PRELIMINARY

Bell System

Transmission Engineering Technical Reference

PRIVATE LINE INTERCONNECTION

• • •

Voice Applications

June 1970

ENGINEERING DIRECTOR - TRANSMISSION

326-120

NOTICE

This Technical Reference is published by American Telephone and Telegraph Company as a guide for designers and manufacturers of customer-provided communications systems and terminal equipment which connect with Bell System private line services. American Telephone and Telegraph Company reserves the right to revise this Technical Reference for any reason, including (but not limited to) conformity with standards promulgated by USASI, EIA, CCITT, or similar agencies, utilization of new advances in the state of the technical arts, or to reflect changes in the design of equipment or services described therein. The limits of responsibility and liability of the Bell System with respect to the use of customer-provided systems and equipment are set forth in the appropriate Tariff regulations.

PRIVATE LINE INTERCONNECTION
VOICE APPLICATIONS

CONTENTS PAGE

CONTENTS PAGE

CONTENTS PAGE

1. INTRODUCTION

General

1.01 Tariff FCC No. 260 and corresponding intrastate Tariffs in many states have been revised to provide for the connection of customer-provided systems and terminal equipment to Telephone Company private line services. The Tariffs provide for direct electrical connection of this customer-provided equipment or systems through appropriate connecting arrangements furnished, installed, and maintained by the Telephone Company. These connecting arrangements are required effective with the dates specified in the Tariffs. The Tariffs also provide for indirect acoustic or inductive connection externally to Telephone Company equipment. Customer-provided voice transmitting equipment which involves direct electrical or indirect connection must comply with the minimum protection criteria specified in the Tariff (see Section 4.03).

1.02 The private line arrangements and parameters discussed in this Technical Reference apply to FCC interstate private line Tariff offerings. Most local telephone companies offer similar intrastate arrangements. Where intrastate arrangements are anticipated the local Telephone Company must be contacted to determine what arrangements are available.

1.03 The responsibility of the customer and of the Telephone Company for these offerings as set forth in the applicable FCC Tariff is given in Paragraphs 1.07 and 1.08.

1.04 In these offerings, the Telephone Company is responsible only for the facilities and equipment it provides, and not for the overall system design and performance. However, to provide assistance to the users of these offerings, this Technical Reference contains a description of the overall transmission design considerations that the Telephone Company uses when it engineers similar facilities. These include transmission considerations, signaling considerations, suggested maintenance techniques, and trouble investigating techniques. This material is not furnished with the intent to provide complete design specifications or parameters.

1.05 The descriptions of the private line offerings in this Reference are limited to voice applications. The transmission characteristics of private lines, when used for data and alternate voice data applications can be found in the Technical Reference, ***Transmission Specifications for Voice Grade Private Line Data Channels,*** available through the Engineering Director-Data Communications. Technical References describing private line voice connecting arrangements are available through the Engineering Director—Customer Telephone Systems.*

1.06 Those persons seeking further information about ***these offerings*** should contact their Telephone Company representative through the local business office. For inquiries ***involving design considerations for the manufacturing*** of equipment, please contact: Engineering Director-Transmission.*

* American Telephone and Telegraph Company

195 Broadway

New York, New York 10007

Responsibility of the Telephone Company

1.07 Tariff FCC No. 260 states:

The Telephone Company shall not be responsible for installation, operation or maintenance of any customer-provided terminal equipment or communications systems. Private line service is not represented as adapted to the use of customer-provided equipment or systems and where such equipment or systems are connected to Telephone Company facilities the responsibility of the Telephone Company shall be limited to the furnishing of facilities suitable for private line service and to the maintenance and operation of such facilities in a manner proper for such private line service; subject to this responsibility the Telephone Company shall not be responsible for (1) the through transmission of signals generated by the customer-provided equipment or systems, or for the quality of, or defects in, such transmission, or (2) the reception of signals by customer-provided equipment or systems.

The Telephone Company shall not be responsible to the customer or otherwise if changes in the criteria contained in the Tariffs (and in Section 4 of this Technical Reference) or in any of the facilities, operations, or procedures of the Telephone Company render any customer-provided facilities obsolete or require modification or alteration of such equipment or system or otherwise affect its use or performance.

