

T1 PCM Repeated Line - Transmission Considerations for Engineering

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1. General

- 1.1 Purpose This practice:
- Establishes a uniform process for the selection, design and application of T1 repeatered span lines.
 - Provides the information required to engineer the T1 repeatered span line on PCM (pulse code modulation) carrier systems for underground, buried and aerial cable operation.
- NOTE: The selection process for T1 repeatered span lines. Includes interoffice, customer loop, digital loop carrier and hicap applications.
- 1.2 Filing Instructions File this practice in numerical order in your practices set.
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2. Overview

2.1 Introduction

Performance monitoring of T1 is of major importance in a digital network. The transition of the voice network to a voice/data network increases performance requirements. Therefore, all new T1 digital spans within GTE are engineered to meet the T1 -DDS parameters which have more stringent performance standards and engineering rules than T1 or T1C parameters.

This practice presents the design criteria required to engineer the T1 span line to meet the performance requirements of a digital network during the inception, development and introduction of T1 services. The requirements presented here are generic to the digital equipment types covered. The66 requirements are both general and flexible to provide correct features for a wide range of equipment.

2.2 Acronyms, Terms and Definitions

The following chart provides definitions for the acronyms and terms used in this practice.

Acronym/Term	Definition
AGCS	A G Communication Systems
ALBO	Automatic Line Build-out
AMI	Alternate Mark inversion
AT&T	American Telephone and Telegraph, inc.
B8ZS	Bipolar with Eight Zero Substitution
BER	Bit Error Rate
BPV	Bi-Polar Violation
BRI	Basic Rate interface
CCC	Clear Channel Capability
C C S	Common Channel Signaling
C O	Central Office
COT	Central Office Terminal
CPE	Customer Premises Equipment
CRC6	Cyclical Redundancy Check
CSR	Customer Station Rearrangement
CSU	Channel Service Unit
CXR	Carrier
dBm	Decibel6 above of below one milliwatt
dBmc	Decibel(s) above reference noise, C-Message weighting
DCS	Digital Cross-Connect System
DC	Direct Current
DCO	Digital Central Office
DDS	Digital Data Service
Digroup	24 DSO channels
DLC	Digital Loop Carrier

(continued)

2. Overview, continued

2.2

Acronyms,
Terms and
Definitions,
continued

Acronym/Term	Definition
DP	Data Port
DS0	Digital Signal Level 0 (64 kb/s)
DS1	Digital Signal Level 1 (1.544 Mb/s)
DS1C	Digital Signal Level 1C (3.152 Mb/s)
DSU	Digital Service Unit
DSX	Digital Signal Cross-Connect
DT	Digroup Terminal
DTE	Data Terminal Equipment
DTI	Digital Trunk Interface
EFS	Error Free Second
ES	Errored-Second
ESF	Extended Superframe
FEXT	Far-End Crosstalk - crosstalk in which the interfering circuit and the interfered with circuit are both transmitting in the same direction, i.e., between transmit pairs. (Reducing and eliminating crosstalk is an important goal of T1 design.)
HF	High Frequency
H-R	Host Remote
ICOT	Intercity and Outside Trunk
IDF	Intermediate Distribution Frame
ISDN	Integrated Services Digital Network
kft	Kilo-feet/1 000 feet
KM	Kilometer (1000 meters)
LBO	Line Build-Out
LE	Loop Extender
LIDF	Line Distributing Frame
LTS	Line Terminating Shelf
MAT	Metropolitan Area Trunk
MDF	Main Distribution Frame
MS	Milliseconds (one thousandth of a second)
MUX	Multiplexer
MXU	Multiplexer Unit

(continued)

2. Overview, continued

2.2

Acronyms,
Terms and
Definitions,
continued

Acronym/Term	Definition
NEXT	Near-End Crosstalk - crosstalk in which the interfering circuit and the interfered with circuit are transmitting in opposite directions, i.e., between transmit and receive pairs. (Reducing and eliminating crosstalk is an important goal of T1 design.)
NIJ	Network Interface Jack
NFL	Noise Path Loss
OCU	Office Channel Unit
OTR	Office Terminating Repeater
PBX	Private Branch Exchange
PAR	Planning Analysis Report
PCM	Pulse Code Modulation
PIC	Primary Interexchange Carrier/Principal Interlata Carrier
POTS	Plain Old Telephone Service
QRSS	Quasi Random Signal source
RLS	Remote Line Switch
RLU	Remote Line Unit
RSU	Remote Switching Unit
RSC	Remote Switching Center
RSM	Remote Switching Module
RT	Remote Terminal
RZ	Return to Zero
SPC	Stored Program Control
SRL	Structural Return Loss
T1DM	T1 Data Multiplexer
TE	Terminal Equipment
UI	Unit Interval
VF	Voice Frequency
ZBTSI	Zero Byte Time Slot Interchange

2.3

Description of
Repeatered
Line

The T1 repeatered line provides a four-wire transmission path for PCM (pulse code modulated) cable carrier systems that transmit bipolar pulse trains at bit rates of 1.544 Mb/s (DS1). At each office, the transmission path will terminate on an office repeater. It will then be connected and/or cross-connected to a (T1) compatible equipment such as a D-Type channel bank, multiplexer, office repeater or interface directly into the central office digital switch.

In PCM systems, each pair of wires between two central office locations is defined as a span line. The segment between two adjacent repeater locations is called a span line section or repeater section. The aggregate of all PCM carrier pairs between the two central offices is the span. If a system passes through intermediate offices between terminal locations, it is comprised of span lines in tandem for each direction of transmission. In bi-directional operation, both directions of transmission share the same cable and repeater housings. In unidirectional operation, separate cables and repeater housings for each direction are used.

2. Overview, continued

2.3 Description of Repeatered Line, continued

The illustration below shows the transmission paths of a single system that passes through an intermediate office. This is an example of bi-directional operation using bi-directional line repeaters. The two regenerators of a line repeater are designated side 1 and side 2. Line repeaters are powered by DC current flowing through a loop formed from the simplexes of the two cable pairs associated with side 1 and side 2.

The 1.544 Mb/s bipolar PCM line signals of T1-type equipment (such as channel banks, repeatered lines and digital switches) are designated DS1, meaning "digital signal at the first level." At the standard cross-connect point for DS1 signals, designated DSX-1, the signal level is 3 ± 0.3 volts base-to-peak.

Office and line repeater unit characteristics are listed in Table 20, on page 61. The repeater housings are listed in the table at the bottom of this page.

For installation instructions pertaining to repeater housings, refer to Lenkurt Practice 631-863-200, Carrier System GTE Lenkurt 91A - PCM Repeater Housing - Installation.

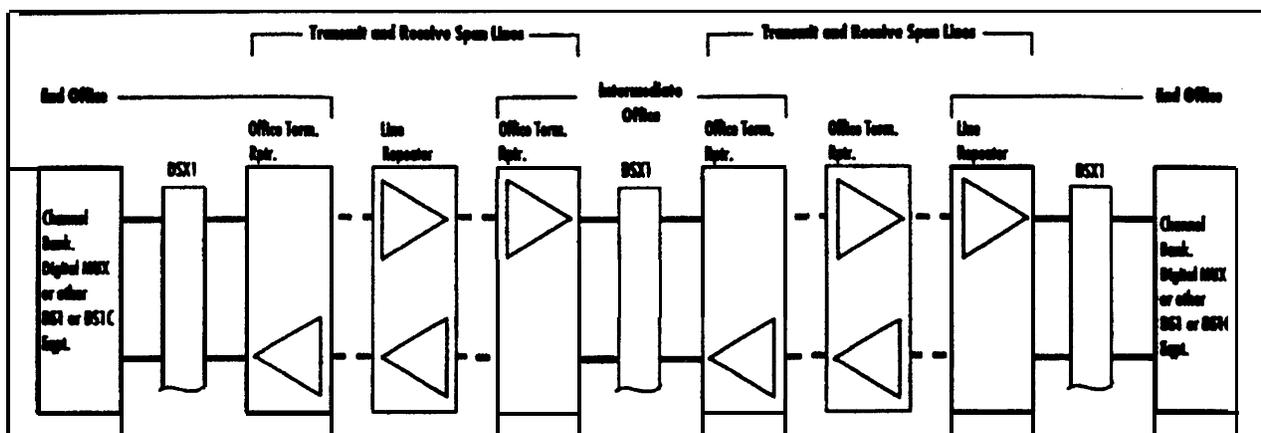


Exhibit 1 - Transmission Paths of a PCM System

Housing Type	Manufacturer	Repeater Capacity	Size	D-Shield, 24-ga. Cable	Pressurization
91170	Siemens	10	Full	Two 24 pair (1)	Pressurized
91171	Siemens	25	Full	Two 52 pair	Pressurized
91176	Siemens	25	Full	Two 52 pair	Unpressurized
91179 (shelf)	Siemens	25	Full	None	Unpressurized
91180 M1	Siemens	6	Mid	One 30 pair	Pressurized
91180 M2	Siemens	6	Mid	One 28 pair (2)	Pressurized
91181 M1	Siemens	12	Mid	Two 30 pair	Pressurized
91181 M2	Siemens	12	Mid	Two 28 pair (2)	Pressurized
91182 M1		25	Mid	Two 52 pair	Pressurized
91182 M2	Siemens	25	Mid	Two 54 pair (2)	
91183 M1	Siemens	5	Mid	One 24 pair	Pressurized
91183 M2	Siemens		Mid	One 28 pair (2)	Pressurized
91184 M1	Siemens		Mid	Two 104 pair	
91184 M2	Siemens	50	Mid	Two 106 pair (2)	Pressurized
621204-000-1XX	Alcatel	12	Mini	Two 28 pair	Pressurized
621205-000-1XX	Alcatel	25	Mini	Two 54 pair	Pressurized
621206-000-1XX	Alcatel	50	Mini	Two 106 pair	Pressurized

Table 1 - Repeater Housings

The notes listed below correspond with numbers in parenthesis in the table above.

- (1) Two 28-pair dual D-screen stubs.
- (2) Dual D-screen.

2. Overview. continued

2.4 Associated Documents

The following chart lists documents that contain information useful to the users of this practice. The list includes GTE Telephone Operations practices, Lenkurt practices and other documents.

Practice Number	Title
032-201-150	Test Cords, Plugs and Adapter Assemblies
103-735-100	91100 PCM Cable Test Set
200-002-725	Acceptance Testing - DS1 Span
256-050-203	Cabling Methods - Central Office Running Switchboard Cable (an AGCS document)
256-224-216	Cabling Methods - GTD-5 EAX (an AGCS document)
331-050-xxx	Statistical Methods
331-350-500	Host-Remote Link DS1 Transmission Verification and Testing Procedures
342-910-105	9104A 24/48 Channel PCM Repeatered Line Equipment-inside Plant (a Lenkurt document)
342-910-106	9104A 24/48 Channel PCM Repeatered Line Equipment-Outside Plant (a Lenkurt document)
342-910-114	91A Spare Line Transfer Equipment (a Lenkurt document)
342-911-107	9002B PCM Channel Bank (a Lenkurt document)
342-911-111	9004A PCM Channel Bank (a Lenkurt document)
342-911-122	9122A Asynchronous Digital Multiplexer (a Lenkurt document)
342-911-133	9004B PCM Channel Bank (a Lenkurt document)
631-863-200	91A PCM Repeater Housing Installation (a Lenkurt document)
632-611-200	Cable Splicing Screened Cable - All Types
634-020-500	Acceptance Testing Cable Completion.
791-400-070	Distributing Frames, HF Cross-Connect Bay - Engineering Applications
795-805-073	Telephone Central Office Grounding of Transmission Equipment
836-910-074	9148A Modified Duobinary Line Retrofit Engineering Considerations (a Lenkurt document)

(continued)

2. Overview, continued

2.4

Associated Documents, continued

Practice Number	Title
636-910-080	DSX Cross Connections (a Lenkurt document)
636-910-081	9104A 24/48 Channel PCM Repeatered Line Equipment Transmission Engineering Considerations (a Lenkurt document)
852-050-050	Cable Voice Frequency Loading Systems
887-050-085	Carrier System Protection - Engineering Considerations
903-020-070	Protectton General Considerations
920-100-100	Cable Conductor, Paper insulated
920-200-100	Cable Conductor, Polyethylene Insulated
ALCL-20-106	Miniature Repeater Housings wth internal Tilt Feature, General Description (an Alcatel document)
ITTR-20-700	T1 Digital PCM Span Line Engineering Design Considerations (an Alcatel document)

3. Transmission Objectives

3.1 Pulse Transmission

Pulses sent along a PCM repeatered line are regenerated at each repeater point. The repeater "looks" at each time slot and "recognizes" whether or not a pulse is present. Pulses generated by terminal equipment or the previous repeater are subject to attenuation and phase distortion from the cable. Each repeater, therefore, contains an automatic equalizer or automatic line build-out (ALBO) to restore satisfactory pulse shape for pulse detection and regeneration. If the repeater logic determines that there is a pulse, the repeater puts out a new 3-volt base-to-peak pulse that is nearly free of noise, distortion, or interference incurred in the preceding section. Timing jitter resulting from the signal impairments accumulates and may ultimately limit the maximum length of the repeatered line.

For transmission engineering considerations, only the attenuation factor of the cable at 772 kHz (half the DS1 timing frequency) is needed. This shortcut is valid because the power spectrum of the pulse train is maximum at approximately this frequency. The single frequency method cannot be extended to other kinds of calculations, e.g., interference between different T-carrier, PCM or other transmission systems.

3.2 Error Rate

Because of degradation factors, a pulse may be regenerated incorrectly; that is, a pulse may be sent out where none was present, or vice versa. In a return to zero (RZ) bipolar signal with alternate mark inversion (AMI), a pulse that is an error shows up as a bipolar violation. The transmission error rate is calculated by dividing the total number of pulses in error (that are generated in the transmission medium) by the total number of pulses received. An error rate of 1 in 10^6 means there is one error in one million pulses.

3. Transmission Objectives, continued

3.2 Error Rate, continued

The total span error rate is the arithmetic sum of the error rates of individual repeater sections. The total system error rate is the arithmetic sum of the error rates of the tandem spans. For the system error rate to be better than 1 in 10^6 , the individual spans must have a better than 1 in 10^6 error rate. Because of the effect of impulse noise from central office equipment, end sections are shortened to increase the signal-to-noise ratio of the office repeater. Sometimes the section adjacent to the end section must also be shortened. If the system has more than three tandem spans, end sections are made still shorter.

Span lines are engineered on the basis of a spread or distribution in error rates. When designed according to requirements of this practice, there is a high probability that the maximum span and system error rates will not exceed the values set forth in the following paragraphs for ninety-five percent of the cable pairs.

Between terminals of a T-carrier system, a maximum system error rate of 1 in 10^6 results in good voice communications and hence, this rate has been the system objective. Pulse errors cause impulse noise on the individual voice channels, but at this rate they are not noticeable to the average listener. Because of increasing demand for DDS service and for greater system integrity, current design objectives require a bit error rate of 1×10^{-9} , consistent with DDS objectives.

3.3 DDS Communications

Digital data systems (DDS) require the repeatered line system to have a much better error rate performance than that required for voice transmission. This is because a data bit (pulse) may represent the discrete bit or control code for the terminal equipment or customer's business machine. Receiving an errored bit may cause the terminal equipment to have a wrong output or worse (e.g., failure to acknowledge the remote sending end terminal). Also, where DDS is carried in longer tandem spans, the error rate limit for the line is more difficult to achieve. A typical DDS equipment layout is illustrated below.

NOTE: DDS systems incorporating forward error correction error may be able to operate in a repeatered line system of voice quality where the DS1 error rate may be as high as 1×10^{-6} .

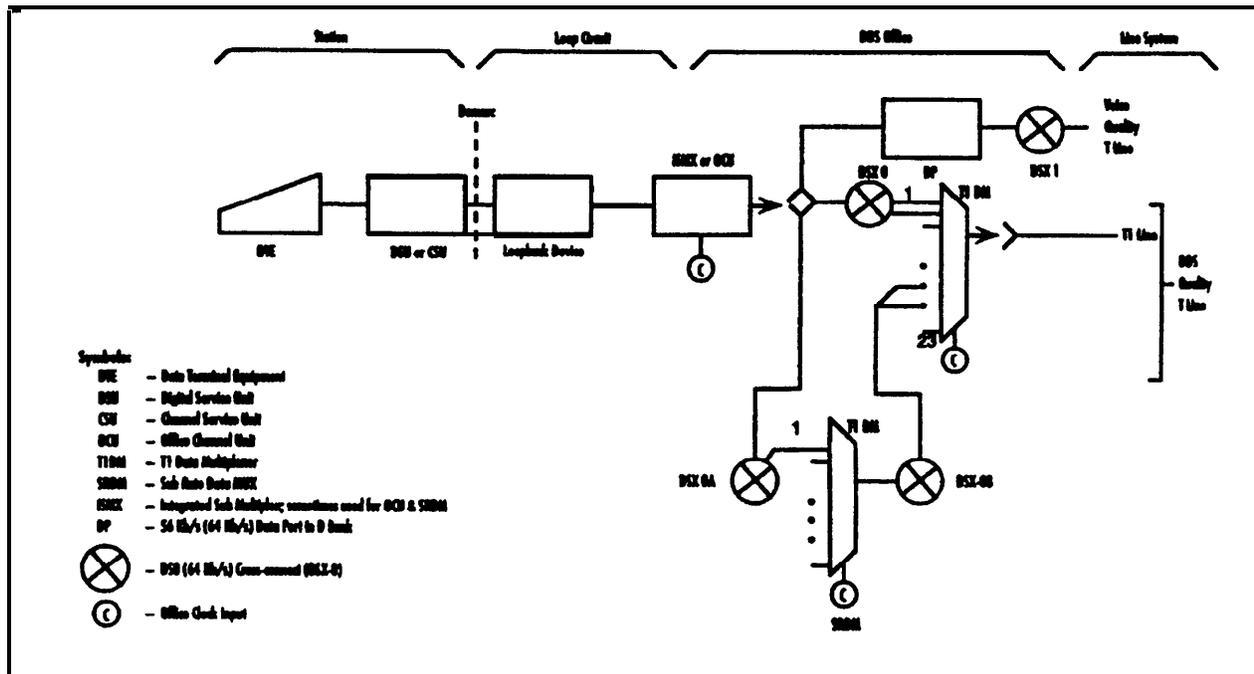


Exhibit 2 - Typical DDS Equipment Layout

3. Transmission Objectives, continued

3.3
 DDS
 Communications,
 continued

Because of these factors and to meet the DDS quality requirements, fixed error free second (EFS) limits are allotted in each component of the DDS network model illustrated below. The DDS reference model comprises a long-haul network interconnecting two local serving areas where there are two local carrier lines in tandem with one baseband loop. The longest possible DDS configuration is when customer "A" connects to customer "B" via the loop and the span line systems through two or more hub offices and does not exceed 432 errored seconds (ES) at 56 kb/s. The shortest is a station-to-station link which passes through only one central office. In an actual DDS network, a station may terminate directly in the intermediate or hub office. The applicable EFS criteria for such a case follows that assigned for a loop facility.

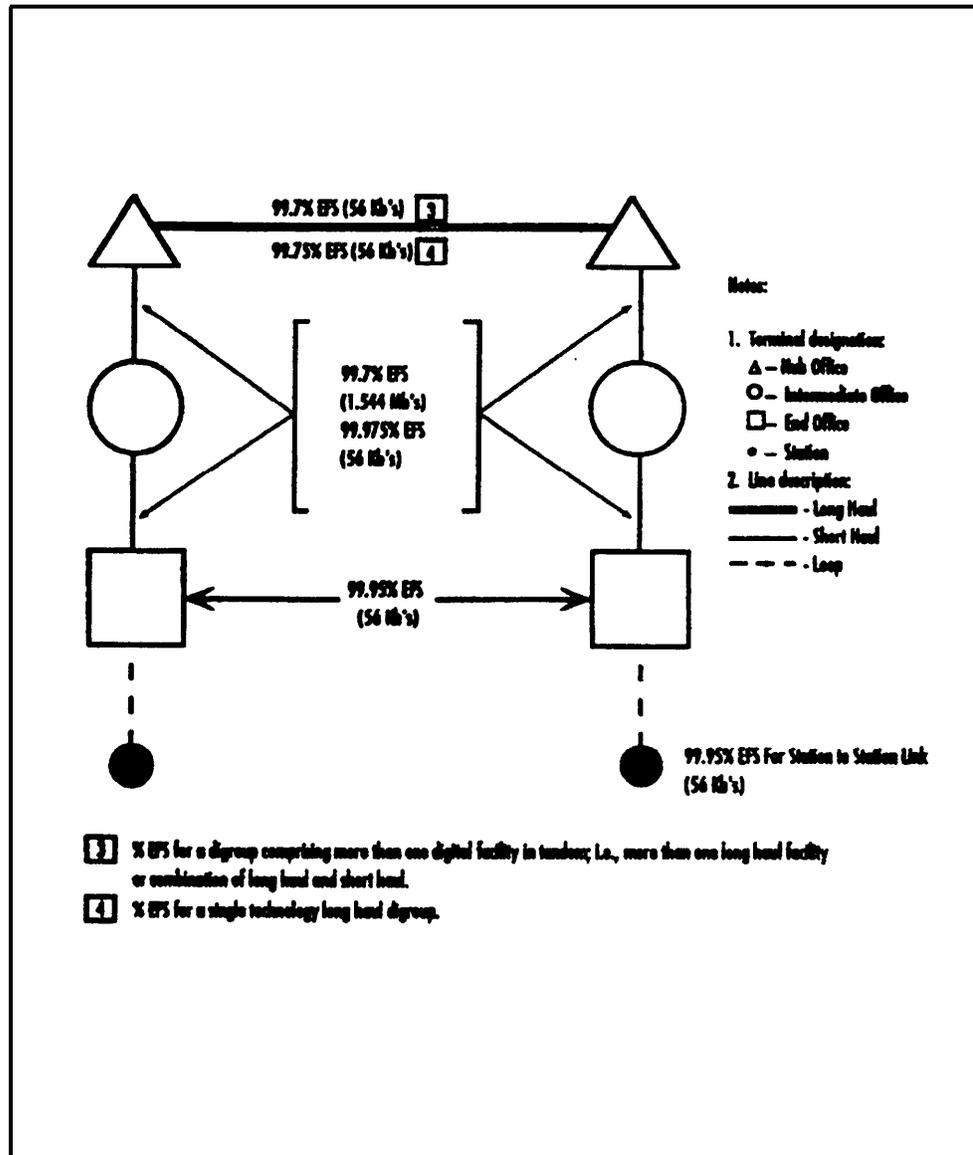


Exhibit 3 - DDS Network Model with % EFS Assignments

3. Transmission Objectives, continued

3.3 DDS Communications, continued

NOTE: The allocation of error contributions in the reference model is done in the following manner:

- Two baseband loops account for 2/10 (10% for each loop).
- Four local digital lines account for 3/10 (7.5% for each line).
- One long haul network connection accounts for 5/10 (50%).
The total station-to-station allowance is 0.5 % errored seconds (ES) at 56 kb/s or 432 ES/day.

3.4 Errored-Second Allowance

Errored-Second Allowance (ES Allowance) is a quality criteria for digital data systems. ES Allowance is measured in terms of percent error free seconds (% EFS) or error seconds (% ES). For convenience of measurement, this criterion is then translated to an error-second allowance (ES allowance) using the equation:

$$\% \text{ ES} = 100 - \% \text{ EFS}$$

$$\text{ES allowance} = \frac{\% \text{ ES} \times T \text{ (test duration in seconds)}}{100}$$

A two-hour test during a normal busy period may be used for pre-service testing. Since errors may appear as one bit or a burst of EFS at any time of the day, a longer test period may be necessary to maintain system quality. A twenty-four-hour period assures a better measurement of system quality. (Refer to Table 17, ES Allocation for DDS Systems table on page 55.) The ES allowances given in the DDS Network Model illustration on page 1 take into consideration the twenty-four-hour maintenance test periods.

For the DS1 signal level, the conversion of % EFS to errored-second allowance must account for the fact that one DS1 error will be distributed to only one of twenty-three to twenty-four possible DSO 56 kb/s channels. This relationship, called N-factor, is defined as the average number of DSO channels experiencing an errored second as a result of one DS1 errored second. The computation is as follows:

$$\text{ES}_{\text{ds1}} = 23 \frac{\text{ES}_{\text{ds0}}}{N}$$

(Where:

ES_{ds1} = Errored-second allowance at 1.544 Mb/s

ES_{ds0} = Errored-second allowance at 56 kb/s;
allocated with a value of 22 for a span line.

