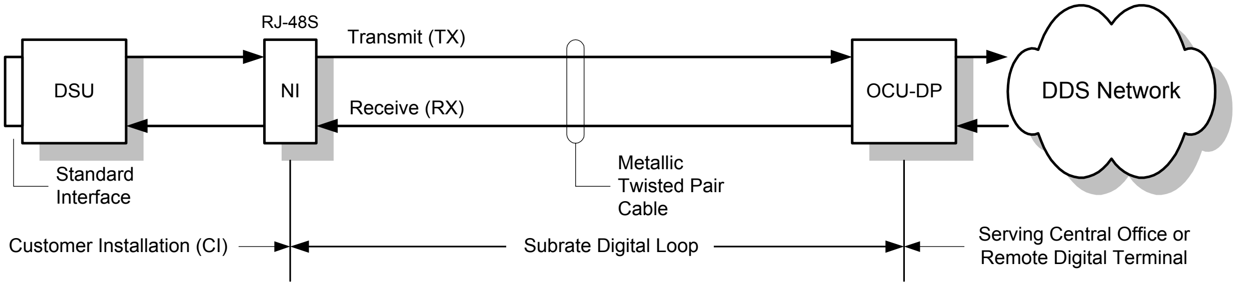
Application Note No. 9

Subrate Digital Loops

1. Introduction

This application note describes the technical aspects of subscriber loops associated with dedicated digital services, which operate at standard speeds from 2.4 to 64 kb/s. This application note focuses on the higher speeds of 56 and 64 kb/s, since these speeds are the most common. These loops are called Subrate Digital Loops (SRDL) and require two metallic twisted cable pairs, one for each direction of transmission, as shown in Fig. 1. The SRDL is the access portion of an end-to-end synchronous digital service variously called Digital Data Service, Dataphone® Digital Service or Dedicated Digital Service, all of which use the acronym DDS. The DDS channels can be operated in the point-to-point and point-to-multipoint modes, except that the 64 kb/s user rate is point-to-point only.

Fig. 1
Subrate Digital Loop



Even though the SRDL is a fully synchronous loop, any standard asynchronous user rate, usually in increments of 9.6 kb/s up to 57.6 kb/s, can be accommodated by modern terminal equipment using standard rate adaptation methods. In this way, the SRDL is similar to Switched 56 (SW56) loops, which also can handle synchronous and asynchronous user speeds.[1] However, unlike SW56, the SRDL requires a dedicated (unswitched) channel between the terminals. On a DDS connection, end-user terminal equipment starts sending as soon as it is powered. Transmission of information will be possible if both ends are sending at the same speed. Some equipment will detect the rate automatically; otherwise, the end equipment must be manually set.

In many applications, the SRDL is connected at the serving central office to a large DDS network as shown in Fig. 2(a). This illustration also shows the application of the complementary channel unit, the DS0-DP. The DS0-DP provides an interface that is compatible with T1 Data Multiplexers (T1DM) as well as other DS0-DP channel units. In small installations, the DS0-DPs, if used, may be connected back-to-back for cross-connection in the central office or a channel bank with cross-

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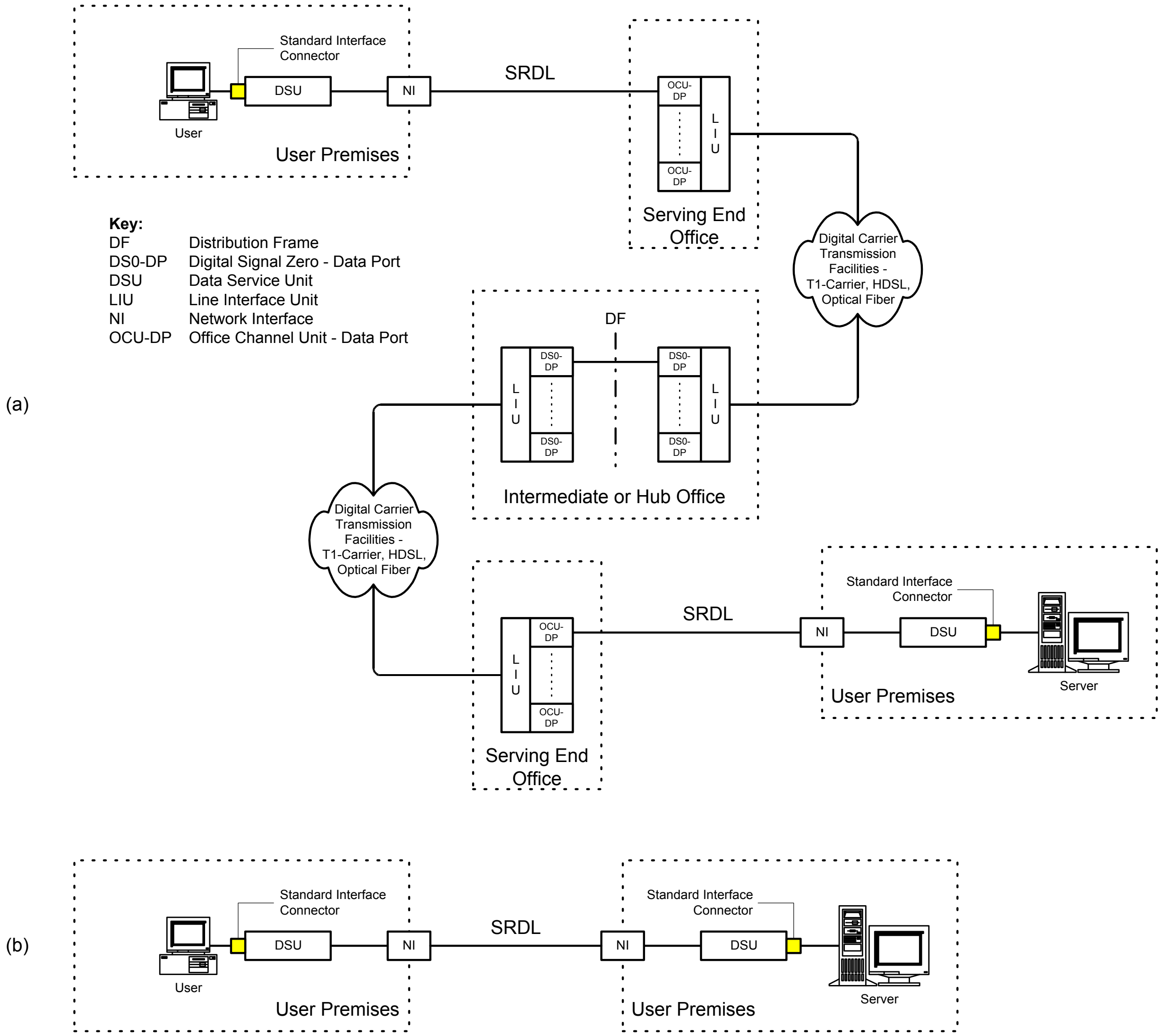
[1] See Application Note No. 5, *Switched 56*

connection capabilities may be used. In larger central offices, a Digital Cross-Connect System (DCS) normally is used for this purpose.

The SRDL can also provide a simple local connection between two terminals in the same exchange area. In the latter situation, shown in Fig. 2(b), the SRDLs and associated terminal equipment are isolated from the larger DDS network.

Fig. 2
Dedicated Digital Service Network



2. *Implementations*

The SRDL terminates in a user's Data Service Unit (DSU) at one end and in an Office Channel Unit Data Port (OCU-DP) at the serving central office or Remote Digital Terminal (RDT). By using an RDT, which can be a simple channel bank installed in a remote cabinet, regular digital carrier facilities may be used to extend the SRDL beyond the normal transmission limits of the DSU and OCU-DP.

Fig. 3 shows some typical implementations of the SRDL. In (a), user Data Terminal Equipment, or DTE, (in this case a serial port on a Local Area Network router) is connected to a DSU. On the network side, the DSU is connected to two metallic twisted pairs (facility) at the Network Interface (NI). All equipment and wiring on the user side of the NI is referred to as the Customer Installation, or CI. The two twisted pairs terminate at the serving central office (CO) in an OCU-DP channel unit in a channel bank. The OCU-DP channel unit, among other things, adapts the user rate to the 64 kb/s DS0 rate used within the network. The channel bank acts as a primary multiplexer (MUX) and consolidates 24 DS0 rate channels into an aggregate speed of 1.544 Mb/s on the high speed, or network, side of the MUX.

In (b), the primary MUX is owned and operated by the user and located on the user's premises. The MUX is connected to the NI via a user-owned Channel Service Unit (CSU). The MUX consolidates several types of traffic including analog switched traffic (shown only to illustrate the versatility of the primary MUX). A DS1 facility serves as the transport for the individual DS0 channels. The DS1 facility can be Repeatered T1-Carrier or High Bit-Rate Digital Subscriber Line (HDSL), or it can be imbedded in a higher speed fiber optic transmission system or digital microwave radio. The DS1 facility terminates in a DCS at the central office, which is used to cross-connect the individual channels to their respective networks. Note that the channel bank in the central office uses a DS0-DP instead of an OCU-DP. The DS0-DP is required when the channel is connected to another multiplexer and ultimately to a DDS network.

