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Meridian Digital Centrex

ISDN U-Loop and S/T-Bus Engineering

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Meridian Digital Centrex

ISDN U-Loop and S/T-Bus Engineering

Reference Manual

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About this guide

This guide provides the information you need to engineer the loops associated with the ANSI standard 2B1Q version of the ISDN Network Termination 1 (NT1).

How to use this guide

This guide is organized into three sections:

- *Engineering ISDN loops* briefly describes the loops associated with the NT1.
- *U-loop engineering* provides engineering rules and procedures for installing the U loop.
- *S/T-bus engineering* describes the engineering of the S/T-bus.

Related guides

There are two guides related to this one, which can provide you with information you need if you are planning the network and the customer premises equipment:

- *Network Termination 1 (NT1) Description*, 297-2451-107, is an introduction to the NT1 and the network.
- *NT1 and S/T-Bus Installation Guide*, 297-2451-207, helps you install the network.

A corresponding set of documents is provided for the AMI version of the NT1:

- *Network Termination 1 (NT1) Description*, 297-2451-106
- *NT1 and S/T-Bus Installation Guide*, 297-2451-206
- *ISDN S/T-Bus and U Loop Engineering Guide*, 297-2451-181

Engineering ISDN loops

This guide contains rules and procedures for engineering the loops associated with 2B1Q ISDN basic rate access (BRA) applications. The rules have been based on

- performance requirements for the 64 kb/s digital data service
- transmission characteristics of ISDN systems
- outside plant constraints
- flexibility of inside wiring configurations
- specifications associated with the integrated service line card (ISLC) and the Network Termination 1 (NT1)

U loop

In the ISDN network, the service connection to the ISDN central office (CO) is referred to as the U loop. This 2-wire access loop connects the NT1 at the customer premises to the ISLC in the central office. This equipment is designed to adapt to various U-loop configurations, assuming that they are non-loaded (no loading coils) and are within the Operating Loss Limits. The U-loop loss must take into account the total loss of all cabling between the NT1 and the ISLC (CO wiring, outside plant, and customer premises wiring). The loss level is affected by various factors, such as cable type and bridged taps, and may be established by actual measurements at 40 kHz, or by calculation using cable records.

S/T bus

The connection between the terminal equipment (TE) and the NT1 for basic rate ISDN access is referred to as the S/T bus. This bus consists of a minimum of four wires, and is located at the customer premises. A variety of S/T bus wiring configurations are supported, to allow flexibility for the installation of the NT1 and associated TEs.

The main operating limits are cable loss and propagation delay, which determine the length of the S/T bus and the separation distance between TEs.

ANSI standards compliance

The ISLC and the NT1 comply with the ANSI U loop performance specifications by meeting the requirements for the null loop and ANSI test loops #4 - #15. These loops include mixed gauges and bridged taps which exhibit a U-loop loss within the Application Loss Limit of 40 dB at 40 kHz as outlined in 'U-loop parameters' in part 2 of this guide.

The NT1 meets the performance requirements of all ANSI-specified S/T bus configurations consisting of point-to-point, short passive, and extended passive busses. The NT1 also meets the requirements of the additional bus configurations defined in the ANSI Appendix.

ANSI references

1. 'Integrated Services Digital Network - Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification)', ANSI T1.601-1988.
2. 'Integrated Services Digital Network - Basic Access Interface for S and T Reference Points (Layer 1 Specification)', ANSI T1.605-1988.

U-loop engineering

This part of the manual provides guidelines and engineering rules for installing the U loop. (Refer to the ANSI standard for ANSI loops numbers 4 to 15.)

U-loop parameters

The ISDN basic access system provides bidirectional transmission of digital information at 160 kbaud over a single customer 2-wire access loop. The specifications for the main U-loop parameters are listed in Table 2-1.

Table 2-1
U-loop parameters

Parameters	Specification
Line transmit rate	160 kbaud
Information rate (customer data)	144 kb / s (2B + D)
Operating loss limits (with 49 disturbers)	46 dB at 40 kHz (BER = 10^{-7})
Recommended application loss limit	40 dB at 40 kHz (BER = 10^{-7})
Line code	2B1Q (2 binary, 1 quaternary)
Transmitted peak voltage	2.5 V nominal into 135 ohms resistive load
Terminating impedance	135 ohms, ± 10% resistive (0 kHz to 160 kHz)

Definitions

- Bit error rate (BER): The BER performance objective for ISDN systems is set at 10^{-7} to ensure satisfactory transmission of digital data using the B1, B2, and D channels.
- Operating loss limit: Operating loss limit is the achieved loop loss with 49 disturbers and 0 dB margin. The operating loss may be reduced by impulse noise and other loop impairments (refer to Table 2-2).
- Application loss limit: The recommended application loss limit is the loss to which the loop can be engineered and is obtained by subtracting the applicable margin (from Table 2-2) from the operating loss limit.

Table 2-2
Loop impairment assumptions

Parameter	Loss
Impulse noise (estimate)	3 dB
Added crosstalk margin for 99 disturbers	2 dB
Other loop impairments	1 dB
Total maximum margin (buried cable)	6 dB

Recommendations for U-loop engineering

The main recommendations for U-loop engineering include:

- the general loop conditions that must be satisfied to meet 10^{-7} BER
- allowable cable gauges for various bridged tap configurations
- the existing transmission systems that can share the same multi-pair cable with ISDN systems

Loop conditions

The selected U loops should satisfy the general conditions described in the following paragraphs. As a minimum requirement, a loop should be suitable for POTS deployment.

Inductive and capacitive devices

Inductive and capacitive devices (e.g., loading coils, build-out capacitors, bridge lifters, and induction mitigation devices) are not allowed on ISDN loops, as these devices severely attenuate the ISDN signal.

Bridged taps

The 2B1Q transmission system was designed to handle any combination of loop and bridged tap gauges.

The maximum recommended loop length is engineered such that the sum of the 40 kHz loop loss plus the 40 kHz loss due to all bridged taps is within the application loss limit.

When calculating the loop loss, add 1.7 dB to the application loss for every 1 k foot (up to 3 k feet) of a single bridged tap. For bridged taps 3 k feet and longer, simply add 5.1 dB to the application loss. (Refer to the section “U loop qualification” for more detail.)

For multiple bridged taps, determine the loss for the individual bridged taps as described above, and calculate the loss value by adding the individual losses to the application loss.

When no bridged taps exist on the loop, the loop can be made up of any gauge. It is recommended that the 'no bridged tap' cable length is engineered such that its 40 kHz loop loss is within the application loss limit of 40 dB.

When required, and when the conditions of the outside plant permit, the cable length can be engineered such that its 40 kHz loop loss is within the operating loss limit of 46 dB. (Refer to Table 2-3.)

Table 2-3
Maximum recommended cable length

Cable gauge (AWG)	Cable length in km (k feet)	
	Application loss limit	Operating loss limit
26	14.5 (4.40)	16.5 (5.00)
24	21.5 (6.55)	25.0 (7.60)
22	29.0 (8.80)	32.0 (9.75)
mixed	18.0 (5.50)	20.4 (6.20)

Crosstalk compatibility of ISDN systems

Two systems sharing the same multi-pair cable are crosstalk compatible if neither system induces or receives an unacceptably high interfering noise to or from the other system via electromagnetic coupling.

The ISDN U loop is crosstalk compatible (within the same cable binder group) with all existing systems (e.g., POTS, DDS, Datapath, T1 systems) when these systems have been deployed according to their respective crosstalk limited reach. Carrier systems such as Added Main Line (AML) and multi-channel subscribers such as Anaconda S6A are not compatible with ISDN, and should not share the same cable.

