Sound Advice In Telecommunications

Application Note No. 6

ISDN Basic Rate Interface

1. Introduction

This application note focuses on the access, or subscriber loop, portion of the Integrated Services Digital Network (ISDN) Basic Rate Interface (BRI).[1] While this discussion is mostly concerned with the Physical Layer, or Layer 1, of the Open Systems Interconnection (OSI) reference model[2] as it applies to the ISDN, mention is made of the next two higher layers. These are the Data-Link Layer (Layer 2) and Network Layer (Layer 3). However, to put ISDN access into perspective, this note also discusses architectures and applications, but only as they apply to what is now called the Narrowband ISDN (NISDN).

The Broadband ISDN (BISDN), which is based on Asynchronous Transfer Mode (ATM) switching and traffic control technologies and Synchronous Optical Network (SONET)[3] multiplexing and transmission technologies, is still emerging. BISDN may be considered to be an extension of NISDN.

The ISDN is a wide area digital communications network (WAN) that provides a large number of services through a small number of standard network interfaces. Some attributes of the ISDN are:

- The ISDN is derived from the integration of existing and anticipated digital switching and transmission systems and is compatible with existing and emerging analog and digital services.
- Handles both circuit mode Bearer channels (B-channels) and a packet mode Data channel (D-channel, also called Delta-channel) simultaneously through a single access point (see Appendix for a brief discussion of circuit mode and packet mode).
- Switching and transmission is done in the digital domain; however, POTS calls may be completed to analog lines using analog facilities.
- Allows sharing of various information resources, located inside or outside the network, by subscribers and service providers.
- Provides various kinds of communication processing and information handling functions.
- Simplifies operation and administration of the network.
- Is compatible with frame relay and X.25 packet switching networks.

Since the ISDN includes existing digital network implementations and facilities, a particular call type, data speed or service may be neither available nor needed on an end-to-end basis. For example,

---

[1] The BRI is one of the two electrical interfaces available in the ISDN. The other is the Primary Rate Interface, or PRI. The PRI, which operates at 1.544 Mb/s, is not covered in this application note.

[2] Description of the OSI reference model is beyond the scope of this application note. Interested readers should see ITU-T Recommendation X.200.[1]

[3] SONET is the North American version of the Synchronous Digital Hierarchy (SDH) defined in ITU-T G-Series recommendation .[2]

- An ISDN caller may have service capabilities (for example, data rates or call features) not available to the called user, in which case the services are limited to those of the called user
- When an ISDN caller with enhanced services calls a line with an analog telephone set, some of the services may not be available
- The ISDN supports Clear Channel Capability with a full 64 kb/s available in each Bearer channel. However, when the ISDN interworks with Switched 56 service and some IXC networks, the user's data speed is limited to 56 kb/s in each B-channel
- A particular call may need only 9.6 kb/s data speed. Even though the Bearer and Data channels operate at higher speeds, the ISDN is compatible with the lower speeds through rate adaptation protocols

2. Standards

A large number of standards, international (CCITT/ITU-T), national (ANSI) and regional (Bellcore) have been produced to describe the ISDN. Some of these are listed here. Of the CCITT recommendations, only those included in the "Blue Book," published in 1989, are listed below. Many individual recommendations have been updated by ITU-T, but these are not listed (an example is [3]). The reader is referred to the current ITU-T catalog for updated information.

The **general aspects** of the ISDN, such as operational requirements, service capabilities, maintenance and network management, are given in the following:

CCITT (and ITU-T)

- Vol. II, Fascicle II.2, Telephone Network and ISDN - Operation, Numbering, Routing and Mobile Service, Rec. E.100 - E.333, CCITT Blue Book, Geneva, 1989.
- Vol. II, Fascicle II.3, Telephone Network and ISDN - Quality of Service, Network Management and Traffic Engineering, Rec. E.401 - E.880, CCITT Blue Book, Geneva, 1989.
- Vol. III, Fascicle III.7, Integrated Services Digital Network (ISDN) - General Structure and Service Capabilities, Rec. I.110 - I. 257, CCITT Blue Book, Geneva, 1989.
- Vol. III, Fascicle III.8, Integrated Services Digital Network (ISDN) - Overall Network Aspects and Functions, ISDN User - Network Interfaces, Rec. I.310 - I. 470, CCITT Blue Book, Geneva, 1989.
- Vol. III, Fascicle III.9, Integrated Services Digital Network (ISDN) - Internetwork Interfaces and Maintenance Principles, Rec. I.500 - I.605, CCITT Blue Book, Geneva, 1989.
- Vol. VI, Fascicle VI.12, Public Land Mobile Network, Interworking with ISDN and PSTN, Rec. Q.1000 - Q.1032, CCITT Blue Book, Geneva, 1989.

ANSI

- ANSI T1.218-1991, Telecommunications - ISDN Management - Overview and Principles
- ANSI T1.241-1994, Telecommunications - Integrated Services Digital Network (ISDN) Management - Service Profile Verification and Service Profile Management - ISDN Interface Management Services
- ANSI T1.604-1990, Telecommunications - Minimal Set of Bearer Services for the ISDN Basic Rate Interface

- ANSI T1.614-1991, Telecommunications - Packet-Mode Bearer Service Category Description
- ANSI T1.620-1991, Telecommunications - Integrated Services Digital Network (ISDN) - Circuit-Mode Bearer Service Category Description

Bellcore
- TR-TSY-000846, ISDN X.25 Supplementary Services
- TR-TSY-000448, ISDN Routing and Digit Analysis

The **Digital Subscriber Signaling System No. 1 (DSS-1)** is used to convey the Data Link and Network Layers (layers 2 and 3) between the user's terminal equipment and the network termination (NT1). DSS-1 and related requirements are described in the following:

CCITT (ITU-T)
- Vol. VI, Fascicle VI.10, Digital Subscriber Signaling System No. 1 (DSS 1), Data Link Layer, Rec. Q.920 - Q.921, CCITT Blue Book, Geneva, 1989.
- Vol. VI, Fascicle VI.11, Digital Subscriber Signaling System No. 1 (DSS 1), Network Layer, User-Network Management, Rec. Q.930 - Q.940, CCITT Blue Book, Geneva, 1989.

ANSI
- ANSI T1.602-1989, Telecommunications - Integrated Services Digital Network (ISDN) - Data-Link Layer Signaling Specification for Application at the User-Network Interface
- ANSI T1.607-1990, Telecommunications - Integrated Services Digital Network (ISDN) - Layer 3 Signaling Specification for Circuit-Switched Bearer Service for Digital Subscriber Signaling System Number 1 (DSS1)
- ANSI T1.608-1991, Telecommunications - Integrated Services Digital Network (ISDN) - Signaling Specification for X.25 Packet-Switched Bearer Service for Digital Subscriber Signaling System Number 1 (DSS1)
- ANSI T1.615-1992, Telecommunications - Digital Subscriber Signaling System No. 1 (DSS1) - Layer 3 Overview
- ANSI T1.617-1991, Telecommunications - Integrated Services Digital Network (ISDN) - Signaling Specification for Frame Relay Bearer Service for Digital Subscriber Signaling System Number 1 (DSS1)
- ANSI T1.623-1993, Telecommunications - Digital Subscriber Signaling System Number 1 (DSS1) - Signaling Specification for the User Signaling Bearer Service

Bellcore
- TR-TSY-000793, ISDN D-Channel Exchange Access Signaling and Switching Requirements (Layer 2)
- TR-TSY-000861, ISDN Layer 3 Protocol Detail for the Support of Supplementary Services

Finally, the **Physical Layer (layer 1)** requirements, which includes the electrical and mechanical characteristics of the user terminal equipment and network interfaces, are described in the following:

CCITT (ITU-T)
- Vol. III, Fascicle III.5, Digital Networks, Digital Sections and Digital Line Systems, Rec. G.801 - G.961, CCITT Blue Book, Geneva, 1989.