In both (a) and (b), the DS0 channels are cross-connected to other DS1 facilities by a DCS in the central office. These other DS1 facilities may go to another central office in the exchange area or to the inter-exchange carrier (IXC) Point-of-Presence (POP). In (c) and (d), the SRDLs pass through the serving central office and go directly to the IXC POP for connection to a DDS network.

In all cases, (a) through (d), a CSU or DSU is installed on the user's premises immediately after the Network Interface (NI) and located between the NI and other user equipment. The CSU is used where the service is via DS1 facilities, and a DSU is used where the DTE is connected via standard interfaces (for example, EIA-232, EIA-530, or V.35). DSUs are discussed later; CSUs for DS1 service are discussed in another application note.[2]

DDS can be implemented with or without secondary channel. When no secondary channel is required, it is called Standard DDS. The secondary channel consists of an additional bit in the data stream that is shared for network control and low-speed user data and that is carried along with the user's payload bits. This application note focuses on Standard DDS implementations.

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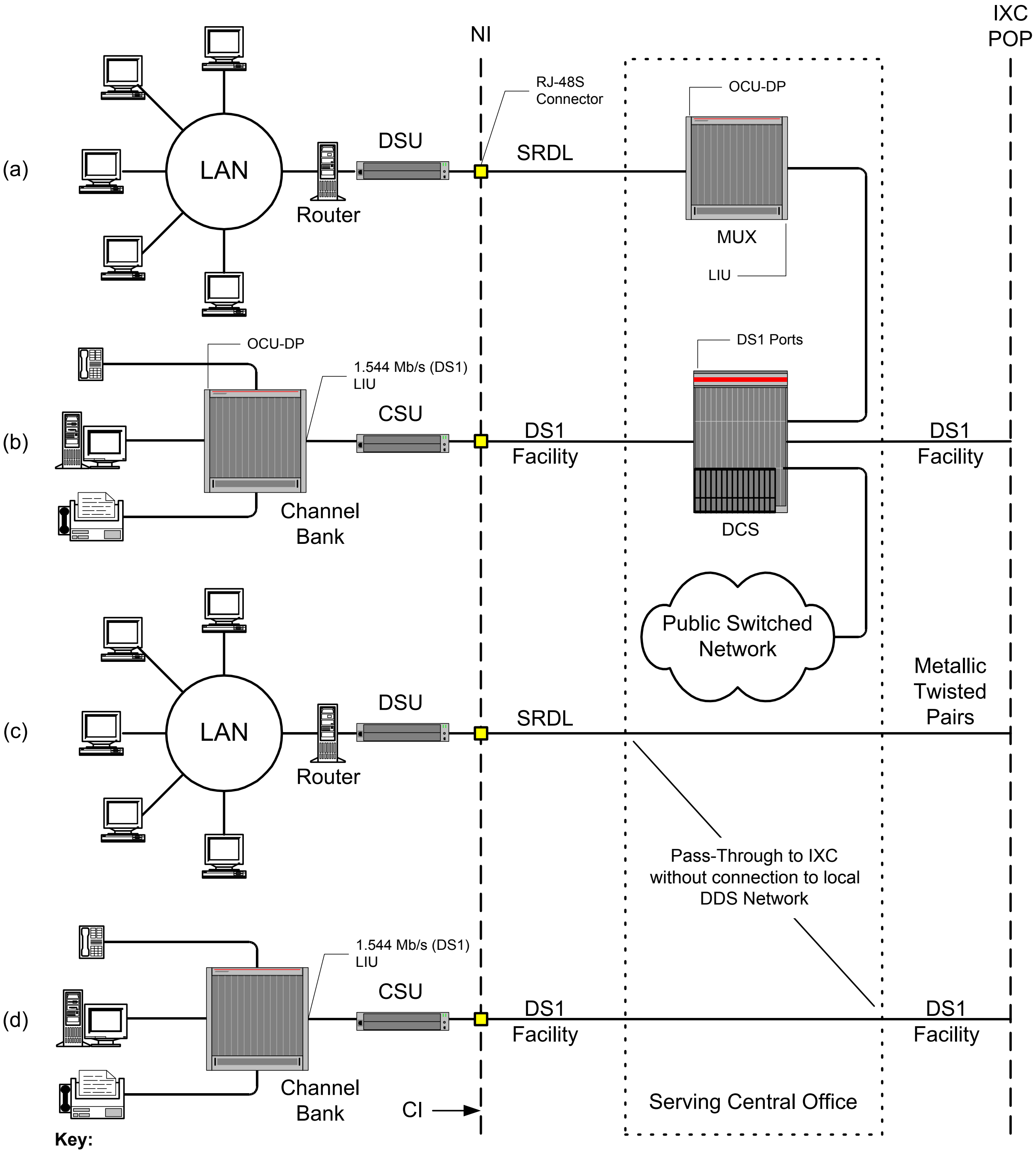
[2] See Application Note No. 5, CSU Applications in DS1 Service.

Fig. 3
SRDL Implementations

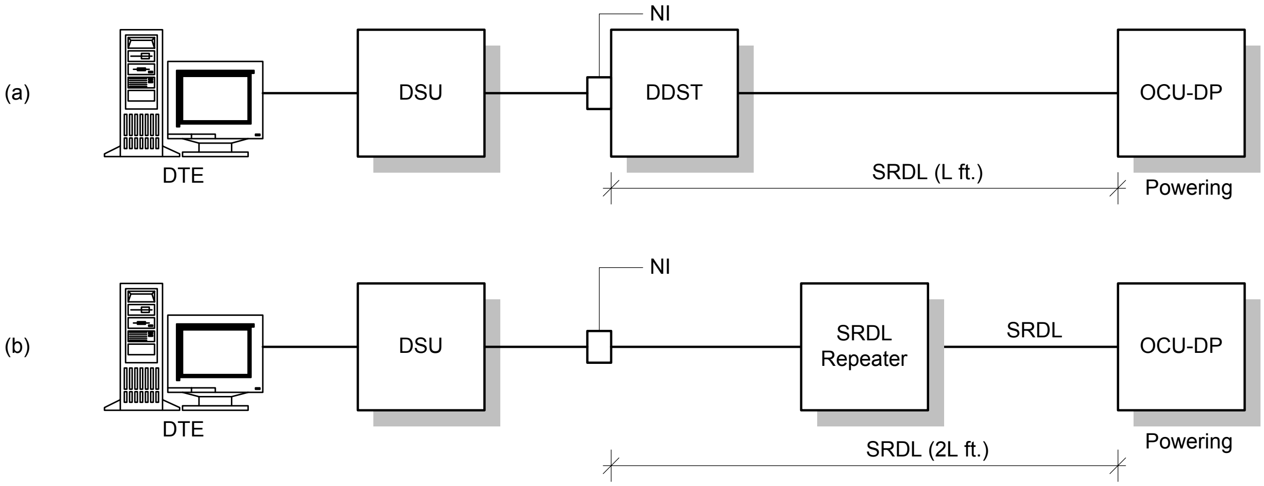


Key:

CI	Customer Installation
CSU	Channel Service Unit
DCS	Digital Cross-Connect System
DSU	Data Service Unit
IXC	Inter-Exchange Carrier
LAN	Local Area Network
LIU	Line Interface Unit (DS1 rate)
NI	Network Interface
POP	Point-of-Presence

All OCU-DPs provide up to 20 mA of sealing current on the SRDL. This sealing current, in addition to keeping high resistance oxide film from building up on cable splices, also provides a signaling path for the Channel Loopback (loopbacks are discussed later). Some OCU-DPs also are capable of providing powering current to SRDL repeaters[3] and Digital Data Station Terminations (DDST). When the OCU-DP is placed in the powering mode (by option switch on the channel unit), it provides approximately 40 mA of current on the SRDL. The DDST is the digital equivalent of the Data Station Termination (DST) used with analog special access and provides convenient test access and loopback capabilities. The DDST is an active device placed at the Network Interface (NI) by the Telecommunications Operator (TO). The repeater regenerates the SRDL signals and effectively doubles the loop length between the central office and the user. See Fig. 4.

Fig. 4
SRDL Repeater and DDST Applications



3. Industry Standards and Interworking

The applicable industry standards for the SRDL are listed below. Industry standards provide for interworking between different manufacturer's equipment.

- AT&T PUB 62310, Technical Reference, Digital Data System Channel Interface Specification, Nov. 1987 (including addendums 1, 2 and 3)
- ANSI T1.107-1995, Digital Hierarchy - Formats Specifications.
- ANSI T1.410-1992, Carrier-to-Customer Metallic Interface - Digital Data at 64 kbit/s and Subrates.
- Bellcore Technical Reference, TR-NWT-000341, Digital Data Special Access Service, Transmission Parameter Limits and Interface Combinations, Feb. 1993.

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[3] Also called DDS repeater.