U-loop qualification

To determine whether a loop qualifies for ISDN loop service, follow this procedure:

1. Select the loop to be used as an ISDN U loop.
2. Make sure that the loop meets the engineering recommendations.
3. Enter the recommended application loss limit in Table 2-4 for cable as 40 dB.
4. Enter the total length of each type of cable that makes up the loop in Table 2-4, and multiply these by the loss constants to determine the total loss for each type of cable.
5. If the loop contains bridged taps, use Figure 2-1 to determine the loss associated with each bridged tap, and enter the values in Table 2-4.
6. Enter the losses associated with central office (CO) wiring and customer premises (CP) wiring in Table 2-4.
7. Using Table 2-4, determine the total loss of the selected loop.
8. If the total loop loss from Table 2-4 is less than or equal to the recommended application loss, the loop qualifies as an ISDN U loop.
9. If the loop qualifies as an ISDN loop but does not operate with the required BER, refer to “U-loop diagnostics”, or select another loop and repeat this procedure.

Table 2-4
Calculating ISDN loop loss

Gauge (AWG)	Insulation type	Unit loss dB/km (dB/k foot)	Length km (k feet)	Loss (dB)
19	PIC	3.3 (1.0)		
19	PULP	3.6 (1.1)		
22	PIC	4.6 (1.4)		
22	PIC	4.9 (1.5)		
24	PIC	5.9 (1.8)		
24	PULP	6.3 (1.9)		
26	PIC or PULP	9.2 (2.8)		
Customer premises wiring		5.9 (1.8)		
Central Office wiring		9.2 (2.8)		
Bridged tap 1				
Bridged tap 2				
Bridged tap 3				
Bridged tap 4				
Bridged tap 5				
Bridged tap 6				
Total loop loss in dB				
Recommended application loss limit for cable = 40 dB				

As an example of this procedure, consider the loop represented in Figure 2-2, assuming PIC type buried cable throughout the loop. To determine if the loop meets ISDN service qualifications:

1 The selected loop is represented in Figure 2-2.

2 The loop meets the engineering recommendations.

3 All cable is buried, so the recommended application loss limit is 40 dB; enter this value in Table 2-4.

4 The total length of 24 AWG cable (L1 plus L2) is 2.3 km (7.5 k feet), and the total length of 26 AWG cable (L3) is 0.8 km (2.7 k feet). Enter these values in Table 2-4, and multiply by the loss constants.

5 From Figure 2-1, the loss for bridged tap BT1 is 3.06 dB, and for BT2 is 1.2 dB. Enter these values in Table 2-4.

6 Enter the lengths of the CO and CP wiring in Table 2-4, and multiply by the loss constants.

7 Add all items to give a total loop loss of 26.84 dB.

8 The total loop loss is less than the recommended application loss, so the loop qualifies as an ISDN loop.

Table 2-5 is a completed table using the values in this example, calculated in thousand foot units.