ANSI

- ANSI T1.601-1992, Telecommunications - Integrated Services Digital Network (ISDN) - Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification)
- ANSI T1.605-1991, Telecommunications - Integrated Services Digital Network (ISDN) - Basic Access Interface for S and T Reference Points (Layer 1 Specification)

Bellcore

- TR-NWT-000393, Generic Requirements for ISDN Basic Access Digital Subscriber Lines,
- TR-NWT-002397, Layer 1 Test Plan for ISDN Basic Access Digital Subscriber Line Transceivers,
- SR-TSY-001423, ISDN Basic Access DSL Layer One Analysis Process Description,
- SR-NWT-003036, ISDN Customer Equipment and Wiring Issues: Primary Market Research,
- SR-TSY-000800, ISDN Impact on Power
- GR-1507-CORE, Generic Requirements for Layer 1 Activation/Deactivation
- SR-NWT-001602, Generic Requirements of a System for NT1 Powering and Backup Powering
- SR-NWT-002362, A Test Procedure for Layer 1 of the ISDN T-Interface in NT1 Equipment
- SR-NWT-001953, Generic Guidelines for ISDN Terminal Equipment on Basic Access Interfaces
- SR-NWT-002361, Generic Guidelines for ISDN Terminal Equipment on National ISDN-2 Basic Rate Interfaces,
- SR-3239, Generic Guidelines for ISDN Terminal Equipment on National ISDN-3 Basic Rate Interfaces,

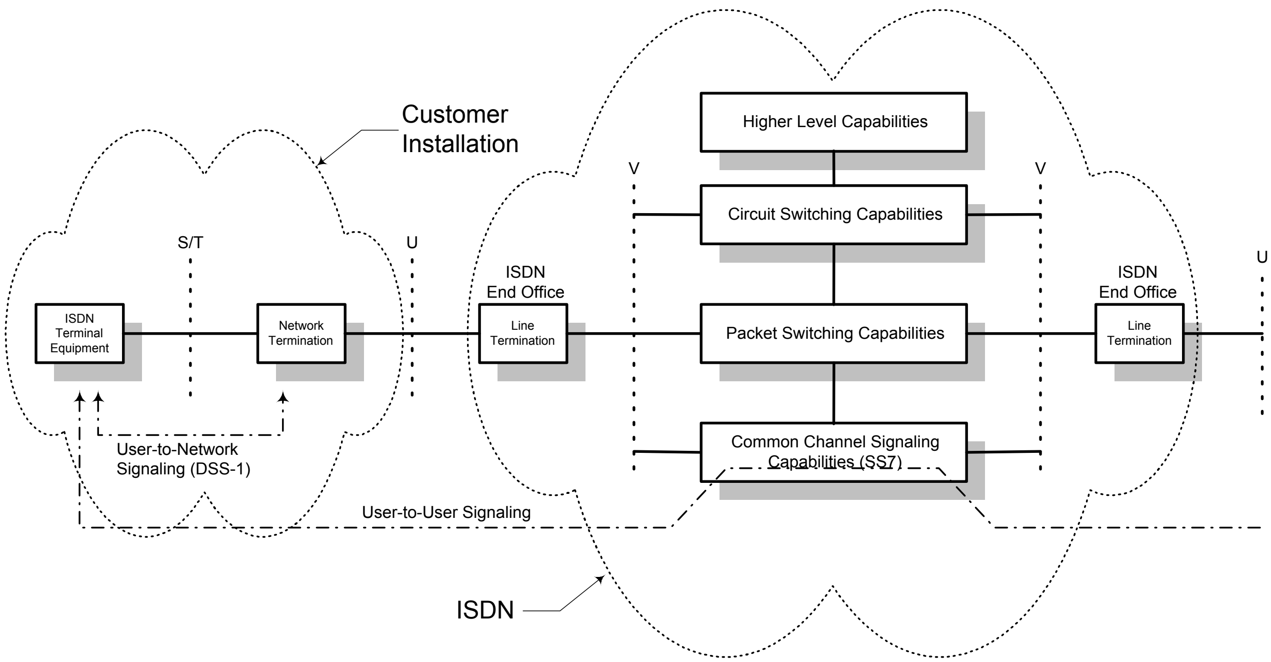
3. ISDN Architecture

Fig. 1 shows the basic architectural model of the ISDN. The circuit switching and packet switching requirements of the ISDN are shown along with the basic requirement for a common channel signaling system (CCSS). Presently, this CCSS is Signaling System No. 7. The functions between the two V-reference points are usually shown as a cloud on simple network diagrams.

In the United States, the Network Interface (NI), or point of demarcation between the network and Customer Installation (CI), is a modular jack located on the network side of the network termination unit. The CI is described in more detail later. The network interface is a physical layer (OSI Layer 1) electrical reference point called the U-reference or, more commonly, the U-interface. The Line Termination (LT) in the serving central office has electrical characteristics identical to the U-interface. The U-interface is a 2-wire bi-directional interface.

The V-reference shown in Fig. 1 usually is not physically realized. It is an internal reference point that represents the functional boundary between the network side of the LT and the Exchange Termination (ET). For the BRI, the V-reference is comprised of the two B-channels, one D-channel and a C-channel. The C-channel is a control channel that supports management functions. The ET is a functional group containing Layer 2 and 3 network-side functions and usually is integrated with the LT.

Fig. 1
Basic ISDN Architectural Model



Signaling information between the user and the network termination (NT), such as addressing and alerting, is transferred via the D-channel using the Digital Subscriber Signaling System No. 1 (DSS-1). The ISDN switching system distributes the user's information to the appropriate destinations of the circuit switching and packet switching networks. Once in the end office, signals for call handling are transferred through the ISDN using Signaling System No. 7. In Fig. 1, higher-layer capabilities represent applications at the higher levels of the OSI reference model such as line information database (LIDB) lookup and similar services.

4. Channelization

Information is carried in the ISDN using full-duplex, circuit switched B-channels and full-duplex packet switched D-channels. B-channels operate at 64 kb/s and the D-channel in the BRI operates at 16 kb/s. B-channels may be combined to give the user higher composite rates for a particular application or call session. Combining is by the BONDING (Bandwidth ON Demand INteroperability Group) protocol or PPP (Point-to-Point Protocol), such as ML-PPP (multi-link PPP). BONDING normally is a synchronous protocol but implementations are available to use with asynchronous terminal equipment, such as a PC serial port.

When a Terminal Adapter is used to connect V-series terminal equipment (for example, a serial port on a PC or a modem), CCITT Rec. V.120 specifies the necessary electrical and mechanical conversion.[4] V.120 supports only a single B-channel, but multiple data links or logical circuits on the user side of the Terminal Adapter may be statistically multiplexed onto the single B-channel.

The interface bit-rate at the R-reference point must be less than the B-channel rate (64 kb/s). The highest asynchronous rate supported is 57.6 kb/s in a B-channel. Since asynchronous transmission uses a start and stop bit, which are not required on synchronous facilities, the V.120 protocol removes them. The remaining 8 user bits are sent across the ISDN. The start and stop bits are reinserted by the Terminal Adapter at the other end. V.120 supports lower rates and transports the data by padding, or adding additional bits to fill the data frame at the B-channel rate.

Even though the B-channel primarily is used in the circuit switched mode, it also supports packet switched data. The B-channel operates in a variety of modes including:

- Circuit switching for transparent 64 kb/s (clear channel) or non-transparent at lower rates
- Packet switching, supporting packet mode terminals. In this case, the B-channel carries Layers 2 and 3 of the OSI reference model according to, for example, CCITT Recommendation X.25.
- Semi-permanent connections involving either circuit or packet switching modes

A B-channel is intended to carry a wide variety of user information. A distinguishing characteristic is that the B-channel does not carry signaling information for circuit switching in the ISDN. Signaling information used for circuit switching is carried by the D-channel. Typical information carried by the B-channel includes

- Speech and analog voiceband data encoded at 64 kb/s using PCM.
- Wideband speech and music encoded using ADPCM and a single 64 kb/s channel.
- Speech encoded at rates lower than 64 kb/s alone, or combined with other digital information.
- Digital data corresponding to circuit- or packet-switching user classes of service at bit rates equal to or lower than 64 kb/s. In the case of single information data streams at rates less than 64 kb/s, the data rate is adapted to be carried on the B-channel at 64 kb/s. Multiple streams may be multiplexed together in the same B-channel, but for circuit switching, the entire B-channel is switched to a single user-network interface.