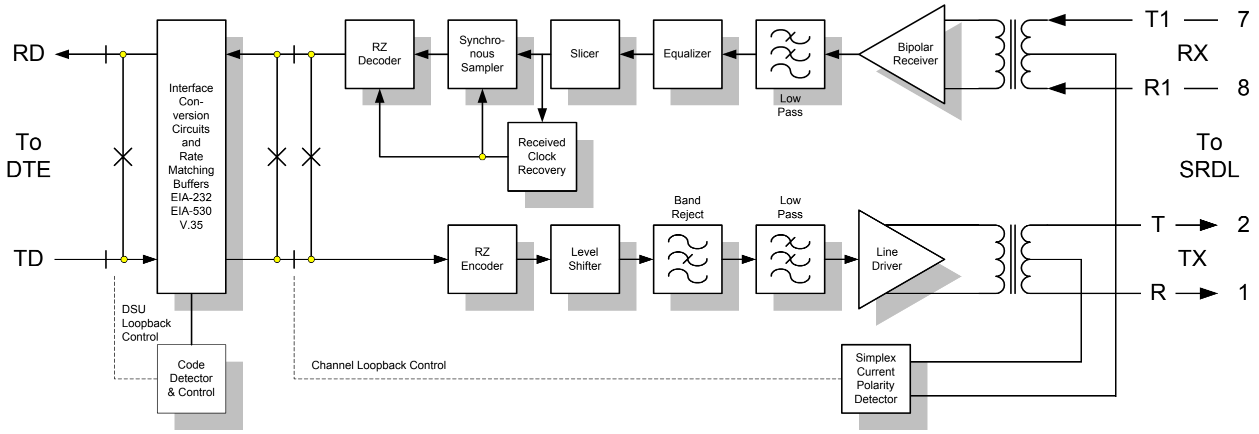
- Bellcore Technical Reference, TR-NPL-000157, Secondary Channel in the Digital Data System: Channel Interface Requirements, Apr. 1986.
- AT&T Technical Reference, TR54075, Subrate Data Multiplexing, Nov. 1988.

4. Data Service Units

The block diagram in Fig. 5 shows the main functional components in a DSU. The DSU serves two distinct purposes. The first purpose is to isolate the Customer Installation (CI) from the network and, thus, protect the network from possible harmful problems in the CI. The exact requirements are specified in FCC Part 68 and include signal filtering, signal power level, impedance matching, longitudinal and differential voltage limitations, loopback and specific limitations on longitudinal balance.[1] Most of these requirements concern the filters and line drivers on the transmit side of the DSU and the coupling transformers on both the receive and transmit sides.

The second purpose of the DSU is to provide standard interfaces to user DTE. Interface functions are shown on the left side of Fig. 5. In particular, most DSUs provide EIA-232, EIA-530 and V.35 interfaces with one or more standard rates. The DSU adapts the user rate to the line rate. For example, a synchronous line rate of 56 kb/s could be used with a user rate of 19.2 kb/s (either synchronous or asynchronous) through rate adaptation. Standard synchronous rates are discussed in the next section.

Fig. 5
Data Service Unit Block Diagram



Most DSUs have a Scrambler option. The Scrambler normally is used under two circumstances. First, on a 56 kb/s circuit with secondary channel when the HDLC protocol is used, the Scrambler option ensures that the data from the DTE in the primary and secondary channels are not zero simultaneously. Second, on a 64 kb/s circuit, the Scrambler prevents data that mimics network control codes from passing into the network from the DTE. If the Scrambler is required, it must be set to On in both the local and remote DSUs.

5. Standard SRDL Rates

Table 1 lists the standard DDS user rates and the actual line rates on the SRDL. All rates shown in this table are synchronous. The user rates and line rates are the same for the speeds through 56 kb/s provided there is no secondary channel involved. When secondary channel is used, the line rate include the user rate plus additional overhead for the shared network control and secondary channel bits. The line rate at 64 kb/s always is 72 kb/s, which includes the user rate of 64 kb/s and 8 kb/s for framing. No secondary channel is available with the 64 kb/s rate. The table only shows the rates described in industry standards. Other rates, particularly 19.2 kb/s and 38.4 kb/s, are available in many modern DSUs and supported by almost all modern OCU-DPs.

6. Line Coding

The SRDL uses the Alternate Mark Inversion (AMI) line code, which is modified under certain circumstances. These modifications provide a convenient method of sending network control codes and to ensure that the ones-density requirements are met for clock recovery at the receiver. This latter requirement is called zero suppression. The 64 kb/s user rate does not require zero code suppression.

Data bits are carried on the 56 kb/s SRDL in an unstructured format, with 7 data bits, D1 D2 D3 D4 D5 D6 D7. The least significant bit (D1) is sent first. In the direction from the SRDL to the network, the OCU-DP adds a binary-1 to the seven data bits and thus provides an 8 bit word to the network DS0 channel. In the other direction, the OCU-DP removes this 8th bit and sends only 7 bits out onto the SRDL.

Table 1
Standard SRDL Rates

User Rate	Overhead Rate	Line Rate	Secondary Channel
2.4 kb/s	0.0 kb/s	2.4 kb/s	No
2.4 kb/s	0.8 kb/s	3.2 kb/s	Yes
4.8 kb/s	0.0 kb/s	4.8 kb/s	No
4.8 kb/s	1.6 kb/s	6.4 kb/s	Yes
9.6 kb/s	0.0 kb/s	9.6 kb/s	No
9.6 kb/s	3.2 kb/s	12.8 kb/s	Yes
56.0 kb/s	0.0 kb/s	56.0 kb/s	No
56.0 kb/s	16.0 kb/s	72.0 kb/s	Yes
64.0 kb/s	8.0 kb/s	72.0 kb/s	No

The 64 kb/s SRDL uses 9 bits with the loop byte structure of D1 D2 D3 D4 D5 D6 D7 F D8. The F-bit is a framing bit which follows the repeating pattern 101100 . . . . The OCU-DP strips this bit before the data is formed into the DS0 channel. Similarly, the DSU strips the F-bit from the received data before the data is converted to conform to the DTE interface requirements.

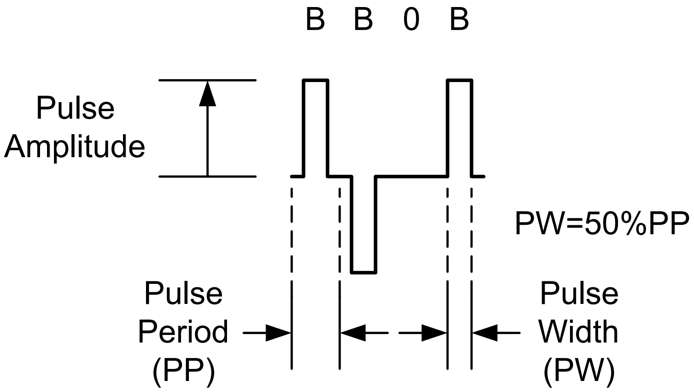
With AMI, a binary 0 is transmitted as no pulse, or zero volts. A binary 1 is transmitted either as a 50% duty cycle positive or negative pulse, opposite in polarity to the previous binary 1. See Fig. 6.

The pulse width, pulse period and pulse amplitude are given in Table 2. Two consecutive pulses with the same polarity indicate a line code violation (specifically, bipolar violation, or BPV). However, intentional BPVs are used to convey network control information and to suppress strings of more than 6 or 7 consecutive zeros (depending on the direction, as will be discussed later). The following notations apply to the SRDL:

0 Zero volts transmitted, binary 0
B ± 1.40 v-p with polarity determined by the normal AMI line code, binary 1
V ± 1.40 v-p with polarity in violation of the AMI line code, binary 1
X Either **0** or **B** depending on the need for the desired polarity of a BPV

The AMI line code is used to ensure that the signal carries no undesired dc component. Any intentional violations must also ensure that there is no latent dc component. Therefore, in the line code used with the SRDL, a timeslot is reserved (designated by the symbol X) prior to any intentional violations. This timeslot is for application of a pulse or no pulse in such a way that successive violations (designated by the symbol V) alternate in polarity. The desired polarity of intentional violations (V) is achieved by assigning a value 0 or B to X such that the total number of Bs since the last V is odd. Since it is not desirable to have adjacent pulses of the same polarity, the X and V timeslots are separated by a no pulse condition (binary 0), which gives an easily recognizable X0V pattern in each intentional BPV sequence. Table 3 shows several control code sequences that use the X0V pattern (this table does not show all possible code mapping sequences). These patterns are repeated as long as the control code condition is being transmitted.

Fig. 6
AMI Line Code



Several network control codes that use the X0V pattern are shown in Fig. 7. The Idle Code, or BBBBX0V, is shown in (a). This pattern is sent, for example, when the user has no active data to send in either direction over the SRDL and may be used for supervisory purposes by the DTE.[4] Note that X equals 0 if the number of Bs since the last V is odd or X equals B if the number of Bs since the last V is even.