Responsibility of the Customer

1.08 Tariff FCC 260 states:

Where private line service is available under this Tariff for use in connection with customer-provided terminal equipment or communications systems, the operating characteristics of such equipment or systems shall be such as not to interfere with any of the services offered by the Telephone Company. Such use is subject to the further provisions that the customer-provided equipment or systems do not endanger the safety of Telephone Company employees or the public, damage, require change in or alternation of, the equipment or other facilities of the Telephone Company; interfere with the proper functioning of such equipment or facilities; impair the operation of the Telephone Company's facilities or otherwise injure the public in its use of the Telephone Company's services. Upon notice from the Telephone Company that the customer-provided equipment or systems are causing or are likely to cause such hazard or interference, the customer shall make such change as shall be necessary to remove or prevent such hazard or interference.

2. DEFINITION OF SERVICE

Standard Offering

2.01 This Section contains descriptions of the Telephone Company's standard voice grade private line offerings which are interconnected at one or both ends with customer-provided voice communications systems or terminal equipment. For purposes of discussion, these standard offerings will be broken down into the following five categories.

(a) Nonswitched, point-to-point private lines

(b) Private lines with switched access to the telecommunications network (includes a description of Private Branch Exchange (PBX) operation)

(c) Foreign Exchange private lines

(d) Entrance Facilities for extending customer-provided communications channels to his premises

(e) Customer-provided communications channels interconnecting with Telephone Company-provided PBXs or terminal equipment on the same premises.

Each of these major categories will be described in more detail in the following Sections. Fig. 1 and Table A describe a set of standard symbols and abbreviations that will be used for all the figures in this Reference. A glossary of telephone terminology used in the Technical Reference is provided in Section 10.

TABLE A

ABBREVIATIONS USED ON FIGURES

TELCO (or T)	Telephone Company
PBX*	Private Branch Exchange
CP (or C)	Customer-Provided
I/F	Customer — Telephone Company Interface
C.O.	Telephone Company Central Office
4-WTS	4-Wire Terminating Set
TIE TRK CKT	Tie Trunk Circuit
TLP	Transmission Level Point
TS	Test Set
N	4-Wire Terminating Set Balancing Network
HP/LP FILTER	High-Pass/Low-Pass Filter
OSC	Oscillator
DET	Detector
S.F. Sig Unit	Single-Frequency Signaling Unit
ICT	Idle Circuit Termination

* In this Reference, the designation PBX (when it is provided by the Telephone Company), is intended to include both CENTREX and PBX services.

Nonswitched Point-to-Point Private Lines

2.02 Within this category are the 2-point and the multipoint private lines. They are served over nonswitched facilities with no access to the message network. A 2-point private line involves a channel between two terminal locations. A multipoint circuit involves channels to several locations which are bridged together at some central point(s). This Technical Reference will cover only the engineering considerations for 2-point private lines. The design of the bridging arrangements and the special signaling and balancing considerations for multipoint private lines are beyond the scope of this reference. Customers who have multipoint circuit requirements are invited to consult their Telephone Company representative through the local business office for advice on their individual requirements. For inquiries involving design for manufacturing of communications equipment for use on multipoint private line facilities, please contact the Engineering Director—Transmission.

2.03 Typical voice applications for 2-point private lines are order wires, loudspeaker intercom circuits, and key system private lines. Diagrams for typical 2-point private lines are shown in Fig. 2 and 3.

2.04 The Terminal equipment at a given location may be provided by either the Telephone Company or the customer, and may use either 2-wire or 4-wire voice transmission facilities.

Private Lines Capable of Switched Access to the Telecommunications Network

2.05 This category of private lines involves the following services which terminate in PBX switching equipment on the customer's premises at one or both ends:

(a) PBX Tie Trunks (Fig. 5)

(b) PBX Off-Premises Stations (OPSs) (Fig. 6)

(c) Common Control Switching Arrangement (CCSA) Access Lines (Fig. 7)

Generally, PBXs associated with these services have switched access to the telecommunications network though some may not have.

PBX Operation

2.06 Before describing the various types of private lines in this category, the function of switching equipment (the PBX) used with these private lines will be discussed. A PBX is a system for interconnecting telephone instruments on one premises with other telephones on the same premises. Connections can also be made from a telephone (usually called a PBX "station") to the Telephone Company's telecommunications network or to private line services terminated in the PBX. There are two basic types of PBXs: manual and dial.