N = N-factor and defined to be 2.1 for short haul
DS1 quality time systems.

23 = The number of DSO data channels in one
DS1 signal.)

The allowances for DS1 in the DDS system shown in the ES Allocations for DDS Systems table (Table 17, page 55) are computed from the equation above.

3. Transmission Objectives, continued

3.5 Equivalent Bit Errored Rate (BER)

Another way of interpreting the quality of a line system for DDS is by relating the errored-second allowance to bit error rate (BER). Referring to the previous section, Errored-Second Allowance, one or a group of errored bits may be contained in an errored second. For deriving BER, it is assumed that each errored second has two errors. The average amount of time (seconds) required to realize one errored second is:

$$\frac{1}{ES} = \frac{1}{[1 - (\% EFS/100)]}$$

And this is substituted into the BER equation:

$$BER = \frac{2}{\left(\frac{1}{ES \times \text{Bit Rate}} \right)}$$

The values shown in the ES Allocations for DDS Systems table (Table 17, page 55) were calculated by using this relationship.

4. Outside Plant Considerations

4.1 Introduction

Selecting the proper cable plant for digital span lines is critical. The quality of the selected facility has a direct impact on GTE's maintenance efforts and the quality of service provided to GTE's customers. The following sequence of cable facility selection ensures optimum span performance.

4.2 General Design Considerations

Selecting screened cable, one-cable or two-cable operation, locations for repeaters, and repeater section length depends upon future requirements of the route. All systems that will use the span must be considered, regardless of the terminal locations. Select cables and cable facilities based on the following:

- Number of cables.
- Type of cable.
- Age of facilities.
- Condition of cables.
- Frame-to-frame termination and uniformity.
- Splicing integrity.
- Suitability of locations for installing repeater housings.
- Minimum exposure to electrical and mechanical hazards.

Major factors controlling the design of the span include:

- Output-to-input crosstalk coupling loss between cable pairs.
- Cable-pair attenuation.
- Ultimate number of systems.
- Central office noise.
- Ambient temperature range.

4. Outside Plant Considerations, continued

4.3 Type of Cable Operation

Repeatered lines may be designed with each direction of transmission in a separate cable (two-cable or unidirectional operation) or with both directions of transmission in the same cable (screened cable or one cable operation).

Screened cable operation is the preferred method for providing T1 service. Section lengths are limited only by cable attenuation characteristics, similar to two-cable operation. Rarely is NEXT a limiting factor.

Two cable operation, though not advocated, achieves maximum spacing and system density. In this case, section lengths are limited only by cable attenuation characteristics, as long as the repeater housings used have sufficient near-end crosstalk (NEXT) coupling performance.

For one cable (non-screened) operation, NEXT is the limiting factor in repeatered line design. The choice of one cable, screened cable or two cable operation is based on:

- Cable route.
- Circuit requirements.
- Availability of suitable cables.
- Economic factors.

A small pair count non-screened cable may still prove economical for low density routes. Where circuit requirements are high or where the integrity of the pair count is not known or would be too costly to provide, two cable operation is recommended. A two cable installation permits full utilization of all cable pairs for T1 systems, with full length repeater spacing. S-Screen, D-Shield or Dual D-Screen cables can be used for one cable operation if engineering rules are followed.

4.4 Selecting Cables

Base cable selection and design on:

- Cable route.
- Circuit requirements.
- Availability of suitable cables.
- Economic factors.

NOTE: Cable selection is also based on GTE policies in place at the time the selection is made. The dominant selection factor must be to provide

The application of T-carrier to a cable is a relatively permanent undertaking. Cables can be expected to remain in place for twenty or more years. Care must be taken in the selection of main cable facilities. Cable pairs made available initially are to accommodate two to five years expected growth. Select cables that are:

- In good condition.
- Properly installed.
- A type suitable to meet needs.
- Not of advanced age.
- Requiring minimal rearrangements.

If systems will be carried in cables that also contain exchange facilities, pre-testing, cable grooming and rearranging must be performed initially to obtain the cable conditions described previously. Bridge taps, build-out capacitors, load coils and cable stubs must be eliminated. Rearranging and working on cables that have been placed in service is difficult, time consuming and undesirable from the standpoint of service reliability. If new cables are introduced, their design and arrangement must be compatible with future plans and facilities.

4. Outside Plant Considerations. continued

4.4 Selecting Cables, continued

Table 18 on page 56 (T1 Cable Section Lengths) provides section lengths for various types of cable.

4.4.1 Screen Cable

Screen cable has an insulated metallic screen separating pairs for the two directions of transmission. The transmit and receive signals are carried in the same cable, but separated by a screen. (See Exhibit 8, Core Makeup of Screen Cables, pages 62 and 63.) The high NEXT coupling loss for screen cables generally enables one cable operation at maximum repeater spacing with 100 percent fill. Screen cables include:

- D-Shield
- Dual D-Screen.
- Extended T-Screen.
- MAT and ICOT.
- S-Screen.
- T-Screen.

4.4.2 PIC Cables

Even count PIC cables (See Exhibit 9, Core Makeup of Even Count PIC Cables, pages 64 and 65) may be used for T1 operation. Usually one unit is used for one direction of transmission and another unit for the other direction. As always with one-cable operation, NEXT is the limiting factor. As shown in Table 19, Near-End Crosstalk Losses (dB) 772 kHz on pages 57 and 58, the estimated $m - \sigma$ value of 22-gauge (0.63mm) unit type, air-core (less than 100- pair) PIC cable is:

- 68 dB for adjacent unit separation.
- 75 dB for nonadjacent unit separation.

For 13- or fewer systems, nonadjacent units can be chosen. As an example, in the 50-pair cable of Exhibit 9 (page 64 and 65), $m - \sigma$ of 75dB is applicable to the diametrically opposite 13-pair units. Maximum T1 section L_{d2} for voice communication would be 30.4 dB (29 dB aerial). This does not exceed the 31.6 dB (30.8 dB aerial) value of L_{d1} from Table 16, T1 Cable Section Lengths (page 56). Therefore, L_{d2} is limiting, not L_{d1} .

If more than 13- systems in a 50-pair cable are required, some of the pairs will have to be in adjacent units. This will produce a severe decrease in $m - a$ and, consequently, a reduction in section length.

The 100-pair and m -pair cables in Exhibit 8 can accommodate 25- T1 systems and 50- T1 systems, respectively, without using adjacent units.

4. Outside Plant Considerations, continued

4.4 Selecting Cables, continued

4.4.3 Unit and Layer Type Cables

The geometric configurations of the two types of 900-pair (Exhibits 10 and 11, pages 66 and 67) are characteristic for 900-pair, 22-gauge (0.63 mm) unit and layer types, but there are some variations.

NOTE: Refer to GTE Telephone Operations Practices 920-100-I 00 and 920-200-100 for core makeup of various paper and PIC cables.

In one-cable operation, carefully assign units for opposite directions of transmission. Pairs for both directions may be in the same 100-pair splicing layer group. (See Exhibit 10, 900-Pair, Mixed-Color, Unit-Type Cable, page 66.)

For example, count 401-500. (This count is for illustration only because the repeater spacings required for such an arrangement would be too short for practical systems.) There is a lower degree of NEXT coupling if the pairs for the two directions are in adjacent 100-pair layer groups, e.g., one direction in count 401-500 and the other direction in count 501-600. An even lower degree of NEXT would exist if groups 401-500 and 701-600 were used. This is because of the greater physical separation of the groups in the cable or nonadjacent group assignment.

4.5 Selecting Conductors

The twenty-five- and fifty-unit repeater housings are designed on the assumption that base facilities, are made available in twenty-five-pair even-count groups. In a one-cable arrangement, a minimum of twenty-five-pairs for each direction of transmission (total of fifty pairs) is connected to repeater housings during the initial installation. For a two-cable operation, a minimum of fifty pairs in each cable must be connected to the housings. This standard minimizes entrances into main cable splices. Repeated reentry into splices is a costly practice and degrades performance and reliability of existing spans.

To avoid having unused pairs and inefficient use of the cable, five-, six-, ten-, and twelve-unit housings are not recommended when twenty-five-pair even-count group cables are used.

NOTE: Customer T1s, are an exception to this rule, because of the low density of these services on exchange cables. Small-sized repeater housings may provide for current requirements plus growth. If unused pairs do exist within the carrier unit, they must be bunched and grounded, or protector modules must be provided for all unused pairs.

Normally, all unused repeater housing stub pairs are spliced to the main cable. Occasionally, low-density routes will use main cables having insufficient pairs to accommodate all repeater housing stub pairs. In such cases, the unused stub pairs must be:

- Folded back at the splice.
- Left unterminated (open).

4.6 Splicing

Make splices to meet T1 standards in GTE Telephone Operations Practice 632-61 I-200, Cable Splicing Screened Cable - All Types. These standards maintain adequate NEXT separation. All inputs and outputs within 305 meters (1000 ft) of a repeater housing must be isolated with metal foil tape (or its equivalent). Fault locating and order wire pairs must be spliced through the repeater housings. Splicing this way permits loading, installation of crosstalk-suppression filters and/or sectionalizing (if cable trouble develops).

4. Outside Plant Considerations, continued

4.6 Splicing, continued

To maintain splicing integrity in cables, most installation and operating procedures specify that cables be spliced:

- Color group to like color group.
- Layer to layer.
- According to a well-defined plan.

PIC cables must be spliced binder group to binder group, regardless of the size of the binder group. PIC cables are color coded and usually are spliced pair to pair, as well as binder group to binder group. After selecting a pair count, the conductors can be found in a certain physical position within the cable.

The standard splicing arrangement may have been altered in cables subjected to rearrangement and direction-of-feed change. Because the physical arrangement of the conductors is important in one-cable operation, establish the integrity of the splicing arrangement (if it does not conform to specifications).

When the housings are installed and before the housing splices are closed, take attenuation measurements between adjacent repeater housings. Taking the measurements at that time:

- Verifies the suitability of the installation in each repeater section.
- Prevents reopening splices in an effort to correct unsuitable pairs.

Soldered conductor splices for carrier use are not necessary because the repeaters are powered over the line and sealing current is always present. A solderless connecting method is used to join wires in the installation of repeater housings. (Hand-twisted wires are not acceptable.)

4.7 Cable Treated with Reclamation Compounds

Current GTE Telephone Operations policies do not allow the use of reclamation compounds to reclaim cables containing water. Cable sections containing water must be replaced.

If a proposed T1 route includes a section which previously has been reclaimed, perform an acceptance test on the reclaimed section:

If the Reclaimed Section...	Then...
Meets the acceptance tests requirements.	It is permissible to use the reclaimed section.
Does not meet the acceptance tests requirements.	Replace the reclaimed section.

NOTE: Acceptance Requirements are stated in GTE Telephone Operations Practice 634-020-500, Acceptance Testing-Cable Completion, in the section about cable facility acceptance.

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5. Office Cabling

5.1 Tip Cables

For T1 operation, terminating cables that contain T-carrier systems running from the cable vault to a carrier frame, should bypass the main distribution frame. This will assist in reducing the office impulse noise on the carrier pairs.

Tip cabling from the cable vault to the carrier frame can be done by either of two methods. Each method has different separation requirements. The methods are as follows:

1. Run separate tip cables (one for transmit and the other for receive) to the carrier frame from the main splice in the cable vault. If this method is used, the following separation requirements for these cables must be met:
 - Separation consistent with specifications in GTE Telephone Operations Practice 795-805-073, Transmission Equipment - Central Office Grounding.
 - Separation from other signaling and receive cables by a minimum of six inches.
 - Separation between transmit and receive cables by a minimum of six inches. (The tip cables have a high HF transmit and low HF receive level. Because of this high level contrast, separation must be maintained between them, even though these cables are shielded.)
2. Extend from the main splice to the carrier frame using D- or S- screen cable. (With this method there are no separation requirements, except those set forth in GTE Telephone Operations Practice 795-805-073, Transmission Equipment - Central Office Grounding.)

5.2 Protector and Distribution Frames

The preferred method of interconnecting outside cables and the T1 office terminating equipment is through HF carrier cross-connect equipment as described in GTE Telephone Operations practices:

- 791-400-070, Distributing Frames - HF Cross-Connect Bay - Engineering Applications.
 - 887-050-085 Carrier System Protection - Engineering Considerations.
- AND
- Lenkurt practice 836-910-080, DSX Cross Connections.

This modular equipment:

- Can be mounted in dedicated rack assemblies.
- Can be mounted on the same rack as the line side of the line terminating shelves.
- Has facilities for crossconnecting the line side of the line terminating shelves.

NOTE: The line side of the crossconnect must be equipped with only gas tube or solid state protectors.

5. Office Cabling, continued

5.2 Protector and Distribution Frames, continued

With the growth in T1 services to customers and pair gain devices it is difficult to terminate all T1 facilities on dedicated HF protectors because of small quantities and lack of dedicated counts. It is acceptable to terminate such facilities on the main distribution frame (MDF) in SPC offices, because the MDF no longer represents a point of high noise in the electronic/digital environment. The responsible Transmission Engineering group makes the final decision for the termination point for any given office. The Transmission Engineering group must consider administrative as well as noise issues.

The recommended arrangement, when utilizing the MDF, is to use only the vertical side and to run separate transmit and receive shielded terminating cables (such as GTS-8510) directly to the line terminating shelves. If both sides of the frame are used, jumpers must be shielded. Refer to GTE Telephone Operations Practice 887-903-026, Five-Pin Protector Modules Application. For modular MDFs, the OSP term blocks must be used in a fashion similar to the vertical side of older frames.

5.3 Cabling Between Frame and Equipment

Separate cables for each transmission direction must be used between the carrier protection frame and the office terminating equipment. Suitable multi-pair and single-pair cable types are listed in the table below.

Cable Type Specifications	Manufacturer	Cable Type	Gauge	Number of Shielded Pairs	Average Loss at 70° F db/100'
GTS-8507	General Cable	4162A	22	1	0.47
	General Cable	4162B	22	5	
	General Cable	4162C	22	8	
	General Cable	4162D	22	10	
	General Cable	4162E	22	12	
GTS-8510	General Cable	6307946	22	12	0.39
	General Cable	6307961	22	26	
	General Cable	6307987	22	51	
	General Cable	6308001		101	
	AT&T	ABAM	22	Multi	0.39
	AT&T	750	22	Multi	0.73
	AT&T	751	22	Single	0.52
	General Cable	MPC 459	22	Multi	0.59
	AT&T	1249	22	Multi	
	General Cable	MPC 459	26	Multi	0.46
	AT&T	1249	26	MUM	

Table 2 - Central Office Cabling Loss at 772 kHz

When multi-pair cable is used, pair count and color coding in unit complements must continue the pattern established in the tip cable. Also, if possible, incoming span lines at different levels should be in different cables, or a separate shielded pair should be used for each span line.

Shielded cables such as AT&T ABAM, 750 type, GTS-8507 or GTS-8510 can be used to ensure system integrity and to eliminate the need for separation between input and output cables on cable racks, DSX frames etc. Transmit and receive digital facility leads (cables) require no separation when balanced pair, shielded cables or individually shielded pairs are used for cabling within the CO facilities.

NOTE: Separation from other conductors must be consistent with specifications in GTE Telephone Operations Practice 796-806-073, Transmission Equipment - Central Office Grounding.

5. Office Cabling, continued

5.4 DSX-to-Office Terminating Repeaters

Use GTS-8510 or ABAM shielded cable for interconnecting office repeaters and terminal equipment. Using that type cable prevents PCM signals from disturbing other sensitive equipment in the office. Short, unshielded jumpers on the DSX are an exception to the above. Adjacent, directly connected equipment does not require shielded cable.

Maximum cable lengths between the DSX-1 cross-connect and the office equipment are specified in Lenkurt practice 836-910-080, DSX Cross Connections.

6. T1 Design Applications

6.1 General Rules

All T1 span sections (end, adjacent or full) must have a minimum loss of 9.0 dB. This does not mean that the actual cable loss must equal or exceed 9.0 dB, but if the cable loss is less, then appropriate pads, LBOs etc., must be provided to achieve a loss of 9.0 dB or greater.

This requirement addresses the maximum input level the line repeater can accommodate. Failure to meet this requirement overdrives the line repeater and generates crosstalk problems at that repeater point.

NOTE: Customer end sections are excluded from this requirement. CPE is required to have pad capabilities to coordinate levels from essentially -0.1 dB to specifically address such situations. Those pads must be fully utilized prior to placing additional treatment on the network.

A route junction is a point where two or more systems enter a common sheath at different levels. To address FEXT concerns, there must be level coordination at these points. If systems of different levels:

- Share the same binder group in the common cable, these levels must be within 3dB.
- Are in different binder groups in the common cable, these levels must be within 10 dB.

Where systems meet at a repeater point, that point is not considered a route junction and level coordination is generally not required (provided the cable loss requirements, i.e. 9dB, are met. However, it is recommended that levels be maintained within 10 dB.

6.2 Repeater Capabilities

The T1 line repeater contains an automatic line build-out equalizer, accommodating cable losses from 7.5 dB to 35 dB at 772 kHz. Maximum cable section loss will be less than this to:

- Allow for pair-to-pair loss variations.
- Allow for cable loss specified at 13 °C (55 °F) and increasing with temperature.

The repeater is designed for optimum signal to NEXT performance at 31 dB. At cable losses greater than 31 dB, the ALBO network is ineffective; however, the repeater gain and equalizer are adequate to permit operation to 35 dB of loss. The T1 office repeater contains a line build-out network ranging from 3dB to 7.5 dB at 772 kHz (depending upon repeater type) ahead of its regenerator. The maximum average loss of an end section cable, including tip cable and the 7.5 dB LBO loss, is 26 dB. This allows for additional impairments peculiar to office repeaters.

6. T1 Design Applications, continued

- 6.3
Cable Loss
Values, L_{d2}
- Screened cable and two-cable operations are used for T1 transmission, Both:
- Are not NEXT limiting.
 - Do not affect system performance.

NOTE: The repeater spacings and the corresponding section losses can be taken directly from Table 18, T1 Cable Section Lengths, on page 56.

- 6.4
Maximum
Section Loss,
 L_{d2}

One-cable (nonscreened) operation, is where NEXT is limiting. In this situation, repeater spacing is affected by the number of interferers. The greater the number of NEXT contributors, the shorter the designed span length must be. Calculate the repeater spacing based on:

- Cable physical geometry.
- Crosstalk performance.
- Ultimate number of T1 systems to be equipped.

The maximum spacing of repeaters in dB for one cable operation is determined by the smaller of two factors, L_{d1} and L_{d2} .

The value of L_{d1} is:

- Based on cable attenuation only.
- 31.1 dB for aerial cable.
- 32.2 dB for underground or buried cable.

The value of L_{d2} is based on NEXT coupling. The value (for DDS communication) is calculated by applying the following formula.

Where:

- L_{d2} = Maximum section loss based on crosstalk coupling.
- $m - \sigma$ = NEXT coupling loss
- 33.5 = A constant
- n = Ultimate number of systems
- f_T = $\frac{\text{Engineering loss at } T \cdot F}{\text{Engineering loss at } 55^\circ \text{ F}}$

The formula to calculate the value is:

$$L_{d2} = \frac{(m - \sigma) - 33.5 - 10 \log n}{f_T}$$

In the formula, "m" and " σ " are the mean value and the standard deviation of the NEXT coupling loss distribution in dB at 772 kHz. The values of "m" and " σ " depend on the type cable and the proximity of the cable pairs for the two directions of transmission.

The spread in NEXT values, symbolized by " σ ", will be rather large if the pairs are in the same splicing group. The spread will be smaller if the pairs are in nonadjacent splicing groups because the physical separation of pairs varies over a smaller range.

The term $(m - \sigma)$ is the value of NEXT coupling between pairs in the two splicing groups that will be exceeded by about eighty-four percent of all pair combinations. On a bell-shaped curve of a normal distribution, sixty-eight percent of the crosstalk coupling values fall between $m - \sigma$ and $m + \sigma$; therefore, because of symmetry, only sixteen percent fall below $m - \sigma$. Values of m and $m - \sigma$ for various types of cable and pair assignments are listed in Table 19, Near-End Crosstalk Losses (db) at 772 kHz, 58. on pages 57 and 58.

6. T1 Design Applications, continued

6.4
Maximum
Section Loss,
 L_{d2}
continued

The quantity of (n) is the ultimate number of systems and f_T is the temperature conversion factor. Values of (10 log n) for up to fifty systems are listed in the table below.

n	10 Log n	n	10 Log n	n	10 Log n	n	10 Log n	n	10 Log n
1	0	11	10.4	21	13.2	31	14.9	41	16.1
2	3.0	12	10.8	22	13.4	32	15.1	42	16.2
3	4.8	13	11.1 11.5	23	13.6 13.8	33	15.3 15.5	43	16.3
4	6.0	14		24		34		44	
5	7.0	15	11.8	25	14.0	35	15.4	45	16.5
6	7.8	16	12.0	26	14.2	36	15.6	46	16.6
7	8.5	17	12.3	27	14.3	37	15.7	47	16.7
8	9.0	18	12.6	28	14.5	38	15.8	48	16.8
9	9.5	19	12.8 13.0	29	14.8 14.9	39	15.9 16.0	49	17.0
10		20		30		40		50	

Table 3 - Values of 10 Log n for Use In T1 L_{d2} Equations

Values of f_T for the maximum cable temperature of 38°C and 60°C (100°F and 140°F) are included in Table 18, T1 Cable Section Lengths, on page 56. Minimum cable temperature is not significant because cable losses and crosstalk susceptibility decrease as temperature goes down.

The constant term (33.5) in the equation includes a 6 dB reduction in the value of m. This makes L_{d2} conservatively low to allow for variations in cable manufacturing and splicing and for additional interference from far-end crosstalk coupling.

This method is most often used for finding the maximum section loss L_{d2} , and also the span length. This method may also be used for finding the greatest number of systems, n, for a given design loss when m and σ are given, or the minimum required value of m - σ (NEXT) when L_{d2} and n are given, etc.

Because of their shorter repeater spacing requirements, avoid adjacent groups. If adjacent groups are used, the chart below lists the penalties to take on the number given in Table 18 T1 Cable Section Lengths, on page 56.

For...	Use a Penalty of...
25 systems	5 dB.
50 systems	8 dB.
More than 100 systems	10 dB.
200 or more systems	13 dB.
Nonadjacent groups of:	
● 50 systems	2 dB.
● 100 systems	4 dB.

6.5
Adjacent/
Nonadjacent
Group
Assignment

In a 900-pair layer type cable (Exhibit 11, page 67), an adjacent group assignment is, for example, counts 1-100 and 101-200; a nonadjacent group assignment is counts 1-100 and 201-300. To be nonadjacent, groups must not have pairs in adjacent layers; counts 1-400 and 501-900 do not qualify as nonadjacent. Nonadjacent group assignment should be confined to the outer ring of the cable.

6. T1 Design Applications, continued

6.6 T1 End Section Engineering

T1 end sections are those sections adjacent to the central office. The loss on these sections is limited because of possible exposure to switching transients in the central office. For purposes of end section engineering, a central office is defined as any type of switching system, analog or digital including RSUs, RSCs, etc., utilized for pair gain applications. RLUs, MXUs, DMS-IUs, etc., are not considered to be central offices, even if housed in a building, and therefore, do not require end sections.

NOTE: When a full or nearly full section to a pair gain device, it may be necessary to remove the 3 or 7.5 dB LBO or equalizer in the terminating repeater. Such pads are to be left where the total loss (Loss + LBO) exceeds the Input limitations of the repeater. Refer to the manufacturer's expectations (For example, the 7.5 dB LBO for the 91871 in the 914 MXU should be switched out when the section loss exceeds 27 dB).

End sections are limited to half the maximum full section loss as calculated by the lesser of L_{d1} or L_{d2} . This loss encompasses cable only, and does not include office wiring or the loss in the 3.0 dB pad or 7.5 dB equalizer of the office terminating repeater. Ideally, the facility should terminate on a dedicated carrier frame. However, this is not always practical, particularly where customer T1s are involved. The MDF may be utilized in SPC offices for termination of T1s to customers or DLCs. In such instances, use shielded jumper wire on the MDF, consistent with section 5.2, Protector and Distribution Frames.