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[4] The use of the Idle Code is analogous to the Request-to-Send (RTS) Off indication in EIA-232.

Table 2
Pulse Parameters

Parameter	56 kb/s	64 kb/s
Pulse period	17.86 µs	13.89 µs
Pulse width	8.93 µs	6.94 µs
Pulse amplitude[5]	± 1.40 volts-peak	± 1.40 volts-peak

Since binary 0s are encoded as no pulses, long strings of binary 0s will have no imbedded clock and the data receiver will lose synchronization. The Zero Suppression Sequence guarantees enough pulses for clock recovery. The 6-bit pattern, 000X0V, is sent by the OCU-DP whenever it detects six binary 0s in sequence coming from the network. The 7-bit pattern, 0000X0V, shown in (b), is sent by the DSU whenever user data consists of seven consecutive binary 0s.[6] With this pattern, the original 7-bit sequence of all zeros is replaced by one or two pulses depending on the required value for X. In the illustration, it is assumed that the number of Bs since the last V is even for Zero Sequence 1, giving X=B, and odd for Zero Sequence 2, giving X=0. The OCU-DP (or DSU) decodes the local loop codes as 7-bit (or 6-bit) sequences of all zeros. Both zero suppression sequences ensure adequate pulse density in the local loop for clock recovery.

Table 3
Network Control Code Sequences for 56 kb/s and 64 kb/s Rates

Sequence	Pattern
User-to-NI Direction	
Idle Code	BBBBX0V
Zero Suppression	0000X0V (substituted for 0000000
NI-to-User Direction	
Idle Code	BBBBX0V
Zero Suppression	000X0V (decoded as 000000)
Out-of-Service	S00BX0V
Out-of-Frame	S0BBX0V
DSU Loopback	00B0X0V

Note: S indicates a “don’t care” bit value.

Ones-density is specified in terms two parameters - the maximum number of consecutive zeros and the average number of pulses. For the 56 kb/s and 64 kb/s SRDL, the maximum number of consecutive zeros is 26 and the minimum average pulse density is 1 pulse in 18 pulse periods.

Another sequence, shown in (c), is the Out-of-Service Sequence, 000BX0V, which is sent to indicate trouble in the DDS network. It is generated by the OCU-DP in response to the associated codes generated by the DDS network. Alternately, if the OCU-DP experiences loss of signal from

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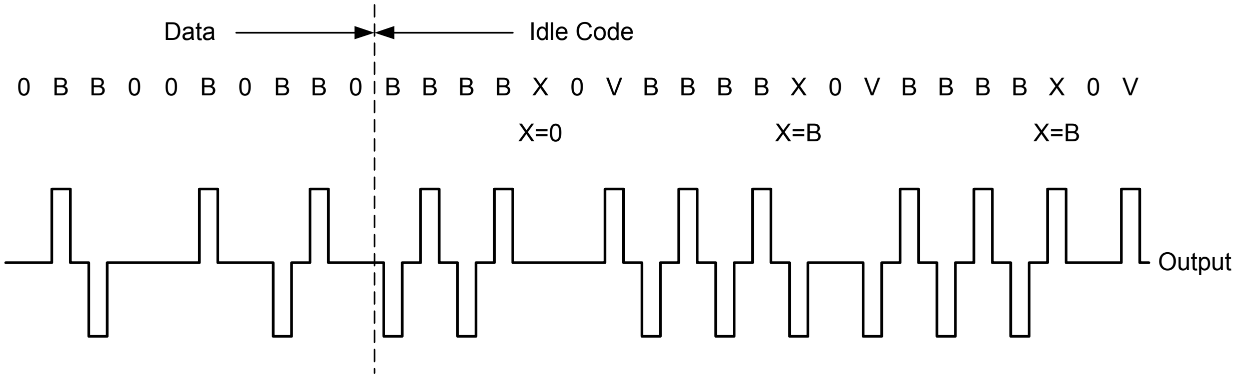
[5] The pulse voltages apply only to the 56 kb/s and 64 kb/s SRDL and are measured at the output terminals of the DSU or OCU-DP with a 135 ohm resistive load.

[6] Industry standards do not explain why an asymmetric code is needed.

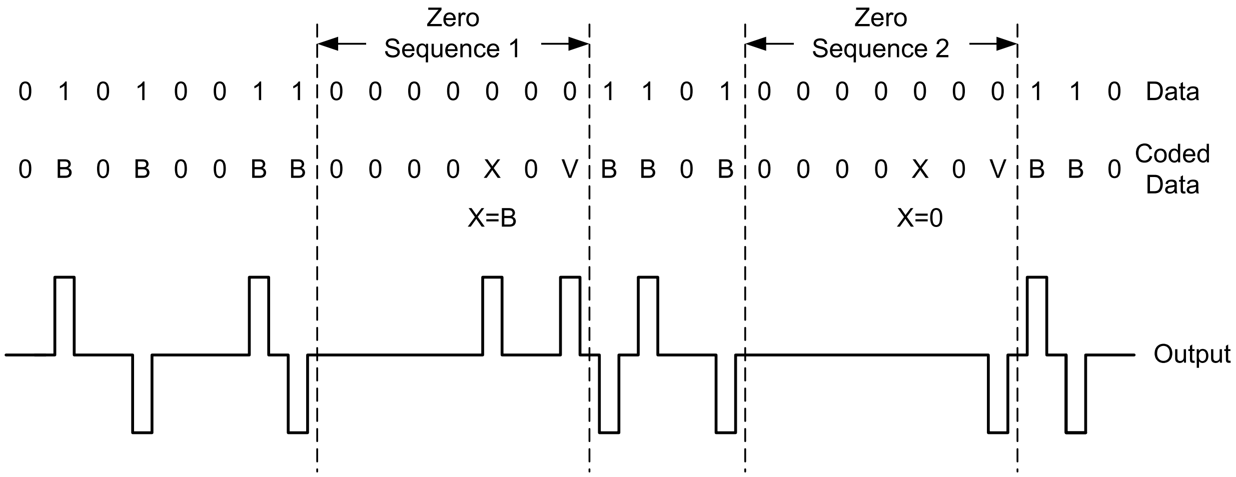
the SRDL, it will generate the equivalent network code sequence and send it into the network via the DS0 channel.

Fig. 7
Control Sequences That Use the X0V Pattern

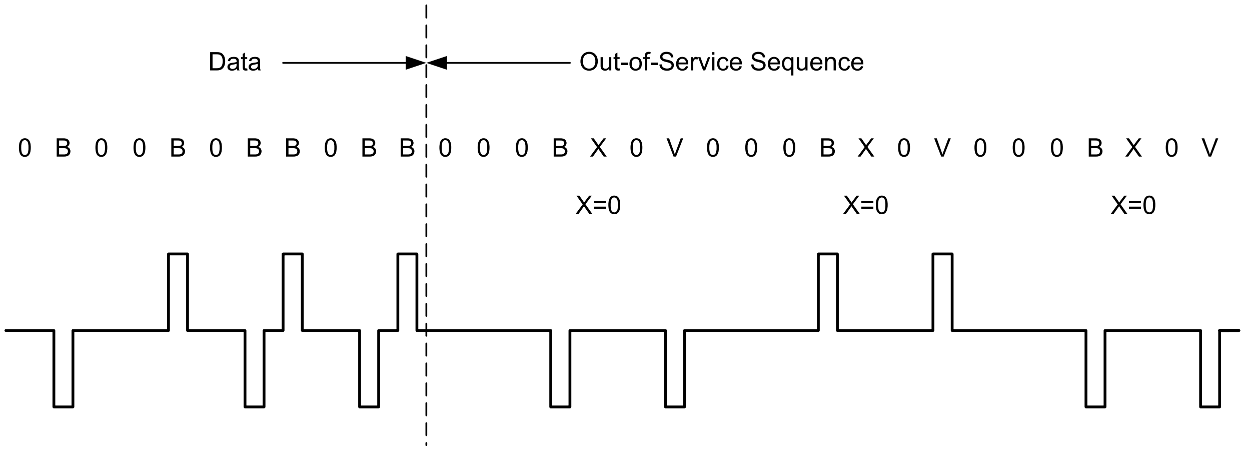
(a) Idle Code Sequence



(b) Zero Suppression



(c) Out-of-Service



7. Loopbacks

Loopbacks provide for remote testing and are helpful in isolating problems between the network and customer installation. The definitions of loopback codes in industry standards are confusing and incomplete. However, the following descriptions will provide insight into the application of loopbacks and will aid the reader with their use in the field.