To support the various services, a number of B-channel connection types have been defined. Most simple Terminal Adapters support three - Data, Speech, and 3.1 kHz. The Data connection type is unrestricted in that the data bits are passed transparently through the ISDN without any alteration. With 56 kb/s interworking, the data may have to be in a specific form, but this is a function of the terminal equipment. The Speech connection type allows the greatest *network* flexibility and the least *user* flexibility. It allows echo cancellation and intermediate analog transmission, which will alter the data bit values in transit. It primarily is intended for digitally encoded speech, as its name indicates. The 3.1 kHz connection type is more restrictive on the network concerning how the data is manipulated, and is more suitable for analog voiceband data than the Speech connection type. The D-channel operates at 16 kb/s in the BRI and 64 kb/s in the PRI. The D-channel is primarily intended to carry signaling information for circuit switching within the ISDN, but it also may be used to carry user packet switched data. Although the D-channel operates at 16 kb/s in the BRI, user packet switched data usually operates at 9.6 kb/s or less.

5. Basic Rate Interface

The BRI provides two independent B-channels and one D-channel. The BRI channel configuration is called 2B+D, giving a user payload rate of 144 kb/s (= 2 x 64 kb/s + 16 kb/s). The Digital Subscriber Line, DSL, (or local BRI loop) actually operates at 160 kb/s, which includes the 144 kb/s payload plus an additional 16 kb/s of overhead for synchronization and framing. The BRI is bit sequence independent, which means there are no restrictions on the binary values of the user data nor the sequence of those values.

The U-interface uses a 4-level Pulse Amplitude Modulated (PAM) line code called 2B1Q, which stands for 2-binary, 1-quaternary. As user data is presented to the NT1, it is scrambled and interleaved with scrambled maintenance and operation channel (overhead) bits. The scrambled bits are combined with synchronization bits. Each pair of bits is then coded to a quaternary (quat) value, which correspond to pulses with the voltage levels shown in Table 1. The quat value shown in this table is a reference value and not a voltage value.

Table 1
2B1Q Line Code

Binary Pair	Quat Value	Pulse voltage
10	+3	+2.5 v-p (+15/6)
11	+1	+0.833 v-p (+5/6)
01	-1	-0.833 v-p (-5/6)
00	-3	-2.5 v-p (-15/6)

The shape of the pulses at the BRI, normalized to a height of 1.0, is shown in Fig. 2. The basic pulse shape is the same for all quat values, the only difference is the polarity and pulse height (voltage). Since the 2B1Q line code uses 2 bits per signal element (pulse), the symbol rate of 80 kbaud corresponds to the line bit rate of 160 kb/s. A signaling rate of S kbaud can be adequately carried in a channel of bandwidth S/2 kHz or, in this case, 40 kHz.

Fig. 3 shows a block diagram of the LT or NT1 integrated circuit implementation. The LT and NT1 are very similar. The only significant differences are

- The LT provides dc line powering or sealing current; the NT1 derives power from the loop or loops the sealing current.
- The LT is timed by the central office timing source and provides timing to the loop; the NT1 is loop-timed

Fig. 2
Template for Isolated BRI Pulse

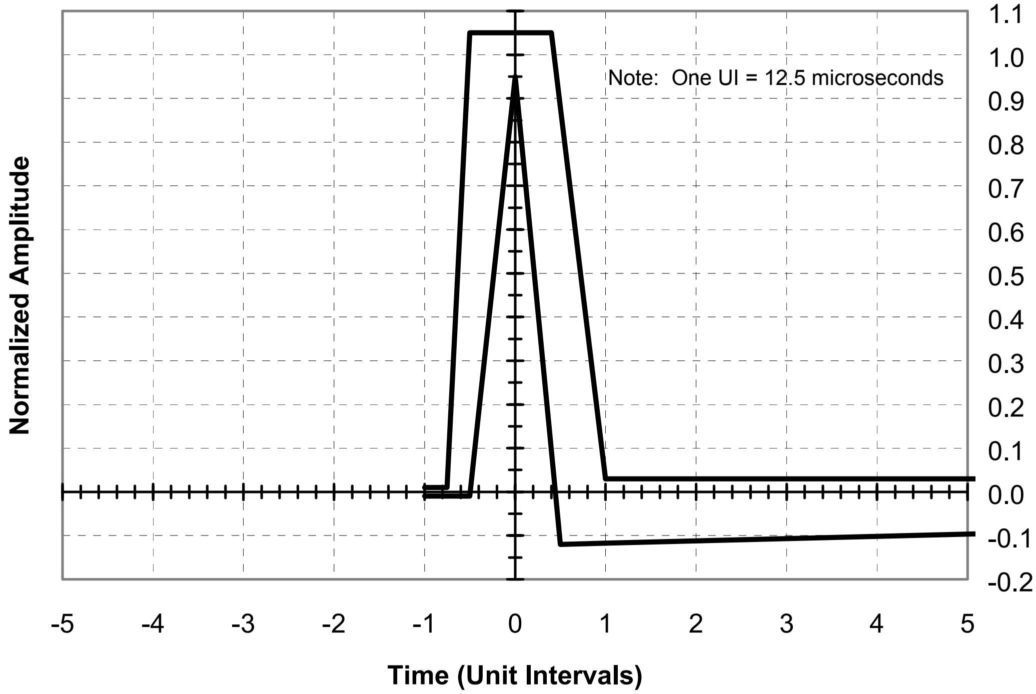
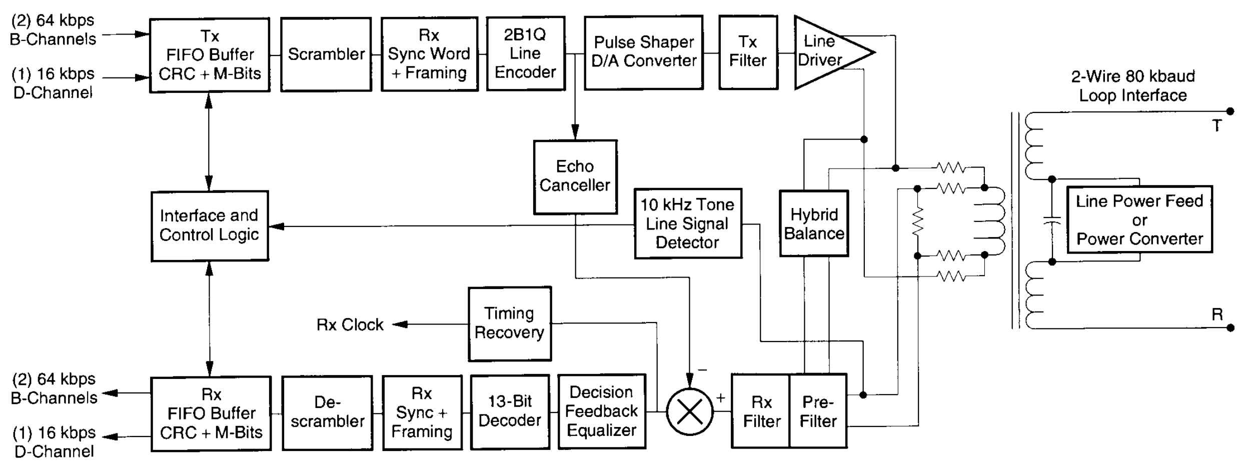


Fig. 3
LT or NT1 Block Diagram



6. *BRI Applications*

Following is a partial list of the many possible applications for the BRI. Each one of these has many forms.