Figure 2-1
Added loop loss vs single bridged tap length

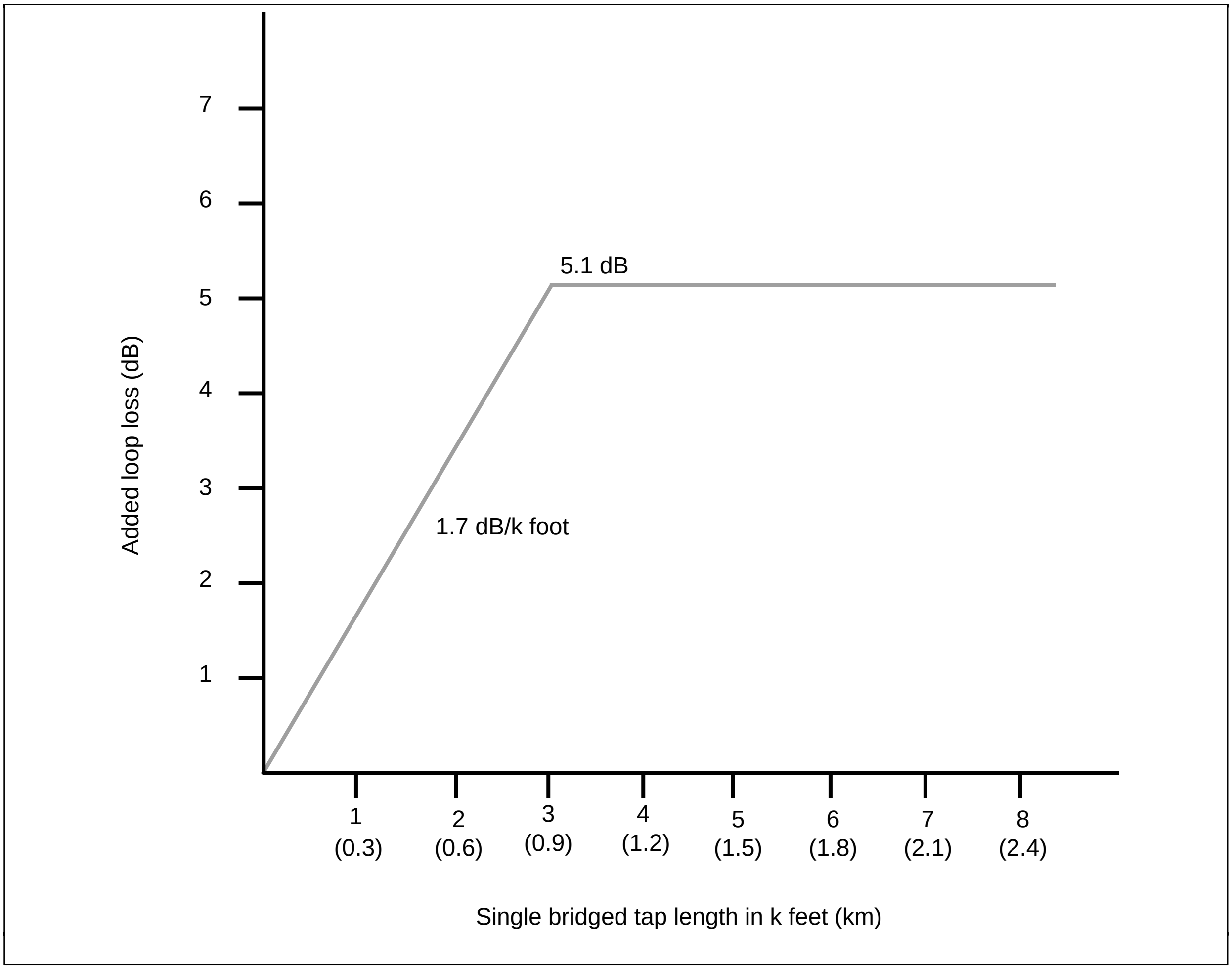


Figure 2-2
Sample calculation loop

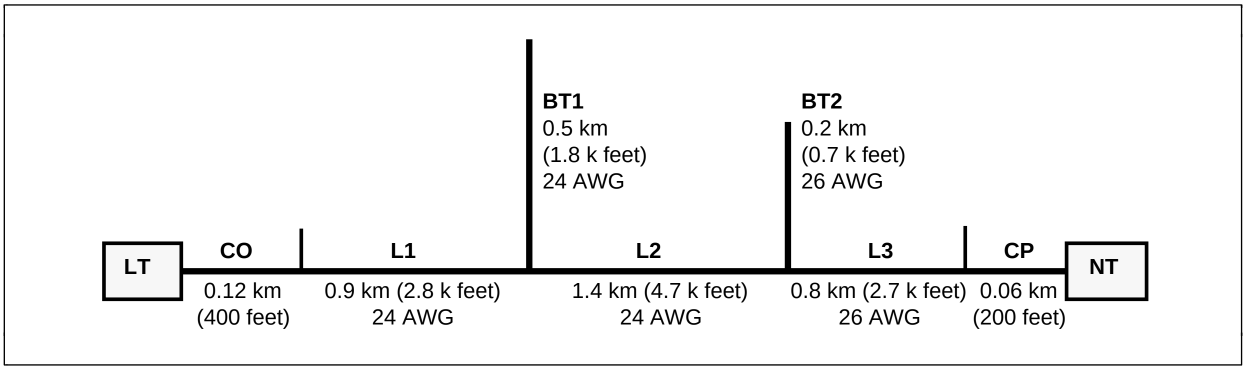


Table 2-5
Calculating ISDN loop loss-completed sample table

Gauge (AWG)	Insulation type	Unit loss dB/km (dB/k foot)	Length km (k feet)	Loss (dB)
19	PIC	1.0		
19	PULP	1.1		
22	PIC	1.4		
22	PIC	1.5		
24	PIC	1.8	7.5	13.50
24	PULP	1.9		
26	PIC or PULP	2.8	2.7	7.56
Customer premises wiring		1.8	0.4	0.72
Central Office wiring		2.8	0.2	0.56
Bridged tap 1			1.8	3.06
Bridged tap 2			0.7	1.20
Bridged tap 3				
Bridged tap 4				
Bridged tap 5				
Bridged tap 6				
Total loop loss in dB				26.6
Recommended application loss limit for cable = 40 dB				40

U-loop diagnostics

If the loop's BER exceeds 10^{-7}, there could be several factors involved: loop loss, background noise, and bridged taps are typically the factors affecting ISDN system performance.

Loop loss

The BER may exceed the specified level if the measured loop loss is higher than the recommended application loss limit (40 dB for buried cable). Loop loss should be measured by applying a continuous wave signal at 40 kHz to one end of the loop, and measuring its level in 135 ohms termination at the other end with a transmission test set.

Background noise

The total background noise in a 100 kHz band induced on the loop from all sources of interference should not exceed 65 dBrn (unweighted) for a loop loss of 40 dB to achieve a BER of 10^{-7}. If the loop loss is lower, for example by 6 dB, the allowed background noise is higher by that amount (e.g., for a 37 dB loop loss, the value would be 71 dBrn). The values for background noise versus loop loss are listed in Table 2-6.

The total background noise measured in a 50 kHz band induced on the loop from all sources of interference should not exceed 57 dBrn for a loop loss of 40 dB to achieve the required BER. If the loop loss is lower, for example by 6 dB, the allowed background noise is higher by that amount (e.g., for a 34 dB loop loss, the value would be 63 dBrn). (Refer to Table 2-6.)

Background noise can be measured using a 50 kHz measuring device with a 100 kHz bandwidth and 135 ohms termination impedance.

Impulse noise

To meet a BER of 10^{-7} on a loop loss of 40 dB at 40 kHz, the zero count impulse noise threshold is 63 dBrn in a 100 kHz bandwidth, and 62 dBrn in a 50 kHz bandwidth. The zero count impulse noise threshold results in a 2B+D error count of no more than 6 errors/B-channel in 15 minutes and 1 error/D channel in 15 minutes.

The values for impulse noise threshold levels versus loop loss are listed in Table 2-6 for a BER of 10^{-7}.

Bridged taps

The loop may not meet a BER of 10^{-7}, if it doesn't meet the bridged tap recommendations provided earlier in this section. Bridged taps could be the cause of unsatisfactory performance if the cable records are incorrect, particularly in cases in which only the total length of the bridged taps is known and no gauge or individual length information is available. In these cases, consider removing the bridged taps, or select another loop.

Table 2-6
Background and impulse noise threshold levels vs loop loss for a BER of 10^{-7}

Loop loss (dB)	Background noise (dBrn) 100 kHz band	50 kHz band	Impulse noise threshold level (dBrn) 100/50 kHz band	Using HP4935A (50 kb)
40	65	57	63	62
39	66	58	64	63
38	67	59	65	64
37	68	60	66	65
36	69	61	67	66
35	70	62	68	67
34	71	63	69	68
33	72	64	70	69
32	73	65	71	70
31	74	66	72	71
30	75	67	73	72
29	76	68	74	73
28	77	69	75	74
27	78	70	76	75
26	79	71	77	76
25	80	72	78	77
24	81	73	79	78
23	82	74	80	79
22	83	75	81	80

S/T bus engineering

This part of the manual provides guidelines and engineering rules for installing both simple and complex S/T-bus wiring configurations. It is recommended that the simple S/T-bus configurations be installed whenever possible. These configurations can be installed in most office and industrial sites, and require you only to follow fairly simple guidelines. However, for the more complex installations, detailed engineering rules are also provided.

Bus parameters

The ISDN S/T-bus provides the communication between the NT1 and the terminal equipment (TE) at a full duplex rate of 192 kb/s over four wires consisting of receive and transmit pairs. Table 3-1 lists the main parameter specifications of the S/T-bus.

Table 3-1
S/T-bus parameters

Parameters	Specification
Line transmit rate	192 kb/s ± 100 ppm
Information rate	144 kb/s (2B + D)
Operating loss limits:	
point-to-point	7 dB relative to the nominal pulse height
extended passive	5.5 dB relative to the nominal pulse height
Operating delay limits (round trip):	
point-to-point	10 - 42 µs
short passive (fixed timing)	10 - 13.9 µs
short passive (adaptive timing)	10 - 13.0 µs
extended passive (adaptive timing)	10 - 42 µs 0 - 2.75 µs (differential between TEs)
Line code	Pseudoternary, 100% pulse width
Pulse height	750 mV ± 10%
Pulse width	5.21 µs ±100 ppm
Termination resistance	100 ohms (both ends of bus) ± 5%

Definitions

• Bit error rate (BER)	The BER performance for the S/T-bus is better than 10^{-8} in order to meet the overall ISDN system performance objective of 10^{-7}.
• Operating limits	The operating limits (loss and delay) are achieved at the specified BER with a 100 mV (peak-to-peak) sinusoidal signal at the receiver (NT1) input.
• Cable loss	Cable loss refers to the voltage attenuation of the transmitted signal level along the S/T-bus, and is dependent on the type of cable used. Cable loss is the limiting factor determining the total length for point-to-point and extended multipoint configurations.
• Round trip delay	Round trip delay refers to the total time delay between transmission of a bit from the NT1 to the TE, and the reception at the NT1 of the corresponding bit transmitted from the TE. This round trip delay consists of the total of the following contributions: • 2-bit offset in framing (10.42 μs) • jitter and phase delay of TEs (0.78 μs maximum) • round trip propagation delay of unloaded bus (i.e., without TEs) • additional round trip propagation delay due to the bus loading (i.e., number of TEs).
• Maximum round trip delay	Maximum round trip delay is the limiting factor determining the bus length for configurations using fixed timing.
• Differential round trip delay	Differential round trip delay refers to the difference in round trip delays from the NT1 to various TEs. The maximum differential round trip delay is the limiting factor in determining the maximum separation between TEs for configurations using adaptive timing.