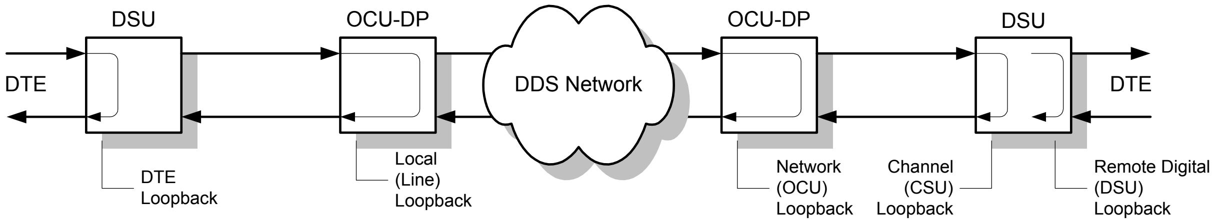
Table 4 lists the loopbacks and some alternate names for them, while Fig. 8 shows their location. All loopbacks discussed initially in this section are non-latching; that is, the loopbacks return to their normal state upon removal of the loopback signal. Latching loopbacks, which normally are used only on SRDLs with secondary channel and on the 64 kb/s SRDL, are discussed later.

The Channel (CSU) Loopback and Network (OCU) Loopback are required by industry standards, but other loopbacks are optional and may not be available on all equipment. All modern OCU-DP channel units have the Local Line Loopback. Also, most modern DSUs are capable of providing a local DTE Loopback and initiating and responding to a Remote Digital (DSU) Loopback.

Table 4
Loopback Names

Loopback Name	**Alternate Name**
DTE Loopback	EIA Loopback
Local Line Loopback	Local Loopback
Network Loopback	OCU Loopback
Channel Loopback	CSU Loopback
Remote Digital Loopback	RDL or DSU Loopback

Fig. 8
Loopbacks



When loopbacks are initiated from within the network (at the DS0 level), particular bit-patterns, or network codes, are used. Where appropriate, these bit patterns are converted to local loop codes by the OCU-DP. The local loop codes are then sent on the SRDL to the DSU. Similarly, when loopbacks are initiated at the DSU, particular local loop codes are sent on the SRDL to the OCU-DP. The OCU-DP then converts these local loop codes to network codes for transmission within the network. Table 5 lists the network codes and corresponding local loop codes. The paragraphs following discuss each loopback in detail.

Table 5
Loopback Codes, Network-to-DSU

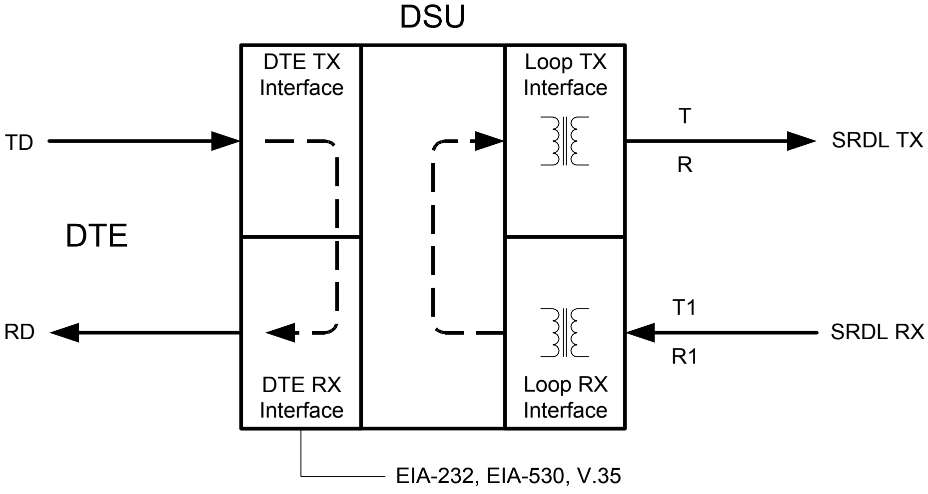
Loopback	**Network Code**	**Local Loop Code**
Network (OCU) Loopback	S0101010	S0B0X0V
Channel (CSU) Loopback	S0101000	Polarity Reversal (see text)
DSU Loopback	S0101100	S0B0X0V

Note: S indicates a "don't care" bit value.

DTE Loopback:

The DTE Loopback is used to test the user interface circuitry in the DSU. It is manually invoked from the DSU control panel or a separate switch on the DSU. Most DSUs have the option of providing a DTE Loopback by itself or with a Channel Loopback at the same time. In this case, the Channel Loopback is manually activated by the user at the DSU and not by a local loop code from the OCU-DP. The DTE Loopback loops the user interface back to itself; meanwhile, the DSU sends Idle Code out onto the SRDL through the Network Interface. If the Channel Loopback is invoked at the same time, the DSU also loops the Network Interface back to itself. Most DSUs also can internally generate various test patterns and send them in the transmit direction on the DTE or Network Interfaces as shown in Fig. 9.

Fig. 9
DTE Loopback (with Channel Loopback)



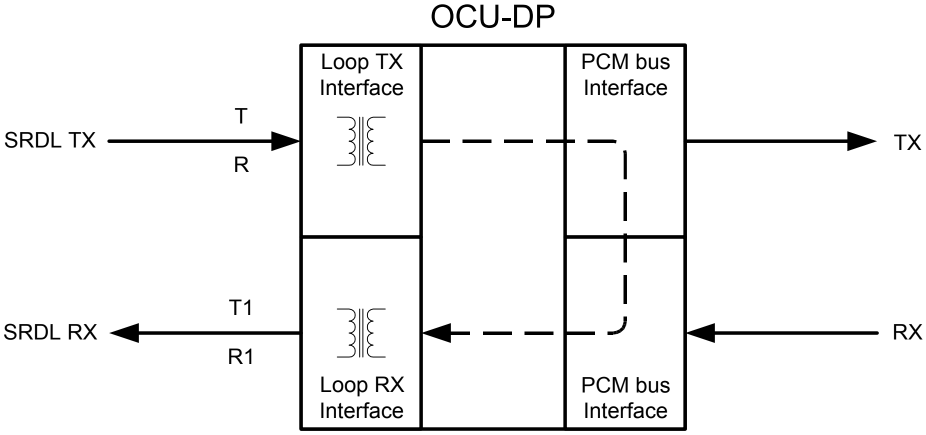
Local Line Loopback:

The Local Line Loopback is not controlled by network codes. Instead, if the Local Line Loopback is available, it is manually controlled at the OCU-DP by a push-button, slide switch or dip-switch. When Local Line Loopback is invoked, the data received at the OCU-DP from the SRDL is decoded, applied to the transmit line coder and returned over the SRDL. This isolates the DDS network from the SRDL and is used to test the OCU-DP data detectors and line coders as well as the SRDL itself. Note that in some literature, the Channel Loopback also is called Local Line Loopback. Fig. 10 shows a block diagram of an OCU-DP with Local Line Loopback invoked.

Network Loopback:

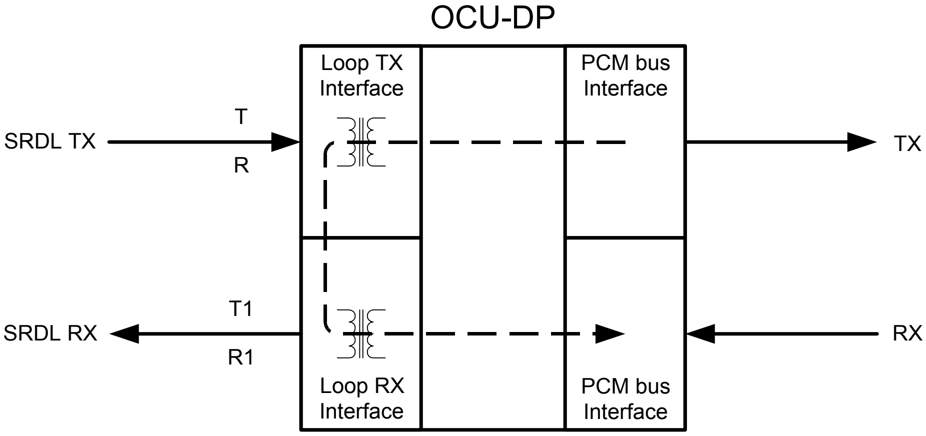
The Network (OCU) Loopback is initiated from within the network and is used to test through the SRDL interface at the OCU-DP. When the OCU-DP detects the network code corresponding to the Network Loopback, it activates a relay that connects the network transmit T1/R1 leads at the local loop interface to the network receive T/R leads as shown in Fig. 11. When the Network Loopback is activated, the OCU-DP is completely disconnected from the SRDL. However, while the OCU-DP is in the process of detecting the network code, it sends the local loop code S0B0XOV on the SRDL.

Fig. 10
Local Line Loopback



The Network Loopback code is sent to the OCU-DP four to six times in succession to activate the loopback. After the loopback has been activated, the signal changes to alternating patterns of the loopback code (to keep the loopback activated, since it is not a latching loopback) and test patterns. The loopback is released by sending four to six successive 7-bit patterns without the loopback code.