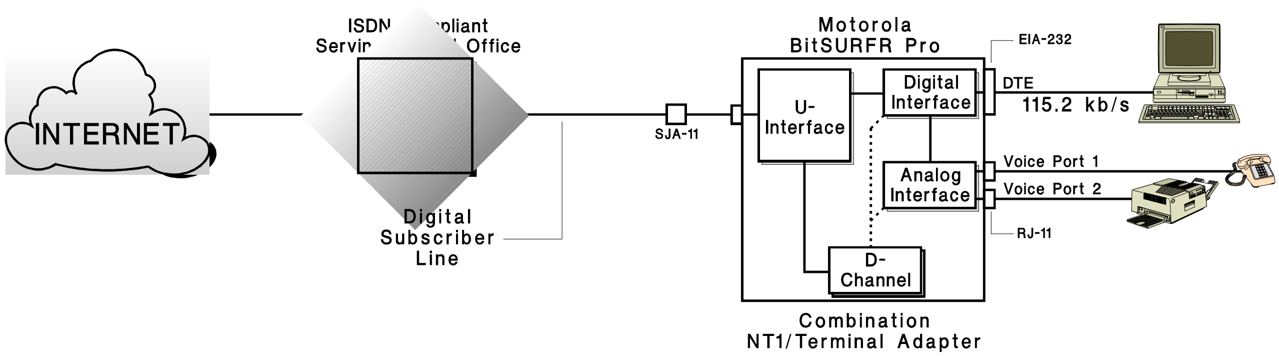
- Telecommuting, where one B-channel is used for voice and the other for data

- Distance learning
- High resolution, quicker faxing (Group IV)
- Conferencing
    - Video conferencing
    - High quality teleconferencing
    - Desktop conferencing
- Dial-up databases
- Internet access
- High quality audio feed for broadcasters (program audio)
- Medical image transfer

To take one of the application examples further, consider Internet access. With V.34 analog voiceband modems, Internet access is limited to 28.8 kb/s.[4] With the BRI, on the other hand, access speed can be increased to 64 or 128 kb/s with the appropriate terminal equipment. A typical application will use a PC with the serial port connected to a terminal adapter as shown in Fig. 4. In this illustration, the TA is combined with the NT1.

PC serial ports are limited to the asynchronous mode and a speed of 115.2 kb/s, in which case each B-channel in the BRI is operated at 57.6 kb/s and BONDING or ML-PPP is used to combine the channels. In order to use the application shown, the PC must be equipped with the appropriate Internet access software and communications (COM) port driver to allow higher than normal speed on the serial port. In this example, the D-channel is used exclusively for call setup and takedown and is not available to the user for packet switched data.

Fig. 4
Internet Access Using the BRI



The combined TA and NT1 in this example is the Motorola BitSURFER Pro, which can be configured for a variety of applications:

- Two analog ports (for example, one telephone set and one fax machine or voiceband modem), where each port uses one B-channel
- One analog port (one B-channel) and one serial port (the other B-channel)
- One serial port that uses both B-channels (with BONDING or PPP)

---

[4] This speed is rarely, if ever, acheived in practice especially on interexchange calls.

7. BRI Customer Installation

The basic details of the Customer Installation are shown in Fig. 5. This section only provides a brief review of the CI. A complete description of premises design for ISDN can be found in [5].

The CI is comprised of the T-, S- and R-reference points, or interfaces. Different modular connector wiring configurations are used for each. For example, the R-interface usually (but not always) is a regular RJ-11 jack for connection to existing analog terminal equipment or 25-pin D-shell connector for connection to a PC serial port.

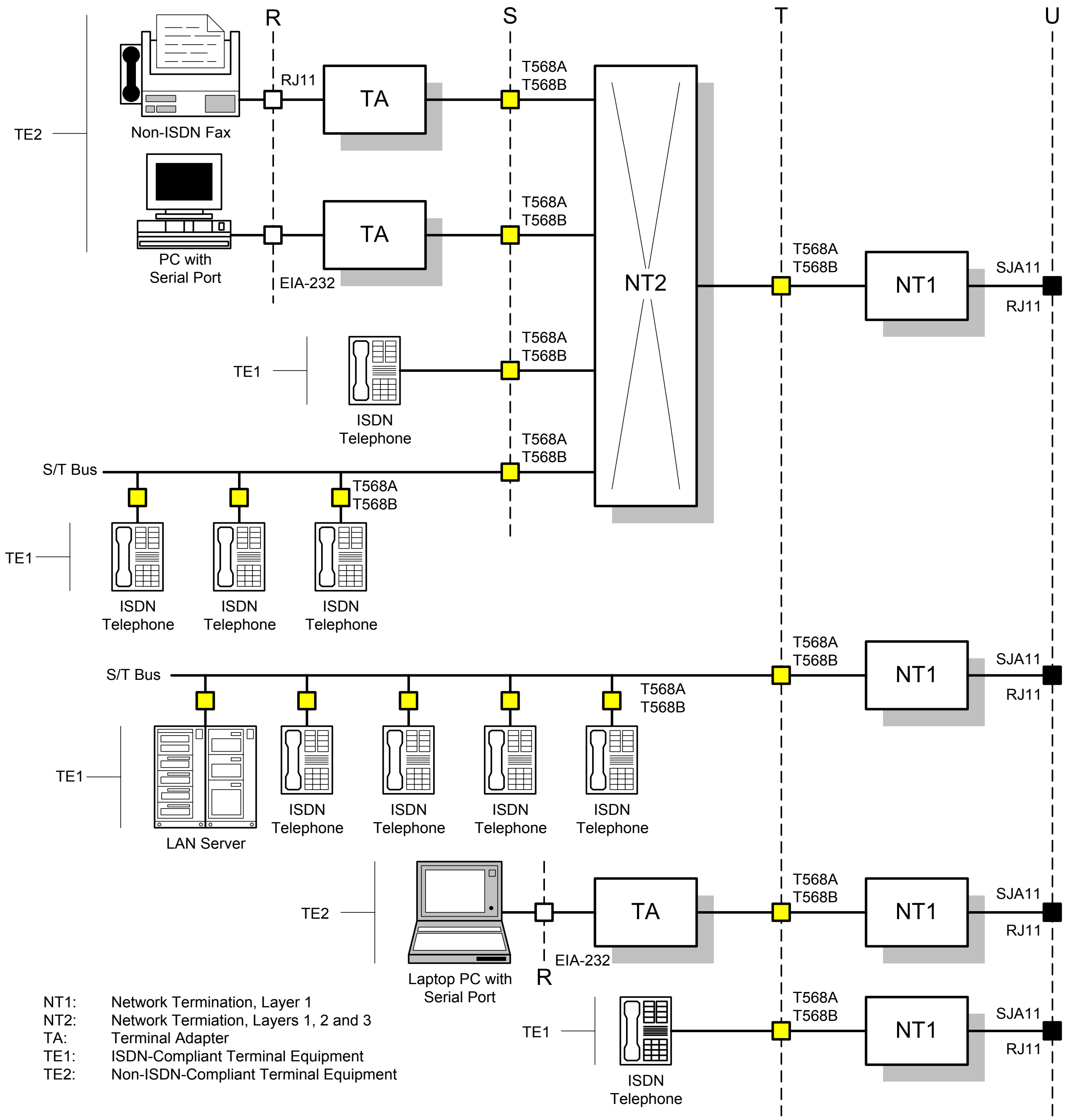
The U-Interface uses the SJA-11 or RJ-11 modular connectors shown in Fig. 6. The SJA-11 connector is an 8-position connector and is the most common type found on Terminal Adapters with integral NT1. The RJ-11 also is used with the U-interface and, while slightly cheaper and simpler, is easily confused with the RJ-11 used with analog terminal equipment. An RJ-11 plug fits into an SJA-11 jack.

The S/T-interfaces use either the T568A or T568B jacks. Fig. 7 shows the CI wiring for the T568A connector. The T568B connector is similar, with the only difference in the assignment of pairs 2 and 3, which are swapped. More information on the RJ-11 and SJA-11 jacks may be found in [6] and on the T568A and T568B jacks in [6, 7]. All equipment, such as the NT1 and NT2, are provided by, and the responsibility of, the customer.

