. Line repeaters have side 1 and side 2 regenerators. Side 1 normally regenerates the CO signal and side 2 regenerates the remote terminal signal. See Fig. 5.

Fig. 5
Line Repeater Side 1 and Side 2

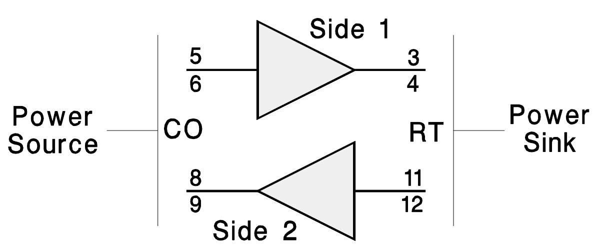



Fig. 6(a) shows the simplified schematic of a repeatered T1-carrier line repeater with the connections necessary on the upstream side of the line repeater to loopback the upstream signal. This configuration is used to check the signal up to the line repeater but does not check the repeater itself. Unplug the repeater and connect the test set as shown. The test set receiver should be set for “Auto” framing, the transmitter framing and payload set for “As Input” and transmitter timing set for loop timing. In this configuration, the receiver detects the signal, if present, and the imbedded framing. This is then used to set the transmitted signal framing.

The test results depend on what is connected to the line at the central office. If an active interface is connected to the line, such as a digital trunk interface, the interface probably is transmitting an unframed all-ones signal in response to the Loss of Signal (LOS) while the test set was being connected. In this case, the test set should detect and return the all-ones signal. If the line is good at this point, the digital interface will send a Yellow alarm when it detects the test set's signal. The test set should display the Yellow alarm. The foregoing sequence is typical but not the only one. Check the digital interface documentation to determine its action upon a Loss of Signal at its input.

If a test set is connected at the central office, it should be set to send "As Input," and the test set at the repeater should be set to send QRW. If the line is good, the QRW should be returned error-free. Other setups at the central office and remote terminal are possible, but they should be complimentary. That is, one end should send a test pattern, and the other should return the test pattern for analysis and error testing.

Fig. 6(a)
Loopback on Upstream Side of Line Repeater

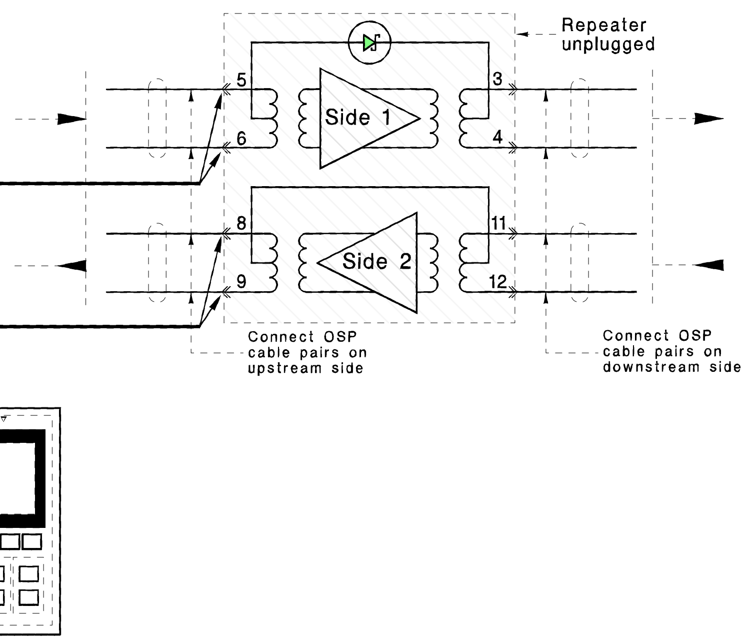
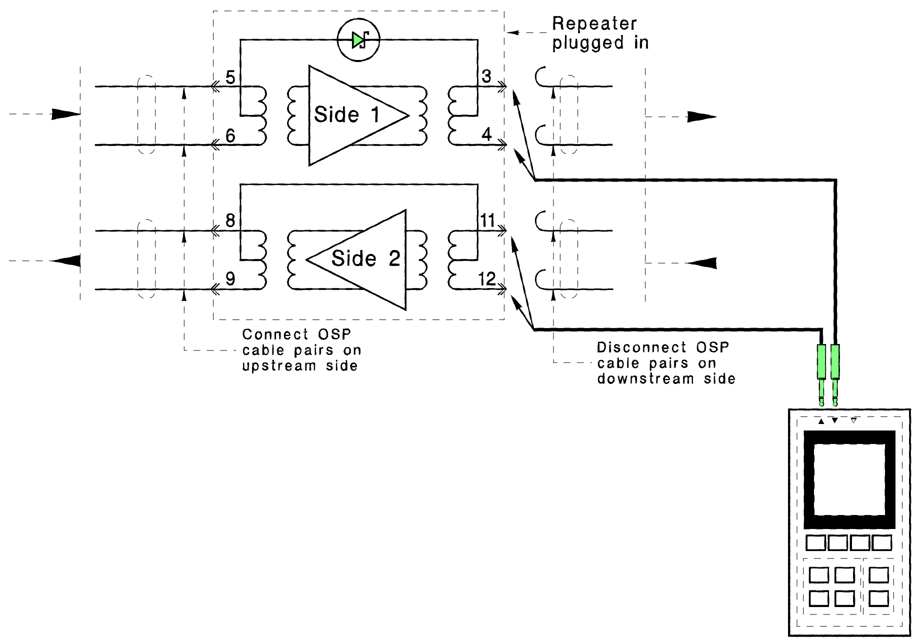