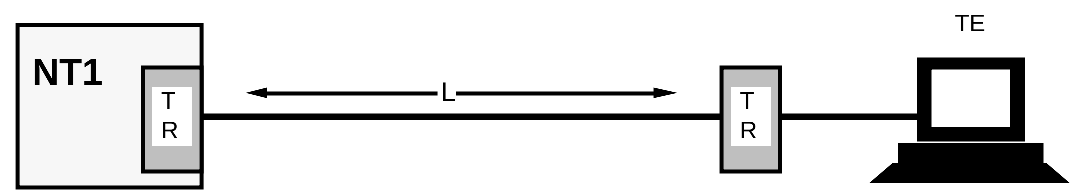
Wiring configurations

This manual discusses five types of S/T-bus configuration:

- point-to-point
- short passive
- extended passive
- short branched passive
- branched passive

Any of these configurations can be used with either the stand-alone NT1 or the modular version. In the modular NT1, two S/T-buses can be connected to the Star NT1 unit, which provides two S/T interfaces. Figure 3-1 illustrates the basic point-to-point loop, and Figure 3-2 shows the basic configuration using a star NT1 unit, which is, in effect, two point-to-point loops. Figures 3-3 to 3-6 illustrate the short passive, extended passive, short branched passive, and branched passive bus configurations, respectively.

Figure 3-1
Point-to-point configuration



Note: L is length limited by cable loss

Figure 3-2
Star configuration

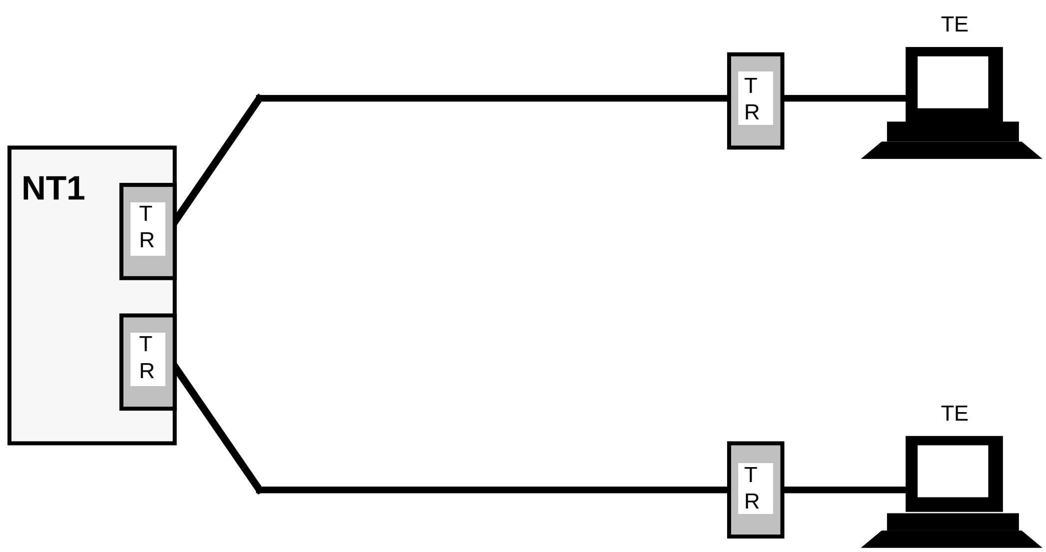
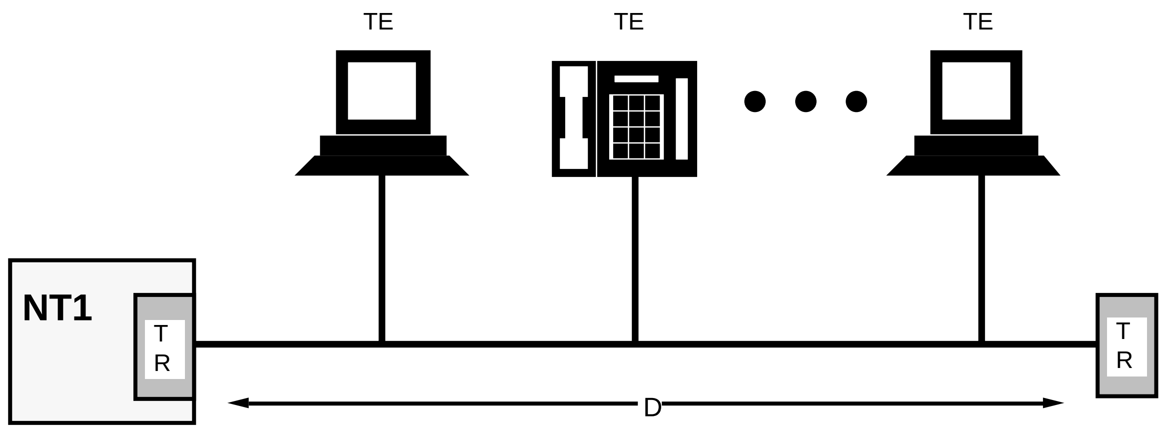
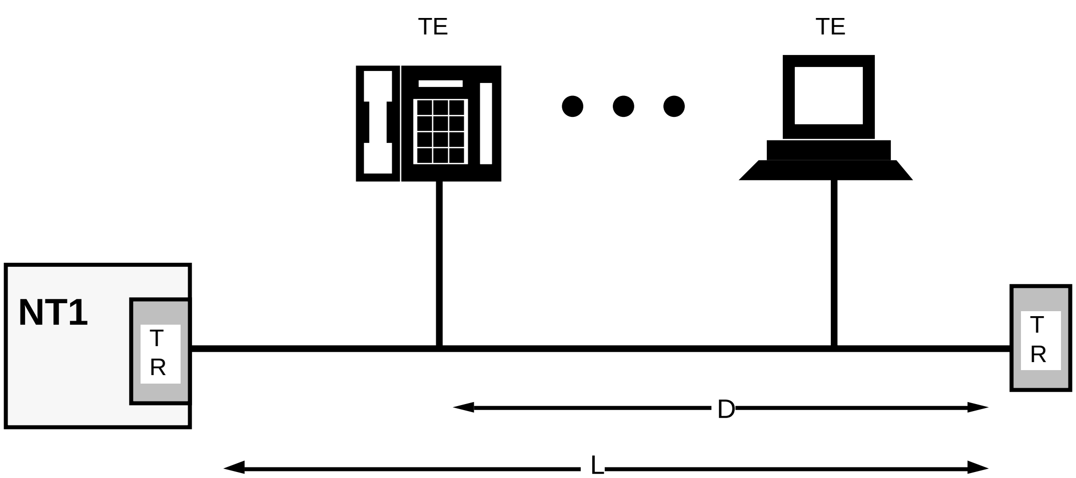