The NT1 is part of the Customer Installation (CI). It is a network termination that operates only at Layer 1 (physical layer) of the OSI reference model. Its functions are:

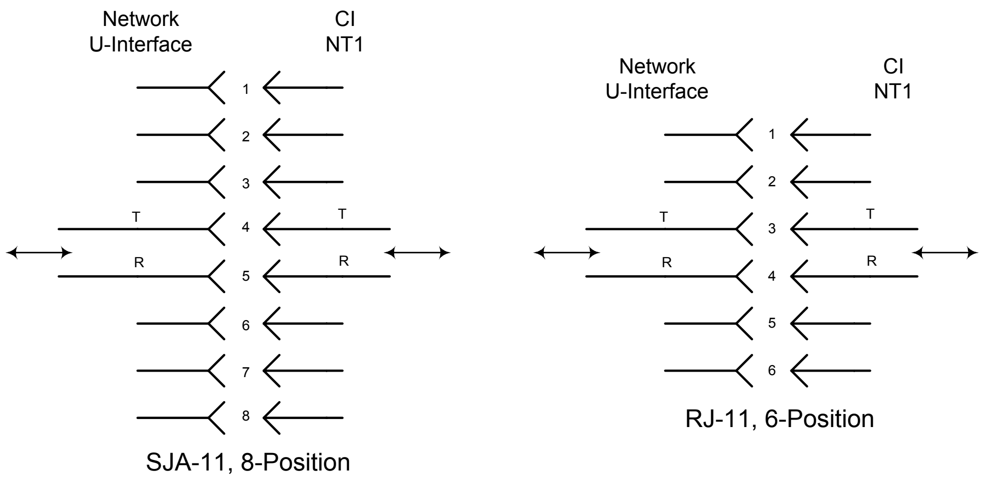
- Convert the 2-wire U-interface to the 4-wire T-interface
- Line transmission termination
- Timing
- Power transfer or sealing current looping (if sealing current is provided by the LT in the serving central office)
- Layer 1 multiplexing
- Layer 1 contention resolution at the T-interface

Fig. 5
Customer Installation Interfaces



NT1: Network Termination, Layer 1
NT2: Network Termiation, Layers 1, 2 and 3
TA: Terminal Adapter
TE1: ISDN-Compliant Terminal Equipment
TE2: Non-ISDN-Compliant Terminal Equipment

Fig. 6
SJA11, 8-Position Modular Connector
for ISDN BRI Network Interface

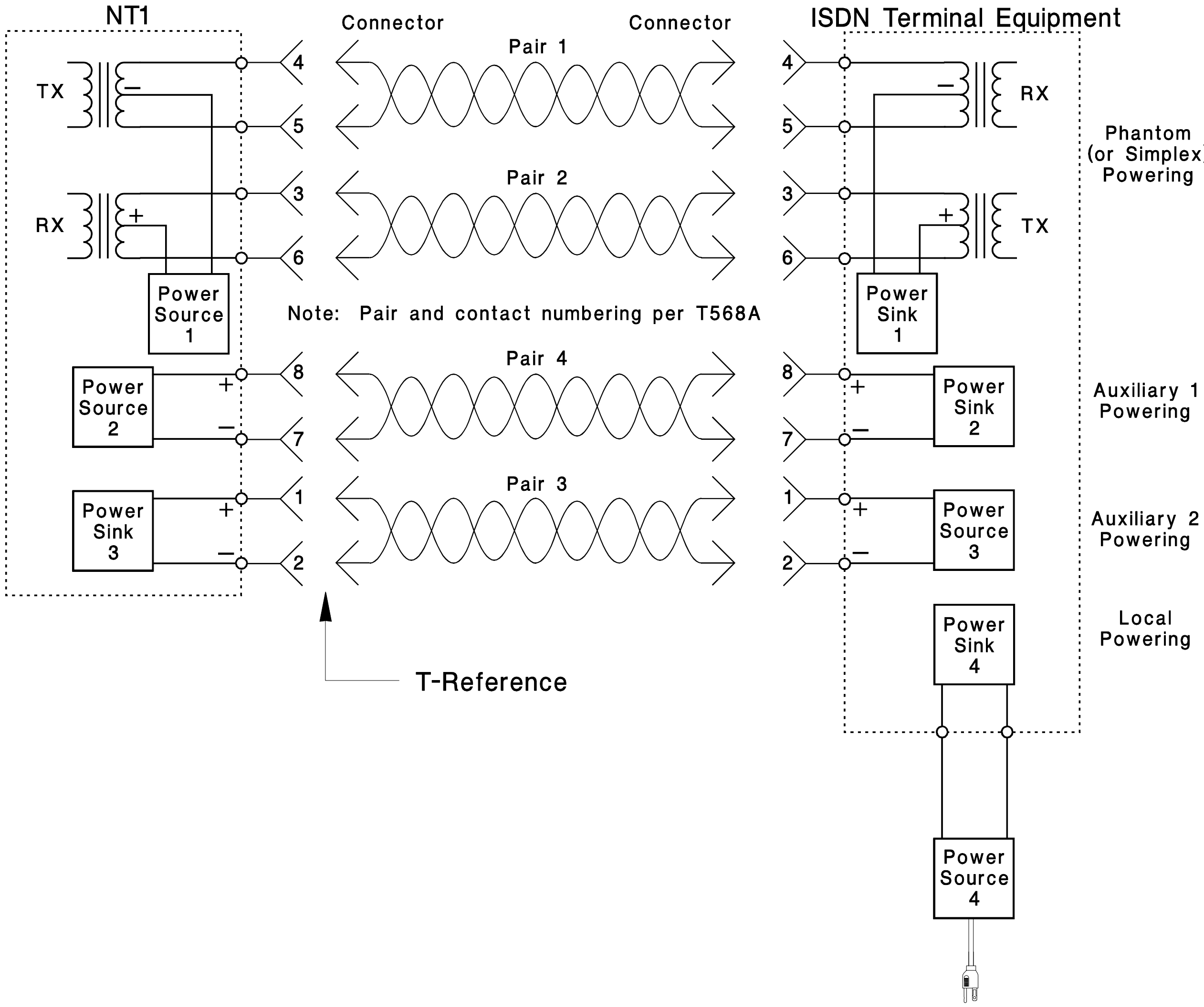


The NT2 also is part of the CI, and it operates at Layers 1, 2 and 3 of the OSI reference model. The NT2 usually is an ISDN compliant PBX, local area network bridge or router, or terminal controller. Depending on the configuration, these devices may have a built-in NT1 and they may have circuit-switching and packet-switching capabilities. The network side of the NT2 is the T-interface (which is the user side of the NT1). The user side of the NT2 is the S-interface. NT2 functions are:

- Layer 2 and 3 protocol handling
- Layer 2 and 3 multiplexing
- Switching
- Concentration
- Maintenance functions
- Interface termination and other Layer 1 functions

Terminal equipment can be virtually any type of non-ISDN compliant terminal equipment now in use, such as the 500 set, modem, Group III fax machine or serial port on a PC, as well as terminal equipment that is specifically designed to be ISDN compliant. Non-ISDN compliant terminal equipment is designated TE2 and is connected at the R-reference. The R-interface may be industry standard loop-start or ground-start telephone set interfaces [8], serial port interfaces, such as EIA-232 or EIA-530, or proprietary. A Terminal Adapter (TA) converts the non-ISDN compliant R-interface to the ISDN compliant S- or T-interface.