Fig. 6(b) shows the connections necessary on the downstream side of the line repeater to loopback the signal toward the upstream end. This configuration is used to test the line repeater itself and assumes the facility from the central office to the repeater is known to be good (by testing as described in the previous paragraphs). It is necessary to disconnect the outside plant cables on the downstream side of the repeater. This is to remove the loading effect of the cables and downstream devices when the test set is connected to the downstream side of the line repeater. Normally, the cables are disconnected in the splice enclosure in which the repeater housing stubs are spliced to the outside plant feeder or distribution cables. As with the tests on the upstream side of the repeater, the actual test results depend on what is connected at the central office.

The signal levels measured at the *input* of side 1 or side 2 of the line repeater will depend on the loss from the upstream or downstream repeater, respectively. The losses may be different in each direction. If the upstream or downstream device is a CO repeater, the loss in properly designed systems generally will be less than approximately 23 dB. Therefore, the measured signal level will be in the range of 0 to -23 dBdsx. If the upstream or downstream device is a line repeater, the loss normally will be less than approximately 32 dB. Therefore, the measured signal level at this point will be in the range of 0 to -32 dBdsx.

Fig. 6(b)
Loopback on Downstream Side of Line Repeater




The output signal level on either side 1 or side 2 will be close to 0.0 dBdsx. Be sure to observe the test set termination rule: If the line being tested terminates in an active device, the “Bridging” mode should be used. If the test set is to terminate the line (as in the case with the outside plant cables disconnected from the repeater), the “Terminate” mode should be used.

If a valid signal is measured at the input of a line repeater but not at the output, the repeater is either bad or not powered. Therefore, if this situation is encountered, double-check the test set connections. The voltage drop across the line repeater should be measured. This measurement is made between the side 1 input and output. For mini-repeaters, the measurements should be made between pins 5 or 6 and pins 3 or 4 on the repeater connector. The voltage should be about 7.7 vdc, but the exact value will depend on the line repeater manufacturer and model and environmental factors such as temperature. For line repeaters set to Loop power (rather than Through power as is usually the case), the voltage drop is measured between the side 1 input and side 2 output.

In all tests at the line repeater, a properly connected test set should indicate the line powering current. Usually this is 60 ± 1 ma. No measured line current indicates a problem upstream or incorrect test set connection. Note that, unless a line powering test set is available, it is not possible to loopback the signal toward the downstream side if the downstream devices require line power.