2.07 All PBXs have one feature in common: there is a customer-employed attendant who can intervene to assist in placing a call or to exercise

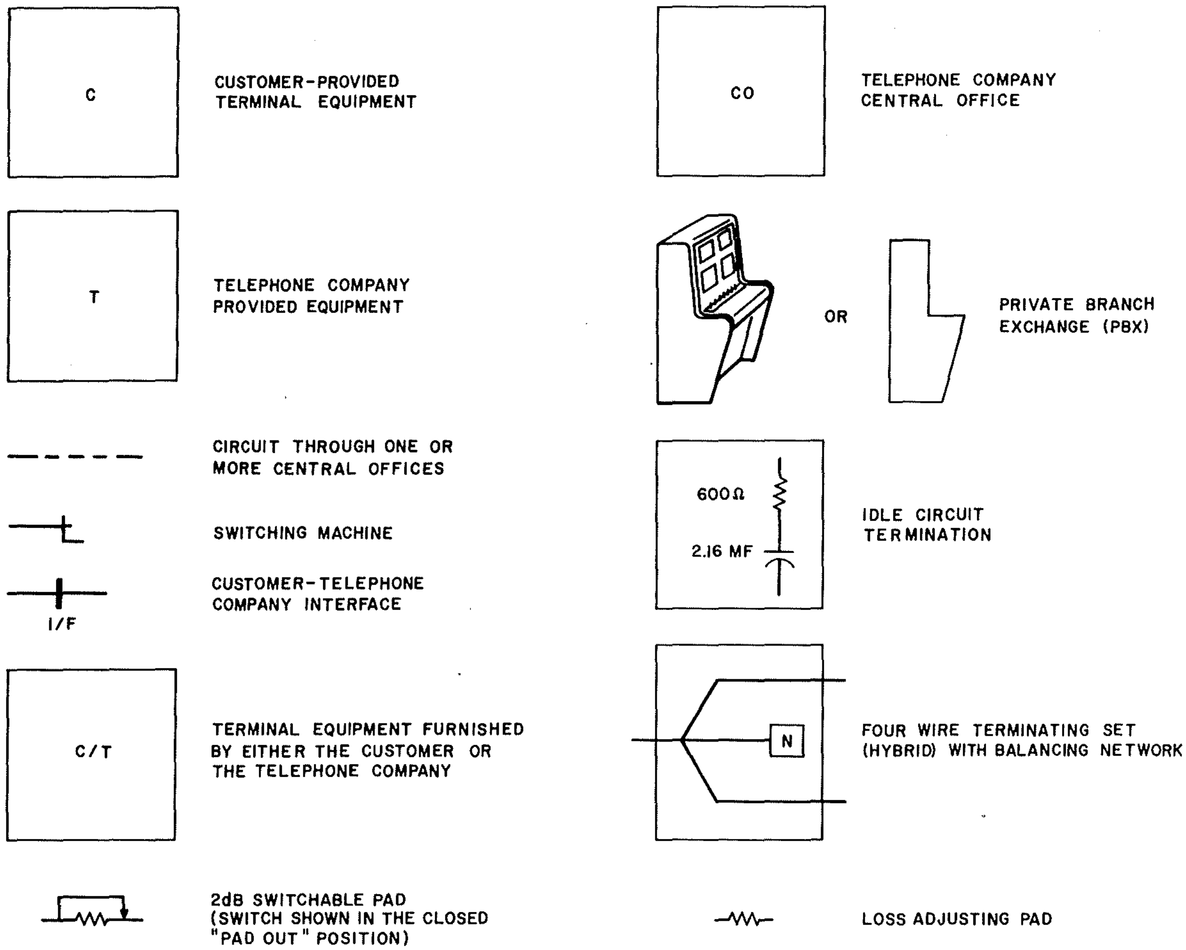


Fig. 1—Symbols

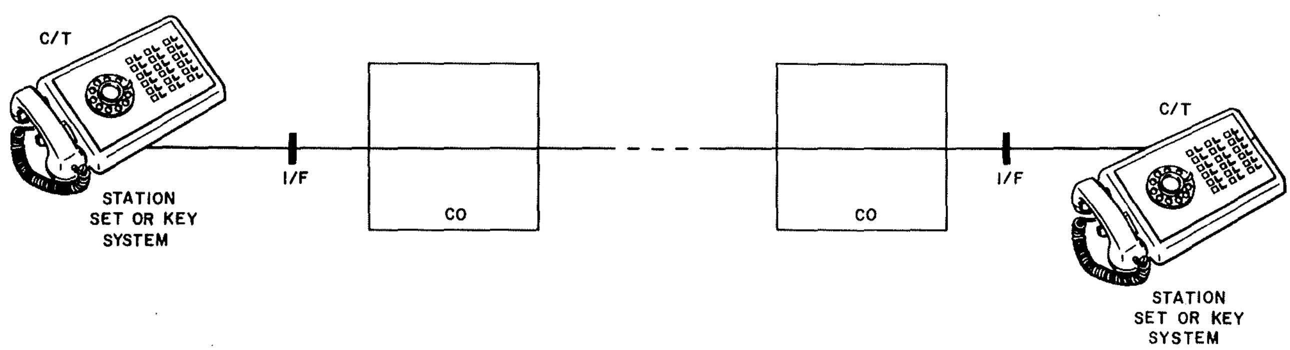


Fig. 2—Two-Point Private Line Circuit (2-Wire Terminal Equipment)