Fig. 7
Application of T568A, 8-Position Modular Connectors

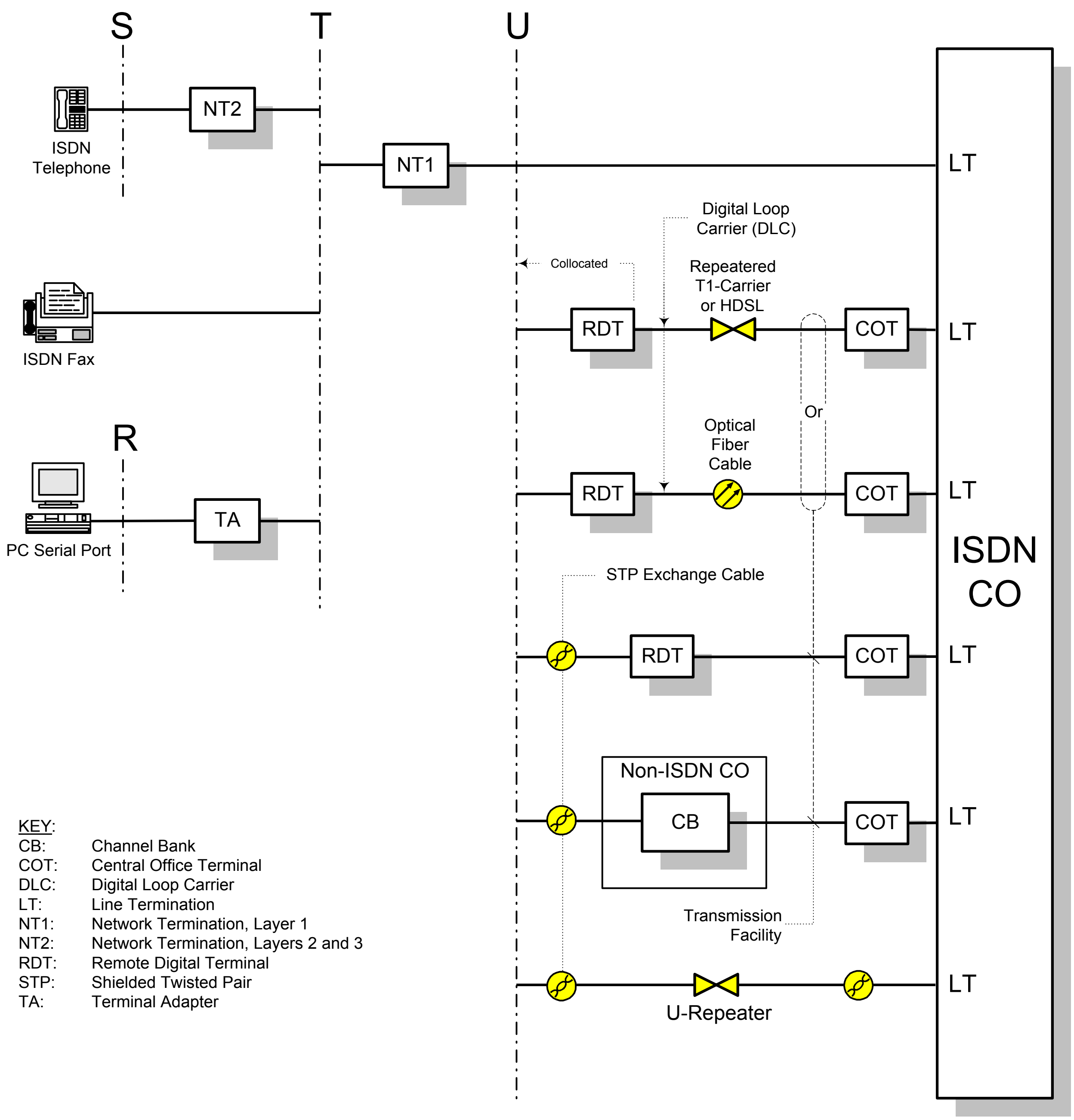


ISDN compliant terminal equipment is designated TE1 and can be connected either to an S- or T-reference point. The S- and T-interfaces are electrically identical but they serve different functions. Equipment connected to the T-interface can directly communicate only with the U-interface (through the NT1). Such equipment cannot communicate directly with other TE1 connected to the same T-interface. On the other hand, TE1 connected to the S-interface can communicate with other equipment connected to that same S-interface through the NT2. The ISDN standards allow up to eight ISDN Terminal Equipment (TE1) to be connected to each S- or T-interface. However, some end offices (or more specifically, some versions of the Nortel DMS-100) do not support more than two TE1 on one interface.

8. BRI Access Configurations

The BRI may be provided through several different transmission technologies. Some possibilities are shown in Fig. 8. In most situations (probably 90%), the existing shielded twisted pair (STP) exchange cables will be used. When STP is used, the digital loop is called a Digital Subscriber Line (DSL). The length limits of the DSL are described later. In special or unusual installations, a U-Repeater, also called Basic Rate Interface Transmission Extension (BRITE), may be used to extend the DSL to approximately twice its normal distance.

Fig. 8
BRI Access Configurations



Other methods use Remote Digital Terminals (RDT), also called Digital Loop Carrier (DLC) Remote Terminals (RT). These methods are used to extend the distance between the serving central office and the Network Interface to 200 miles, or more. The RDTs may be served by repeatered

T1-carrier or optical fiber cables. It is only necessary that the transmission systems have Clear Channel Capability. With repeatered T1-carrier, this requires that the B8ZS[5] line code (or ZBTSI[6]) be used.

If the RDT is collocated with the Customer Installation, the U-interface will be conveniently available within a short distance of the RDT. However, the RDT does not have to be collocated; STP exchange cables may be used between the customer and RDT. It only is necessary to locate the RDT within the distance limitations of the DSL.

Conversion of central offices to ISDN requires capital and time. It may be desirable to delay conversion of a particular central office because of low demand for ISDN services. In this situation, ISDN may be provided to customers of that serving central office by installing a channel bank with ISDN BRI channel units. Fig. 8 shows such an installation in a non-ISDN central office. It only is necessary that the exchange cable length between the serving central office and the customer meet the distance limitations for the BRI.

9. ISDN Digital Subscriber Line Design

The loop associated with the BRI is called Digital Subscriber Line, or DSL. The DSL was originally designed to be deployed without extensive engineering or qualification on any nonloaded loop meeting the Resistance Design requirements.[7] This basically is 18,000 ft. of 24 AWG cable. When BRI service is requested by a customer, many companies (particularly Bell Operating Companies) simply check plant records to determine if the loop is less than 18,000 ft. If the service does not actually work, then another cable pair is chosen or loop tests are performed to determine the cause or reassignment is made. This method assumes highly accurate records and probably provides a 90% success rate on the first try.

It may be necessary to qualify older cable plant for DSL service. Old cables are always air core PIC or pulp insulated and some may have a history of flooding. Moisture in air core cables greatly affects their transmission characteristics. Also, it is possible that errant load coils exist on the pairs to be used for DSLs, and these must be removed before the loop can be used. Table 2 summarizes the requirements for the DSL.

A given DSL will include central office cabling, outside plant cable pairs and cabling and wiring in the Customer Installation. The insertion loss of each segment may be allocated as listed below and shown in Fig. 9. The allocations shown are not standardized, and the length, or corresponding loss, of the end segments will depend on the cable type and the design temperature. The central office and outside plant cable losses my be adjusted to specific situations. The loss in the CI wiring was somewhat of an arbitrary choice by the National ISDN User's Form - NIUF - and was meant to represent a worst-case; it, too, may be adjusted to specific situations. The important thing to remember is that the total of all three segments - central office wiring, outside plant cable, and CI wiring - should not exceed 42 dB at 40 kHz.

---

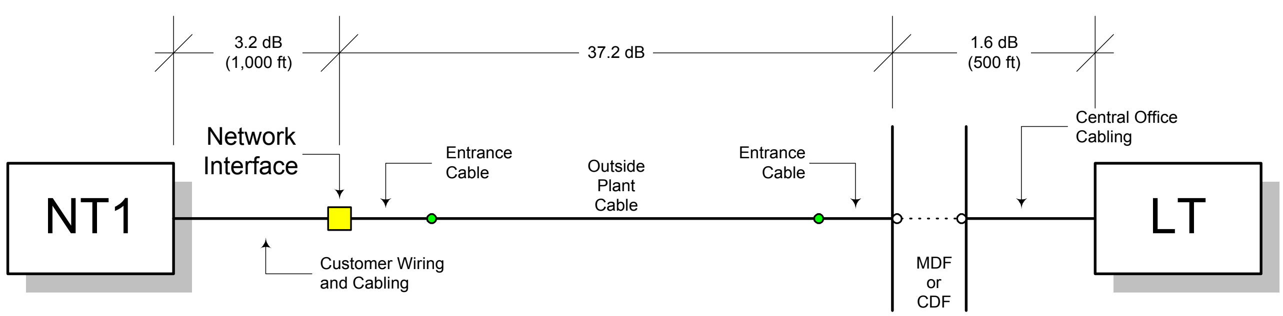
[5] B8ZS stands for Bipolar with Eight Zero Substitution. See [4] for a description of B8ZS.
[6] ZBTSI stands for Zero Byte Time Slot Interchange. It is not recommended as a long-term solution to providing Clear Channel Capability.
[7] See [8] for a description of Resistance Design.