## 5. Path Performance Acceptance Requirements

All path tests described in this section are for out-of-service digital lines; that is, the lines cannot carry live traffic during the tests. DS1 services are tested to determine acceptable path performance using test patterns. These patterns are specific bit sequences that stress parts of the digital line in different ways. Test equipment must have the capability of providing at least four test patterns:

- All-ones test pattern (unframed, used with either AMI or B8ZS line codes)
- Quasi-random word (QRW or QRSS) test pattern (used with either AMI or B8ZS line codes)
- 3-in-24 test pattern (used with AMI line code)
- 1-in-8 test pattern (used with B8ZS line code)

The all-ones test pattern causes the line driver to deliver the highest power possible of any conceivable data sequence. It therefore stresses the equipment to verify that maximum power can be delivered to the line and also ensures that the line driver can deliver the Alarm Indication Signal, or AIS. The QRW simulates real data by providing a sequence of bits with equal probability of a binary one or binary zero. The 3-in-24 pattern provides 3 binary ones (pulses) in 24 bits transmitted and stresses the line receiver to ensure it can properly detect the maximum number of consecutive binary zeros that will be transmitted on a line using the AMI line code. The 1-in-8 test pattern stresses a line by providing the maximum number of consecutive binary zeros that can be transmitted on a line using the B8ZS line code.

Typical test specifications require only short duration tests. Normally the QRW test is made twice with each test lasting 15 minutes. The all-ones test and zero stress pattern tests (3-in-24 and 1-in-8) are made for 5 minutes each with the expectation of no errors. If all tests are satisfactory, the circuit is acceptable If any one test fails, it is repeated. If the second test passes, the circuit is acceptable. If the second test fails, the circuit is not acceptable and requires repair. Short term tests such as these only provide a snapshot of the circuit’s performance and will not indicate performance degradation caused by local anomalies such as grounding problems and impulse noise. Longer tests give higher confidence. When time permits or where the location’s susceptibility to degradation is suspect, a 24 hour test period should be used.

For both short and long duration tests, the test parameters of interest are errored seconds (ES) and severely errored seconds (SES). The acceptance criteria for each are shown in Table 2.

Table 2
Performance Requirements (Source ANSI T1.510)

| | Short Duration Tests 15 Minute Stages | | | | | | Long Duration Tests 24 Hours | |
|---|---|---|---|---|---|---|---|---|
| | **Errored Seconds (ES)** | | | **Severely Errored Seconds (SES)** | | | **ES** | **SES** |
| **Parameter Limit For →** | 15 Minute | 30 Minute | 45 Minute | 15 Minute | 30 Minute | 45 Minute | 24 Hour | 24 Hour |
| **Access** | 0 | ≤ 3 | ≤ 5 | 0 | 0 | ≤ 2 * | ≤ 150 | ≤ 7 |
| **Transit** | 0 | ≤ 3 | ≤ 5 | 0 | 0 | ≤ 2 * | ≤ 150 | ≤ 16 |
| **End-to-End** | 0 | ≤ 6 | ≤ 9 | 0 | 0 | ≤ 2 * | ≤ 300 | ≤ 21 |

* Accept at 2 only if the cause of the SES is an isolated event

## *6. Definitions*

Bit Error Rate - The ratio of the bits received in error to the total number of bits transmitted in the measurement interval.
Errored Second (ES) - Any one-second interval with at least one error.
Error Free Second (EFS) - Any second in which no errors are received. %EFS is the percentage of the total seconds in the measurement period that are completely error-free.
Consecutive Severely Errored Second (CSES) - A consecutive string of between three and ten SESs.
Severely Errored Second (SES) - Any one-second interval in which the bit error rate is worse than 1E-3.

## *7. References*

Application Note No. 2, *DSX Applications in Small Central Offices*, Reeve Engineers, 1995.
Application Note No. 3, *CSU/DSU Applications in DS1 Rate Service*, Reeve Engineers, 1995.

## Note to Readers:

Readers are encouraged to send their opinions, suggestions and comments. Subscribe to application notes or contact the author at any of the following addresses:

Whitham D. Reeve
Reeve Engineers
P.O. Box 190225
Anchorage, AK 99519-0225

**Tel**: 907-243-2262
**Fax**: 907-258-2850
**e-mail**: w.reeve@ieee.org

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