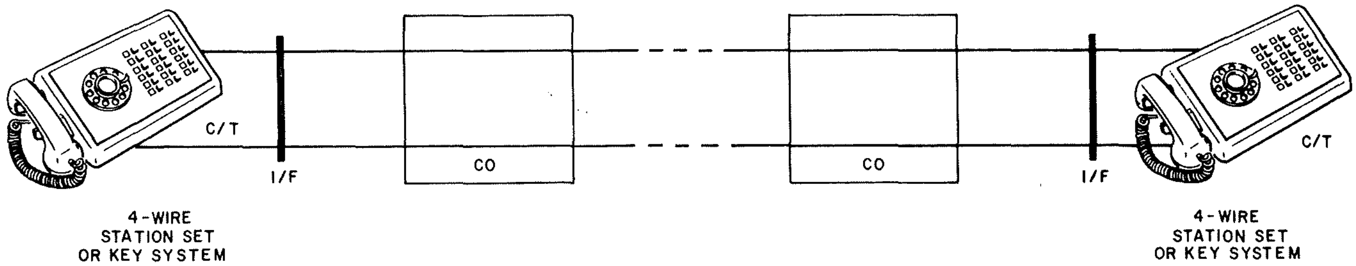


Fig. 3—Two-Point Private Line Circuit (4-Wire Terminal Equipment)

control functions. The control functions embrace both system operation (eg, applying ringing signals to manual tie lines) and implementing administrative instructions issued by the customer (eg, denying certain stations access to central office lines).

2.08 In the early PBXs, the attendant position is a switchboard. The switchboard has jacks for each station, Central Office Trunk, and private line. The attendant has a number of cord circuits, and a series of keys whereby the attendant headset can be connected or a ringing signal can be applied to any of the cord pairs. When a handset of a station is lifted off of its switchhook, a lamp is lighted on the switchboard. The attendant connects one plug from a cord circuit to the jack for that station. The attendant can then operate a key to connect her headset to the station through the cord. When the caller's wishes have been determined, the call is completed by the attendant inserting the mating plug of the cord circuit into the jack for the called station and operating the key to send ringing current to ring the bell of the called telephone. This sequence is the basic manual switchboard operation. Outgoing calls to the telecommunications network are handled by the attendant inserting the second plug into a jack of a central office trunk and dialing the call. Incoming calls from the telecommunications network are handled in much the same way as an intra-PBX station-to-station call.

2.09 In later PBXs, dial equipment was developed for installation on customer premises. This enables PBX stations to dial each other, instead of having to go through an attendant. Dial PBXs offer some convenience and transmission advantages, but the main advantage is the reduction in the number of attendants required to operate a large PBX. Later developements permit the stations to dial their own outside calls on the telecommunications network, and to dial over tie trunks to reach stations on other PBXs.

2.10 Modern developments have made available the replacement of the switchboard by an attendant cordless console which physically resembles a ***CALL DIRECTOR***® station. The console permits the attendant to handle all calls where the calling party requires assistance, and to handle transfers of calls from one station to another. All connections are made by the PBX switching machine.

2.11 A PBX central office trunk is used to provide the PBX with access to and from the telecommunications network at the Telephone Company's local serving central office. Technical specifications are covered by Telephone Company design practices since a PBX central office trunk is not considered a private line service unless it connects to a foreign central office, as described in Paragraph 2.15. A PBX central office trunk is depicted in Fig. 4.

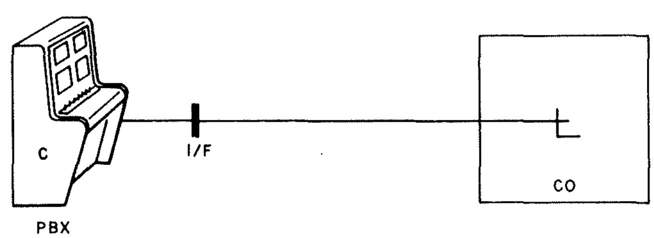


Fig. 4—PBX Central Office Trunk (Not a Private Line Service)

PBX Tie Trunks

2.12 A PBX tie trunk is a private line which directly connects two PBXs without any intermediate switching (see Fig. 5). Tie trunks