Figure 3-3
Short passive bus configuration



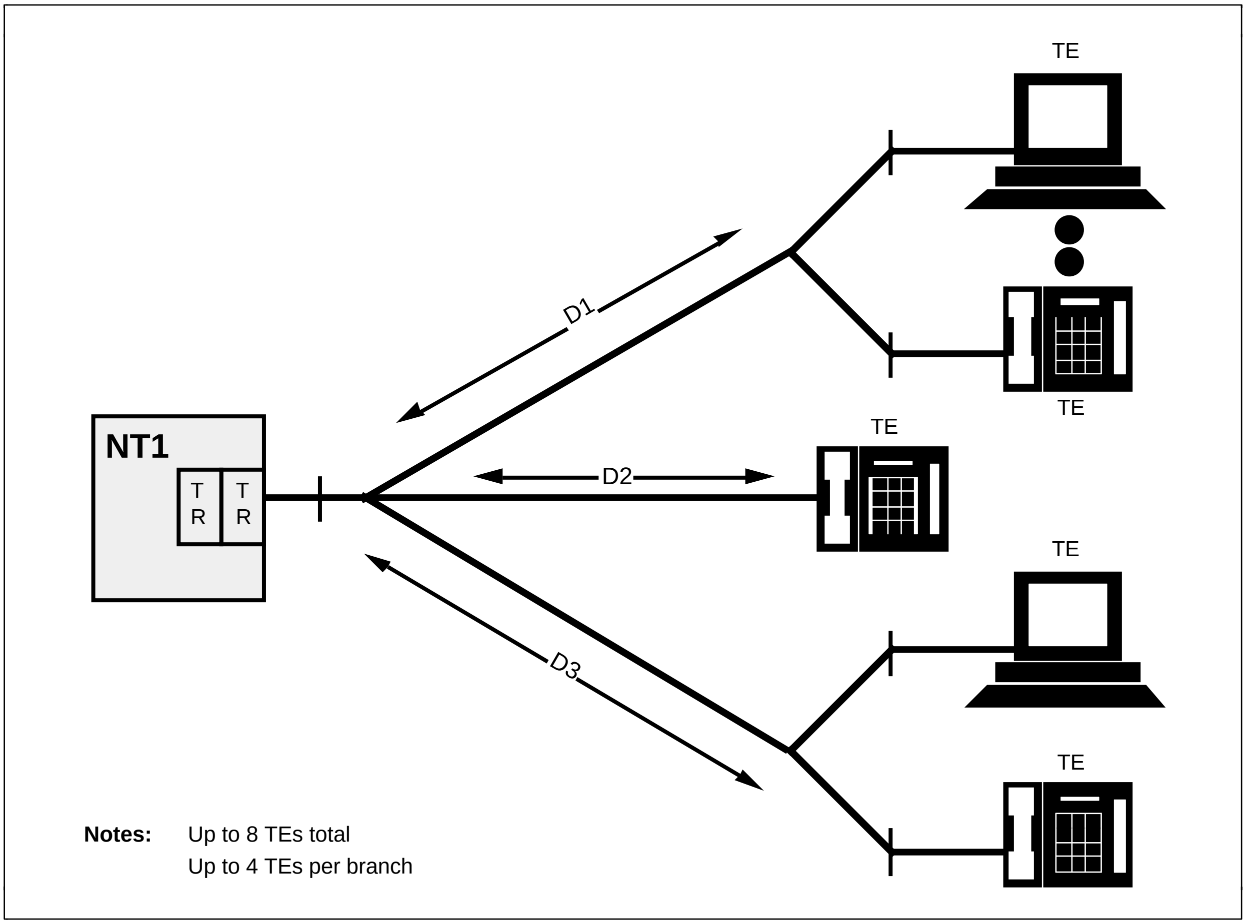
Notes: Up to 8 TEs are allowed
D is separation limited by delay

Figure 3-4
Extended passive bus configuration



Notes: Up to 4 TEs are allowed
L is length limited by cable loss
D is separation limited by differential delay

Figure 3-5
Short branched passive bus configuration



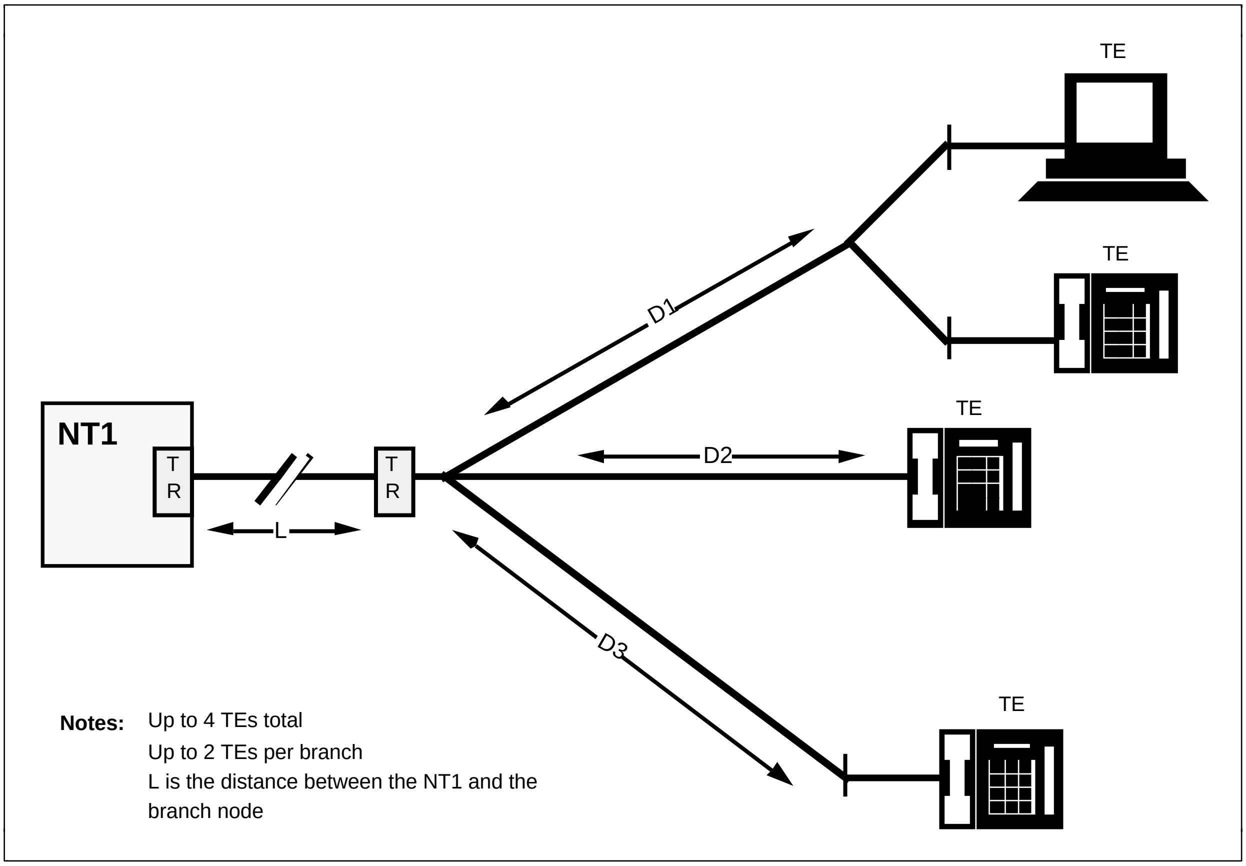
General installation rules

The following rules and recommendations for installing the S/T-bus apply to all bus configurations:

1. Terminating resistors (TR) of 100 ohms are required on the S/T-bus to terminate the transmit and receive wire pairs. The location of the TRs in each configuration are shown in Figures 3-3 to 3-6. (Refer to *NT1 and S/T Bus Installation Guide*, 297-2451-207, for more information about TRs.)
2. The NT1 receiver uses two timing methods to sample incoming data:
   - fixed timing is used for short multipoint (short passive and short branched) bus configurations
   - adaptive timing is used for point-to-point and extended multipoint (extended passive and branched) bus configurations.

   (Refer to *NT1 and S/T Bus Installation Guide*, 297-2451-207, for timing selection procedures for the NT1.)

Figure 3-6
Branched passive bus configuration



3. Polarity integrity should generally be maintained on all S/T-bus wiring, including all wiring, cross-connects, and teladapt cables (non-reversal) between the NT1 and all its associated TEs. Although not strictly required for point-to-point applications, it is recommended that the same practice be followed.