6.6.1 End Section Build Out

The various cable types making up the office cabling between the LTS, MDF, carrier frame, vault, etc.:

- Are discontinuities in the PCM signal path.
- Cause unwanted pulse reflections.

To absorb these reflections, a 7.5 dB LBO or 3 dB pad must be strapped into the office repeater. For new routes, the office repeater end section line build-out option should be the 7.5 dB LBO. The 3 dB pad decreases the end section repeater noise margin. Strapping out the LBO is not recommended.

If the PCM signal is passed through an intermediate office using an express repeater shelf, discontinuities in office cabling are absorbed by a 3 dB level coordinating pad. This pad is installed on the line repeater in the express repeater shelf.

6.6.2 Mixed VF and Carrier Cable

As explained in the section 3.2, Error Rate, if the end section cable contains switched VF pairs, central office impulse noise may be coupled to the carrier pairs through NEXT. This dictates a reduction in end section cable loss. Non-switched VF pairs are allowed in the same cable units with T1. Switched VF pairs are not allowed in the same units as T1 carrier.

6. T1 Design Applications, continued

6.6
T1 End Section
Engineering,
continued

6.6.2 Mixed VF and Carrier Cable

The illustration below shows the incoming T-carrier system pair in a simple entrance section. Noise reaches the office repeater via path A. In this path A, secondary induction is expected to be much greater than any direct induction of noise within the office if carrier pairs and switched VF pairs are contained in the same sheath.

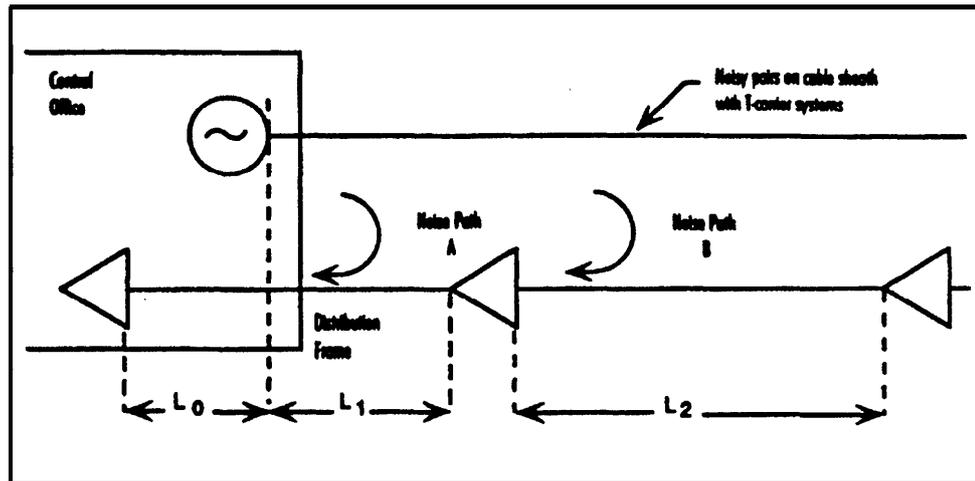


Exhibit 4 - Impulse Noise Coupling in Repeater Sections Near the Central Office

The objective in designing end sections is to regulate the difference between the loss in the path by which the noise arrives at the repeater input (Noise Path Loss or NPL) and the cable loss incoming to the repeater. This difference must be at least 66 dB for DDS communication. Achieve this by limiting end section cable loss L_1 to fifty percent of the loss based on full sections. Because both signal and noise are attenuated equally by L_0 , the loss limit does not include office wiring and the office repeater input pad or equalizer.

The end section reduction corresponds to the range of noise levels that may be encountered depending on:

- Office size.
- Cable size.
- Crosstalk coupling.

If the system involves more than three tandem spans, further reduction below the fifty percent value chosen is required in accordance with the table below.

Number of Tandem Spans	Reduction In Cable Loss, dB (below 50% or 65% value)
2 or 3	0
4	0.9
5	1.6
6	2.3
7	2.0
8	3.3
9	3.7
10	4.0

Table 4 - Effect of Tandem Spans on End-Section Cable Loss

6. T1 Design Applications, continued

6.6
T1 End Section
Engineering,
continued

6.6.3 End Sections for Customer T1s

Place a T1 loopback device and appropriate NIJ at the CPE demarcation point to facilitate T1 testing from the central office. Design end sections for customer T1s at the customer end for a maximum cable loss of 15 dB. This loss, coupled with the insertion loss of the active loopback devices, meets the maximum objective of 16.5 dB total loss at the customer demarcation point. (There is no minimum loss requirement for customer T1 s.) Line power will terminate or loopback at the point of demarcation.

6.7
Adjacent
Section
Engineering

Adjacent sections are those sections immediately adjacent to the central office end section. If a single cable operation is utilized, impulse noise (switch noise) may be coupled into the adjacent section if VF pairs are present in the cable. Because of this, there may be a requirement to limit the loss to less than that of a full section. The maximum length in this case would be determined by the following formula:

$$L_2 \text{ max} = L_1 + \text{NPL} - 66$$

(Where, NPL = $m - \sigma$.)

NOTE: In this case $m - \sigma$ is for the binder separation between the CXR pairs and VF pairs, not the $m - \sigma$ between the transmit and receive CXR pairs.

Because a typical conservative value for NPL is 75, this equation can generally be simplified to:

$$L_2 \leq L_1 + 9$$

(Where, L_2 is the noise limited loss for the adjacent section and L_1 is the cable loss of the end section.)

The maximum loss of the adjacent section is then determined by the smallest of the values $L_2 \text{ max}$, L_{d1} or L_{d2} . Adjacent sections can be designed the same as full sections when two cable operation is used.

6.8
Full Section
Engineering

Full or mid sections are those sections in the middle of a T-carrier span. The sections are isolated from the central office impulse noise by the end and adjacent sections. Maximum spacing for mid-sections is limited only by the loss and NEXT factors (L_{d1} and L_{d2}).

Do not engineer repeater points too close together. Although the ALBO in the repeaters will compensate for losses from 7.5 dB to 35 dB, low losses between repeater points can create the potential for FEXT problems. FEXT problems are manifested in:

- Spare span switching failures associated with DLCs.
- OR
- Data errors on customer T1 s.

Space repeaters at least 20 dB apart, unless limited by L_{d2} . Repeater sections limited to 15 dB or less, whether because of L_{d2} or other physical constraints, must be treated with external span pads.

Select the appropriate pad value that brings ~~an~~ calculated section loss to a minimum of 20 dB. (Repeater sections terminating at Digital Loop Carriers must utilize the proper options on the span terminating units and LBOs to coordinate these levels if possible. Use span pads only when it is not possible to achieve level coordination within the DLC itself).

6. T1 Design Applications, continued

6.8 Full Section Engineering, continued

Using a span pad will not contribute to NEXT problems, but will attenuate the levels adequately to mitigate the FEXT effects. Span pads must be clearly indicated on span design records. Note also that span pads should generally be placed on the receive side of the repeater, preferably behind the protectors.

6.9 Short Sections

The mean loss values for near-end-coupling are listed in Table 19, Near-End Crosstalk Losses, on pages 57 and 58. The values listed are applicable if the section loss is 10 dB or more. For shorter sections a correction factor (I) is added to $m - \sigma$. Here, (I) is the reduction in crosstalk coupling (increase in coupling loss) because of the reduced length of exposure (L). Values for (I) are graphed in the following illustration.

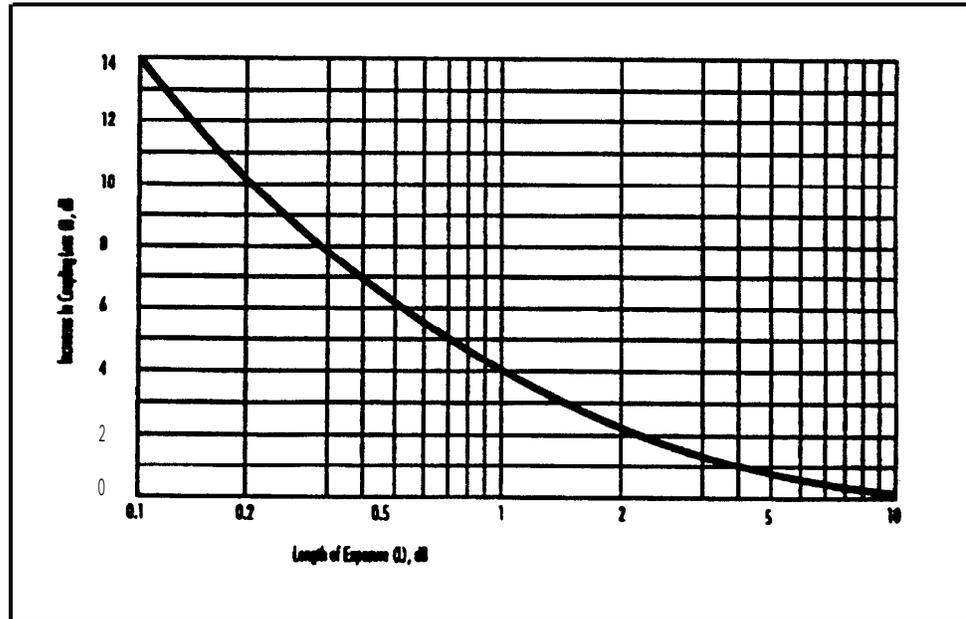


Exhibit 5 - Increase In Coupling Loss (I) Short Sections

6.10 Measurement of Near-End Crosstalk

The values of m and $m - \sigma$ in Table 19, Near-End Crosstalk Losses (on pages 57 and 58) are typical. If cable integrity is in doubt, make a random test of cable pairs before installing equipment. If all repeater sections in a span cannot be tested, then test at least one section for each type of cable and each different assignment of splicing groups.

NOTE: Ensure group integrity at all splices or the evaluation of NEXT coupling in one repeater section may not be applicable to another section on the same cable.

In two 100-pair splicing groups, there are 10,000 different crosstalk coupling paths between combinations of pairs in the two groups. Measuring all possible combinations is not practical. For accurate statistical analysis, the number of measurements must be at least 200.

6.11 Design Applications, continued

6.10 Measurement of Near-End Crosstalk, continued

The steps in calculating m and σ from the measured values of NEXT are described in the table below. Five values are shown to illustrate the method. If the splicing groups for the two directions of transmission have more than fifteen pairs each, select fourteen or fifteen pairs randomly from each group and measure, in turn, NEXT Coupling Loss between each combination.

	Column A NEXT (dB)	Column B NEXT -m (dB)	Column C (NEXT -m) ²
	70	0	0
	72	+2	4
	69	-1	1
	67	-3	9
	72	+2	4
Total	350	0	18

Table 5 - Calculation of Mean Value (m) and Standard Deviation (σ) of NEXT

7. Span Design Considerations

7.1 Route Junctions (T1)

A route junction is formed where two or more systems enter a common sheath at different levels. The exhibit on the next two pages, "Route Junctions", are referred to throughout this section. In Exhibit 12 on page 68, Figures A through C show examples of route junctions for one cable and two cable systems. (For simplicity, through systems from office A to office B are not included.)

The joining of two separate routes at a common repeater housing, continuing in the same sheath, is not considered a route junction.

Where practical, place repeater housings at each route junction or keep the routes in separate cables until the common routes can join at a repeater housing. (Refer to Figures D and E in Exhibit 12 on page 68.) This simplifies the engineering because each section from the junction can be engineered separately without regard to the sections in other directions.

If this is not possible, a far end crosstalk (FEXT) problem may come about because of level differences in cable section #3 (for two cable operation) and in the times toward office C in cable section #9 (for one cable operation). Levels in the exposure section must be controlled by imposing a limit on the difference between losses L_A and L_B . The limits are charted below.

If the Interfering Pairs Are...	Then the Limit is...
The same unit in the L_C cable section	3 dB.
In different units	10 dB.

The total loss in each route ($L_A + L_B + L_C$) is still subject to the limitation of L_{d1} , and for one cable operation, L_{d2} .

NOTE: If the L_C cable terminates directly at office C, the restriction concerning office noise may be applicable.

7. Span Design Considerations, continued

7.1 Route Junctions (T1), continued

In one cable operation, the controlling value of L_{d2} for each route is the smaller of the L_{d2} values for the two sections in the route. For example, if L_{d2} is 28 dB for section #7, 21 dB for section #8 and 26 dB for section #9, Then $L_A + L_C = 26$ dB maximum and $L_B + L_C = 21$ dB maximum.

In calculating losses around a junction involving end sections, include (if they contribute to the level difference in the exposure section):

- The 3 dB pad loss or 7.5 dB equalizer loss in the office repeater.
- The office wiring loss.

7.2 Repeater Housing Splicing Arrangements

Acceptable arrangements for splicing the repeater housings into the main cable are illustrated in Exhibits 14, 15, and 16, pages 70 through 73. The standard one-cable and two-cable operations use the same arrangement for splicing the repeater housings into the main cable.

Direction of transmission information and pair count associated with repeater housings:

- Will be uniform throughout a span.
- Need to be indicated only once on the detail plans for that span.

NOTE: To prevent resplicing when interconnecting another company, with an agreement between GTE Telephone Operations and the other company is required to determine which company will transmit on side one.

7.3 Extended Superframe (ESF)

Extended Super Frame (ESF):

- Extends the DS1 superframe structure from twelve to twenty-four frames (4632 bits).
- Redefines the 8 kb/s channel consisting of framing bits previously used for terminal and robbed bit signaling synchronization.

The ESF format consists of:

- A 2 kb/s channel for basic frame and robbed bit signaling synchronization.
- 2 kb/s for Cyclical Redundancy Check (CRC6) code.
- 4 kb/s for a maintenance data link.

7.4 Clear Channel Capability (CCC)

Clear Channel Capability (CCC), also called clear channel or customer clear channel, is the capability of passing unrestricted data. There are two methods available to provide CCC. The two methods and their characteristics are:

- ZBTSI - ZBTSI has the ability to provide CCC over existing facilities, but reduces the transfer rate of the data link by 2 kb/s and also introduces significantly more delay.
- B8ZS - B8ZS allows for the data link to operate at 4 kb/s and introduces much less delay than ZBTSI. The drawbacks of B8ZS are that it purposely introduces Bipolar Violations (BPV) in the bit stream, and therefore, requires the replacement of many pieces of terminal equipment to be compatible.

B8ZS is favored method among both local and interexchange carriers. The standard method of providing CCC within GTE Telephone Operation6 is B8ZS

8. TI C Design Considerations

8.1 Introduction Current GTE Telephone Operations policy is to discontinue use of TI C equipment and facilities. All T1C equipment has been coded Additions and Maintenance (A&M) status. No new TI C facilities are being designed or placed. It is acceptable to provide growth and expand existing routes out to the present planned capacity. Therefore, this section is provided to support the maintenance of the existing TIC facilities.

8.2 Route Junctions Route junctions are not allowed in TI C applications.

T(1C)

8.3 TIC Fault Locating and Order Wire Pairs Cable fault locating and order wire pairs must not be in the same splicing unit used for TIC. If x-pairs are available in that unit, they must be selected (an x-pair is a spare pair, not normally part of the cable count). Fault locating and order wire pairs must be loaded for VF transmission and the pair numbers indicated on the construction detail drawings.

NOTE: If the fault locating and order wire pairs are in the same cable as the carrier, special T1C crosstalk suppression inductors may be required in the repeater housings.

8.4 T1 C Repeater Capabilities The T1C line repeater contains an automatic line build-out equalizer accommodating cable losses from 9 dB to 54 dB at 1.576 MHz. Maximum cable section loss is typically designed lower than this, allowing for:

- Pair-to-pair loss variations.
- The fact that cable loss is specified at **13° C (55° F)** and increases with temperature.

The maximum allowable individual cable pair loss, measured at 1.576 MHz and referred to **13° C (55° F)**, is 52.8 dB. The TIC office repeater contains a 12 dB line build out (LBO) network ahead of its regenerator. The maximum average loss of an end section cable, including the 12 dB LBO, is 45 dB. This lower limit makes allowance for additional impairments peculiar to office repeaters.

TI C line repeaters become progressively more sensitive to cable characteristics as the cable loss increases. This requires separate ALBO equalizer designs for pulp/paper, PIC, and MAT/ICOT cable.

NOTE: Refer to Lenkurt Practice 342-910-106,9104A 24/48 Channel PCM Repeated Line Equipment Outside Plant, for applicable repeater type.

Because the TIC office repeater receives its signal over a shortened end section and 12 dB LBO, one equalizer design is satisfactory for all cable types.

8. T1 C Design Considerations, continued

8.5 T1 C Maximum Section Loss

The Table 20, T1C Cable Section Lengths, on page 59, and Table 21, T-Screen and Z-Screen Cable Section Lengths, on page 60, give the maximum lengths of intermediate and end sections for various types of cable. These values include:

- Loss margin for the effects of temperature variations.
- Pair-to-pair loss variations.
- Route map inaccuracies.
- Repeater circuit variations.
- Type of repeater housings.

Because these are difficult to accurately characterize, loss margins were derived from a series of field tests on practical configurations of T1C span lines.

NOTE: For repeater spacing on cables not covered in Table 20 and 21, refer to the manufacturer's documentation.

8.6 T1 C Limitations on Maximum Section Loss

Maximum section loss is based only on cable attenuation and the requirement that the incoming signal level at the repeater be within a certain range. Other limitations on maximum section loss may be imposed by one or more of the following:

- Near-end crosstalk coupling in one-cable and screened-cable operation
- Far-end crosstalk in two-cable operation.
- Near-end crosstalk coupling in repeater housing.
- Near-end crosstalk coupling in cable stub splices.

NOTE: The reflection losses resulting from the use of different gauge cables or different type cables are usually insignificant and may be ignored.

8.6.1 Near-End Crosstalk Coupling in One-Cable and Screened-Cable Operation

For T1C operating in one-cable or screened cable, near-end crosstalk (NEXT) may be the limiting factor in the design of section length. The crosstalk interference for any T1C system is the sum of NEXT coupling from all the interfering T1C systems. NEXT requirements must ensure that sufficient margin against crosstalk exists to satisfy the error rate objective of the system. Plant considerations for using non-screened cable, the criteria for a pair K passing T1C system requirements, are as follows:

- The one-tenth (0.1) percent point of the grand power sum distribution for unit K must be no less than 80 dB at 1.576 MHz.
- If the grand power sum distribution for unit K is truncated at some minimum value, then it is required that the minimum grand power be not less than 80 dB at 1.576 MHz.

If the one-tenth (0.1) percent point criteria is equivalent to:

$$M_k - 3.1 \sigma_k \geq 80 \text{ dB at } 1.576 \text{ MHz}$$

(Where M_k is the average or mean value and σ_k is the standard deviation of the normal grand power sum distribution $Q\{1,K\}$, $Q\{2,K\}$, ..., $Q\{n,K\}$ for unit K.)

8. T1 C Design Considerations, continued

8.6
T1 C Limitations
on Maximum
Section Loss,
continued

8.6.2 Far-End Crosstalk in Two-Cable Operation

Far-end crosstalk (FEXT) may be created when two or more systems enter a common sheath. This is not allowed for T1C. Systems must:

- Join only at repeater housings.
- OR
- Use separate cable until they can be joined in a repeater housing.

NOTE: Refer to section 8.9, T1C Single Stub Bi-Directional Housings, for the one exception to this rule.

8.6.3 Near-End Crosstalk Coupling in Repeater Housing

The newer repeater housings have adequate NEXT and are designed for T1C operation. Certain loss factors must be considered to offset manufacturing irregularities. These are included in the given section lengths of Table 20, T1C Cable Section Lengths table on page 59. When using the full size series of repeater housings, subtract ten percent from the maximum intermediate section length.

8.6.4 Near-End Crosstalk Coupling in Cable Stub Splices

High level output cable pairs must be separated from all low level input pairs by means of cable screen or shield wrapping at all repeater housing stub splices. Inadequate shield wrapping in stub splices may accumulate enough near-end crosstalk to degrade the performance of the system.

NOTE: Refer to Lenkurt Practice 631-863-200, 91A A PCM Repeater Housing installation, for splicing procedures to minimize this problem.

8.7
T1C End
Section
Engineering

To limit the effect of central office impulse noise, end sections are limited in length. (Refer to Table 20, T1C Cable Section Lengths table on page 59 and Table 21, T-Screen and Z-Screen Cable Section Lengths table on page 80.) Another reason for restricting the end section is its influence on the adjacent section length. This section may be susceptible to impulse noise through NEXT coupling paths to the low level repeater inputs at the first repeater housing. The end section must be designed for a maximum loss of 45 dB including:

- LBO loss in me office repeater.
- Loss from me office tip cable.

For example, an office repeater adds 12 dB loss and about 0.7 dB for tip cable or an equivalent of 2.271 kft for 22-gauge filled PIC cable. (The actual buried end-section length is limited to 5.765 kft.) If the end section becomes less than 2.735 kft (less than half the limited length), the restriction for the adjacent section, shown in T1C Cable Section Lengths table, applies.

8. T1 C Design Considerations, continued

8.8 Treatment of VF Pairs in T1C Units

In T-Carrier applications it is assumed that all pairs in a cable unit will be spliced to the repeater housing. A near-end interaction crosstalk path is created when any pairs in this unit are connected through the housing to provide a fault locating, order wire, pressure alarm, or special service circuit. Energy from all repeater outputs is coupled into the service pairs. These pairs then can act as radiators back into all repeater inputs. This effect becomes important when twenty-five or fifty outputs are coupled back into a repeater whose normal input has been attenuated by a maximum section loss.

The risk of this coupling causing a repeater to make bipolar violations can be eliminated by adding an inductor in series with each wire that bypasses the repeaters. Because of the high frequency nature of the crosstalk, a load coil is relatively ineffective in blocking the coupling path. If this problem arises, 2-millihenry - 10 ohm inductors are available to correct the problem. These are added in series with all pairs connected through the housing.

If non-switched VF pairs must pass through unequipped repeater positions, then both the repeater bypass and load coil plug-in units are available equipped with the crosstalk control inductors to block these coupling paths.

8.9 T1 C Single Stub Bi-Directional Housings

The midi-type repeater housings present a special T1C far-end cross talk problem because of their single stub. In the bi-directional mode, the relative level between the side 1 and side 2 input depends on the loss of the cable sections adjacent to the housing. These inputs must not differ by more than 12 dB at 1.576 MHz. This allowance is higher than generally allowed for a route junction because there are only six interferers present and therefore the crosstalk power sum is low.

The critical application for these housings is adjacent to the office. The cable section adjacent to the end sections must not exceed the sum of the end section cable loss plus 24 dB. For example, if the end section cable loss is 20 dB, then the adjacent section cable loss is limited to 44 dB at 1.576 MHz.

8.10 Mixing of High and Low Q Clock T1 C Repeaters

The midi-type model one line repeaters contain non-standard low Q clock recovery circuits and produce more jitter than standard T1C repeaters. When a low Q repeater must be replaced with a high Q unit, the upstream jitter buildup may be such that a high Q clock repeater cannot track the incoming jitter. This results in occasional bipolar violations at the output of the first high Q repeater. This can occur when the output from more than approximately eleven consecutive low Q clock repeaters meets a high Q clock repeater.

To minimize this jitter build-up, it is recommended that high Q repeaters be strategically placed in the existing system so there are no more than eleven consecutive low Q repeaters before a high Q repeater.

The above recommendation also applies when tandem spans of low Q and high Q repeaters must be interconnected. The new high Q clock line repeaters should be installed in all new T1 C spans.

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8. T1 C Design Considerations, continued

8.11 Engineering Existing Cable Facilities for T1C use

Evaluate older cables for T1C application. If the same cable and the same T1 repeater points can still be used, it may be economical to utilize them. These facilities (i.e. types of cable, section lengths, and types of housings) must be reviewed to meet T1C requirements stated previously in this document.

NOTE: NEXT is always the limiting factor in evaluating because of the typically inferior performance of the old facilities compared to the later types.

NEXT interference is the result of coupling from transmit pairs to receive pairs located in adjacent units or non-adjacent units in the cable and in the repeater housing. Because NEXT coupling paths can differ for each source, the total margin is computed and the resulting value represents the margin expected for the proposed system.

Several factors dictate the allowable section loss for T1 C spans. The most restricting factor appearing along the span is the NEXT coupling loss from all interfering pairs in one-cable or screened cable operation. Lacking information on NEXT losses for repeater housings and other factors at 1.576 MHz, it is assumed that these contribute a fixed value equal to that given in the notes for Table 20, T1C Cable Section Lengths on page 59 and 60.