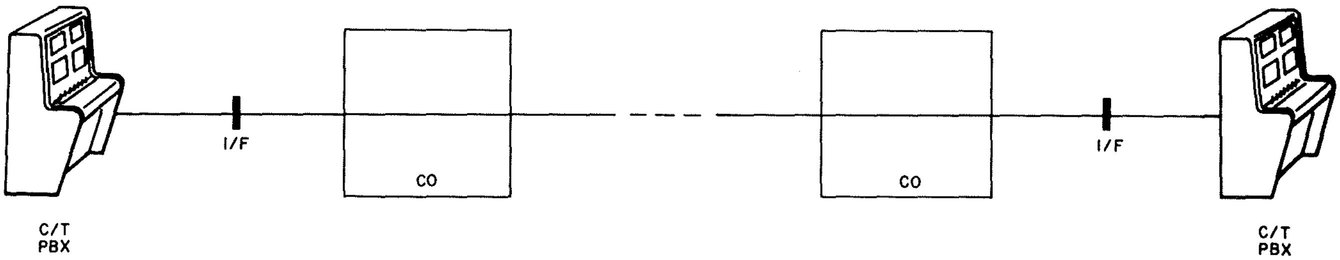


Fig. 5—PBX Tie Trunk

may perform many functions, from a simple one-link connection between PBX stations at both ends to being a part of a "tandem tie trunk network." A tandem tie trunk network consists of a number of PBXs interconnected by tie trunks. Connections between the various PBX locations on the network are made by switching tie trunks together through the PBXs to form tandem connections. A number of special designations for PBX tie trunks in a tandem tie trunk network are given in Paragraphs 2.34 -2.37 and are shown in Fig. 16.

PBX Off-Premises Station Lines

2.13 An off-premises station is an extension of PBX station service to a telephone instrument, key system station, or to other station terminal equipment on different premises than the PBX. The off-premises station has wide application in businesses that have only one PBX, but that have quarters in several buildings within a city. Off-premises station lines can also be extended to other cities, as shown in Fig. 6.

Common Control Switching Arrangement (CCSA) Access Lines

2.14 Customers with large scale communications needs may find it advantageous to use a private network which is similar in design and operation to the Telephone Company's telecommunications network. These networks, called ***Common Control Switching Arrangement (CCSA) networks,*** use dedicated portions of Telephone Company central office switching machines, as well as private line facilities, to complete calls. Calls are entered into and received from a CCSA network over CCSA access lines. A typical switching hierarchy for a CCSA network is shown in Fig. 7. CCSA access lines may be provided to Telephone Company or customer-provided individual telephone instruments, key systems, as well as to PBXs.

Foreign Exchange Services

2.15 This category of private line services covers those private lines with one end switched at a Telephone Company foreign exchange central office or toll switchboard. ***Foreign Exchange (FX)*** is a term which is used to indicate service requested by the customer at any central office other than the central office which would normally serve the customer's location.