- 1.6 dB corresponding to approximately 500 ft of wiring between the switching system LT (or RDT BRI channel unit) and the distributing frame in the central office (or RDT distribution frame)
- 37.2 dB for outside plant facilities
- 3.2 dB corresponding to approximately 1,000 ft of wiring between the network interface and the NT1

Table 2
DSL Design Requirements

Parameter	Requirement
Cable	Nonloaded cable only
DC loop resistance	1,300 ohms maximum
Loop length	18 kft maximum (15 kft for 26 AWG cable)
Bridged taps	No individual bridged tap greater than 2 kft No more than 6 kft total of all bridged taps
Insertion loss	42 dB maximum at 40 kHz between 135 ohm terminations.
Insulation resistance	Greater than 300 kohms T to R or T or R to ground
Wideband circuit noise	$\leq$ 37 dBrn50kb
Voiceband circuit noise	$\leq$ 20 dBrnC
Power influence	$\leq$ 80 dBrnC
Voiceband pair balance	$\geq$ 60 dB
Impulse Noise	0 counts in 30 minutes at 57 dBrn50kb threshold

Fig. 9
DSL Loss Allocation



When a loop exceeds the loss limit of 42 dB at 40 kHz, an ISDN repeater, commonly called a U-Repeater, may be used. Depending on the configuration, the loss between the LT and the U-Repeater may have to be reduced by 2 to 6 dB. The loss between the U-Repeater and the NT1 normally can be designed to the full 42 dB limit. Fig. 11 shows a few configurations.

In the upper part of Fig. 10, the U-Repeater is locally powered. In this case, the loss between the LT and the U-Repeater can reach the full 42 dB limit. The disadvantage of this configuration is the requirement for a local dc power supply with battery backup.

In the middle part of Fig. 10, the U-repeater is loop powered by a special powering module in the serving central office. This powering module will provide either a constant voltage in the range of 100 to 130 vdc or a constant current in the range of the 40 to 43 mA. Due to the insertion loss of the powering module, the loop limit between the LT and U-Repeater is reduced by 2 to 6 dB depending on the manufacturer (2 dB reduction is shown in the figure).

The lower part of Fig. 10 shows the application of Remote Digital Terminals (RDT) or channel bank to extend the LT functionality to a non-ISDN compliant central office or other remote location. This is similar to the situation shown in Fig. 9 except that the loop beyond the central office with the RDT uses a U-Repeater. The ISDN BRI channel unit in the RDT must have a repeater powering option.

Table 3
Twisted Pair Data at 40 kHz

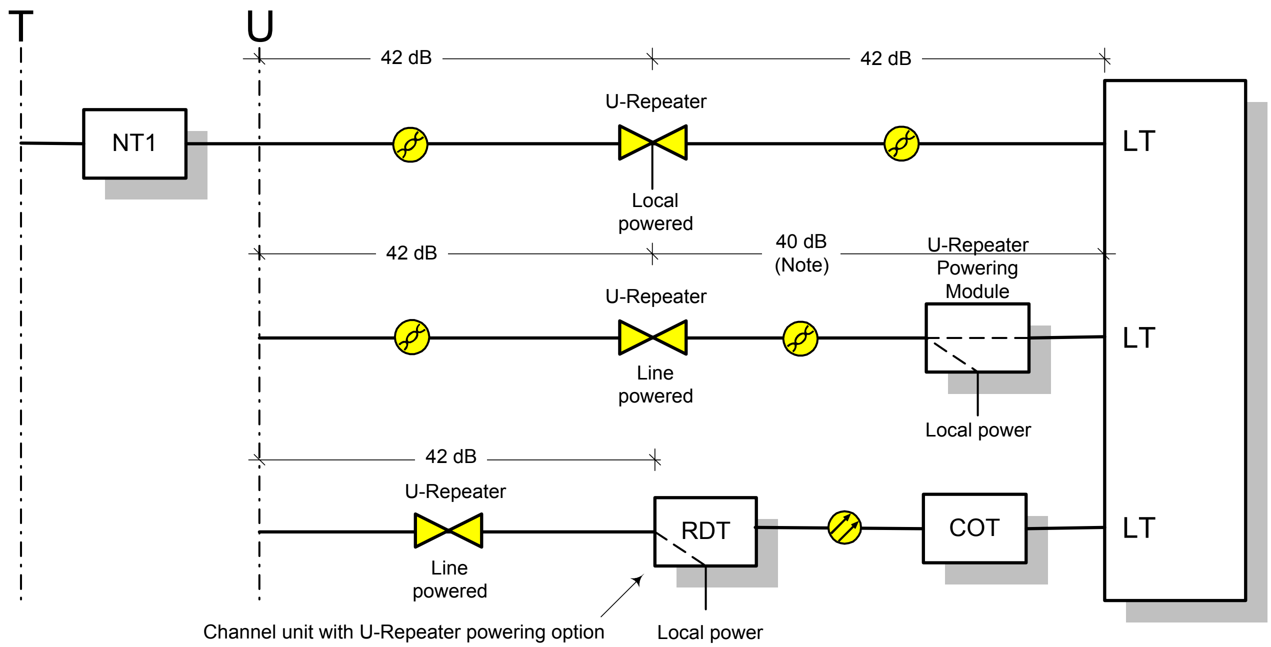
	19 AWG	22 AWG	24 AWG	26 AWG
Loss at 21°C (dB/kft)	0.77	1.32	1.90	2.70
Loss at 38°C (dB/kft)	0.81	1.39	2.00	2.80
Loss at 60°C (dB/kft)	0.86	1.49	2.13	2.98
TC (%/10°C)	3.1	3.3	3.0	2.7
BT Loss (dB/kft)	0.34	0.56	0.76	0.97

Mixed cable gauges are allowed, but normally only one or two gauges will be encountered in any given distribution area. Single gauge is preferred. Table 3 shows the unit loss in dB/kft for each cable gauge at various design temperatures. Also shown is the temperature coefficient and bridged tap loss. The temperature coefficient may be used to adjust the loss given at 21°C to any other design temperature. The bridged tap losses given are valid for bridged tap lengths less than 2.5 kft. The values given in Table 3 may be used with air core PIC, filled PIC and DEPIC. Fig. 11 shows the loss vs. length for each cable gauge assuming no bridged taps and a single gauge.

10. Interference Considerations

The DSL is compatible with most analog loops, subrate digital loops, HDSL, ADSL and repeatered T1-Carrier. It can share a binder group in a common cable with these technologies. However, the DSL interferes, through crosstalk, with analog subscriber carrier (both single and multi-channel) and analog program audio channels for TV and radio studios. The interference with these technologies is most severe when they are in the same binder group as the DSL, as would be expected. Performance degradation of the analog loops may not be noticed when only a few DSLs are operated. However, as more DSLs are assigned to the cable, the cumulative crosstalk power will increase and, at some point, there will be destructive interference. The point at which the interference becomes destructive is not predictable. For universal deployment of the DSL, analog subscriber carrier and program audio channels will have to be removed.

Fig. 10
DSL Repeater Applications



Note: Some U-Repeaters require the loss be reduced from 42 dB by 3 to 6 dB (instead of 2 dB shown).