Table 21, T-Screen and Z-Screen Cable Section Lengths, on page 60, provides intermediate and end section spacing for T1C repeater on earlier T-screen and Z-screen cable. Spacing is considerably shortened compared to newer screened cable because the NEXT performance was originally established for T1 applications.

NOTE: Using S-Screen cable for T1C application is not recommended. S-Screen cable has been designed for T1 application only. If circumstances require such use, no cable smaller than 106 pairs should be used, and maximum utilization should not exceed fifty percent of the total cable pairs.

9. Spare Lines

9.1 Introduction

The current GTE Telephone Operations policy for providing spare lines and spare span line switching is outlined below. (Refer to PAR-22 for specifics.) This outline is to assist the the Operating Areas in both design and maintenance of existing embedded systems and equipment.

9.2 Policy Overview

Select and provide spare lines and spare span line switching based on the following guidelines:

- For interoffice, follow the 1 :N rule, i.e., a minimum of 1 spare line for every N working span, where N = 5, 9, 11, or 24. The maximum value of N is dependent upon the repeater cabinet size deployed, i.e., $N < 25$.
- For certain DLC pair gain systems (such as AT&T-SLC5 and Siemens-914A/E/EX MXU), provide both a spare line and switching. The spare line switch configuration must be consistent with the manufacturers recommendations.
- A spare line will be provided on ail interoffice facilities, but switching will be provided only on facilities to remote offices with 4 or less H-R links.

No new spare line switching equipment will be added except where it is required to meet specific service demands. It is acceptable to provide for growth by expanding existing switching shelves only. Spare span lines and span line switching will not be provided on:

- Customer T1 s (unless requested by the customer and included in the T1 lease cost as a tariffed item).
- Pair gain systems with an ultimate capacity of 49 lines.
- DLC pair gain systems (such as Northern Telecom-DMS1 -Urban and ALCA=TEL-1218) which have load transferring capabilities and, therefore, do not require the span switch.

9.3 Considerations

In two-cable operation with unidirectional repeaters, removal of a line repeater disables two systems, so two spare lines are needed to restore service.

Normal practice is to:

- Drive the spare line at the local terminal.
- Loop it back at the remote terminal.
- Monitor the returned signal at the local terminal.

The spare line is driven to prevent regenerating noise and to prevent false outputs. In dedicated cables, terminated spare lines without a line driving signal should have no output. In cables not dedicated to carrier, T1C spare lines without a line driving signal applied, may pick up enough noise to produce continuous pulses and errors.

NOTE: The spare linedriving signal may be obtained from a working system through a bridging repeater or from a QRSS signal generator.

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9. Spare Lines, continued

9.4 Spare Line Switching

Protection of T1 C lines is crucial because there are forty-eight channels per line repeater. Automatic protection switching is recommended for applications where a repeated line failure would:

- . Isolate a town.
- Cause critical special services to be down for excessive periods.

T1 repeated spans include spare line switching equipment that automatically transfers a working system to a spare line if the working line fails. One set of spare lines, transmit and receive, can be used as backup for one or more sets of working lines.

NOTE: Fixed LBO repeater units cannot be used with this switching equipment.

Spare lines extend from terminal to terminal. Where applicable, the spare lines pass through intermediate offices just as the working lines pass through. Where several working systems terminate at successive offices along a cable route, connecting the spare line through switching equipment at each office enables all the systems to share the same spare line. When a working line fails, the spare line is seized at the end offices of the failed system. This sharing arrangement is called "quasi-sectional" because a transfer ties up the entire spare line, not just the span where the working line failed.

Automatic switching is controlled by the operational error detectors on office repeaters. The error detector responds to loss of signal or to an error rate selectable by a strapping option. After failure is detected, switching at both offices is completed in less than 140 milliseconds.

Strap switching equipment to enable it to loop back at the remote terminal when a working line fails. Strapping in this way enables both directions of the failed line to be fault located from the local terminal. For fault locating the spare line, the required loop already exists if the spare line is driven from the local terminal only.

With bi-directional line repeater units and the remote-looped configuration, the go-and-return fault locating signals produce the same audio frequency from the side 1 and side 2 fault locating outputs. To allow separate monitoring of each direction of transmission, the fault locating filters must have dual amplifiers activated by opposite DC voltage polarity.

NOTE: Information about spare line switching is in Lenkurt Practice, 342-910-114, 91A Spare Line Transfer Equipment.

9.5 DDS Spare Line Switching

As with pulse transmission quality, non error corrected DDS spare line switching is much more stringent than voice communication. Requirements for DDS spare line switching include:

- Spare lines and operating lines must be a one-for-one switching arrangement.
- The spare line must be driven in parallel along a different route to ensure service protection.
- Switching threshold in error detector must be 10⁻⁶ or higher for office terminating repeaters.
- . The spare line must be switched without slippage in data timing.

10. Fault Locating System

10.1 System Layout

Fault locating systems must be installed and maintained in accordance with current GTE Telephone Operations Policy.

in the fault locating system, the fault-locating test set's interrogating signal is transmitted over the repeatered time. At a selected repeater location an audio frequency component of the signal is:

- Extracted by a bandpass filter.
- Returned to the interrogating office over a fault locating pair.

If the filter units are equipped with amplifiers, twelve more locations can be monitored on the same fault locating pair. According to the polarity of the DC voltage fed over the pair to the amplifiers, one set of twelve filters is enabled and the other set of twelve is switched off.

10.2 Filter Units with Amplifiers

When each end office tests only the outgoing direction by using filter units with amplifiers, as many as twenty-four repeater locations (two sets of twelve filter units) can be monitored on one pair. According to the polarity of the DC voltage fed over the pair to the amplifiers, one set of filters (up to twelve) is enabled and the other set is switched Off.

When both directions of transmission are to be tested from one office, spare line switching equipment is required to loop the receive span line to the transmit span line at the remote office. With this arrangement, the maximum number of repeater locations that can be monitored on one fault locating pair is twelve (one set of filter units). This is because DC voltage polarity cannot be used to select a particular set of filters.

DC voltage polarity must be used to select repeater side 1 or side 2 for independent monitoring. Otherwise, audio signals derived from both the "go" interrogating signal and the "return" interrogating signal would be present on the fault locating pair at the same time.

If the capacity of a one-cable or two-cable span is large enough to require multiple housings, each housing must have a separate fault locating filter. (Two-cable, two-housing systems have separate fault locating pairs for each cable.)

The objective in laying out the fault locating system is to attain the highest possible signal-to-noise ratio in the audio frequency return at the interrogating office. Generally:

- Idle noise level on a fault locating pair signal should not exceed 20 dBmc.
- Fault locating pair signal should be at least 10 dB above the noise.

Filter units with amplifiers may be needed when the span:

- Is very long (10 dB or more of loss at 1 kHz)
- Has more than twelve repeater locations.

10. Fault Locating System, continued

10.2 Filter Units with Amplifiers, continued

To ensure the signal level is adequate at all the fault locating frequencies, consider both:

- The filter Output levels Of the cable.
- The attenuation characteristics of the cable.

The Relative Fault Locating Filter Output Levels table, illustrated below, shows without amplifiers, filter output level increases With frequency.

Code	Frequency, (Hz)	Nominal Output Level, dBm	
		Without Amplifiers	With Amplifiers
A	832	-53	-23 dBm (Codes A through M)
B	928	-51	
C	1048	-49	
D	1206	-47	
E	1340	-46	
F	1508	-45	
G	1722	-43	
H	2008	-42	
J	2193	-41	
K	2413	-40	
L	2680	-39	
M	3017	-38	

Table 6 - Relative Fault Locating Filter Output levels

NOTE: Into 900 termination - levels may vary ± 1 dB per impedance of fault locating pair at the filter output. Also, amplifier gain may vary ± 3 dB over the operating temperature range of -40°C to $+60^{\circ}\text{C}$ (-40°F to $+140^{\circ}\text{F}$).

The response of H-88 or D-86 loaded cable is relatively flat over the fault locating frequency band. Typically, the slope between 800 Hz and 3000 Hz is about 0.03 dB/kft. Non-loaded pairs should not be used because of their much greater slope (typically, 0.3 dB/kft). It may be possible to use a nonloaded pair if the span has five or fewer sections and the lowest frequency filters are used.

NOTE: More information about the frequency responses of loaded and no-loaded cable pairs is in GTE Telephone Operations Practice 852-050-050, Cable Voice Frequency Loading Systems and the 857-1XX-XXX section of GTE Telephone Operations Practices (Transmission Data and Cable Characteristics).

10. Fault Locating System, continued

10.3 Filter Frequency Assignment

If filter units without amplifiers are used, the frequencies can be assigned to the repeater locations in alphabetical order by code letter. Use Code M (which has the highest frequency and output level) for the location farthest from the interrogating office. In one-cable operation, because the same fault locating pair serves both directions, the lower frequency filters can be assigned near mid-span and the higher frequency filters at each end. Doing this may cause confusion later when testing.

Because filter units with amplifiers have approximately the same output level for codes A through M, assign frequencies in alphabetical order in either one-cable or two-cable operation. Begin assigning with code A at the interrogating office.

In one-cable operation, office filters at each end can have the same frequency. For testing, disconnect the filter at the interrogating end when the test set is plugged into the office filter unit.

10.4 Route Junction

If a span includes a route junction, fault locating pair(s) are needed for each route (A-B, A-C, and B-C) (refer to Exhibit 6 12 and 13 - Route Junctions on pages 68 and 69). But with only one fault locating filter in a housing, A-C or B-C, repeaters in the cable between the junction and office A or B must be monitored on the A-B fault locating pair. Because this pair does not appear at office C, fault locating can be done from office C only as far as the junction.

10.5 Power Feed to Amplifiers

Refer to Exhibit 17, on page 74, for the equation that will determine whether the 91114 unit must be strapped for a higher voltage. This exhibit determines the power feed to fault locating filter units.

Fault locating pairs must be extended from office to office. If fault locating is done from one end only, the pair should be terminated at the other end with a series network of approximately 900 ohms and 2μ F.

10.6 Fault Locating Pairs

In the main cable, fault locating pairs should be in the same splicing group used for T-carrier. If pairs are not available in that group, they should be selected in another group that, according to the long-range plan, will not be used for T-carrier. X-pairs should be used if available. (An X-pair is a spare pair that is not normally considered a part of the cable count.)

Pairs usually must be loaded for VF transmission (see section 12, Loading VF Pairs). Pair numbers must be indicated on the construction detail drawings.

If the capacity of a one-cable or two-cable span is large enough to require multiple housings, assign different fault locating pairs to co-located housings.

The objective in laying out the fault locating system is to attain the highest possible signal-to-noise ratio in the audio frequency return at the interrogating office. The idle noise level on a fault locating pair must not exceed 20 dBmC (approximately), and the fault locating signal must be at least 10 dB above the noise. If the span is very long (10 dB or more at 800Hz) or has more than 12 repeater locations, filter units with amplifiers may be needed. To ensure that signal level is adequate at all fault locating frequencies, the filter output levels and the attenuation characteristics of the cable must be considered. Filter output level increases with the frequency. (This is illustrated in Table 6, Relative Fault Locating Filter Output Levels. page 38.)

NOTE: For loading alternatives on long routes and/or stretch sections, see section 12, Loading VF Pairs.

11. Order Wire

11.1 Introduction

The order wire is a talking pair that can be associated with Central office line equipment. Order wire is used for Communication between:

- Line repeater locations.
- Any line repeater location and the central office at either end of the span.

Usually only one order wire circuit is required for each route, regardless of the number of span lines. Treat order wire as a subscriber line in one of the span terminating offices. Doing 60 enables craft personnel to:

- Dial any number from a line repeater location.
- Call the testboard at either span terminating office.

Order wire on customer T1s terminate at the last repeater point before the customer premises.

The order wire pair, like the fault locating pair, must be loaded. If the pair's length is such that its DC continuity must be broken, specify this point in the construction details.

11.2 Loop Resistance

Maximum DC loop resistance of the order wire (normally) is 1300 ohms. On longer loops, up to 2800 ohms, order wire talking and signaling batteries can be fed from each end of the span with DC separation capacitors, in series with the loop, at the midspan repeater housing.

On even longer loops or, if one end of the system does not have access to central office switching equipment (e.g., at the remote terminal of a subscriber carrier system), special equipment such as a loop extender (Lorain type 466338-169™, or equivalent) is needed. The loop extender can increase the maximum loop resistance from 1300 ohms to 2800 ohms. Increasing loop resistance with a loop extender allows a length from each end of 24.9 km (fifteen miles) on 22-gauge (0.83 mm) H-88 loaded cable with a 1-kHz loss of 10.8 dB. Approximately the same limit on cable length is imposed by repeater power feed requirements.

NOTE: The order wire is accessible on most housings through external terminals without opening the repeater housing.

Lorain 466338-189 is a trademark of Lorain Products - Reliance Comm/Tec, Lorain, Ohio.

12. Loading VF Pairs

12.1 Load Coils

One or more fault locating pairs in each span cable and one order wire pair per span are needed. Inserting load coils (66 mH or 88 mH) in these pairs at each repeater housing:

- Reduces attenuation.
- Improves impedance.
- Makes both attenuation and impedance parameters more uniform over the voice frequency band.

The frequency response requirements of the fault locating pair:

- Are more stringent than that of the order wire pair.
- Generally will dictate whether or not load coils should be used.

GTE Telephone Operations Practice 852-050-050, Cable Voice Frequency Loading Systems, explains selecting and placing load coils in VF telephone cable circuits. Standard nominal load coil spacings are 0.92 km, 1.4 km, and 1.8 km (3 kft, 4.5 kft and 6 kft) identified by code letters 8, D and H respectively. Thus, H-88 means 88 mH load coils placed every 1.8 km (6 kft).

The nominal spacing of repeater housings on 22-gauge (0.63 mm) paper-insulated cable is 1.8 km (6 kft). Order wire and fault locating pairs are conveniently loaded by installing 88-mH coils in the repeater housings. With other types of cable or coarser gauge pairs:

- Distance between repeater housings can be greater than 1.8 km (6 kft).
- A different loading scheme may be required.

Calculate the theoretical cutoff frequency of a single load section using the following formula:

$$f_{co} = \frac{1}{\pi \sqrt{LC}}$$

Where:

- L = Load coil inductance in henries.
- C = Cable pair capacitance (for the load section) in farads.

For H-88 loading, the theoretical cutoff frequency of a single load section is at least 3500 Hz. The effective cutoff frequency (-10 dB point) is twenty percent to thirty percent lower. Increasing the section length beyond 1.8 km (6 kft):

- o Increases the capacitance.
- o Reduces the upper frequency limit of the VF pair.

Load section capacitance rather than physical length must determine the loading point. A convenient loading system is to locate load coils in repeater housings, and then midway between housings on stretched sections longer than about 2.3 km (7.5 kft). Because of the possible non-standard load coil spacing that may result, making all load coil sections the same length is important. Where this is impractical, use build-out capacitors.

12. Loading VF Pairs, continued

12.2 Frequency Response with Load Coils

The illustration below shows frequency response of 22-gauge (0.63 mm) cable with uniformly spaced 88 mH load coils. On the longest span (1), spacing is 1.8 km (6 kft), on the two shorter spans (2) and (3), spacing is stretched to 2.3 km (7.5 kft). Stretched spacing lowers the cutoff frequency and may preclude use of the highest frequency fault locating filter code M, (3017 Hz). On long spans with stretched spacing, code L (2680 Hz) and code M may not be usable also.

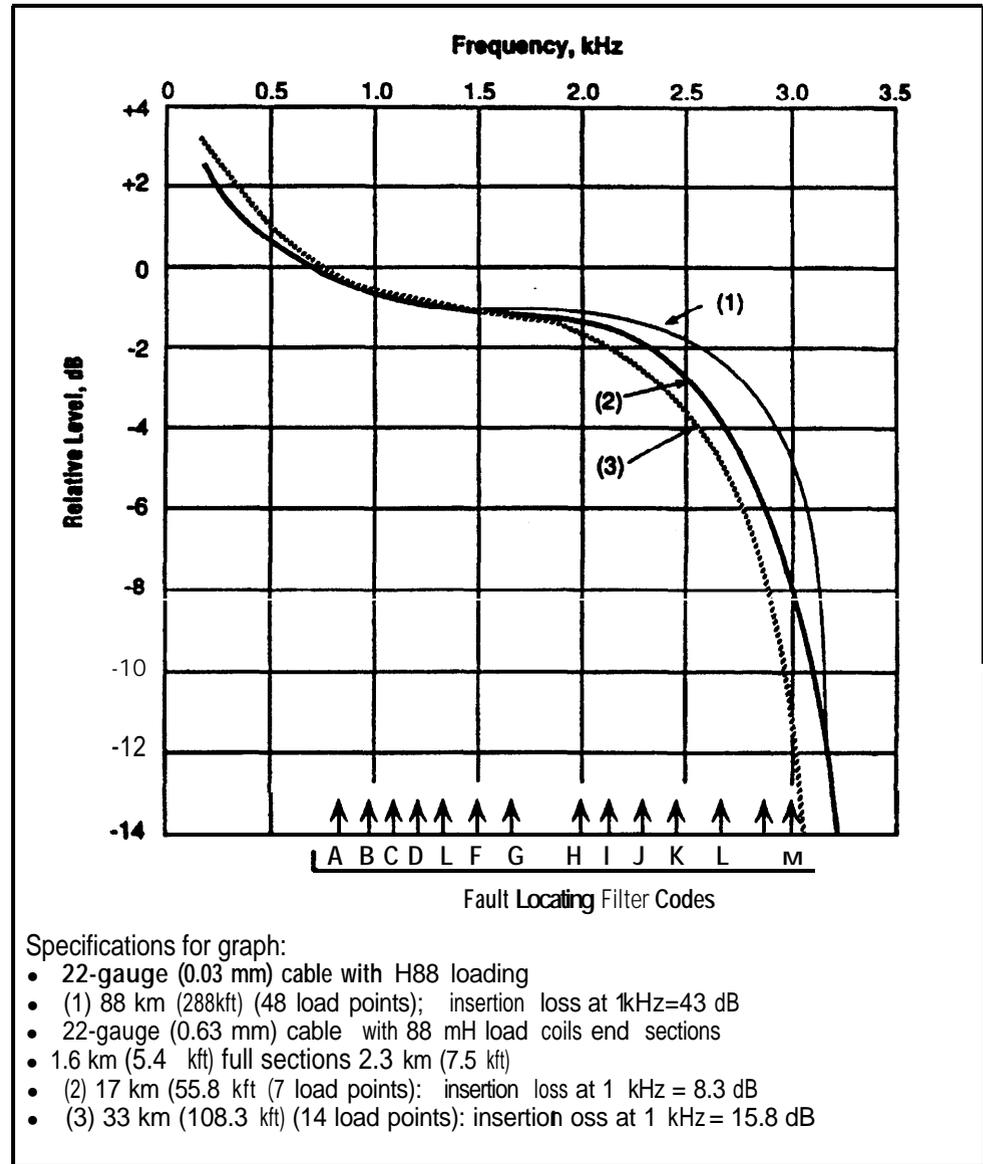


Exhibit 6 - Frequency Response of Loaded VF Pairs

With 2.7 km (9 kft) or longer sections, pairs should be loaded at the register housings and midway between housings. At 2.7 km (9 kft), use 66 mH load coils. This will elevate the cutoff frequency and maintain about the same characteristic impedance as the H88 system.

13. Repeater Bypass Cards

13.1 Description and Use

Repeater bypass cards are available for GTE standard T1 equipment. Use repeater bypass cards:

- To obtain continuity through repeater housings for VF circuits.
- OR
- Where there is a need to extend T1 facilities past a repeater point (such as, an adjacent DLC site).

Do not equip vacant slots with these cards when there is no need. The local Transmission Engineering group determines whether or not the cards are required, and the quantity needed.

14. Lightning Protection

14.1 Description and Use

In geographical areas subject to lightning and induced transients from switching in power distribution systems and loads:

- Install primary protectors in the repeater housings and in offices at the cable side of each repeater Unit.
- Use protected repeater units (secondary protection).

Protection is not required:

- If the span cables are completely underground and ducted.
- If the incidence of severe lightning is low.

if the span includes aerial or buried cable, protection is required at the ends of each section in which all or part of the cable is exposed.

NOTE: Refer to GTE Telephone Operations Practice 887-050-085, Center System Protection - Engineering Considerations, for more information about protection.

15. Span Line Repeater Powering

15.1 Introduction

The line repeaters are DC powered over a loop formed from the simplexes of two cable pairs, one associated with side 1 of the repeaters and the other with side 2. Typical repeater power feed configurations are shown in figures A thru F in Exhibit 18, Typical Repeater Power Feed Configurations on pages 75,76 and 77.

In the DC circuit of a typical repeated line loop shown in figure A, voltage is applied at office "A" and current (60, 100 or 135 mA) is looped back at office "B". Alternatively, voltage may be applied at each office and the separate loops closed at a line repeater. There are no dry line sections. If two short span lines are connected in tandem, it is possible to feed DC power through the intermediate office, depending on the total voltage required.

15. Span Line Repeater Powering, continued

15.2 Operating Voltage

The operating voltage for each line repeater is derived from the loop current flowing through a zener diode in the repeater unit. In the Exhibit 18, Typical Repeater Power Feed Configurations, on pages 75, 76 and 77, the equivalent DC load is represented by a single resistor symbol. The line repeater powering characteristics, including voltage drop, current, and resistance for the various types of T1 line repeater units are shown in Table 22, Office and Line Repeater Unit Characteristics, on page 61.

15.3 Problems from Mixing Repeaters

Mixing line repeaters is not recommended (e.g., mixing of 60 mA and 100 mA repeater simplex currents in the same route, repeater housing, or office repeater shelf requiring different simplex currents.) Mixing can create an administrative problems and routine maintenance problems. The problems result from the potential difference in voltage and current strapping requirements in the office equipment.

Mixing of 60 mA low power line repeaters with standard power repeaters is also not recommended.

Some of the problems resulting from mixing currents and/or repeaters are:

- Power loop around points may be different.
- Simplex power strapping on the office repeater units may be different.
- Simplex power voltage drops will be different for each line repeater.
- Heat dissipation of the office repeater regulator in the simplex power unit increases slightly because of the reduced simplex voltage drop.
- Maintenance routines and troubleshooting can be more difficult because of the different simplex strapping, voltage, and currents.

In special cases where mixing cannot be avoided, the following actions are required:

- Mix repeaters with similar or close equivalent resistances.
- Use the highest current required.
- Derate the mid-size series repeater housing ambient temperature by:
 - **5° C (41° F)** for 60 mA repeaters powered with 100 mA.
 - **10° C (50° F)** if 135 mA repeaters are used.

15.4 Simplex Circuits

In the simplex circuit of one cable pair, the two conductors are in parallel for DC current, thus, the simplex resistance is one-half the resistance of one conductor. In the power feed loop, the simplex circuits of the two pairs are in series, so the loop resistance of the cable pairs between repeaters is the same as the resistance of one conductor. This is illustrated in figure E in Exhibit 18 on page 76.

15.5 Powering T1 Lines

T1 lines may be powered from the:

- Office terminating repeater unit power converter.
- Current regulator.
- Simplex power unit.
- Simplex power converter unit through an office repeater unit.

The preferred method of powering T1 lines is with the office terminating repeater unit. This unit is installed in a line terminating shelf and supplies regulated current to the span line.

15. span Line Repeater Powering, continued

15.6 Repeater Power Feed Selection

On page 78, Exhibit 19, Worksheet for Calculating Simplex Loop Resistance Using 91124/91141/621188x Office Repeaters:

- Illustrates a sample worksheet to be used for calculating the loop resistance using a 91124/91141 office repeater.
- Shows the typical resistance data for each item in the span line.

After calculating the total loop resistance, refer to:

- Table 7, Maximum Simplex Loop Resistance for Office Repeaters, (below), to determine the satisfactory supply voltage.
- Table 8, Loop Resistance Capability of 91 124/91141 -M2 Office Repeaters, page 46, for the maximum allowable loop resistance.