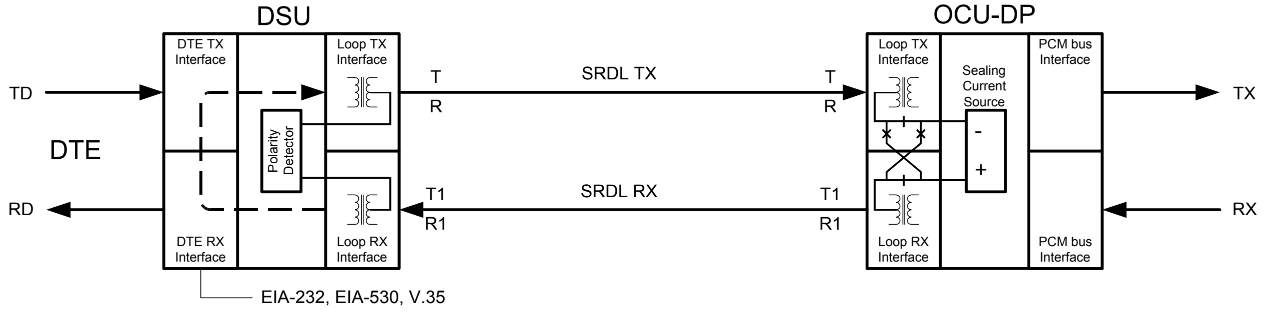
Fig. 11
Network Loopback



Channel Loopback:

When the OCU-DP detects the Channel Loopback code (coming from the network), it reverses the polarity of the sealing current applied to the local loop. Under normal conditions (no reversal) the T1/R1 pair, which is the Receive-In of the DSU and Transmit-Out of the OCU-DP, is positive with respect to the T/R pair. Upon reversal, the T/R pair (Transmit-Out of the DSU) is positive with respect to the T/R pair. A current flow of at least 4 mA is required to activate the loopback. The reversal is detected by the DSU, which activates the loopback. The Receive-In signal at the DSU (on T1/R1) must be equalized and filtered before it is applied to the Transmit-Out line driver circuitry (on T/R), where it is shaped. This loopback is provided in the DSU as close to the network as possible within the constraints of equalizing, filtering and line driving. Fig. 12 shows the Channel Loopback.

Fig. 12
Channel Loopback



The OCU-DP passes the network code S0B0X0V to the DSU, which returns it to the OCU-DP as confirmation that loopback has been activated. As with the Network Loopback, the Channel Loopback code is sent four to six times in succession followed by alternating patterns of the loopback code and test patterns. The loopback is released by sending four to six successive 7-bit patterns without the loopback code.

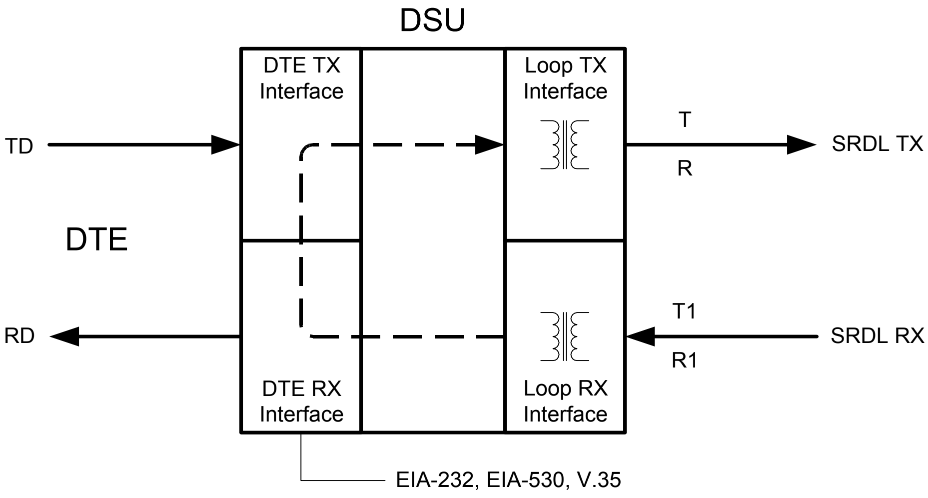
Remote Digital Loopback:

The Remote Digital Loopback is implemented in two different ways:
- When it is invoked from the network, it is called DSU Loopback; or
- When it is invoked from a DSU, it is called Remote Digital Loopback.

When invoked from the network, there are two versions of the DSU Loopback depending on the user rate (and whether secondary channel is involved). The 56 kb/s user rate without secondary channel uses the non-latching codes, and the 64 kb/s user rate uses latching codes. Other rates with secondary channel use both latching and non-latching codes.

For the non-latching case (Standard DDS at 56 kb/s user rate), the DSU Loopback code is sent over the network to the remote OCU-DP. The network code is converted to the S0B0X0V local loop code by the remote OCU-DP and passed to the remote DSU over the loop. As with the Network and Channel Loopbacks previously discussed, the DSU Loopback code is sent four to six times in succession followed by alternating patterns of the loopback code and test patterns. The loopback is released by sending four to six successive 7-bit patterns without the loopback code. Note that the local loop code associated with the DSU Loopback is the same as the local loop code used with the Channel Loopback (although the network codes are different for each type of loopback). See Fig. 13.

Fig. 13
Remote Digital (DSU) Loopback



Some OCU-DP channel units have the option of blocking the DSU Loopback code (sometimes known as Customer Remote Test Control - CRTC). If this option switch in the local OCU-DP is set to block the DSU Loopback command, the local loop code will not be translated to the corresponding network code and, thus, not detected by the remote OCU-DP. Similarly, DSUs can be set to not respond to the Remote Digital Loopback command.

For the latching case, (56 kb/s with secondary channel and 64 kb/s) the following are transmitted over the loop in sequence (S = Don't Care):

- Minimum of 35 Transition In Progress (TIP) bytes of S011101F0
- Minimum of 35 Loopback Select Code (LSC) of S111011F1
- Minimum of 100 Loopback Enable (LBE) bytes of S101011F0
- Minimum of 32 Far End Voice (FEV) bytes of S101101F0

The test set continues to send FEV bytes and monitors for their return for a total of about 2 seconds to ensure the loopback is activated. After loopback activation has been confirmed, testing can commence. The transmission of at least 35 TIP byte sequences will release the latching loopback. Therefore, it is important that the TIP byte sequence be excluded from the actual test sequences to prevent unintended release of the loopback.

9. Loop Design Considerations

The design of Subrate Digital Loops takes into account the loop loss at a specific frequency (depending on line rate), bridge tap lengths and cable gauge. The requirements and other information are summarized in Table 6. Two values of maximum loop loss are given in this table. The 34 dB value is based on older equipment. All modern DSUs and OCU-DP channel units support the higher loss of 45 dB at 56 kb/s and 64 kb/s user rates.

Table 6
Loop Design Data

Parameter	**56 kb/s**	**64 kb/s**
No. Pairs required	2 pairs	2 pairs
Line Rate	56 kb/s	72 kb/s
Nyquist Frequency	28 kHz	36 kHz
Impedance	135 ohms	135 ohms
Receiver loss range (including bridged taps)	0 to 34 dB at 28 kHz (0 to 45 dB modern equipment)	0 to 34 dB at 36 kHz (0 to 45 dB modern equipment)
Maximum individual bridged tap length	2000 ft.	2000 ft.
Total of all bridged taps	2500 ft.	2500 ft.
Background noise	See Table 7	See Table 7
Impulse noise threshold	See Table 7	See Table 7
Load coils	Must be removed	Must be removed
Simplex voltage[7]	7-28 volts	7-28 volts
Simplex sealing current	4-20 mA	4-20 mA

Table 7 gives the noise limits for the 56 kb/s and 64 kb/s SRDL. The limits depend on the loop loss at the Nyquist frequency. Linear interpolation may be used for losses between the values given; for each dB change in loss, within the limits given, 1 dB of change, with opposite sign, is allowed in the noise limits. For example, if the loss increases by 1 dB, the allowed noise decreases by 1 dB. All measurements are made with the test set adjusted for 135 ohm termination impedance.

Table 7
Noise Limits

Loop Loss	**56 kb/s**	**64 kb/s**
Background Noise ①		
Loss ≤ 34 dB	34 dBrn50kb	34 dBrn50kb
34 dB < Loss ≤ 40 dB	28 dBrn50kb	28 dBrn50kb
40 dB < Loss ≤ 45 dB	23 dBrn50kb	23 dBrn50kb
Impulse Noise Threshold ②		
Loss ≤ 34 dB	50 dBrn50kb	50 dBrn50kb
34 dB < Loss ≤ 40 dB	44 dBrn50kb	44 dBrn50kb
40 dB < Loss ≤ 45 dB	39 dBrn50kb	39 dBrn50kb

① Measured with 50 kb noise filter.
② Maximum 7 counts in 15 minutes measured with 50 kb noise filter.

Loop design is done at the so-called Nyquist frequency, which is one-half the line rate. For the 56 kb/s SRDL (no secondary channel), the line rate is 56 kb/s and the Nyquist frequency is 28 kHz. For the 64 kb/s SRDL, the line rate is 72 kb/s and the Nyquist frequency is 36 kHz. A more

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[7] The voltage shown applies only to the provision of sealing current. A higher voltage is used when the OCU-DP provides power to a SRDL repeater or DDST.

thorough treatment of loop design issues is given in *Subscriber Loop Signaling and Transmission Handbook: Digital* by Reeve.[2]

Fig. 14 and 15 give the loop loss vs. loop length at 21°C for 56 kb/s and 64 kb/s SRDL, respectively, assuming a single gauge for the entire loop length and no bridged taps.