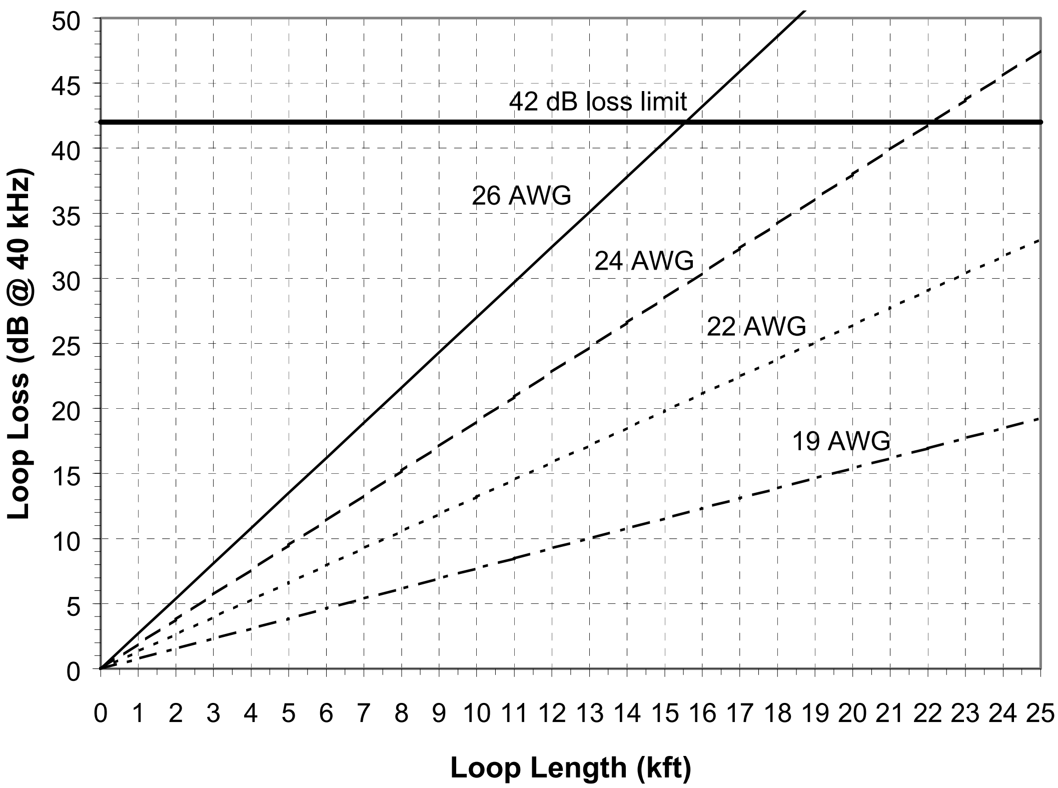
11. Interexchange Carrier Access

ISDN calls usually are routed over the same interoffice transmission facilities as regular message toll service (MTS) and Switched 56 calls. ISDN calls may be subject to service limitations because:

- Many end offices are not interconnected to IXCs via Signaling System No. 7 (SS7)
- Many IXCs do not have clear channel capability (CCC) and, thus, cannot transmit or switch 64 kb/s services. Instead, these IXCs support only 56 kb/s transmission and switching
- Many interoffice transmission facilities in local exchange networks do not support CCC due to not having B8ZS or ZBTSI capability

These are serious limitations to the types of ISDN services available but do not completely preclude long distance calls from an ISDN line. However, the BRI NT1 and associated terminal equipment must be configured for 56 kb/s on each B-channel. This usually is an option, which may be changed through the terminal equipment or NT1 configuration software or hardware switch settings. Depending on the capabilities of the end office and terminal equipment, the D-channel may or may not be available for access to packet switched networks such as X.25. Nevertheless, the D-channel still is used by the end office for call setup, takedown and signaling between the end office and the ISDN user terminal equipment.

Fig. 11
Loop Loss at 40 kHz vs. Loop Length at 21°C
(No bridged taps, single gauge)



12. References

[1] Volume VIII, Fascicle VIII.4, Data Communication Networks: Open Systems Interconnection (OSI) - Model and Notation, Service Definition. Recommendations X.220 - X.290, CCITT Blue Book, Geneva, 1989.

[2] Vol. III, Fascicle III.5, Digital Networks, Digital Sections and Digital Line Systems, Rec. G.801 - G.961, CCITT Blue Book, Geneva, 1989.

[3] ITU-T Rec. G.961, Digital Sections and Digital Line Sections, Digital Transmission System On Metallic Local Lines For ISDN Basic Rate Access, Geneva, 03/93.

[4] Vol. VIII, Fascicle VIII.1, Data Communication Over The Telephone Network, Rec. V.120, Support by an ISDN of Data Terminal Equipment with V-Series Type Interfaces with Provision for Statistical Multiplexing, CCITT Blue Book, Geneva, 1989.

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

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

[7] TIA/EIA-568-A, Commercial Building Telecommunications Wiring Standard, Telecommunications Industry Association/Electronic Industries Association, Sept. 1995.

[8] ANSI T1.401-1993, Telecommunications - Interface Between Carriers and Customer Installations - Analog Voicegrade Switched Access Lines Using Loop-Start and Ground-Start Signaling.

[9] Reeve, W., Subscriber Loop Signaling and Transmission Handbook: Analog, IEEE Press, 1992.

Availability: TIA/EIA standards are available from Global Engineering Documents by calling 1+800-854-7179. Bellcore documents are available from Bellcore by calling 1+800-521-2673. 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. Most CCITT and ITU recommendations through December 1994 are available on CD-ROM at very low cost ($30) from InfoMagic, P.O. Box 30370, Flagstaff, AZ 86003-0370, tel. 1+800-800-6613, fax 1+602-526-9573. Recommendations and standards are also available on CD-ROM or paper directly from ITU, Sales Service, CH-1211, Geneve 20 (Switzerland), fax 41+22-730-5194. The CCITT Blue Book and many individual ITU recommendations are available from NTIS, US Department of Commerce, Springfield, VA 22161, fax 1+703-321-8547.

Appendix: Circuit and Packet Mode

In telecommunications, information is switched and transmitted either by circuit mode or packet mode techniques. In the circuit mode, the digital bits that represent the information, are switched and transmitted in a consecutive and regular flow through a channel set up for the duration of the call. When the call is finished, the channel is disconnected and becomes available to another caller. Voice and video services usually use circuit mode techniques. Time division multiplexing (TDM) techniques are used to interleave more than one channel on a high-speed transmission path, but in current applications, the channels (for example, 64 kb/s B-channels) are switched on an individual basis.

In the packet mode, the digital information bits are organized into packet units and then each packet is switched and transmitted in an intermittent and irregular flow. Packets may be of fixed or variable size depending on the type of network or technology used. Each packet has a destination address associated with it, so that packets from many channels (users) can be routed over common facilities. The addresses of packets are interrogated at intermediate locations in the network and the packets are then routed to their appropriate destinations. The channel through which the packets flow may be set up for the duration of the call or may be determined by the network for each packet. A high-speed transmission path is shared by many users. Data communication services between computers, local area networks, data terminals, point-of-sale terminals and automated teller machines usually use packet mode techniques.

Data communication traffic is bursty (heavy use intervals interspersed by low use intervals) and is more easily handled by packet mode networks than circuit mode networks. Packet switched networks are characterized by significant processing and handling delays, which may vary with each packet. It is for this reason that voice and video are not easily served by packet switched networks. ATM networks are an exception in that they are designed to handle voice, video and data equally well.

There are two general types of packet networks - connection-oriented (for example, X.25 networks) and connectionless-oriented (for example, TCP/IP). A connection-oriented packet network allows service users (that is, entities in the next higher protocol layer) to establish and use logical connections. A connectionless-oriented network allows service users to exchange information without having to establish a connection. A query-response type service is an example of a connectionless-oriented service.

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

Copyright Notice:

Warning & Disclaimer:

Document Information:

Author: Whitham D. Reeve

Revision: 1 (original issue, February 17, 1996)
2 (minor corrections, converted to PDF, November 1, 2003)

File: ISDN BRI No6.doc