Foreign Exchange Line

2.16 As illustrated in Fig. 8, a foreign exchange line provides access for a station set or key

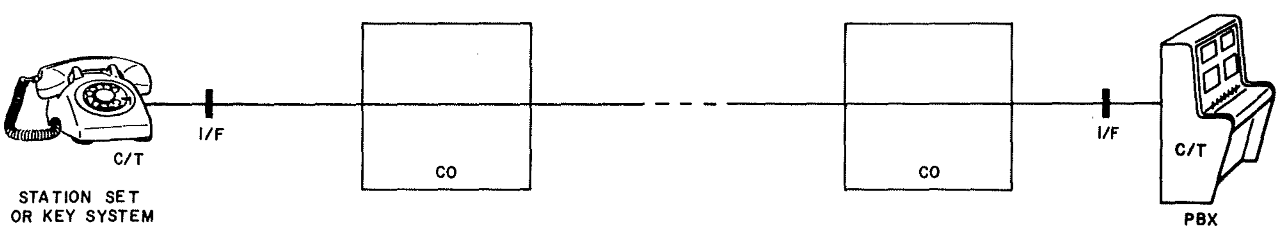


Fig. 6—Off Premises PBX Station Line

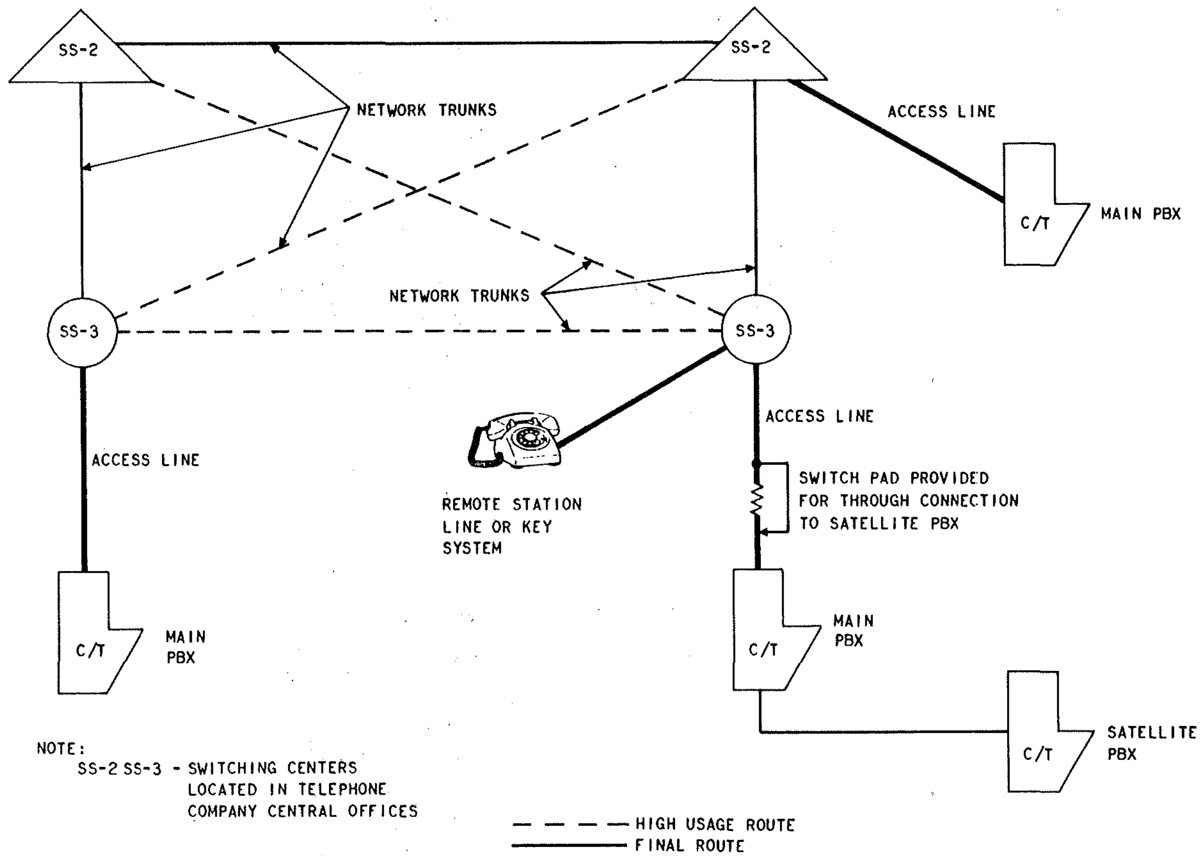


Fig. 7—Common Control Switching Arrangement (CCSA)

system to the telecommunications network at a Telephone Company central office other than the one which would normally serve that station. This results in a requirement for private line interoffice facilities in addition to loop plant.

Long Distance (Toll Terminal) Lines

2.17 A long distance (LD) line provides a direct connection from a station or key system at a customer location to a toll switchboard. Fig. 9 illustrates the case where the toll switchboard is located at a foreign exchange.

Secretarial Line to Foreign Exchange

2.18 Secretarial Service provides telephone answering service when a client is not available to answer his calls. When the answering service switchboard is served from a central office other than the one which normally serves his client, an arrangement shown in Fig. 10 is used when