Maximum Loop Resistance at 60mA Ohms	Maximum Loop Resistance at 100mA (Ω) Ohms (Ω)	Maximum Loop Resistance at 135mA Ohms	Supply Voltage		
			(Ω) Total	One End	Other End
770	460	340	48	-48	
1530	920	680	96	-48	-48
2080	1250		130	+130	
2850					
2850	1710	1260	178	+130	-48
3620	2170	1600	226	+130 & -48	-48
4170	2500	1840	260	+130 & -130	
4170	2960	2180	260	+130	+130
4930	2960		308	+130 & -48	+130
4930		2180	308	+130 & -130	-48
5700	3420	2520	356	+130 & -48	+130 & -48
6250	3750	2760	390	+130 & -130	+130
7020	4210	3090	438	+130 & -130	+130 & -48
8330	5000	3670	520	+130 & -130	+130 & +130
9860	5920	4350	616	+130, -130 & 48	+130, +130 & -48

Table 7 - Maximum Simplex Loop Resistance for Office Repeaters

#

15. Span Line Repeater Powering, continued

15.6 Repeater Power Feed Selection, continued

Negative Return Voltage	Span Line Current (mA)	Loop Resistance (Ohms)		Strapping Information
		Minimum	Maximum (2)	
GND -48V -130v (1)	60	200 1200 2300	2060 2790 4040	C, F, J, L, M C, E, J, L, M E, D, J, L, M
GND -48V -130v (1)	100	200 700 1400	1230 1670 2430	C, F, H, L, M C, E, H, L, M D, 6 H, L, M
GND -46V -130v (1)	140	200 450 950	880 1190 1740	C, F, H, K, M C, E, H, K, M D, E, H, K, M
- -	Regulator Disable	- -	- -	C, F, J, L, N

NOTES: The above table shows only the power source at one end. For a longer span, span current can be provided at both ends. The notes listed below correspond to the numbers in parenthesis in the table above.
 (1) External - 130 V supply.
 (2) The maximum loop resistance takes into account the variances of the office battery.

Table 8 - Loop Resistance Capability of 91124/91141-M2 Office Repeaters

NOTE: The table above also is illustrated in Exhibit 18, on page 77 and is referenced in the first note for figure A in Exhibit 18.

On page 79, Exhibit 20 worksheet for Calculating Simplex Loop Resistance Using 91105 Simplex Power Unit or 91125 Simplex Power Converter Unit illustrates a sample worksheet to be used for calculating the simplex loop resistance when using a 91105 simplex power unit or 91125 simplex power converter unit.

The 91105 unit has strappable resistors for coarse control of loop current and a variable resistor for fine control of loop current. Information about 91105 Simplex Power Converter Unit strapping and loop resistance for office repeaters is in the three tables that follow this paragraph. The tables are labeled:

- Resistance Strapping.
- Voltage Strapping.
- Maximum Simplex Loop Resistance for Office Repeaters.

	Difference Between Max. and Calculated Loop Resistance, Ohms	Strap 91105 Figure 12	Resistance Strapped Into Loop, Ohms
Resistance Strapping	0 to 100	N-R, T-V, T-W	0
	101 to 200	N-R, U-V, T-W	100
	201 to 300	F-R, U-V, T-W	200
	301 to 400	P-R, T-U, T-W	300
	401 to 500	N-P, T-U, T-W	400
	501 to 600	N-P, T-W	500
	601 to 675	T-W	600
	676 to 775	T-V	675
	776 to 875	U-V	775
	876 to 975	T-U	875
	976 to 1000	No Straps	975

Table 9 - Resistance Strapping.

15. Span Line Repeater Powering, continued

15.6 Repeater Power Feed Selection, continued

	Voltages	Strap 91105
Voltage Strapping	+ 130 V and - 130 V + 130 V and -48 V - 130 V and ground - 48 V and ground + 130 V and ground	A-B, C-D, E-F, G-H A-B, C-D, J-F, K-H E-F, G-H, L-M J-F, K-H, L-M A-B, C-D, L-S

Table 10 - Voltage Strapping

NOTE: Refer also to Table 7, The Maximum Simplex Loop Resistance for Office Repeaters on page 45.

The 91125 unit output voltage is automatically varied (up to **260 V DC**) as needed to achieve the preset current. The unit will operate into a range of simplex loop resistance dependent upon the selected loop current. (See table below.)

Selected Loop Current, (mA)	Simplex Resistance Range, (Ohms)
60 100 120	160 160 160 2167

Table 11 - Loop Resistance Range for 91125 Unit

If the calculated loop resistance exceeds the maximum specified in the table above, then it will be necessary to:

- Power the span from both ends.
- Loop the current at a line repeater location.

16. Acceptance Testing

16.1 Cable Facility Acceptance Tests

Cable acceptance tests ensure:

- The engineered design of a cable facility is achieved during construction.
- The expected transmission quality of the overall circuit meets system specifications and objectives.

Successfully completing these tests guarantees the transmission quality of the facility and prevents the use of marginal or defective facilities.

Before a cable is designated for T1 transmission, complete the standard cable acceptance testing procedures to verify DC and high frequency acceptability. (Refer to GTE Telephone Operations Practice 634-020-500, Acceptance Testing Cable Completion.) Cable acceptance tests must be made from the cable side of the protector. All cable pairs, including POTS, Special Service and T1 digital on cable require minimum acceptance tests. The following chart lists the minimum tests required and the standards for those tests.

Test	Standard
Loop Resistance	Loop resistance must measure within ten percent of the actual calculated value, and all sample pairs must measure within two percent of the average.
Resistance Unbalance	Resistance unbalance must not exceed 3 Ω (ohms) or 0.5% of the loop resistance, whichever is greater.
Insulation Resistance	Insulation Resistance must be a minimum of 1000 Meg-ohm miles at a potential of 500 volts for one minute.
Sheath Continuity	Sheath must be continuous.

Additional testing is required for POTS and/or Special Service on either loaded or nonloaded cable. The following chart lists these required tests and the standards for the tests.

Test	Standard
Continuity and Polarity	Continuity tests are to be made on all pairs for shorts, grounds and opens. Shorts and opens must be corrected and pairs must be properly grounded.
Noise Metallic	Circuit noise measurement must not exceed 20 dBmC.
Power Influence	Power influence must not exceed 80 dBmC.
Insertion Loss	Insertion loss is computed and measured at 1004 Hz value only. The measured loss must be within 0.5 dB of the calculated value. A maximum of 8.5 dB is acceptable.

16. Acceptance Testing, continued

16.1
Cable Facility
Acceptance
Tests,
continued

Additional testing is required for POTS on loaded cable. The following chart identifies this required test and the standard for the test.

Test	Standard
Structural Return Loss	Structural return loss (SLR) objectives for each type of facility must be met. The SLR objectives for facilities are charted below.

Facility Type	Objective
19 _{LC}	23.0 dB
19 _{HC}	24.4 dB
22	25.6 dB
24	26.8 dB
26	28.1 dB

Table 12 - SLR Objectives

Additional testing is required for T1 on screened and/or nonscreened cable. The following chart identifies this required test and the standard for the test.

Test	Standard
insertion Loss at 772 kHz	Measured loss with an all 1s6 signal must not be within 2.5 dB of the loss for T1. Considering each direction separately, the range of losses among all pairs measured must not exceed 3.5 dB at 772kHz for T1.

Additional testing is required for T1 on nonscreened cable. The following chart identifies this required test and the standard for the test.

Test	Standard
Signal -To-Noise	Objectives for signal-to-noise margins must be met. The Objectives are in the following table.

Facility e/w Capacity	S/N Margin	Noise Variance
0	8 dB minimum	< 1
≤ 49%	4 dB minimum	< 2
50 - 80%	2 to 4 dB minimum	< 4
≥ 81%	> 1 dB	< 6

Table 13 - Signal-to-Noise Objectives

16. Acceptance Testing, continued

16.2
Test
Equipment

The following chart lists cable acceptance tests and the equipment needed to conduct each test.

Test	Equipment
Loop Resistance Resistance Unbalance	Wheatstone Bridge Communications Technology Corp (CTC), DAVAR System III / ACTS™ RTS 9925"
Insulation Resistance	Biddle Megger 21259™ or 21359™
Sheath Continuity	Wilcom T263™ Communications Technology Corp (CTC), DAVAR System III / ACTS™ RTS 9925"
Continuity & Polarity	Digital VOM or Multimeter Communications Technology Corp (CTC), DAVAR System Hi / ACTS™ RTS 9925™
Noise Metallic Power Influence Insertion Loss	Communications Technology Corp (CTC), DAVAR System III / ACTS™ RTS 9925"
Structural Return Loss	Communications Technology Corp (CTC), DAVAR System III / ACTS™ Level Tracer™
Insertion Loss at 772 kHz Signal-to-Noise	Sierra 413"

Biddle Megger 21259 and 21359 are trademarks of Biddle Instruments, 510 Township Line Road, Blue Bell, Pennsylvania, 19422.

DAVAR System III / ACTS, Level Tracer, and RTS 9925 are trademarks of Communications Technology Corporation (CTC), 4100 McEwen Drive, Dallas, Texas, 75224.

Sierra 413 is a trademark of Sierra, 970 McLaughlin Avenue, San Jose, California, 95122.

Wilcom T263 is a trademark of Wilcom Products Incorporated, Laconia, New Hampshire, 03247.

16. Acceptance Testing, continued

16.3 T1 Span Acceptance Tests

T1 span acceptance tests are part of the overall transmission quality control effort within GTE Telephone Operations. Acceptance tests are required on all T1 facilities at the time of initial construction.

The following chart lists the required tests and the standards for the test.

Test	Standard
Jitter	Jitter must not exceed 0.33 UI RMS or 1.0 UI peak-to-peak measured end-to-end.
Repeater Testing	Complete a 1 in 16 stress test for bench testing the repeater prior to installation.
Span Line Testing	<p>Perform acceptance testing of DS1 service using Errored-Second performance parameters. This test is typically performed using a Quasi Random Signal Source (QRSS). Span line testing for DS1 service are:</p> <ul style="list-style-type: none"> A fifteen-minute 3 in 24 or 1:7 test (for AMI or B8Zs respectively). <p>NOTE: The AMI/B8ZS testing matrices are illustrated below.</p> <ul style="list-style-type: none"> A fifteen-minute All Ones test patterns. me twenty-four-hour QRSS long duration test.

NOTE: If a twenty-four-hour QRSS long duration test is not feasible then perform the fifteen-minute QRSS diagnostic stress tests.

Marginal failures require retesting.

Test Pattern (Framed)	Acceptance		Maintenance	
	Test Duration	Errored Seconds Limits	Test Duration	Errored Seconds Limits
QRSS	24 hours	170		
QRSS	15 minutes	0	5 minutes	60
3 in 24	(2/15 min. tests)			
(AMI only)	15 minutes	0	5 minutes	60
1 : 7				
(B8ZS only)	15 minutes	0	5 minutes	60
All Ones	15 minutes	0	5 minutes	60

Table 14 - AMI/B8ZS Testing Matrix

(continued)

16. Acceptance Testing, continued

16.3
T1 Span
Acceptance
Tests,
continued

Test	Standard																		
Repeater Power Feed	<p>Repeater power feed current tolerances must be completed in both directions of the span line operation. Repeater power feed current tolerances are shown in the following table.</p> <table border="1"> <thead> <tr> <th>Span Line</th> <th>Nominal</th> <th>Measured Tolerance</th> </tr> </thead> <tbody> <tr> <td>T1 (1.544 Mb/s)</td> <td>60 mA</td> <td>57 - 63 mA</td> </tr> <tr> <td>T1 (1.544 Mb/s)</td> <td>100 mA</td> <td>95 - 105mA</td> </tr> <tr> <td>T1 (1.544 Mb/s)</td> <td>120 mA</td> <td>115 - 125mA</td> </tr> <tr> <td>T1C (3.152 Mb/s)</td> <td>60 mA</td> <td>57 - 63 mA</td> </tr> <tr> <td>T1C (3.152 Mb/s)</td> <td>135 mA</td> <td>135 - 45mA</td> </tr> </tbody> </table> <p>Table 15 - Repeater Power Feed Current Tolerances</p>	Span Line	Nominal	Measured Tolerance	T1 (1.544 Mb/s)	60 mA	57 - 63 mA	T1 (1.544 Mb/s)	100 mA	95 - 105mA	T1 (1.544 Mb/s)	120 mA	115 - 125mA	T1C (3.152 Mb/s)	60 mA	57 - 63 mA	T1C (3.152 Mb/s)	135 mA	135 - 45mA
Span Line	Nominal	Measured Tolerance																	
T1 (1.544 Mb/s)	60 mA	57 - 63 mA																	
T1 (1.544 Mb/s)	100 mA	95 - 105mA																	
T1 (1.544 Mb/s)	120 mA	115 - 125mA																	
T1C (3.152 Mb/s)	60 mA	57 - 63 mA																	
T1C (3.152 Mb/s)	135 mA	135 - 45mA																	

T1 Signal Continuity	<p>Test and verify T1 signal continuity. (Loopback the T1 span at office B, and, using a Sierra 415A test set or equivalent at office A, verify that the bit stream is being received.)</p>
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Bit Error Rate	<p>Bit Error Rate (BER) measurements are required for individual span lines, and also for complete systems (including all spans in tandem). Perform tests in both directions of span line operation.</p> <p>If the facility has been designed to DDS standards, then DDS requirements must be met regardless of anticipated traffic. (Refer to Lenkurt Practice 342-910-105, 9104A 24/48 Channel PCM Repeated Line Equipment - Inside Plant.)</p> <p>The following table shows the Bit Error Rate standards.</p>
----------------	--

Error Rate Limit	Span	BER	Errors/Sec
Individual Span	T1 - Voice	(obj) 3.9×10^{-9}	0.006
	T1 - Voice	(max) 3.0×10^{-7}	0.463
	T1 - DDS	(obj) 1.0×10^{-9}	0.005
	T1 - DDS	(max) 5.2×10^{-9}	0.008
Complete System	T1 - Voice	1.0×10^{-6}	1.543
	T1 - DDS	1.8×10^{-7}	0.278

Table 16 - Bit Error Rate Standards

(continued)

16. Acceptance Testing, continued

16.3
T1 Span
Acceptance
Tests,
continued

Test	Standard
DSX Signal Level	<p>Measure the DSX signal levels using an oscilloscope or a digital transmission test set. Measuring the DSX signal level is done in an effort to minimize crosstalk problems within an office. The test objectives are:</p> <ul style="list-style-type: none"> Using a digital transmission test set: <ul style="list-style-type: none"> The OS-1 pulse shape must meet the DSX specification mask, The digital transmission test set will indicate a pulse shape PASS or FAIL state. The signal levels at the DSX OUT jack are: $0 \text{ dBdsx} \pm 2 \text{ dBdsx}$ Using an oscilloscope: <ul style="list-style-type: none"> The signal levels must not exceed, $3.0 \text{ V} \pm 0.6 \text{ V}$, at the DSX OUT jack. Pulse characteristics at the DSX must measure width at 50% = $324 \pm 30 \text{ ns}$. The wave-form must mirror the template illustrated below.

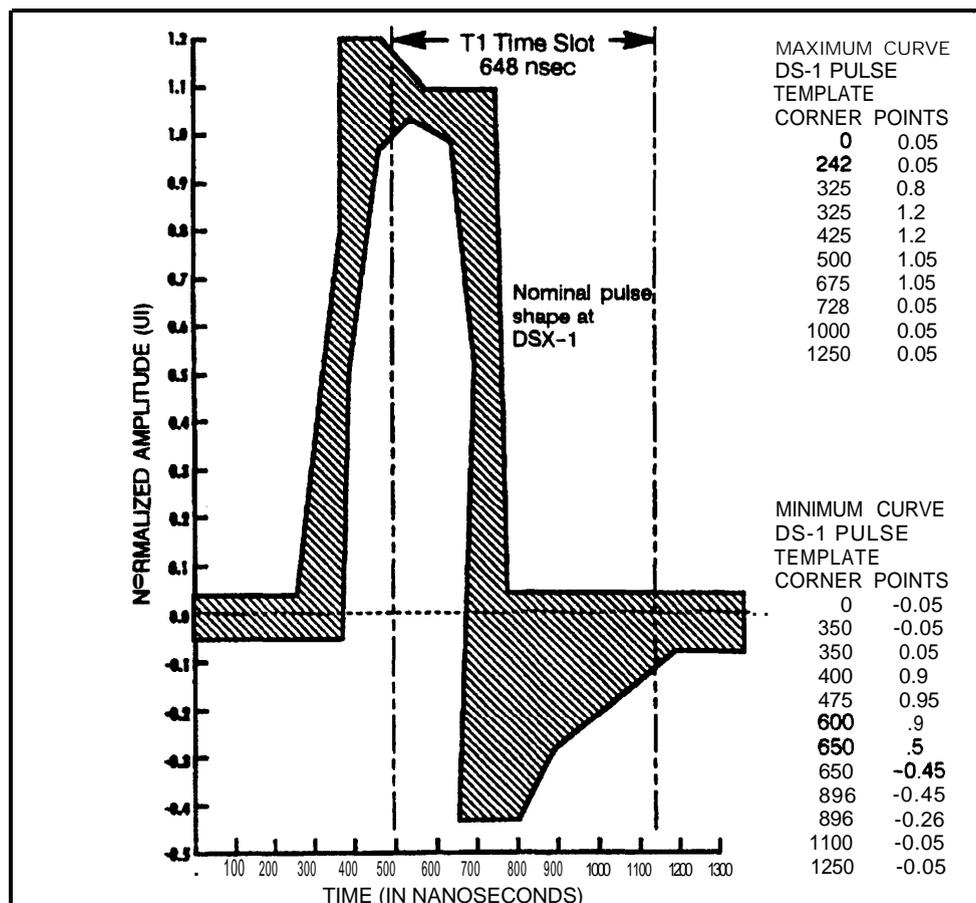


Exhibit 7 – Isolated Pulse Template at DSX-1 Interface

16. Acceptance Testing, continued

16.4
T1 Span
Acceptance
Test
Equipment

The following chart lists T1 span acceptance tests and the equipment needed to conduct each test.

Test	Equipment
Jitter	HP 3787" Wandel & Golterman PJM-1 Meters™ T-Berd 211™
Repeater Testing Span Line Testing	T-Berd 209 A"
Power Repeater Feed T1 Signal Continuity	Sierra 415A™
Bit Error Rate	Sierra 418A™ Bowmar 273A-2 or 273A-2P™
DSX Signal Level	Tektronix 2465™ oscilloscope T-Berd 209A™ or 211™ digital transmission test set and Model PR40A™ printer.

Bowmar 273A-1 and 273A-2P are trademarks of Bowmar/ALI Incorporated, 531 Main Street, Acton, Massachusetts, 01720.

HP 3787 is a trademark of Hewlett-Packard Manufacturing, 14 Street SW (80537), Loveland, Colorado, 80539.

Sierra 413, 415A and 418A are a trademarks of Sierra, 970 McLaughlin Avenue, San Jose, California, 95122. (in Practice 835-000-071)

T-BERD 209A, 211, and Model PR40A are trademarks of Telecommunications Techniques Corporation, 20410 Observation Drive, Germantown, Maryland, 20874.

Tektronix 2465 is a trademark of Tektronix Incorporated, 14150 SW Karl Braun Drive, Beaverton, Oregon, 97077.

Wandel & Golteman PJM-1 Meters is a trademark of Wandel & Golteman Incorporated, 1030 Swabia Court, Research Triangle Park, North Carolina, 27709-3585.

Tables

Termination Points		Liner Description	Bit Rate (Mb/s)	24 Hour Requirement			2 Hr. Pre-Service Test	
				ES Allowance	EFS%	Equivalent BER	ES Allowance	Equivalent BER
Customer Station	End Office	Loop	Service	43.2 (56 kb/s)	99.95	1.8×10^{-8}	N.A.	N.A.
End Office (OCU)	Intermediate (DDS Office)	Short Haul (DDS)	56 kb/s	241 (2) 22	99.7 99.975	3.9×10^{-9} 3.9×10^{-9} 8.9×10^{-9}	19 2	3.5×10^{-9} 3.5×10^{-9} 8.9×10^{-9}
End Office (OCUDP w/Error Corr.)	Intermediate (DSO-DP)	Short Haul (Voice)	56 kb/s (1)	22	99.975	8.9×10^{-9}	19 2	8.9×10^{-9}
Intermediate DDS Office	Hub Office	Short Haul (DDS)	1.544 3.152 96 kb/s	241 (2) 22	99.7 99.975	3.9×10^{-9} 3.9×10^{-9} 8.9×10^{-9}	19 2	3.5×10^{-9} 3.5×10^{-9} 8.9×10^{-9}
Intermediate (DSO-DP w/ Error Corr.)	Hub Office	Short Haul (Voice)	56 kb/s (1)	22	99.975	8.9×10^{-9}	2	8.9×10^{-9}
Hub Office	Hub Office	Long Haul (Comp.)	56 kb/s	260	99.7	1.1×10^{-7}	22	1.1×10^{-7}
		Long Haul (Single)	56 kb/s (3)	216	99.75	8.9×10^{-9}	18 (5)	8.9×10^{-9}
Customer Station	Customer Station	Complete Circuit	Service & Higher Levels in Tandem	432 (4)	99.5	1.8×10^{-7}	36 (5)	1.8×10^{-7}

Table 1 - ES Allocations for DDS Systems

The notes listed below correspond to the numbers in parenthesis in the ES Allocations for DDS Systems table above.

- (1) It is assumed that voice-grade short-haul facilities provide a system error rate of 1×10^{-6} (or better) to haul data channel unit type DDS service. Measurement of ES allowance must be accomplished on each DSO (56 kb/s) signal level and results must meet the criteria given in the table. Data channel units must be strapped to activate the forward error correction function.
- (2) A short haul facility, entirely dedicated for DDS, must be designed with these ES allowance maintenance thresholds. The N-factors for higher digital level other than DS1 have not been established: therefore ES allowance testing must be done at either DS1 or DSO (56 kb/s). In any case, the ES allowance measured at DSO is the controlling criterion. Whenever higher order signals are within their allowance but ES allowance for 56 kb/s is exceeded, the system must be reviewed.
- (3) A long haul facility may be classified as composite digroup or single digroup. The composite digroup is comprised of more than one digital facility in tandem, i.e., more than one long haul facility, or a combination of long haul and short haul type of facilities. The T1 DM to T1 DM ES allowance for the composite digroup is the sum of the ES allowances of the individual digital facilities and the total should be limited to the given value. A single long haul digroup must be restricted to 6400 km (4000 miles) and must be better than the ES allowance maintenance threshold defined in the table. The % ES for shorter distances may be pro-rated by mileage. For new installations, each part of the composite facility is tested and the end-to-end 1.544 Mb/s channel is tested for four days.
- (4) This represents the total end-to-end DDS ES allowance, whether a direct station-to-station configuration or via the different offices of the DDS reference model network. The maximum ES allowance is limited to 432 per day at the DSO (56 kb/s) signal level.
- (5) Long haul and end-to-end criteria for two-hour testing have not been established. The test limits for the two-hour pre-service tests are pro-rated values from the allowance of the twenty-four-hour test limits.

Tables, continued

Cable Type	Gauge	Direct Method (1), (5)								Analytical Method (2)		
		Buried		Aerial		Buried		Aerial		Eng Loss @ 772kHz 13°C (55°F) (dB/ (DFT)	Temperature Correction Factor	
		Full Sect. (KFT)	Ld1 (dB)	Full Sect. (KFT)	Ld1 (dB)	End Sect. (KFT) (4)	L1 (dB)	End Sect. (KFT) (4)	L1 (dB)		Buried f _T @ (100°F)	Aerial f _T @ (140°F)
PIC Filled (3)	19 22 24	108 7.9 6.4	31.3 31.6 32.0	10.5 7.7 6.2	30.4 30.8 31.0	4.0 3.2 3.1	15.6 15.8 16.0	5.3 3.9 3.1	15.2 15.4 15.5	2.9 4.0 5.0	1.031 1.039 1.043	1.060 1.074 1.082
PIC Un-filled (3)	19 22 24	6.9 5.6	30.4 31.4 30.4 6.7 5.4	9.1 8.2 8.5	29.1 30.2 29.5	4.8 2.8 3.5	15.2 15.2 15.7	3.4 2.7	14.6 14.8 15.1	3.2 5.6 4.4	1.046 1.044 1.043	1.088 1.081 1.083
Unit Paper	19 22 24	8.1 6.2 4.7	30.8 31.6 32.0	7.9 6.1 4.5	30.0 31.1 30.6	4.1 3.1 2.4	15.4 15.8 16.0	3.1 2.3	15.0 15.6 15.3	3.8 5.1 6.8	1.033 1.042 1.048	1.063 1.078 1.063
ICOT (6) Atr Core	24	8.7	31.2	8.3	29.8	4.4	15.6	4.2	14.9	3.6	1.055	1.104
ICOT (6) Filled	24	8.0	31.3	7.7	30.2	4.0	15.7	3.9	15.1	3.9	1.046	1.087
MAT (6)	25	6.3	32.1	6.0	30.6	3.2	16.1	3.0	15.3	5.1	1.049	1.092
Alpeth Unit PIC Filled	26	5.1	32.1	4.9	30.9	2.6	16.1	2.5	15.5	6.3	1.046	1.088
Alpeth Unit Un-filled	26	4.5	32.8	4.3	31.4	2.3	16.4	2.2	15.7	7.3	1.042	1.079
Unit/ Layer Pulp	26	3.9	32.0	3.7	30.3	2.5	16.0	1.9	15.2	8.2	1.053	1.100

Table 2 - T1 Cable Section Lengths

The notes listed below correspond with numbers in parenthesis in the table above.