4. NT1 and TE wiring should meet the following limits:

   - the maximum length of the stubs from the S/T-bus to wall jacks is 1 m (3.3 feet)
   - the maximum length of NT1 teladapt cable is 3 m (10 feet)
   - the maximum length of TE teladapt cable is 10 m (33 feet)

Simple S/T-bus configurations

In most office and industrial buildings, a simple S/T-bus can be installed, with a configuration that provides the following benefits:

- they satisfy most deployment applications
- they are compatible with existing in-building wiring practices
- they are independent of cable parameters

The following guidelines for installing these bus configurations have been developed based on worst-case operating limits, and alleviate the need for detailed engineering rules.

Two S/T-bus configurations are recommended. These are simplified versions of the short branched passive bus and the branched passive bus configurations. The configurations support a maximum of two branches with two TEs each (total of four TEs). In these configurations, the TR is located at the NT1 and the branch nodes, and do not require a TR at the TEs

Simplified short branched passive bus

The simplified short branched S/T-bus configuration is illustrated in Figure 3-7. This configuration supports two branches originating at the NT1, and is suitable for applications in which the NT1 is located in wiring closets. The following rules are recommended:

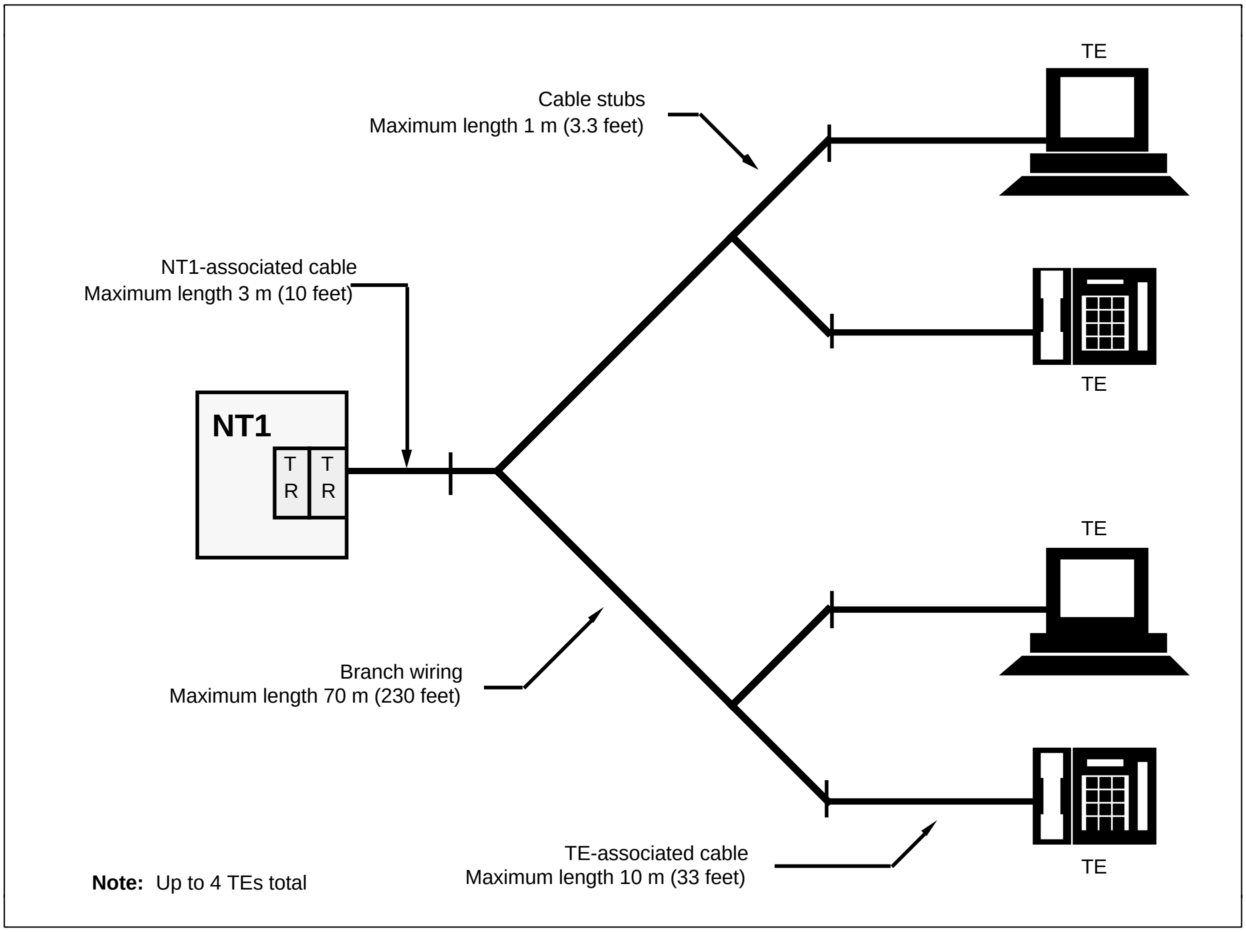
- NT1 timing set to fixed
- a maximum of two branches
- a maximum of two TEs per branch (four TEs total)
- a maximum branch length of 70 m (230 feet)
- two sets of TRs located at the NT1

Simplified branched passive bus

The simplified branched S/T-bus configuration is illustrated in Figure 3-8. This configuration supports two branches originating at the far-end TR, and is suitable for applications in which the NT1 is located near the building service entry point. The following rules are recommended:

- NT1 timing set to adaptive
- a maximum of two branches
- a maximum of two TEs per branch (four TEs total)
- a maximum branch length of 50 m (165 feet)
- a maximum extension length of 220 m (720 feet)
- the TRs are located at the NT1 and the far-end branch node

Figure 3-7
Simplified short branched passive bus configuration



Engineered S/T-bus configurations

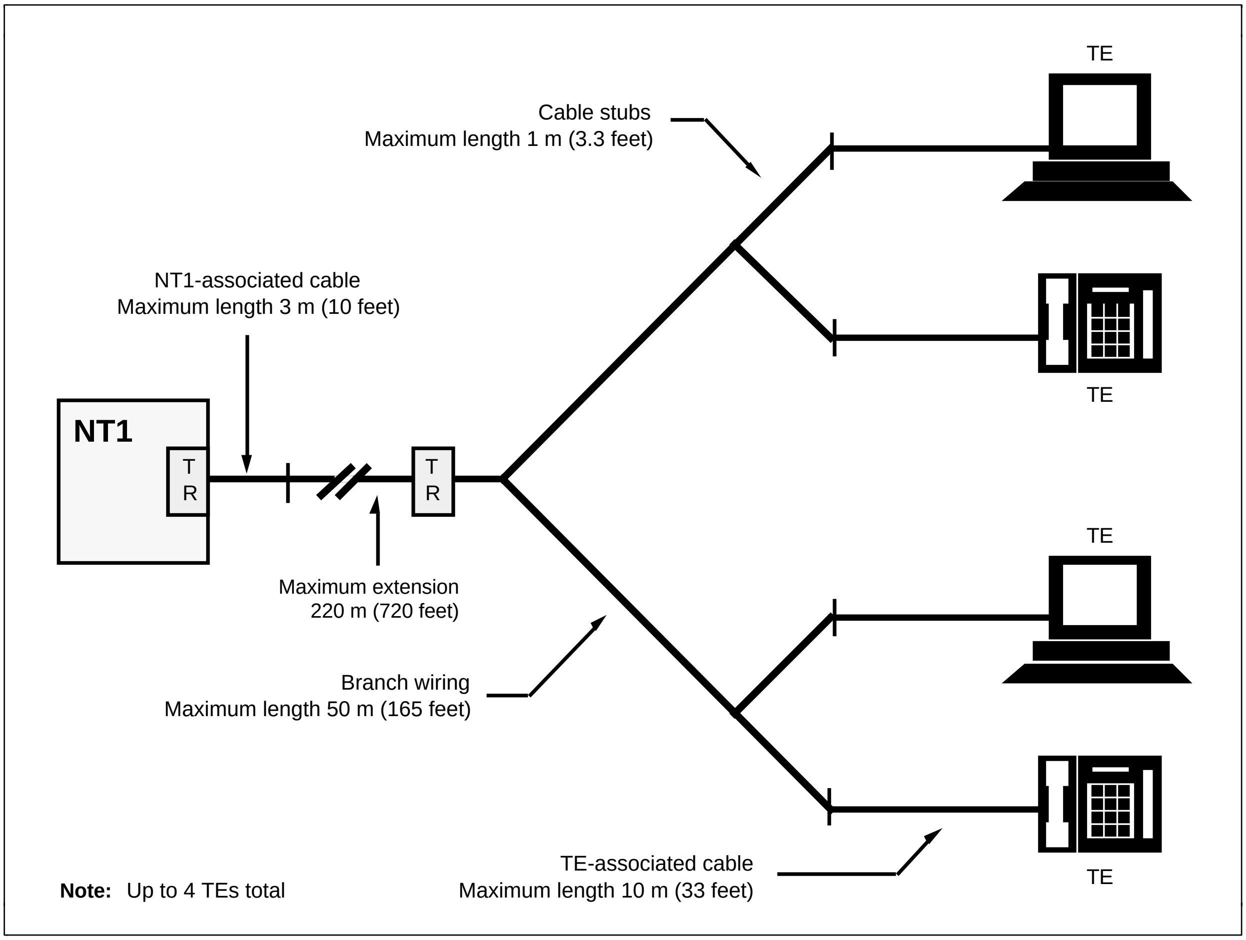
There are situations in which the simplified S/T-bus configurations cannot be installed; for instance, those which require