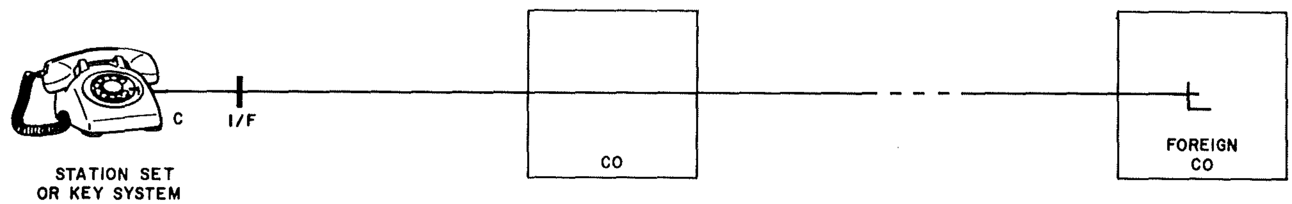


Fig. 8—Foreign Exchange Line

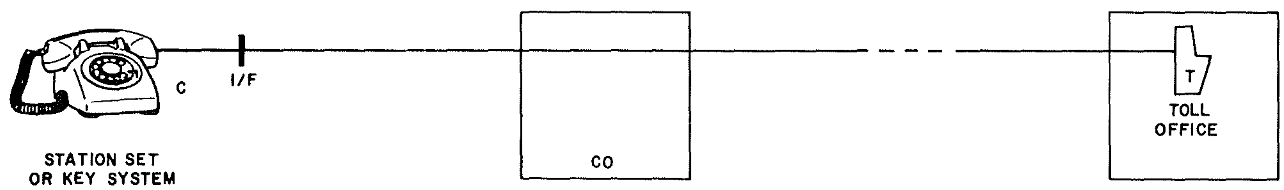


Fig. 9—Long Distance Line

feasible. The bridging of the two lines may result in signaling and transmission impairments.

Foreign Exchange Off-Premises Extension Line

2.19 Fig. 11 illustrates the facility arrangement for a foreign exchange off-premises extension line. In this case, also, the bridging of the two lines may result in signaling and transmission impairment.

PBX Foreign Exchange Trunk

2.20 PBX foreign exchange trunks are used to provide access for PBXs to the telecommunications network at a telephone central office other than the one that would normally serve that PBX. The facility arrangement is shown in Fig. 12 and is similar to that provided for foreign exchange lines. There are differences, however: (1) the type of station termination and (2) the transmission design loss of the facility. A