- (1) (a) Section lengths are computed from the cable attenuation only, Ld1, with typical values of 31.1 dB for aerial cable and 32.2dB for underground cable.
- (b) Application of this method assumes that NEXT crosstalk is not limiting and the T1 engineering considerations (discussed in this section) are applied
- (c) Standard repeaters are considered except as noted. See note #6.
- (2) Factors used in the calculation method of engineering T1 span are discussed in section 6.4, Maximum Section Loss, Ld2 page 24.
- (3) Values are the same for both filled and unfilled PIC; dual D-screen, D-shield, T-screen and Alpeth unit cables.
- (4) End section values shown are for outside plant cable. Maximum average loss including tip cable and office repeater LB0 should not exceed 26 dB.
- (5) For protected line repeaters shorten the allowable repeater spacings by 5% to compensate for repeater secondary protection surge
- (6) T1 line repeaters designed for MAT cables should be used for MAT and ICOT cables.

Tables, continued

Cable (If cable segment is shorter than 10 dB at 772 kHz, a correction factor is required)	Location of Opposite-Direction Pairs	-19 GA-		-22GA-		-24 GA-		-26 GA-		
		m ⁸⁰	m-u	m	m-a	m	m-o	m	m-u	
Paper-insulated, unit type, 200-pair or larger (GTS-8503)	Same 100-pair splice group	88	69	82	71	91	82	84	73	
	Adjacent splice groups		79	90	81	104	97	92	83	
	Nonadjacent splice groups	101	94	103	96			105	98	
	Same 50-pair unit		73	63	75	65	76	66	77	67
	Adjacent 50-pair units		86	78	93	85	89	81	90	82
	Nonadjacent 50-pair units		98	92	108	100	101	95	102	96
Paper-insulated, layer type, 200-pair or larger	Same 100-pair splice group	73	64	75	66	76	67	77	68	
	Adjacent splice groups	81	73	83	75	84	76	85	77	
	Nonadjacent splice groups	91	82	93	84	94	85	95	86	
Paper-insulated, unit type, 200-pair or smaller	Same 50-pair unit	73	63	75	65	76	66	78	68	
	Adjacent 50-pair units	86	78	88	80	89	81	90	82	
PIC unit-type, air-core, less than 100-pair	Same 8-, 9-, 12-, 13-pair unit	69	58	66	57	67	58	68	59	
	Same 25-pair unit			73	62	77	64	78	65	
	Adjacent 8-, 9- 12-pair units	77	(GTS-8502)							
	Adjacent 25-pair unit	-	68	82	69	83	70	84	71	
	Nonadjacent 8-, 9-, 12-, 13-pair units	65	76	84	75	93	85	94	86	
PIC, unit-type, air-core, 100 to 300-pair (GTS-8502)	Same 12-25 pair unit	72	60	75	63	70	60	71	61	
	Adjacent units	67	61	71	78	69	79	70	70	
	Nonadjacent units	96	86	98	87	93	85	94	86	
PIC, unit-type, air-core, 600-pair or less (GTS-8502)	Same 12-50 pair unit	72	60	72	60	70	60	71	61	
	Adjacent units	76	67	76	67	78	69	79	70	
	Nonadjacent units	96	86	96	86	93	85	94	86	
PIC, unit-type, filled, less than 100-pair (GTS-8509)	Same 12- or 13-pair unit	69	62	69	60	-	-	-	-	
	Same 25-pair unit		-	77	66	-	-	-	-	
	Adjacent units				80	70	81	71		
	Nonadjacent units	89	78	93	83	-	-	-	-	
DEPIC, unit-type, filled, 100-pair (GTS-8502)	Same 12- or 13-pair unit		-	66	53	-	-	-	-	
	Same 25-pair unit		-	74	63	-	-	-	-	
	Adjacent units		-	80	71	-	-	-	-	
	Nonadjacent 12- or 13-pair units		-	91	83	-	-	-	-	
PIC, unit type, with staggered pair twists, 200-pairs or more	Same 100-pair splice group			82	71	-	-	-	-	
	Adjacent splicing group		-	90	80	-	-	-	-	
	Nonadjacent splice group		-	103	96	-	-	-	-	
	Same 50-pair unit		-	75	65	-	-	-	-	
	Adjacent 50-pair units		-	88	80	-	-	-	-	
	Nonadjacent 50-pair units		-	100	94	-	-	-	-	
PIC, unit type, with staggered pair twists, 200-pairs or more (GTS-8502)	Same 100-pair splice group	-	-	75	66	-	-	-	-	
	Adjacent splice groups	-	-	83	75	-	-	-	-	
	Nonadjacent splice groups	-	-	93	84	-	-	-	-	
PIC, unit type, with staggered pair twists, 200-pairs or less	Same 50-pair unit	-	-	75	65	-	-	-	-	
	Adjacent 50-pair units	-	-	88	80	-	-	-	-	
PIC, shielded, Z-screen, (GTS-8515)	Across the shield (25-pair)	-	-	86	84	-	-	-	-	
	Across the shield (50-pair)	-	-	96	86	-	-	-	-	
	Across the shield (100-pair)	-	-	100	92	-	-	-	-	
PIC, shielded, I-screen, (GTS-8515)	Across the shield (50-pair)	-	-	88	79	-	-	-	-	
PIC, ETPR filled, "S-screen (Alcatel) or "T"-screen (Superior), (GTS-8573)	16-pair	-	-	-	83	-	-	-	-	
	28-pair	-	-	-	89	-	-	-	-	
	54-pair	-	-	-	94	-	-	-	-	
	106-pair	-	-	-	106	-	-	-	-	
	21 O-pair	-	-	-	106	-	-	-	-	

(continued)

Table 3 - Near-End Crosstalk Losses (dB) at 772 kHz

Tables, continued

(continued)									
Cable (If cable segment is shorter than 10 dB at 772 kHz, a correction factor is required.)	Location of Opposite-Direction Pairs	-18 GA-		-22 GA-		-24 GA-		-26 GA-	
		m	m - u	m	m-σ	m	m-u	m	m-u
PIC, ETPR filled, "D" -screen (GTS-8573)	16-pair	-			96	-	-	-	-
	28-pair	-			100	-	-	-	-
	54-pair	-			105				
	106-pair	-			110				
	210-pair	-			110				
PIC. ETPR filled, Dual "D" -screen (GTS-8573)	16-pair	-			115				
	28-pair				116				
	54-pair				117				
	106-pair				119				
	210-pair				120	-	-	-	-

Table 3 - Near-End Crosstalk Losses (dB) at 72 kHz continued)

μ

Cable Type	Gauge	Eng Loss @ 1.576MHz 13°C (55°F) (dB/KFT)	Full Section Length		End Section Length		Restrictions for Sections Adjacent to End Sections "S"	
			Buried (KFT)	Aerial (KFT)	Buried (KFT)	Aerial (KFT)	Buried (KFT)	Aerial (KFT)
PIC Filled (3)	19	4.0	11.9	11.5	7.985	7.765	3.915	3.735
	22	5.6	a.5	8.18	5.765	5.555	2.735	2.625
	24	7.0	6.79	6.54	4.625	4.435	2.165	2.105
PIC Unfilled (3)	19	4.8	9.83	9.45	6.636	6.386	3.194	3.064
	22	6.6	7.15	6.87	4.873	4.673	2.277	2.197
	24	8.3	5.7	5.48	3.005	3.735	1.815	1.745
Unit Paper (4)	19	6.2	7.74	7.50	5.31	5.24	2.43	2.34
	22	8.0	6.0	5.80	4.033	3.943	1.967	1.937
	24	9.7	4.95	4.85	3.34	3.29	1.61	1.56
ICOT Filled (5)	24	5.5	8.76	8.44	5.93	5.72	2.83	2.72
ICOT Unfilled (5)	24	5.2	9.3	8.91	6.29	6.03	3.01	2.08
MAT (5)	25	7.4	6.37	6.12	4.32	4.15	2.02	1.94

Conditions for restricting adjacent section to end section:

If $L_1 < "S"$, then $L_2 < L_1 + \text{End Section Maximum}$

Table 4 - T1 C Cable Section Lengths

NOTE: For repeater spacing on cables not covered in this table or Table 6, refer to the manufacturers documentation.

The notes listed below and on the next page pertain to the T1C Cable Section Lengths table above. The numbers in parenthesis in the table above indicate a specific, numbered note that applies.

- (1) (a) The section lengths given allow for the following factors:
 - Route map inaccuracies, 1.6 dB.
 - Pair-to-pair loss variations, 2.4 dB
 - Cable and housing manufacturing irregularities; pulp = 0.8 dB, PIC unfilled = 1.6 dB, PIC filled = 1.3 dB, and MAT = 2.0 dB.
- (b) Aerial section lengths include a loss margin of 1 dB to 2 dB for exposure to higher temperature and transient voltages.
- (c) The maximum average section loss for T1C is 52.8 dB and the minimum loss is 9 dB.
- (d) The section lengths given are applicable to both protected and unprotected mid-sized repeaters.
- (e) The lengths are applicable to newer mid-size repeater housings. For full-size housings, subtract ten percent from maximum section length.

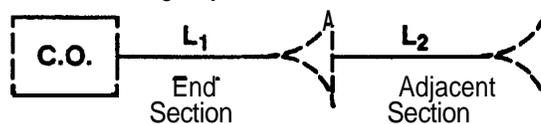
Tables, continued

- (1) (f) For designing DDS circuits, subtract five percent (2.6 dB) from full repeater spacings and use end sections that are 50% of full repeater spacings when the number of tandem spans is three or less. Consider the design rules for fault locating system, order wire and loading VF pairs when making pair assignments for fault locate, order wire and maintenance pairs. Layer and 26 gauge cable are not allowed for T1C.
- (2) End section lengths are for outside plant cable. Maximum average loss including office repeater LBO and cabling must not exceed 45 dB.
- (3) Values are the same for T1C qualified dual-D screen, D-shield, Improved T-screen and alpeth unit cables except that:
 - (a) On twenty-four or larger number of pairs, screen cable operation is assumed for dual D-screen, D-shield and T-screen.
 - (b) For alpeth unit cable, two-cable operation is assumed.
- (4) The bi-directional use of unit cable must follow the spatial considerations defined in section 4, Outside Plant Considerations.
- (5) Values are taken from the available AT&T cable data. Use T1C repeaters designed for MAT for MAT and ICOT cables.

NOTE: Information about factors that may shorten the design of Intermediate sections is in the section 8.6, T1C Limitations on Maximum Section Loss.

Cable Type	Gauge	Location and Number of Opposite Direction Pairs	Intermediate Section Lengths (KFT)		End Section Lengths (KFT)		Restrictions for Adjacent Sections (KFT) "S" (see note)	
			Buried	Aerial	Buried	Aerial	Buried	Aerial
PIC, Shielded Z-Screen	22	Across the Shield (25 pairs)	4.51	4.23	3.073	2.07	1.437	1.36
		Across the Shield (50 pairs)	2.45	2.17	1.67	1.47	0.78	0.70
		Across the Shield (100 pairs)	3.022	2.74	2.06	1.86	0.962	0.88
PIC, Shielded T-Screen	22	Across the Shield (50 pairs)	1.33	1.05	0.91	0.71	0.62	0.34

NOTE: Conditions for restricting adjacent section to section to end section:



If $L_1 < S$, then $L_2 < L_1 + \text{End Section Lengths}$

Table 5 - T-Screen and Z-Screen Cable Section Lengths

NOTE: For repeater spacing on cables not covered in this table or Table 4, refer to the manufacturers documentation.

Exhibits

Figure A. D-Shield Cables

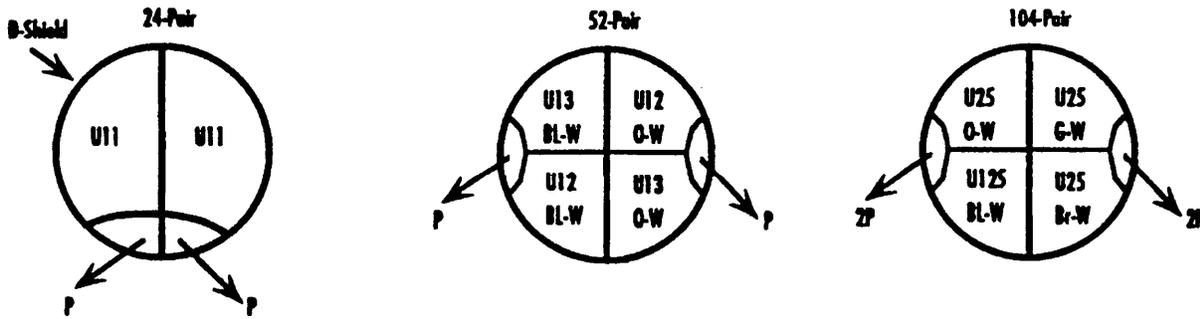


Figure B. Dual D-Screen Cable

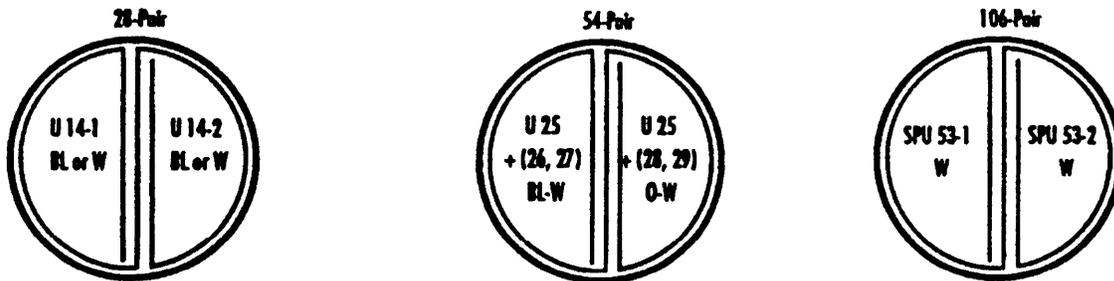


Figure C. Extended T-Screen Cables

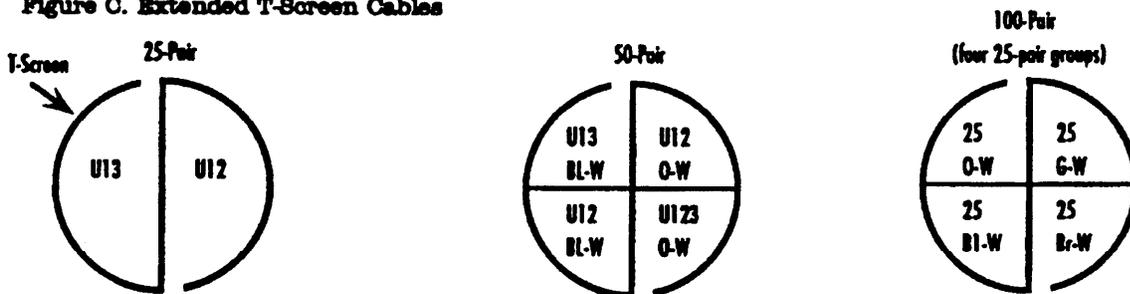
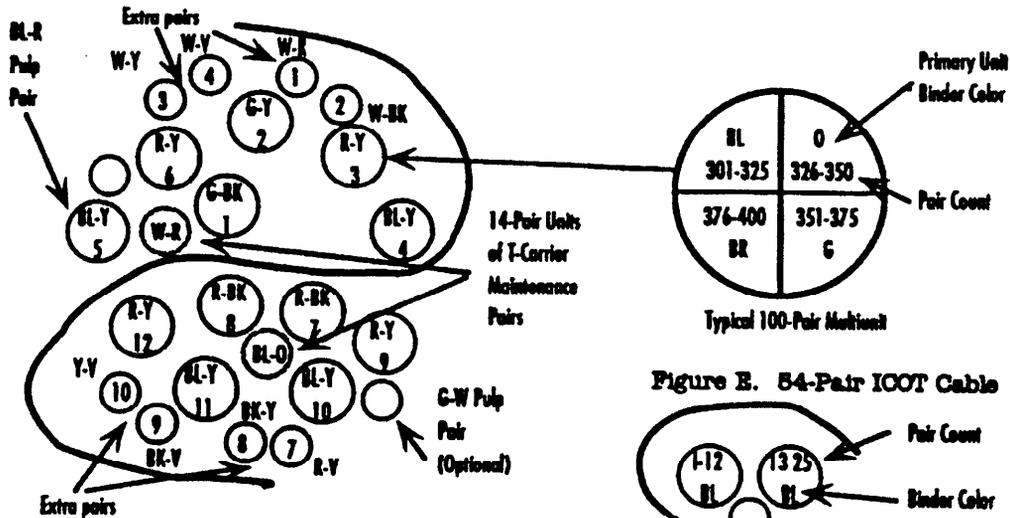


Exhibit 8 - Core Makeup of Screen Cables (Page 1 of 2)

Figure D. 1228-Pair, 25 Gauge



- Notes:
1. Notations such as "B13, BL-W" indicate unit group, binder colors and number of pairs.
 2. P denotes an interstitial pair for order wire or fault locating.

Figure E. 54-Pair ICOT Cable

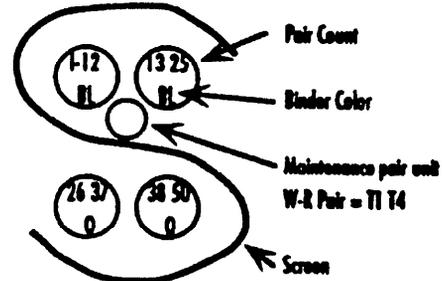


Figure F. 8-Screen and T-Screen Cables

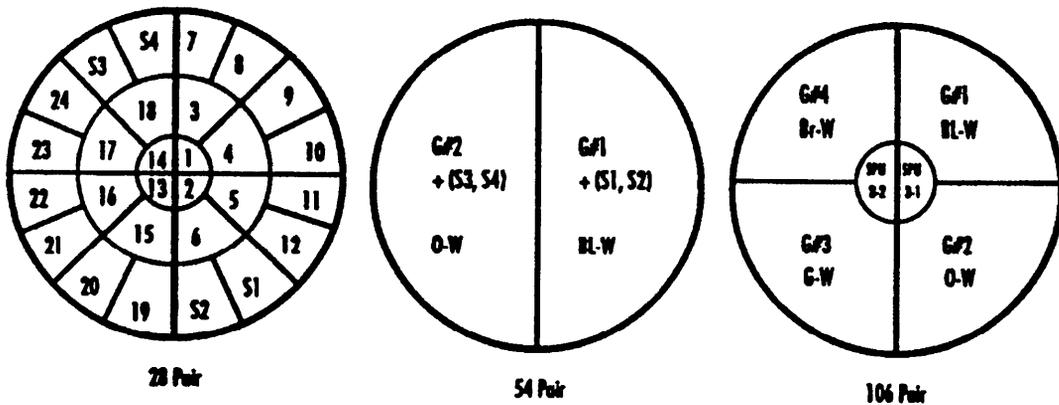


Exhibit 8 - Core Makeup of Screen Cables (Page 2 of 2)

Figure A. One-Cable Operation - T1 Only

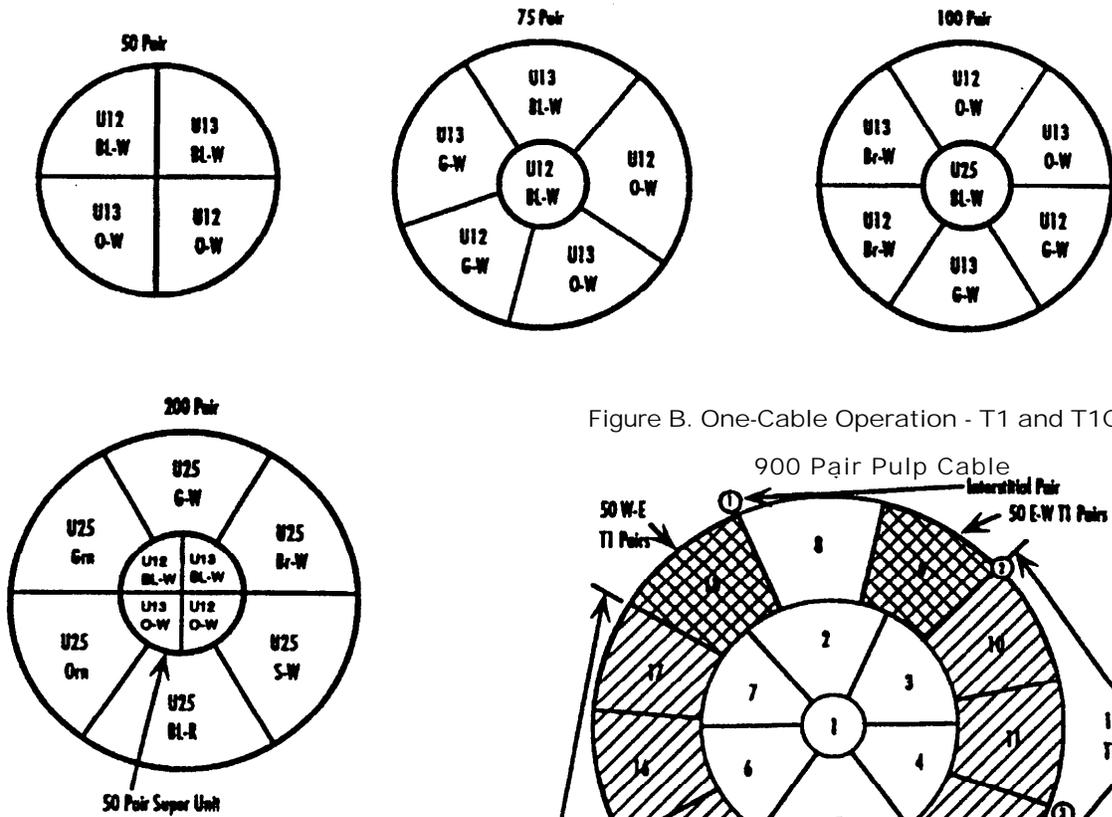
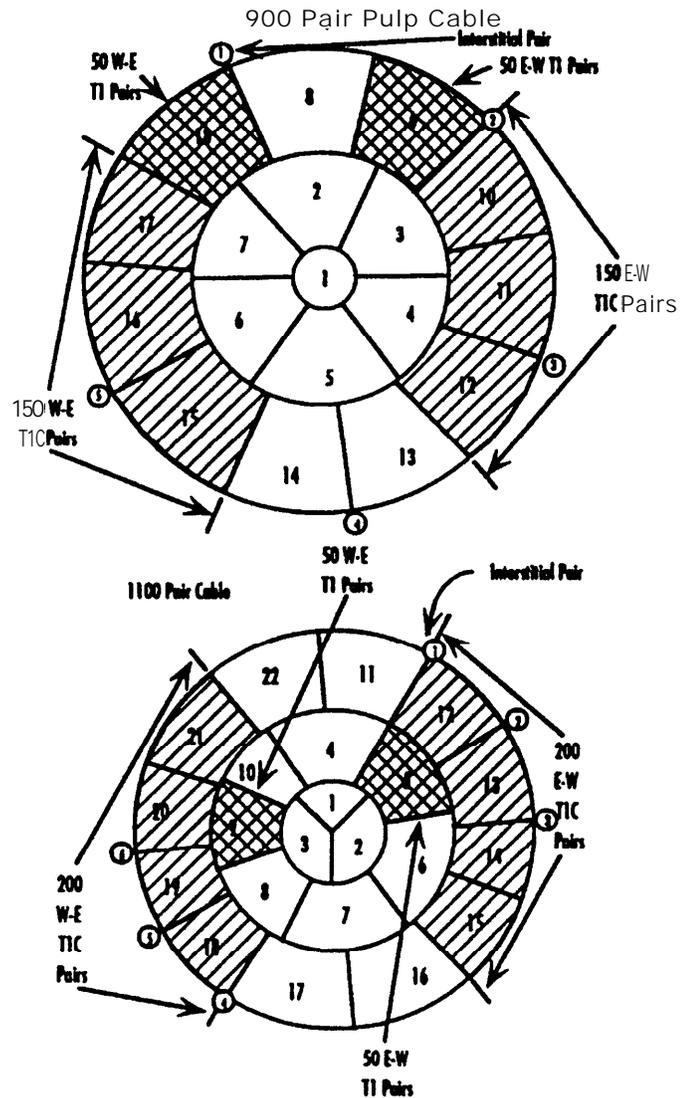