- different bus configurations
- maximum reach or TE separation
- more than four TEs per NT1
- more than two branches

In these cases, operating limits must be determined from the engineering information presented in the following guidelines. These limits take into account the following factors affecting performance:

- cable type
- bus configuration

Figure 3-8
Simplified branched passive bus configuration



- bus loss
- round trip and differential delay
- jitter and phase delay in TEs
- number of TEs

The following configurations are supported:

- point-to-point bus
- short passive bus
- extended passive bus
- short branched passive bus
- branched passive bus

Point-to-point bus

The point-to-point wiring configuration is shown in Figure 3-1. This configuration represents the simplest type of S/T-bus, and is used to provide the greatest possible range between the NT1 and one TE. The following installation rules are recommended:

- NT1 timing set to adaptive
- one TE only
- terminating resistors located at the NT1 and the TE
- maximum cable loss is 6 dB

The bus length in this configuration is limited by the cable loss. Table 3-2 lists the maximum bus lengths corresponding to a 6 dB loss for different cable types.

For example, the 6 dB limit for Z station wire (FT4) results in a maximum range of 910 m (2980 feet).

Short passive bus

The short passive bus configuration is shown in Figure 3-3. This configuration allows the NT1 and TEs to be located anywhere along the bus, accommodating the maximum number of TEs with the greatest possible separation between them. The following installation rules are recommended:

- NT1 timing set to fixed
- a maximum of eight TEs
- terminating resistors located at both ends of the bus

The bus length in this configuration is limited by the maximum round trip propagation delay. Allowing 0.7 μs delay due to loading (eight TEs), the maximum round trip delay for the unloaded cable installation is 2 μs.

Table 3-2 lists the maximum bus length with eight TEs connected to the bus for different cable types. The table also lists the length variation per TE. If the number of TEs installed on the bus is less than eight, the bus length can be increased by the variation amount listed, multiplied by the number of TEs removed.

For example, if four TEs are installed on a short passive bus using Z station (FT4) wire, the maximum bus length is the total of the length listed for an 8-TE installation, 150 m (490 feet), plus the total variation allowed for the four removed TEs, 20 m (64 feet), which is 170 m (554 feet).

The short passive bus may also be configured with adaptive NT1 timing. Using adaptive triming, the maximum round trip delay for unloaded cable is reduced to 1.1μs. (Refer to Table 3-3 for the short passive bus limits with adaptive timing.) Using the same example situation as above, (Z station FT4 wire), the maximum bus length for eight TEs is 85 m (280 feet). For four TEs, the bus length is increased by 20 m (64 feet), resulting in a length of 105 m (344 feet).

Table 3-2
Point-to-point bus limits

Cable type	Gauge (AWG)	Point-to-point m (feet)
Outside PIC	22	1110 (3640)
Outside PULP	22	1000 (3280)
Outside PIC	24	790 (2590)
Outside PULP	24	730 (2390)
Outside PIC	26	540 (1770)
Outside PULP	26	540 (1770)
Inside riser	22	1150 (3770)
Inside riser	24	800 (2620)
Inside riser	26	570 (1870)
Inside Z station (FT1)	22	1150 (3770)
Inside Z station (FT4)	22	910 (2980)
Inside type D (3&4 pair)	24	700 (2300)
Inside type D (25 pair)	24	630 (2070)

Extended passive bus

The extended passive bus configuration is shown in Figure 3-4. This configuration allows multiple TEs to be located at a maximum distance from the NT1. The following installation rules are recommended:

- NT1 timing set to adaptive
- a maximum of four TEs
- maximum cable loss is 3.8 dB
- terminating resistors located at the NT1 and the furthest TE

The two components of the extended bus configuration are total bus length and maximum separation between TEs. The total bus length is limited by cable loss (3.8 dB), and the separation between TEs is limited by the round trip differential delay (2.75 μs).

The differential delay limit includes:

- TE jitter and phase delay
- unloaded bus propagation delay
- propagation delay due to TEs

Table 3-3
Short passive bus limits

Cable type	Gauge (AWG)	Short Passive (8 TEs) Fixed timing m (feet)	Adaptive timing m (feet)	Variation per TE m (feet)
Outside PIC	22	180 (590)	105 (345)	6 (19)
Outside PULP	22	185 (605)	105 (345)	6 (19)
Outside PIC	24	175 (575)	100 (330)	6 (19)
Outside PULP	24	180 (590)	105 (345)	6 (19)
Outside PIC	26	170 (555)	95 (310)	6 (19)
Outside PULP	26	175 (575)	100 (330)	6 (19)
Inside riser	22	190 (620)	110 (360)	6 (19)
Inside riser	24	175 (575)	100 (330)	6 (19)
Inside riser	26	170 (555)	95 (310)	6 (19)
Inside Z station (FT1)	22	170 (555)	95 (310)	6 (19)
Inside Z station (FT4)	22	150 (490)	85 (280)	5 (16)
Inside type D (3&4 pair)	24	160 (525)	90 (295)	5 (16)
Inside type D (25 pair)	24	150 (490)	85 (280)	5 (16)

Using a total jitter and phase delay variation of 22% of a bit period for the phase difference between TEs on the bus and an additional delay of 0.35 μs due to TE loading, the resulting maximum round trip differential delay for the bus is 1.25 μs.

Table 3-4 lists the total bus length and maximum separation between TEs for various cable types. The total bus length is independent of the number of TEs connected to the bus, but the separation is given for four TEs (the maximum permitted). The table also lists the separation variation per TE. If the number of TEs installed on the bus is less than four, the separation can be increased by the variation amount listed, multiplied by the number of TEs removed.