Fig. 14
56 kb/s Subrate Digital Loop Loss vs. Length at 21°C

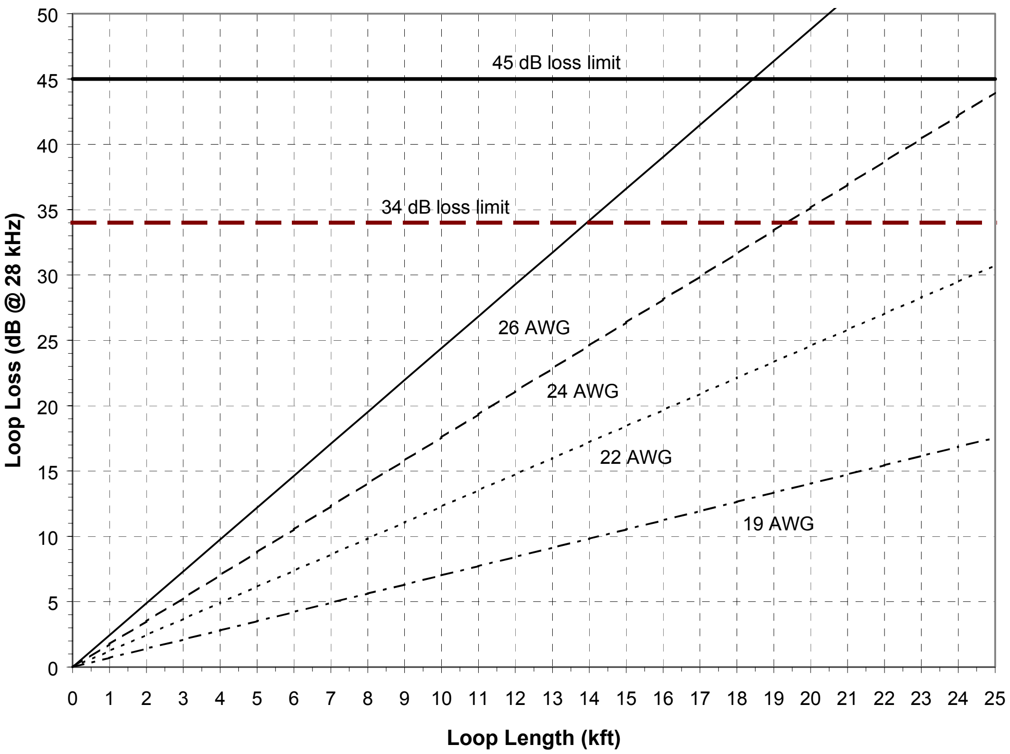
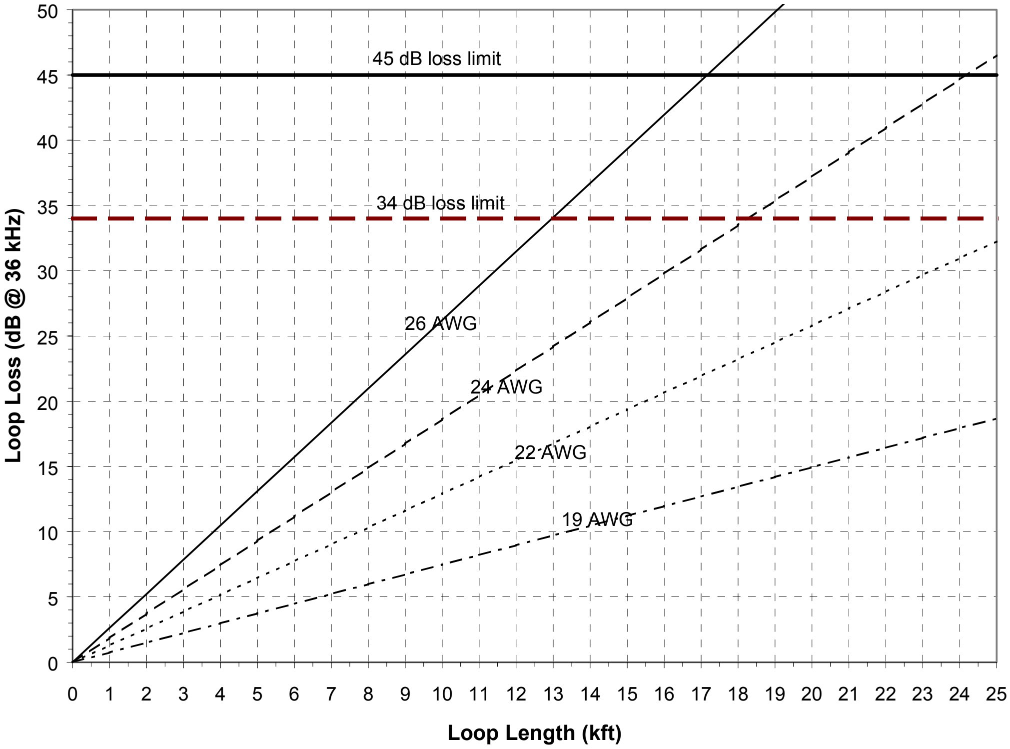


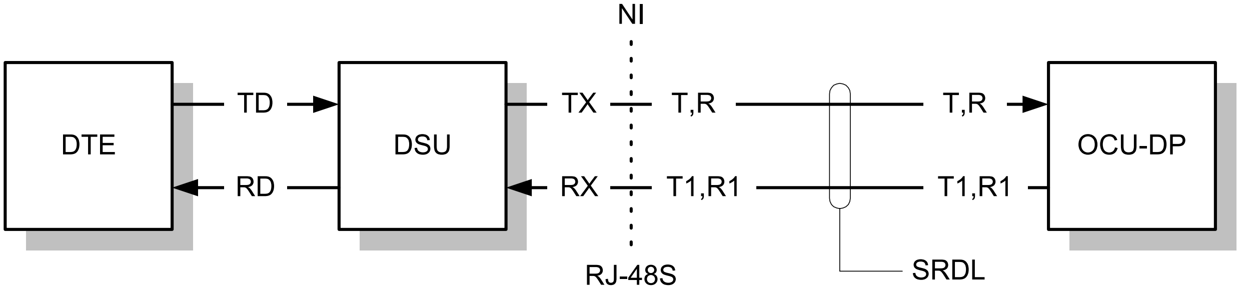
Fig. 15
64 kb/s Subrate Digital Loop Loss vs. Length at 21°C



10. Connector Wiring

The RJ-48S connector configuration is used at the SRDL Network Interface for all user rates. The RJ-48S is defined in ATIS Report No. 5 and is identical to the connector used with Switched 56 service.[3] Fig. 16 shows the signal directions for the two pairs associated with the connector, and Fig. 17 shows the front view of the connector itself. The pin assignments are summarized in Table 8.

Fig. 16
Signal Directions



Fig, 17
RJ-48S Connector

Looking into Jack

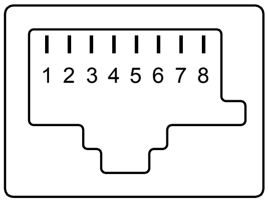


Table 8
RJ-48S Connector Pin Assignments

Pin No.	RJ-48S	Direction
1	R (TR)	From CI to NI
2	T (TT)	From CI to NI
3	N/C	
4	N/C	
5	N/C	
6	N/C	
7	T1 (RT)	From NI to CI
8	R1 (RR)	From NI to CI

Note: N/C indicates No Connection.

11. Testing and Performance

SRDLs are tested to Service Acceptance Limits and Trouble Verification Limits by using a variety of bit pattern tests, which are listed in Table 9. This table also shows the test time. No errors are allowed during these short-term tests. Test patterns other than those shown in the table may be available on some test sets. The first two patterns in the table are pseudo-random bit sequences (PRBS) that simulate live random data with what are really repeating patterns. Since the patterns repeat, received errors are easy to detect, something not possible with truly random data. Generally, the longer patterns should be used at higher data rates because they provide more randomness than shorter patterns.

The next four patterns (DDS 1 through DDS 4) are stress patterns that test the operation of transmitters and receivers. The last pattern (DDS5) is a combination of the other four stress patterns. Stress patterns are used to find problems that are not detectable by pseudo-random patterns.