Figure B. One-Cable Operation - T1 and T1C

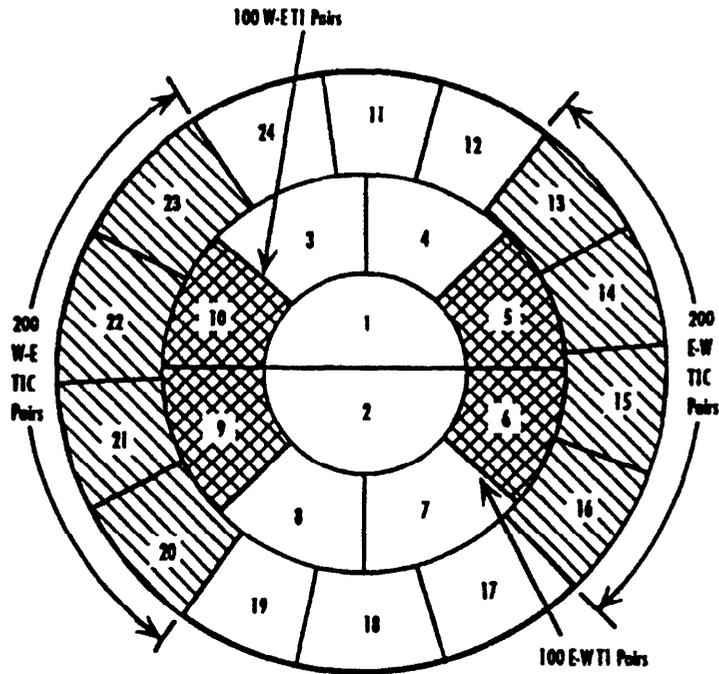


Notes:

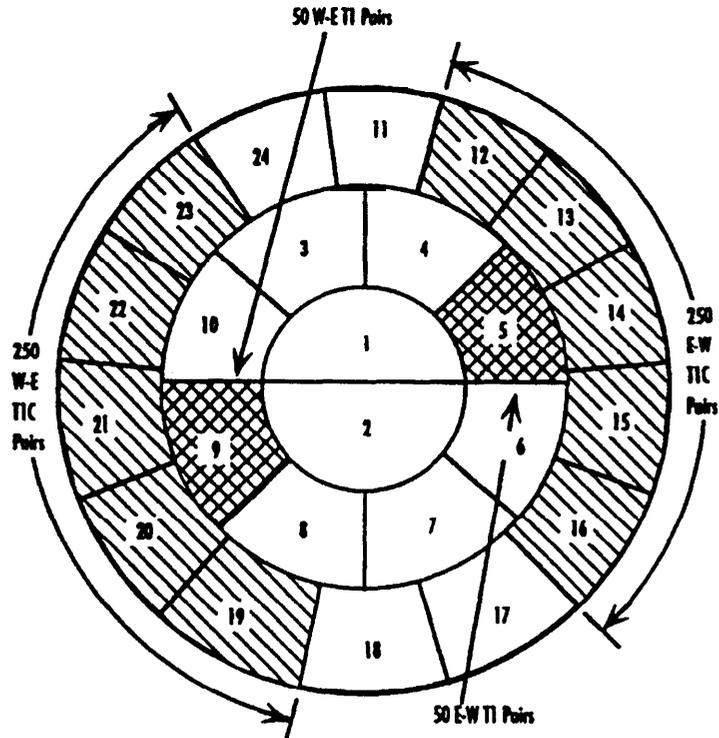
1. The core makeup of the cable is typical for conductors 19, 22, 24, or 26 AWG (0.90, 0.63, 0.50 or 0.40 mm.)
2. Notations such as U25/G-W indicate unit group, binder colors and number of pairs.
3. Interstitial pairs for order wire or fault locating are indicated by ①
4. Shaded unit groups are for illustration only. Other units can be used provided rules defined in this part are followed.

Exhibit 9 - Core Makeup of Even Count PIC Cables (Page 1 of 2)

Figure B. One cable operation with T1 and T1C on 1200 pair cable.

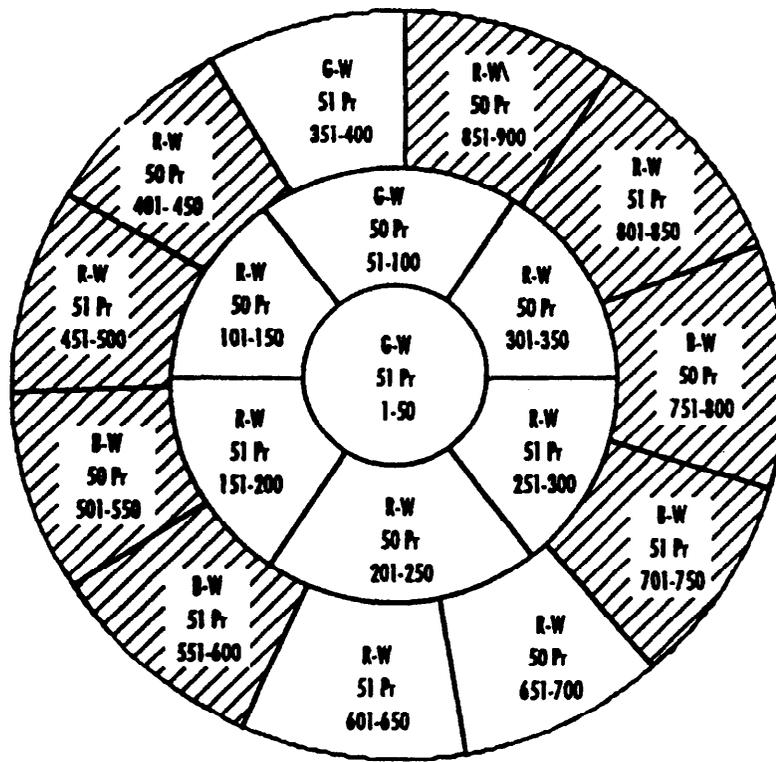


A. 200 TIC Lines and 100 T1 Lines



B. 250 TIC Lines and 50 T1 Lines

Exhibit 9 - Core Makeup of Even Count PIC Cables (Page 2 of 2)



Notes:

1. Pairs 401-600 vs. 701-900 are examples of nonadjacent group assignments

Exhibit 10 - 900-Pair, Mixed-Color, Unit-Type Cable

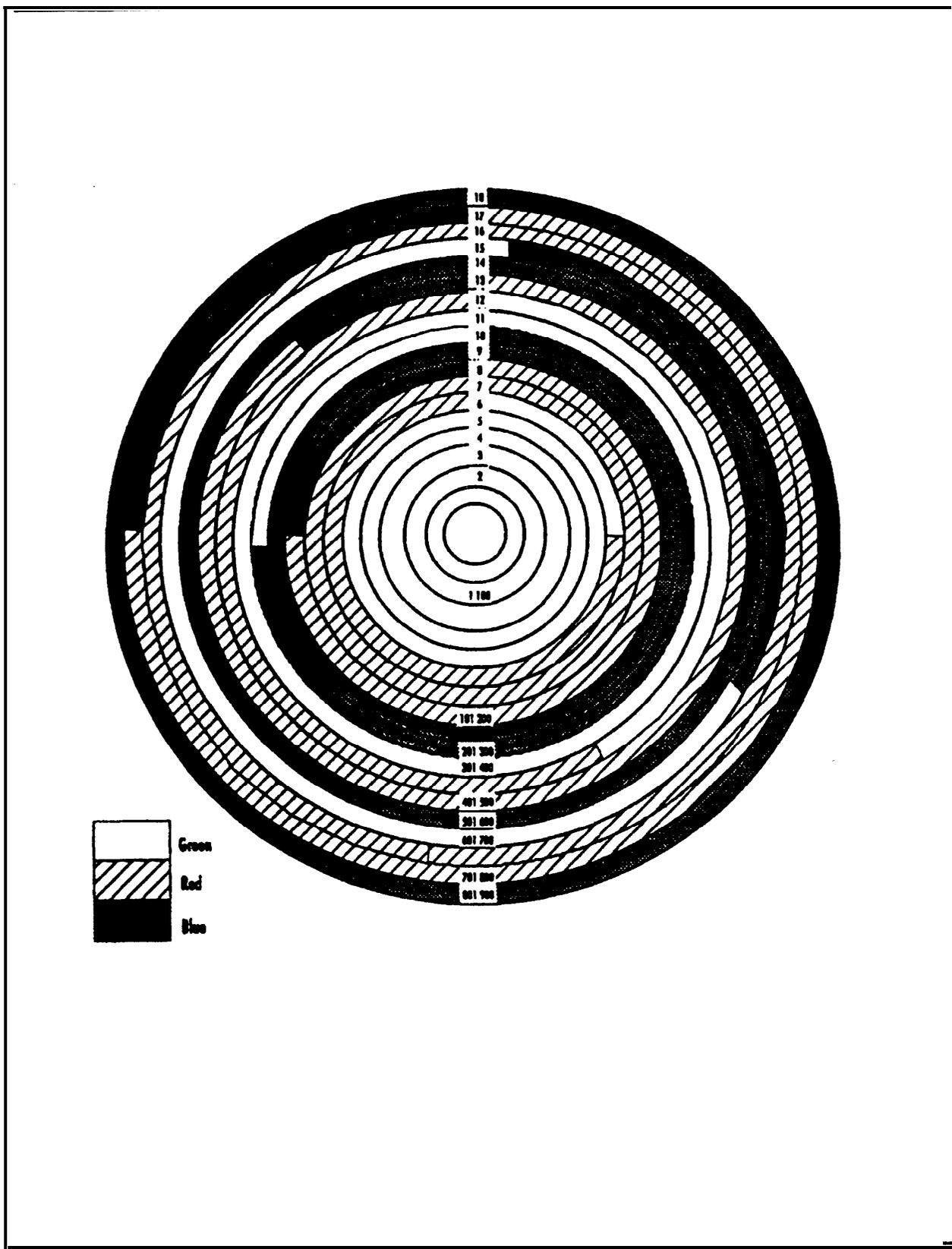


Exhibit 11 - 900-Pair, 22-Gauge, Layer-Type Cable

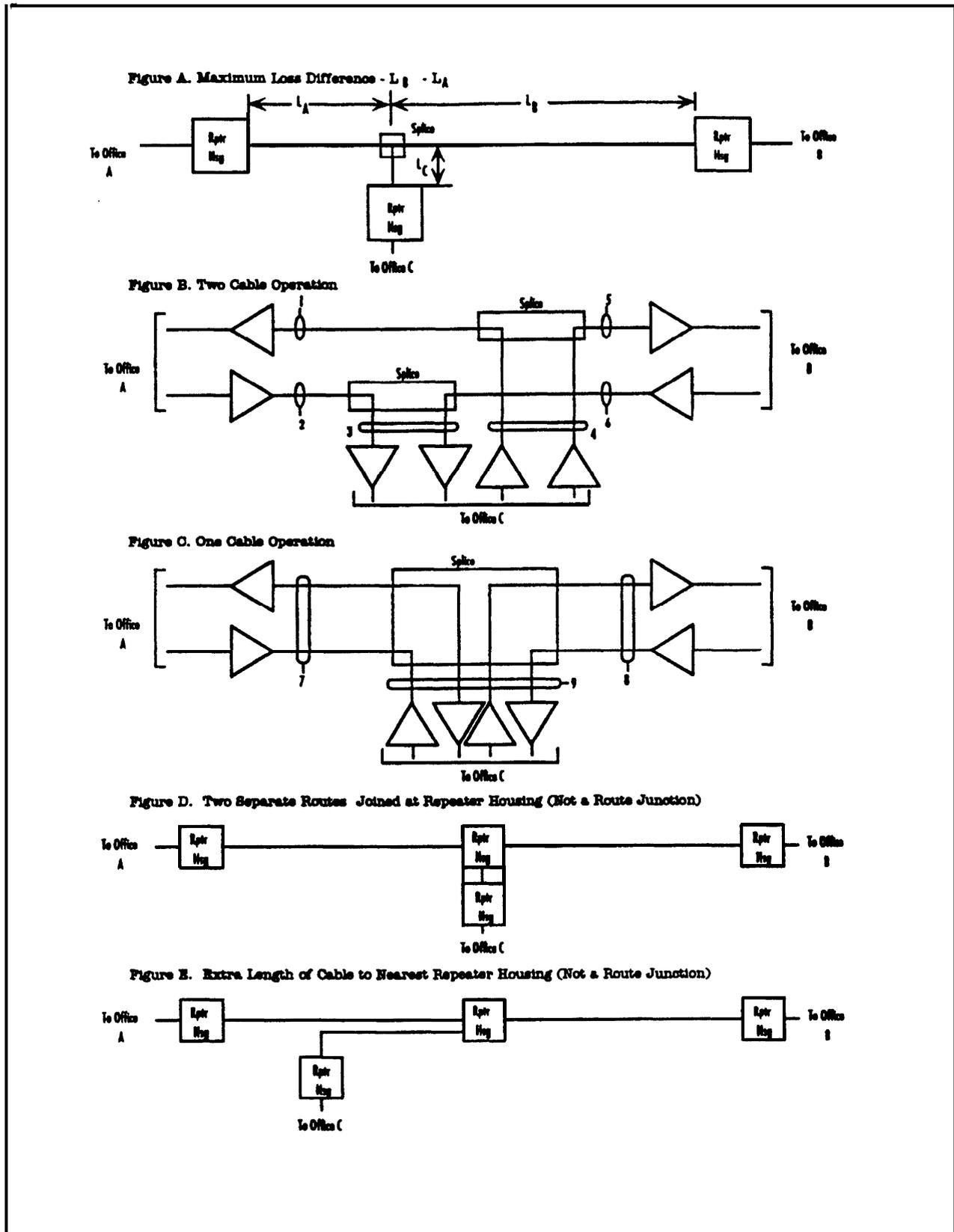


Exhibit 12 - Route Junctions (Figures A, B, C, D and E)

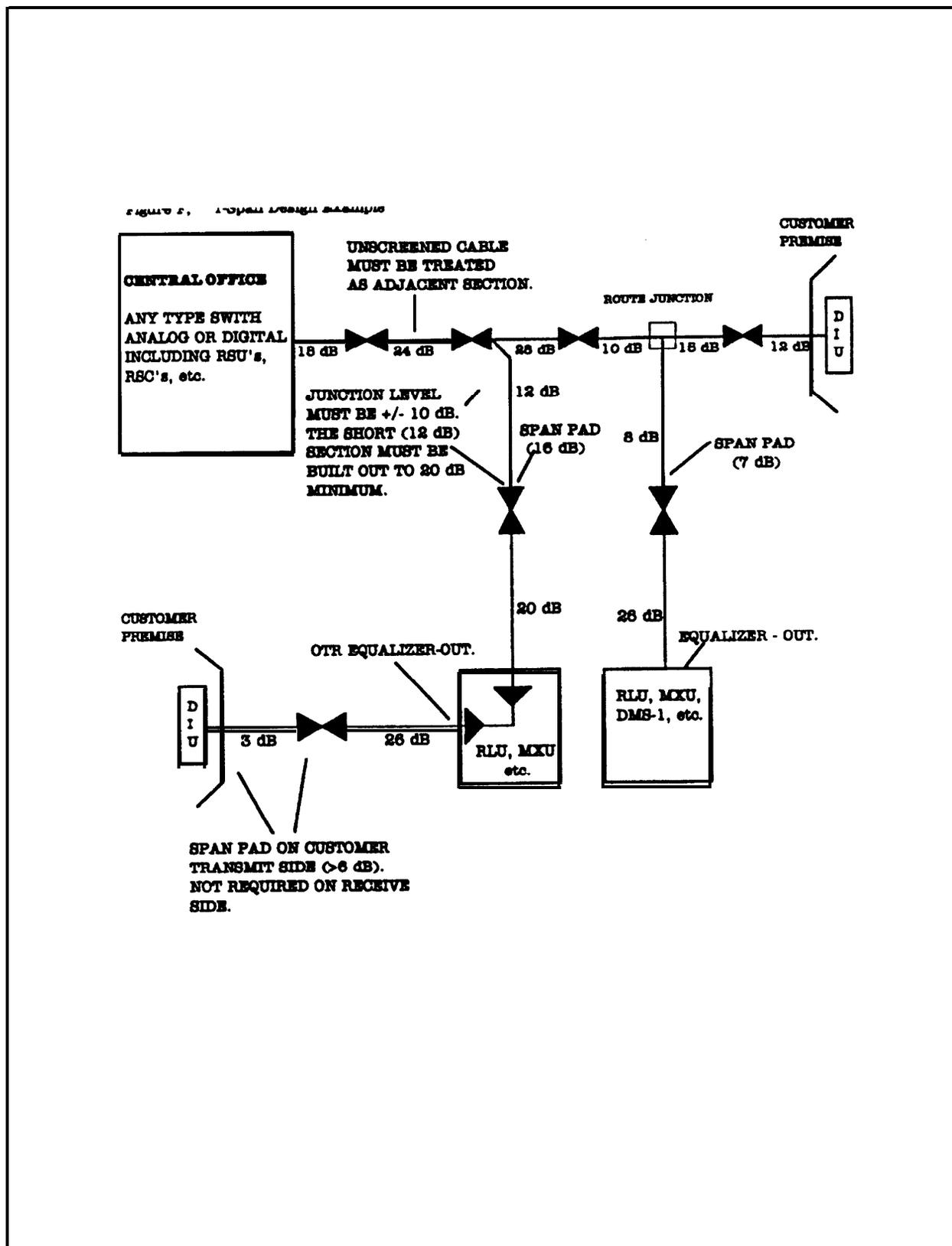


Exhibit 13 - Route Junctions (Figure F)

Figure A. 91180, 91183 One-Cable Bi-directional Operation with Single Stub

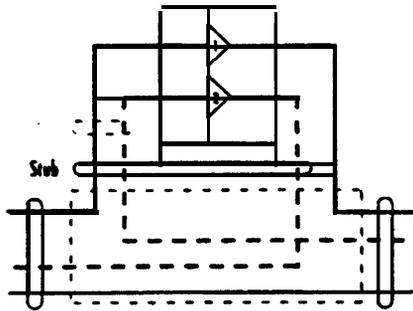


Figure B. 91181, 91182, Two-Cable Bi-directional Operation. Same Housing for Both Directions.

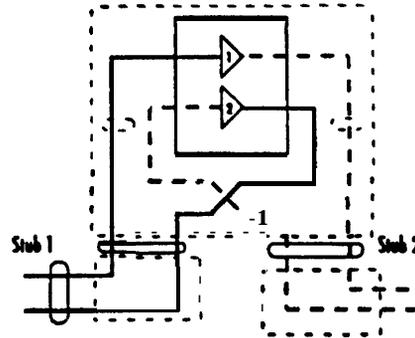


Figure C. 91170, 91171 One-Cable Operation with Bi-directional Repeaters

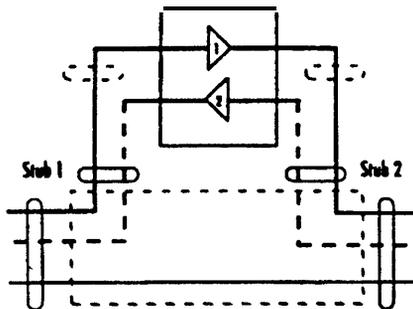


Figure D. Two Cable Operation with Unidirectional Repeaters; Separate Housing for each Direction (E-W not shown)

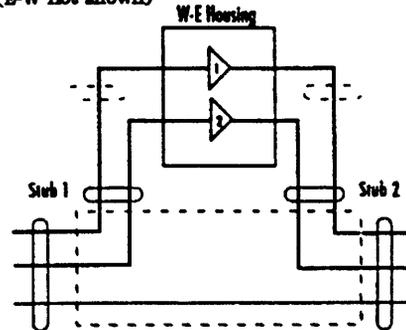


Figure E. 91170, 91171 Two-Cable Bi-Directional Operation, with Bidirectional Repeaters, Same Housing for Both Directions.

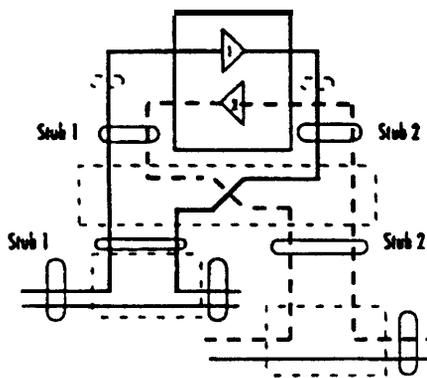


Figure F. Two Cable Operation with Unidirectional Repeaters; Separate Housing for each Direction (E-W not shown); for Multiple Housings at the same Location.

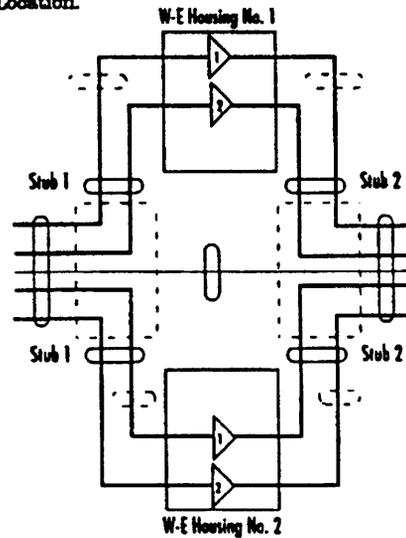


Exhibit 14 - Reporter Housing Arrangements (Page 1 of 2)

Figure G. One-Cable Operation with Unidirectional Repeaters; Separate Housing for each Direction.