For an example, take two TEs installed on an extended passive bus using 24 AWG riser cable for the bus extension (between NT1 and TEs) and Z station (FT4) wire between the TEs. The separation for four TEs is 95 m (310 feet), but since only two TEs are installed, the total variation is 10 m (32 feet), resulting in a maximum separation of 105 m (342 feet). The total bus length for 24 AWG riser cable is 500 m (1640 feet). If a separation of 100 m (330 feet) is used, the maximum remaining extension length is 400 m (1310 feet).

Table 3-4
Extended passive bus limits

Cable type	Gauge (AWG)	Total length m (feet)	Separation 4 TEs m (feet)	Variation per TE m (feet)
Outside PIC	22	700 (2300)	110 (360)	6 (19)
Outside PULP	22	630 (2070)	115 (375)	6 (19)
Outside PIC	24	500 (1640)	110 (360)	6 (19)
Outside PULP	24	460 (1510)	110 (360)	6 (19)
Outside PIC	26	340 (1110)	105 (345)	6 (19)
Outside PULP	26	340 (1110)	110 (360)	6 (19)
Inside riser	22	730 (2390)	120 (390)	6 (19)
Inside riser	24	500 (1640)	110 (360)	6 (19)
Inside riser	26	360 (1180)	105 (345)	6 (19)
Inside Z station (FT1)	22	730 (2390)	105 (345)	6 (19)
Inside Z station (FT4)	22	570 (1870)	95 (310)	5 (16)
Inside type D (3&4 pair)	24	440 (1443)	100 (330)	5 (16)
Inside type D (25 pair)	24	400 (1310)	95 (310)	5 (16)

Short branched passive bus

The short branched passive bus configuration is shown in Figure 3-5. This configuration is a modification of the short passive bus which allows branched wiring originating at the NT1. As with the short passive bus, this configuration accommodates the maximum number of TEs with the greatest possible separation between them, and allows all terminating resistors to be located at the NT1. The following installation rules are recommended:

- NT1 timing set to fixed
- a maximum of eight TEs
- a maximum of four TEs per branch
- two pairs of terminating resistors located at the NT1

The short branched passive bus can be configured with adaptive NT1 timing. Using this timing mode, the maximum branch length depends on the differential branch length (the difference between maximum and minimum length branches).

Table 3-5 lists the short branched passive bus limits for different cable types.

Table 3-5
Short branched passive bus limits

Cable type	Gauge (AWG)	Fixed timing Maximum branch length m (feet)	Adaptive timing Maximum branch length plus differential m (feet)
Outside PIC	22	80 (260)	105 (345)
Outside PULP	22	80 (260)	110 (360)
Outside PIC	24	80 (260)	105 (345)
Outside PULP	24	80 (260)	105 (345)
Outside PIC	26	75 (245)	100 (330)
Outside PULP	26	75 (245)	95 (310)
Inside riser	22	80 (260)	110 (360)
Inside riser	24	80 (260)	105 (345)
Inside riser	26	75 (245)	100 (330)
Inside Z station (FT1)	22	75 (245)	100 (330)
Inside Z station (FT4)	22	70 (230)	95 (310)
Inside type D (3&4 pair)	24	75 (245)	100 (330)
Inside type D (25 pair)	24	70 (230)	95 (310)

Branched passive bus

The branched passive bus configuration is shown in Figure 3-6. This configuration is a modification of the extended passive bus with the TR located at the branch node instead of at the last TE. As with the extended passive bus, this configuration allows multiple TEs to be located at a maximum distance from the NT1. The following installation rules are recommended:

- NT1 timing set to adaptive
- a maximum of four TEs
- a maximum of two TEs per branch
- terminating resistors located at the NT1 and at the far-end branch node
- maximum cable loss is 3.8 dB

The three components of the branched passive bus configuration are extension length (length from the NT1 to the branch node), branch length (length from the branch node to the TE), and differential branch length (difference between maximum and minimum length branches).

Table 3-6 lists the branched passive bus limits for different cable types, and specifies the following limits:

- extension bus length
- the sum of the maximum branch length and the differential between branch lengths

If a TE must be located directly at the branch node, the maximum branch length becomes equal to the differential branch length. As a result, for this case, the maximum branch length is equal to one-half of the lengths given in Table 3-6 (maximum branch plus differential).

For example, take three TEs installed in a branched passive bus with three branches, using Type D (3-pair) wiring. The branch node (extension length) can be located up to 250 m (820 feet) from the NT1. If one TE must be placed at the branch node (zero branch length), the maximum branch length for each of the other TEs is 50 m (165 feet). If the TE nearest to the branch node is 25 m (80 feet), the maximum branch length for the other TEs is 75 m (245 feet).

Table 3-6
Branched passive bus limits

Cable type	Gauge (AWG)	Length extension m (feet)	Maximum branch plus differential m (feet)
Outside PIC	22	340 (1115)	105 (345)
Outside PULP	22	315 (1030)	110 (360)
Outside PIC	24	270 (885)	105 (345)
Outside PULP	24	255 (835)	105 (345)
Outside PIC	26	215 (705)	100 (330)
Outside PULP	26	215 (705)	95 (310)
Inside riser	22	350 (1150)	110 (360)
Inside riser	24	270 (885)	105 (345)
Inside riser	26	220 (720)	100 (330)
Inside Z station (FT1)	22	350 (1150)	100 (330)
Inside Z station (FT4)	22	295 (965)	95 (310)
Inside type D (3&4 pair)	24	250 (820)	100 (330)
Inside type D (25 pair)	24	235 (770)	95 (310)

S/T-bus diagnostics

A problem with the S/T-bus installation may be indicated by failure to achieve synchronization between the NT1 and the TEs, or by an error rate performance over the S/T-bus that doesn't meet specifications. Either of these problems can be indicated by the NT1's LED status display once the NT1 is connected to the bus and TEs. The installation and verification procedures in the *NT1 and S/T Bus Installation Guide*, NTP297-2451-207, will help you resolve any problems that occur.

Cable Characteristics

Table 3-7 lists the parameters of the various cable types used in determining S/T-bus configuration limits. The cables listed are those commonly used for telephony wiring applications, and the characteristics listed are for Northern Telecom cable at 96 kHz and 20° C (68° F).

Table 3-7
Cable characteristics

Cable type	Gauge (AWG)	Loss dB/km (dB/k foot)	Capacitance nf/km (nf/k foot)	Delay µs/km (µs/k foot)
Outside PIC	22	5.4 (1.6)	52 (15.8)	5.5 (1.7)
Outside PULP	22	6.0 (1.8)	52 (15.8)	5.3 (1.6)
Outside PIC	24	7.6 (2.3)	52 (15.8)	5.6 (1.7)
Outside PULP	24	8.2 (2.5)	52 (15.8)	5.5 (1.7)
Outside PIC	26	11.0 (3.3)	52 (15.8)	5.9 (1.8)
Outside PULP	26	11.0 (3.3)	50 (15.2)	5.7 (1.7)
Inside riser	22	5.2 (1.6)	50 (15.2)	5.2 (1.6)
Inside riser	24	7.5 (2.3)	51 (15.5)	5.6 (1.7)
Inside riser	26	10.5 (3.2)	50 (15.2)	5.9 (1.8)
Inside Z station (FT1)	22	5.2 (1.6)	49 (14.9)	5.9 (1.8)
Inside Z station (FT4)	22	6.6 (2.0)	61 (18.6)	6.6 (2.0)
Inside type D (3&4 pair)	24	8.5 (2.6)	58 (17.7)	6.2 (1.9)
Inside type D (25 pair)	24	9.5 (2.9)	71 (21.6)	6.6 (2.0)

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