Table 9
Test Patterns

Pattern	Repeating Bit Sequence	Minimum Test Time	Purpose
PRBS-511	511 bits 2^9 - 1	5 minutes	Simulate live traffic
PRBS-2047	2047 bits 2^{11} - 1	5 minutes	Simulate live traffic
DDS 1	100 bytes 11111111 followed by 100 bytes 00000000 . . .	3 minutes	Stress minimum and maximum signal power
DDS 2	100 bytes 01111110 followed by 100 bytes 00000000 . . .	3 minutes	Simulates HDLC and SDLC packet frames
DDS 3	1 byte 00110010	3 minutes	Simulate Bisync EBCDIC (IBM)
DDS 4	1 byte 01000000	3 minutes	Stress clock recovery
DDS 5	4*DDS 1 + 4*DDS 2 + 200*DDS 3 + 200*DDS 4	5 minutes	Combination

The test patterns normally are sent from one end and returned to the same end via a loopback at some other point in the channel. This is a single-ended test that is quite simple to setup and perform provided the desired loopback can be invoked. The single-ended test requires only one test set and one operator. In many situations, the built-in test features in the DSU are sufficient for user testing. A double-ended test also can be performed, but it requires two test sets and two operators, one at each end (or the DSUs can be used for testing as with the single-ended test). Testing from within the network can be done from a centralized test facility or at the DS1 interface of the channel banks used with the DDS.

The test times shown in Table 9 are minimums for troubleshooting. Actual Service Acceptance tests are performed for at least 15 minutes using any combination of test patterns, preferably DDS5. Similarly, when service trouble is reported, it is verified by a 15 minute test. Table 10 summarizes the requirements for service acceptance and trouble verification.

Table 10
Test Times and Limits

Action	Error Limits	Test Interval	Notes
Service Acceptance	0	15 minutes	*
Trouble Verification	1	15 minutes	**

* If 1 error occurs in the first 15 minute test interval and the test is continued for an additional 15 minute interval, 1 additional error is allowed in the 30 minute total test time (total not to exceed 2). An additional 15 minute interval may be used to increase the confidence level, in which case the total error count is not to exceed 2 for the 45 minute test interval.

** Corrective action required when a Channel Loopback test results in more than 1 error in the test interval.

The foregoing discusses short-term test and verification limits. A different set of criteria is used to determine performance over the long-term. Whereas the number of errors in a 15 minute test are used for service acceptance and verification, an average number of errors per day are used for the long-term tests. The actual criteria depend somewhat on the industry standard used as a reference and, for end-to-end service, on the length of the circuit. However, since this application note is focused on the SRDL, only the long-term local access performance requirements will be reviewed here.

Table 11 summarizes the long-term performance specified by AT&T and ANSI. This table only shows the local access portion; the references provide performance requirements for interoffice and end-to-end service. These performance measurements normally can only be derived from out-of-service tests on the SRDL. However, in the case of DS1 facilities used in the local access portion of the channel, performance can be derived from the Facility Data Link in the Extended SuperFrame Format (ESF) if that frame structure is used.

Table 11
Long-Term Local Access Performance

Parameter	**AT&T Dataphone® Digital Service Performance**[4]	**ANSI DDS Performance**[5]
Errored Seconds	35/day	86/day
% Error Free Seconds	99.96%/day	99.90%/day
Severely Errored Seconds	4/day	9/day
Availability	99.975%/year	99.900%/month

An Errored Second (ES) is any second with at least one error. The Error Free Second is the complement of the ES and is a measure of the percentage of seconds with no errors over the measurement interval (one day). The Severely Errored Second (SES) is any second in which the bit error rate (BER) is worse than 1E-3 (1 bit error in 1,000 bits transmitted). ES, %EFS and SES usually are averaged over a day. Availability is measured at the onset of 10 consecutive seconds that are not severely errored; in other words, the BER is better than 1E-3 for at least 10 consecutive seconds. Unavailability is the complement of Availability and is measured at the onset of 10 Consecutive Severely Errored Seconds (CSES). In both cases, the 10 seconds are measured as part of the Availability or Unavailability, as appropriate. Availability and Unavailability are averaged over a relatively long period, one year or one month depending on the standard.

12. Digital Carrier and Interoffice Facilities

Although this application note focuses on the local loop aspects of the DDS, it is necessary to consider the interoffice facilities and their impact on this type of service. Of particular concern are the effects of analog conversion, digital compression and backbone facility availability.

The DDS is an end-to-end, synchronous digital service, and no analog facilities whatsoever are allowed in the transmission path. Digital compression systems are designed to increase the efficiency of interexchange transmission facilities that are used for voice. These systems change the bit values in the DS0 transmission channels and cannot be used with DDS. In fact, any transmission method that alters byte content or does not guarantee bit integrity end-to-end cannot be used with DDS.

DS1 facilities, or broadband facilities with embedded DS1 channels, normally will be used for interoffice transport of DDS. These facilities may be shared with other communication services. Also, DS1 facilities may be used between the NI and the serving central office. It is necessary to ensure that the ones-density requirements are met on the DS1 facilities. This is a different requirement than the ones-density required on the SRDL itself. In some cases, the user rate will be restricted to 56 kb/s because of ones-density requirements in DS1 transmission systems.

There are several ways of meeting the ones-density requirements on DS1 facilities. One way is to use the B8ZS line code, which applies in particular to repeatered T1-carrier transmission facilities. Another way is to ensure that the eighth bit of every frame is set to one when transmitting data over the channels associated with DDS. Since only seven bits are then available for user data, the payload speed is limited to 56 kb/s. A user rate of 64 kb/s is possible only if the transmission facilities have Clear Channel Capability (CCC). With repeatered T1-carrier, B8ZS is the most practical way to provide CCC.

To meet the overall availability requirements for the DDS, backbone facilities normally are redundant. If these facilities are based on Repeatered T1-Carrier, there will be some type of protection switching. To achieve the highest possible availability, a 1:1 protection scheme will be used. With 1:1 protection, every active span will have a protection span associated with it. This effectively doubles the facility requirements and has the attendant high capital and operational costs. However, based on experience with the facility or route, this level of protection may not be needed. If a more relaxed scheme is appropriate, a number of active spans may be protected by one protection span, say 4:1 or 8:1.

13. Synchronization

Synchronization probably is the single most important consideration in digital networks. One of the design foundations of the DDS is the high performance of the clocks used to synchronize the network elements. Under normal conditions all DDS network elements must be synchronized by clocks traceable to a Stratum 1 Primary Reference Source. Under abnormal conditions, the network elements should be synchronized by clocks arranged in a clear hierarchy and no timing loops should ever be involved.

Generally, the timing source for channel banks located in a central office is a Building Integrated Timing Supply (BITS) meeting the traceability requirements described above. If the channel bank is located in a Remote Digital Terminal or user premises, it normally will be loop-timed; that is, the clock is derived from the received signal and used to clock the transmit signal.[8]

DSUs normally have several synchronization options:

- Clock from DTE (ETC lead)
- Clock from received loop (loop-timed)
- Clock from external source
- Clock from internal source

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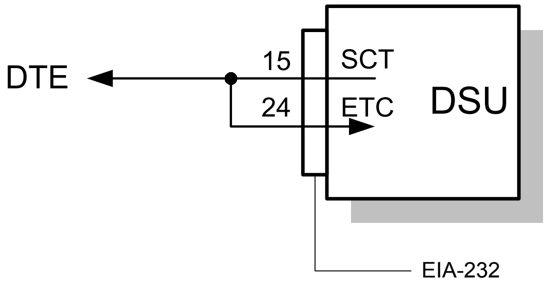
[8] Loop-timing should not be confused with timing loops, the latter being detrimental to any digital network.

In most applications where the DSU is connected to a central office OCU-DP, the DSU will be set to clock from the received loop (loop-timed). In applications where one DSU is connected to another DSU via metallic twisted pairs (no digital carrier facilities involved), one DSU will be set for loop-timing and the other for internal timing (unless the DTE has a higher performance clock than the DSU, in which case, the DSU would be set for DTE timing).

For 56 kb/s and 64 kb/s applications, some DSUs should be connected as shown in Fig. 18 to eliminate timing problems and data errors caused by excessive delays in the DTE transmit clock receiver and transmit clock driver.

Fig. 18
DSU Clocking for 56 kb/s and 64 kb/s



14. References

[1] Code of Federal Regulations, Title 47: Telecommunications, Part 68 - Connection of Terminal Equipment to the Telephone Network, US Government Printing Office.

[2] Reeve, W., Subscriber Loop Signaling and Transmission Handbook: Digital, IEEE Press, 1995.

[3] ATIS Report No. 5, Committee T1 - Telecommunications, A Technical Report on Carrier to Customer Installation Interface Connector Wiring Configuration Catalog, April 1994.

[4] TR62310, Digital Data System Channel Interface Specification, AT&T Technical Reference with addendums 1, 2 and 3 through Dec. 1989.

[5] ANSI T1.510-1994, Network Performance Parameters for Dedicated Digital Services - Specifications.

Availability: AT&T documents are available from AT&T Customer Information Center, Order Entry, 2855 North Franklin Road, Indianapolis, IN 46219-1999, Tel. +1-800-432-6600, fax +1-317-322-6699. Bellcore documents are available from Bellcore by calling +1-800-521-2673. US Government publications are available from the US Government Printing Office by calling +1-202-. ATIS documents are available by calling the Alliance for Telecommunication Industry Solutions at +1-202-434-8845. IEEE Press books are available from IEEE Press by calling +1-800-678-IEEE.

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