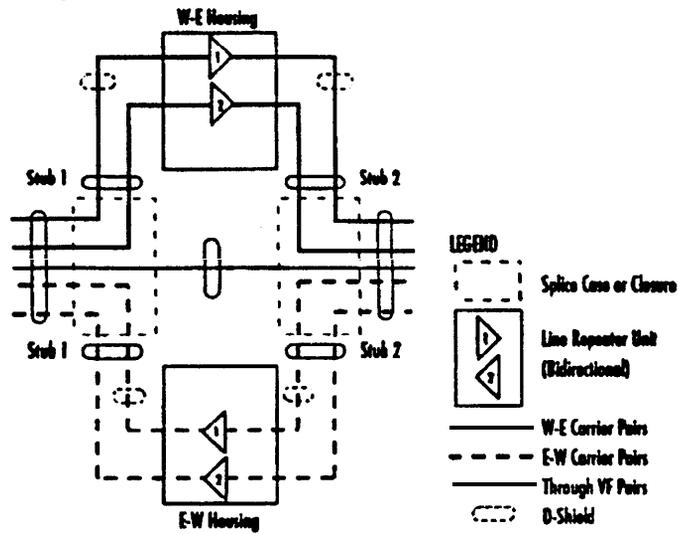


Exhibit 14 - Repeater Housing Arrangements (Page 2 of 2)

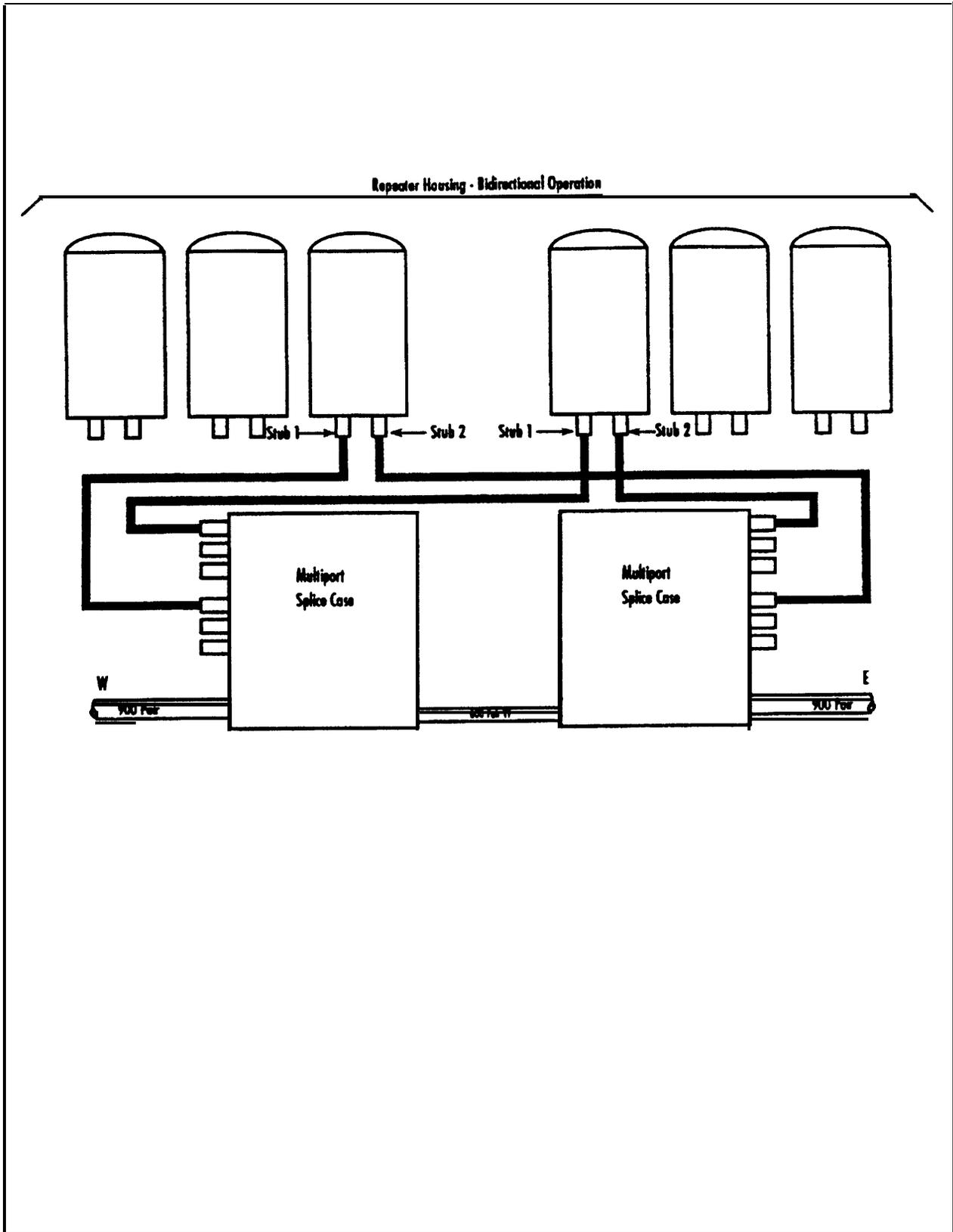


Exhibit 15 - Multiple Housing Splicing Arrangements, Single-Cable Operation

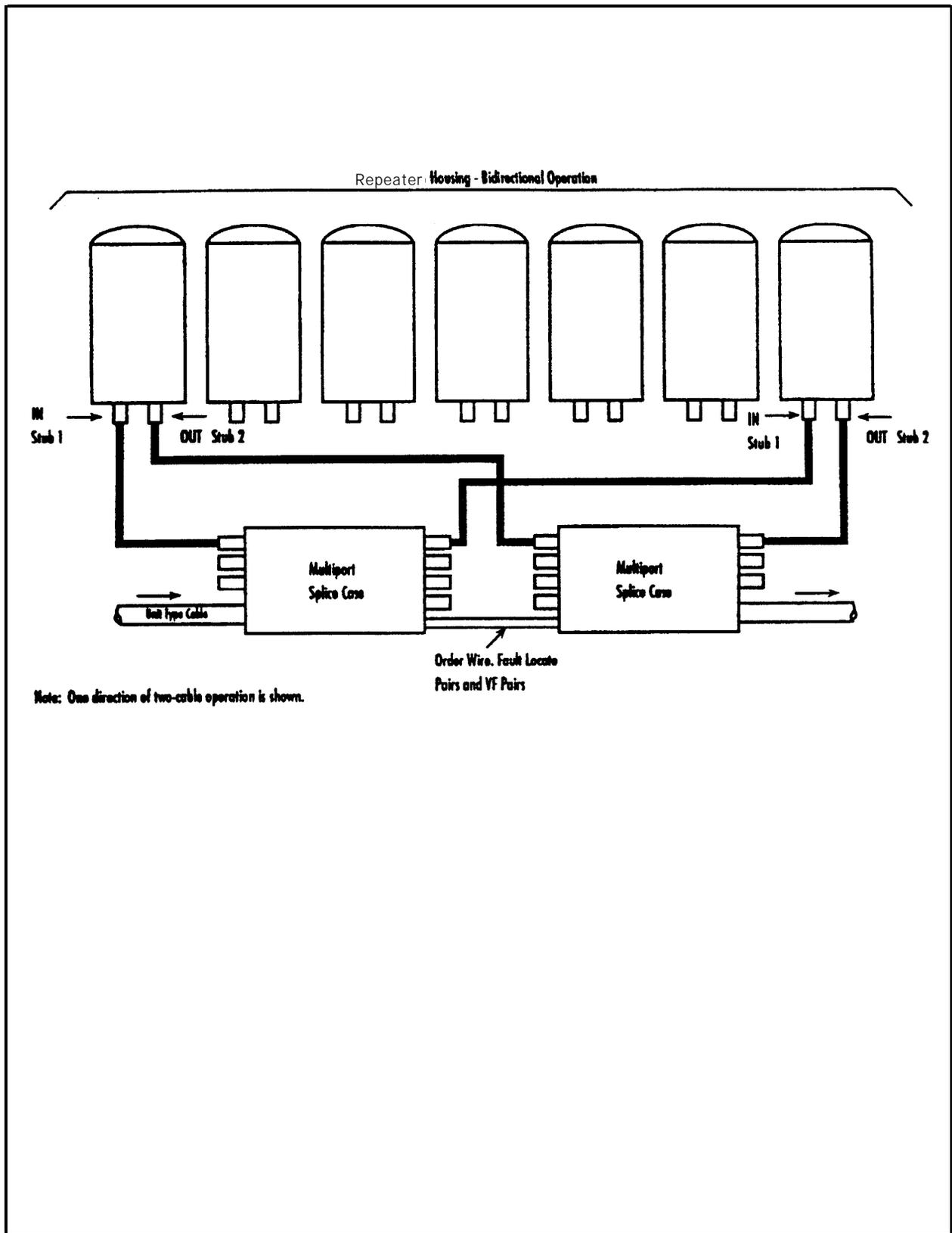


Exhibit 16 - Multiple Housing Splicing Arrangements, Two-Cable Operation

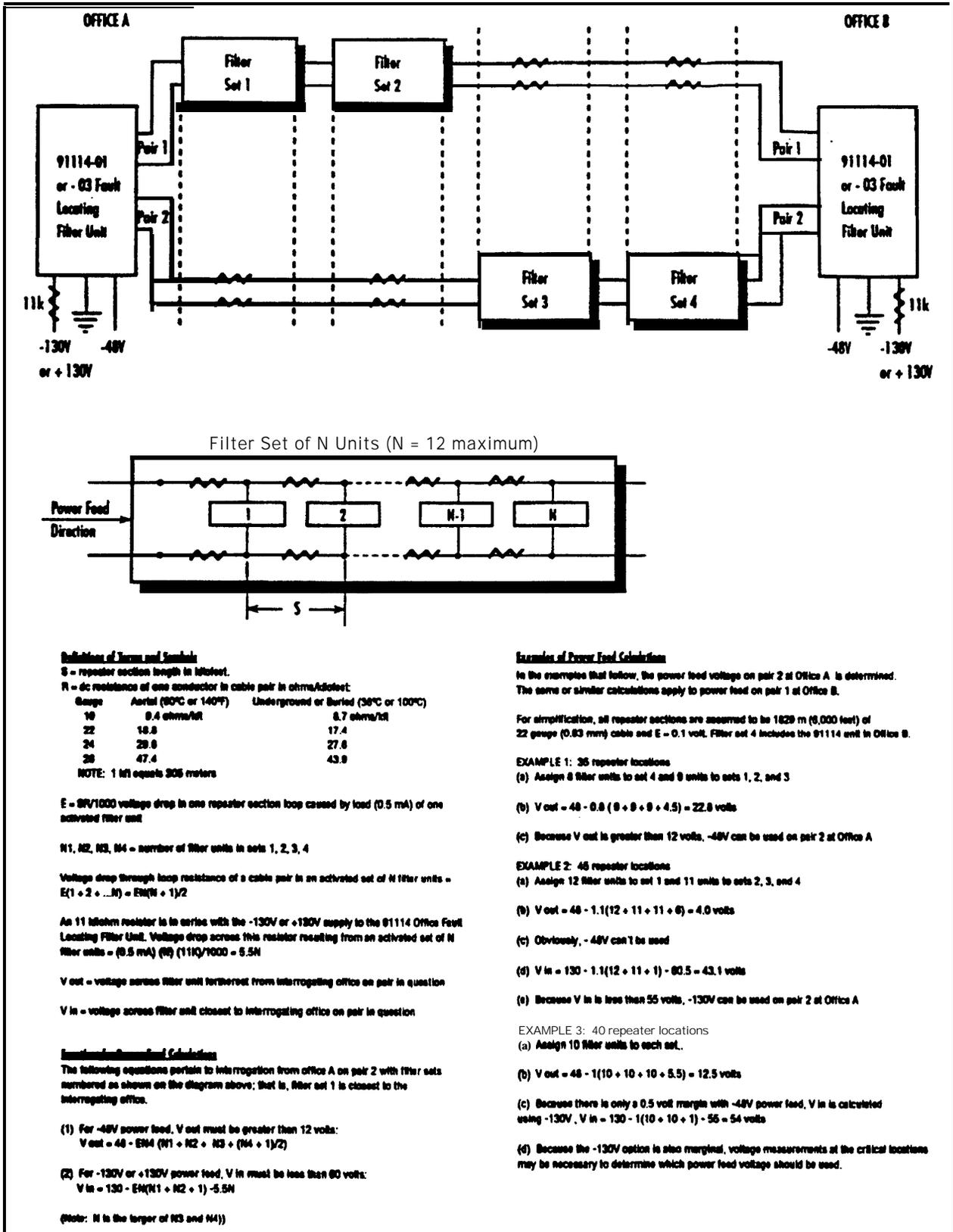


Exhibit 17 - Power Feed to Fault Locating Filter Units with Amplifiers

Figure A. Regulated Repeater Power Feed from 91152 Shelf to DC Loop

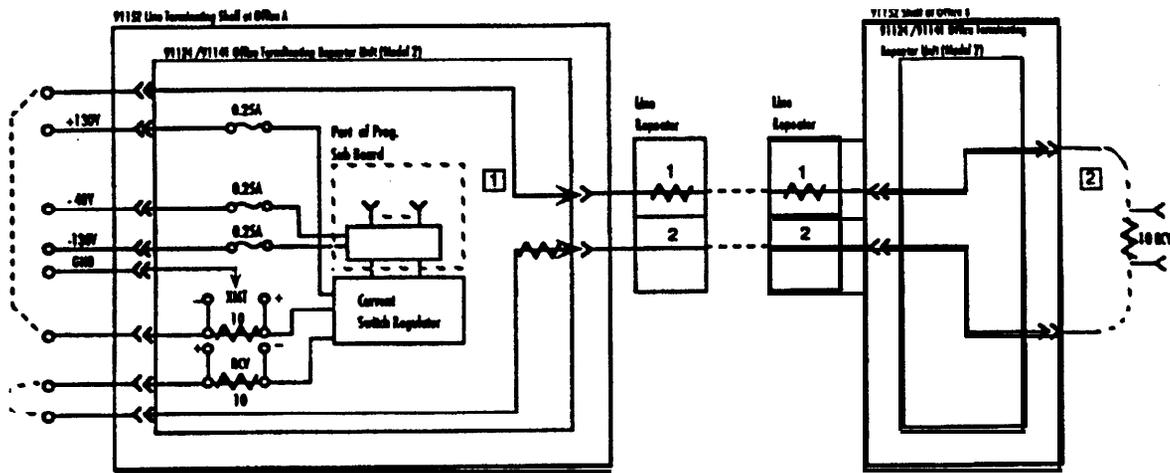
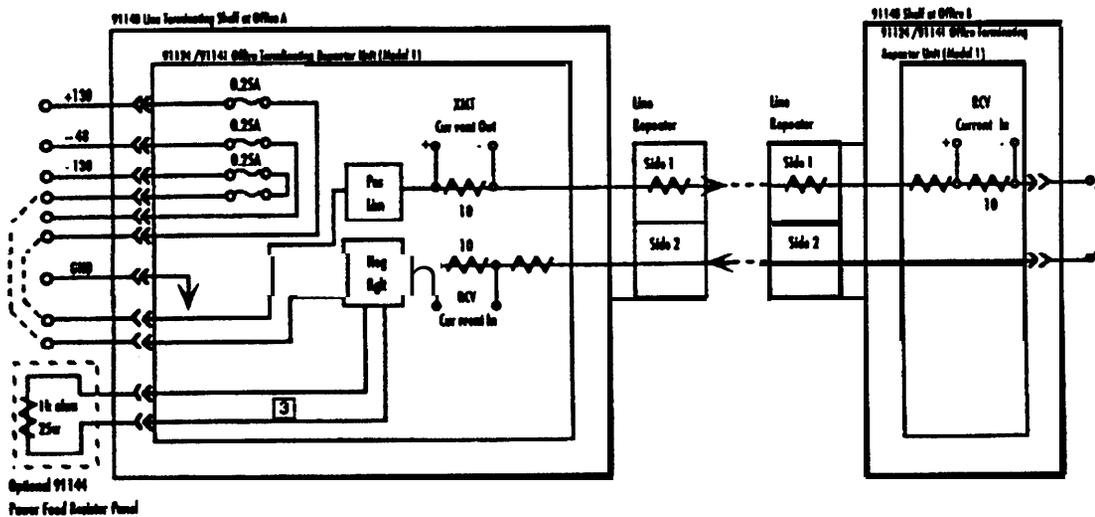


Figure B. Regulated Repeater Power Feed from 91140 Shelf to DC Loop



Notes 1, 2, and 3 correspond to items in figures A and B.

- 1** The 91124/91141 model 2 off ice repeater uses the 91140 or 91152 Line Terminating Shelf. The repeater includes a current switching regulator that automatically adjusts to the required simplex voltage feed of the span line. (Refer to the Loop Resistance Capability of 91124/91141 -M2 Office Repeaters table on page 3 of this exhibit for strapping information.

- 2** The model 2 repeaters are not provided a 10-ohm resistor for receive current monitor at remote office loop application. An external resistor may be installed for remote current monitoring.

- 3** Refer to Lenkurt Practice 342-910-105 9104A 24/48 Channel PCM Repeated Line Equipment - Inside Plant, for 91124//91141 model 1 strapping information covering use of 91144 panel.

Exhibit 18 - Typical Repeater Power Feed Configurations (Figures A and B)
(Page 1 of 3)

Figure C. Regulated Repeater power Feed from 91125 Unit to DC Loop

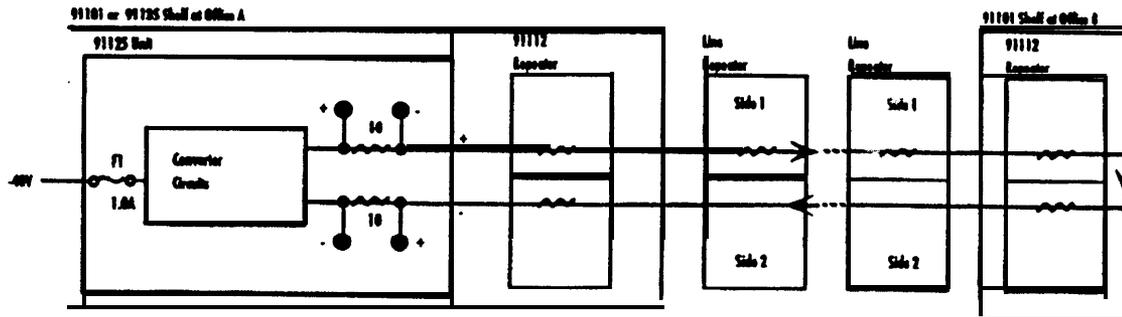


Figure D. Non-Regulated Repeater Power Feed DC Loop

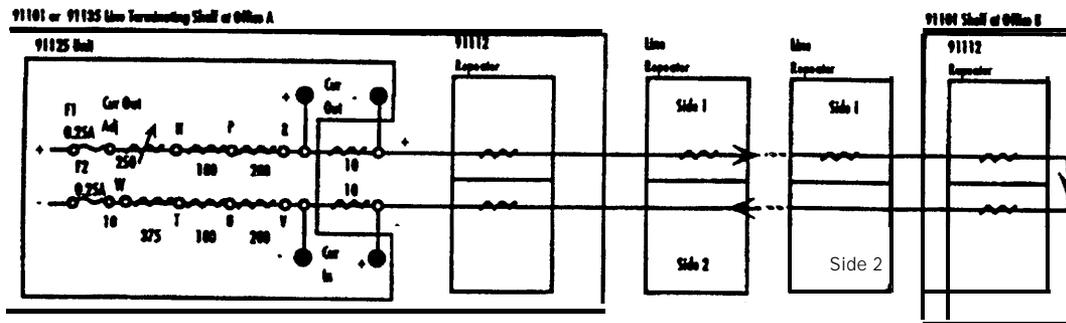


Figure E. Simplex of Two Cable Pairs

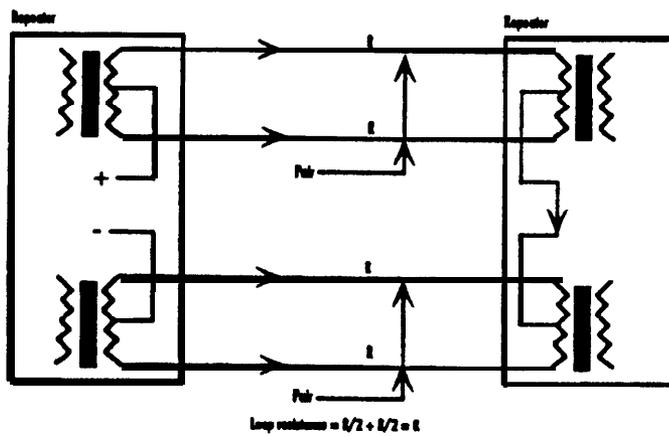


Figure F. Current Looped Back Line Repeater

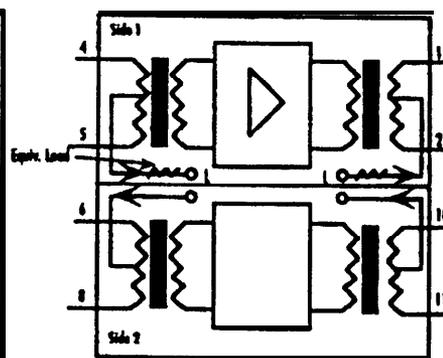


Exhibit 18 - Repeater Power Feed Configurations (Figures C, D, E, and F)
(Page 2 of 3)

Exhibits, continued

The following table lists the loop resistance capabilities of 91124/91141 - M2 office repeaters. (The table is referenced in the first note for figure A In Exhibit 18 on page 75.)

Negative Return Voltage	Span Line Current (mA)	Loop Resistance (Ohms)		Strapping Information
		Minimum	Maximum (2)	
GND -48 -130v (1)	60	200 1200 2300	2060 2790 4040	C, F, J, L, M C, E, J, L, M D, E, J, L, M
GND -40 v -130 v (1)	100	200 700 1400	1230 1670 2430	C, F, H, L, M C, E, H, L, M D, E, H, L, M
GND -48 v -130v (1)	140	200 450 950	880 1190 1740	C, F, H, K, M C, E, H, K, M D, E, H, k, M
--	Regulator Disable	--	--	C, E, J, L, N

NOTES: The above table shows only the power source at one end. For a longer span, span current can be provided at both ends. The notes listed below correspond to the numbers in parenthesis in the table above.

(1) External -130 V supply.

(2) The maximum loop resistance takes into account the variances of the office battery.

Loop Resistance Capability of 91124/91141 -M2 Office Repeaters

Exhibit 18 - Typical Repeater Power Feed Configurations (Table Referenced In Note for Figure A)
(Page 3 of 3)

Exhibits, continued

Span # :					
Item	Description	Quantity	Resistance (Ω)		
			Unit or kft	Per Unit or kft	Sub-Total
Office Repeater	91124 (T1) or 91141 (TIC) 621188x-000 (t1)				100 (1) 100 (1)
Line Repeater	91110 (T1 Unprotected) 91111 (T1 Protected) L238/91185-01(T1 Unprotected) K39/91186/91185-02 (T1 Protected) 621150~000-xxx (T1 Protected) I248/91145-M2 (T1 C Unprotected) L249/91145-M2 (T1 C Protected) 91145-MI (T1 C) 218 AT&T (T1 C) 219 AT&T (TIC) 248 AT&T (TIC) 249 AT&T (TIC)	_____ Units _____ _____ _____ _____ _____ _____ _____ _____ _____ _____		100() @ 100mA 112 Ω @ 100 mA 120 Ω @ 60 mA 72 Ω @ 100mA 132 Ω @ 60 mA 84 Ω @ 100 mA 135 Ω @ 60 mA 120 Ω @ 60 mA 135 Ω @ 60 mA 62 Ω @ 135 mA 91 Ω @ 120 mA 102 Ω @ 120 mA 107 Ω @ 60mA 118 Ω @ 60 mA	
Aerial Cable (60°C or 140°F)	19 Gauge (0.90 mm) 22 Gauge (0.63 mm) 24 Gauge (0.50 mm) 25 Gauge (0.45 mm) 26 Gauge (0.40 mm)	_____ kft _____ _____ _____ _____		9.4 18.8 29.8 38.6 47.4	
Underground or Buried Cable (38°C or 100°F)	19 Gauge (0.90 mm) 22 Gauge (0.63 mm) 24 Gauge (0.50 mm) 25 Gauge (0.45 mm) 26 Gauge (0.40 mm)	_____ kft _____ _____ _____ _____		8.7 17.4 27.5 35.6 47.4	
TOTAL RESISTANCE					Ω
<p>NOTE:</p> <p>(1) This 100 Ohms is an approximation which includes typical secondary protection resistors, transformers, current sensing resistors, etc., in the current path at both ends. It allows for various vintages and manufacturer's equipment types at far end. The value is also accurate enough to represent one office repeater when powering from both ends.</p>					

Exhibit 19 - Worksheet for Calculating Simplex Loop Resistance Using 91124/91141/621188x Office Repeaters

Exhibits, continued

Span # :					
Item	Description	Quantity	Resistance (Ω)		
			Unit or kft	Per Unit or kft	Sub-Total
Office Repeater	91112 (T1)			20	
Line Repeater	91110 (T1 Unprotected) 91111 (T1 Protected) L238 (T1 Unprotected) L239 (T1 Protected)	Units ↓		100 Ω @ 100 mA 112 Ω @ 100 mA 120 Ω @ 60 mA 132 Ω @ 60 mA	
Aerial Cable (60°C or 140°F)	19 Gauge (0.90 mm) 22 Gauge (0.63 mm) 24 Gauge (0.50 mm) 25 Gauge (0.45 mm) 26 Gauge (0.40 mm)	kft ↓		9.4 18.8 29.8 38.6 47.4	
Underground or Buried Cable (38°C or 100°F)	19 Gauge (0.90 mm) 22 Gauge (0.63 mm) 24 Gauge (0.50 mm) 25 Gauge (0.45 mm) 26 Gauge (0.40 mm)	kft ↓		8.7 17.4 27.5 35.6 47.4	
91105 Simplex Power Unit	(a) Two 10 Ω resistors and two 0.25 A fuses. (b) CUR OUT ADJ control fully clockwise.			40	
91125 Simplex Power Unit	Two 10 Ω resistors				
TOTAL RESISTANCE (R _T)					Ω

Exhibit 20 - Worksheet for Calculating Simplex Loop Resistance Using 91105 Simplex Power Unit or 91125 Simplex Power Converter Unit