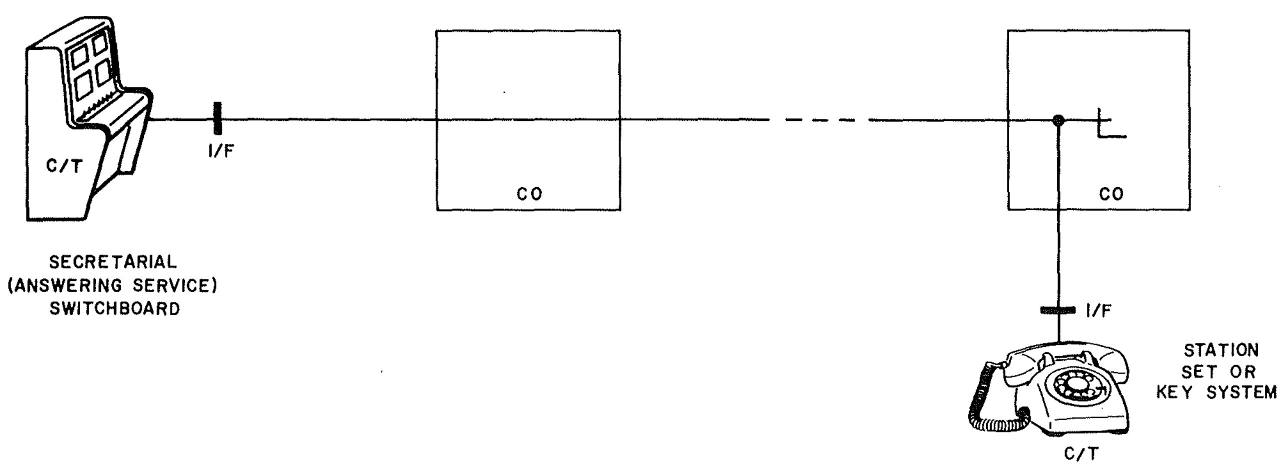


Fig. 10—Secretarial Line to Foreign Exchange

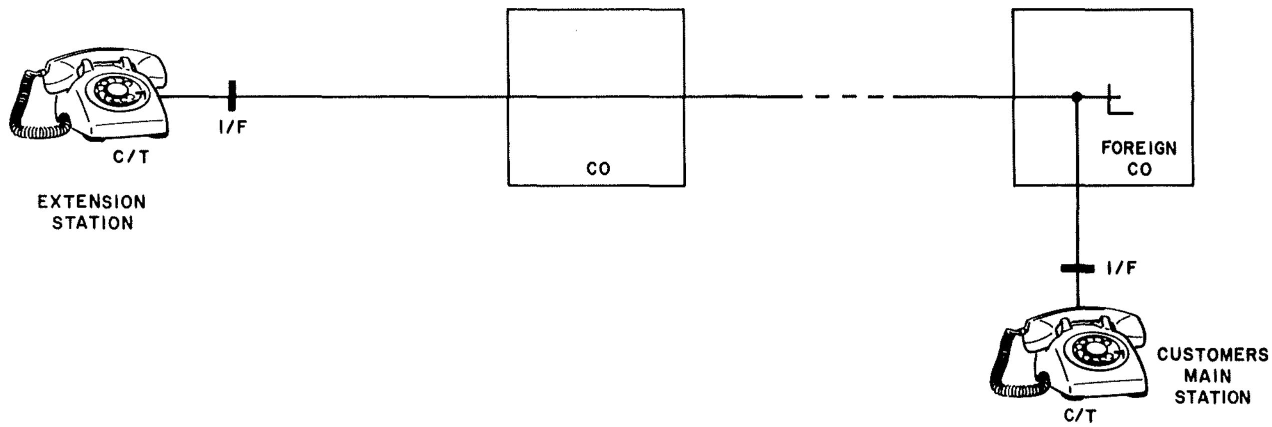


Fig. 11—Foreign Exchange Off Premises Extension Line

discussion of overall private line design considerations is covered in Part 6.

Long Distance (Toll Terminal) Trunk

2.21 A long distance (LD) trunk provides a direct connection from a PBX at a customer's location to a toll switchboard. Fig. 13 illustrates the case where the toll switchboard is located at a foreign central office.

Entrance Facilities

2.22 Entrance Facilities may be used by the customer to extend his communications channel (usually a private microwave radio channel) from his channel location to his premises, where it may terminate in equipment or systems provided by the Telephone Company or the customer. As covered in the Tariffs, applications of Entrance Facilities are limited to airline distances not to exceed 25 miles between the customer's channel

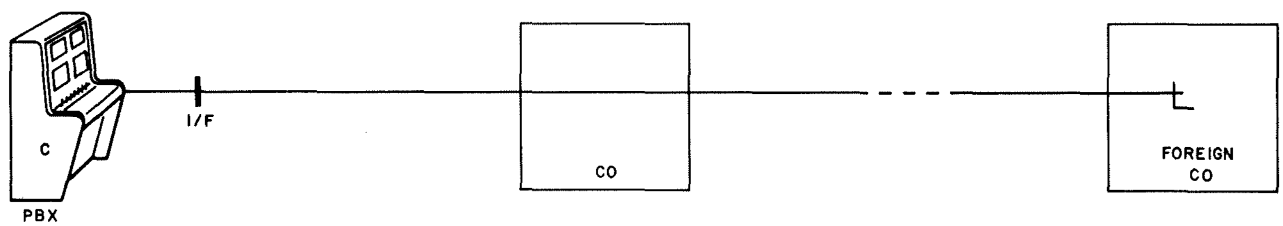


Fig. 12—Foreign Exchange Trunk

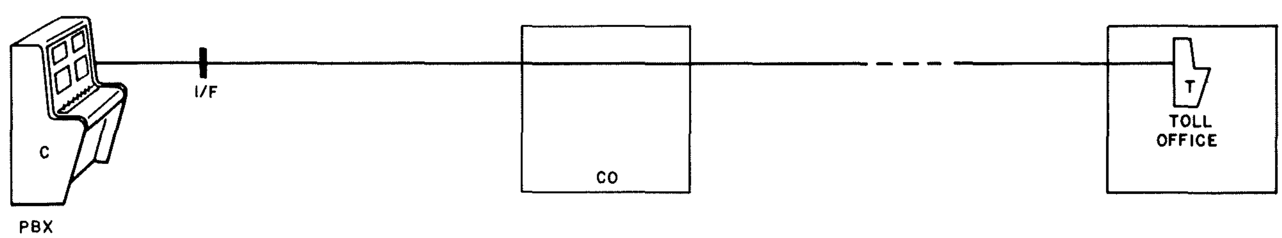


Fig. 13—Long Distance Trunk

and terminal locations. A typical 4-wire Entrance Facility is shown in Fig. 14, where a customer-provided microwave channel is extended to a PBX locaton.

Entrance Facilities may be connected at the premises of the customer to other Telephone Company private line services as specified in the Tariff. Engineering and design information for Entrance Facilities is presented in a separate Technical Reference, ***Voice Grade Entrance Facilities for Extending Customer-Provided Communications Channels,*** which may be obtained from:

Engineering Director - Transmission

American Telephone and Telegraph Company

195 Broadway

New York, New York 10007

Terminations of Customer-Provided Communications Systems (Channels) in Telephone Company PBX or Station Equipment

2.23 A Telephone Company PBX or station terminal equipment may be used to terminate a customer's communications channel (usually a private microwave radio channel) where his channel location is on the same premises with the Telephone Company PBX or station terminal equipment, and continuous Telephone Company service is provided on that equipment.

2.24 This type of operation may be used to provide services such as tie trunks, off-premises extensions and Point-to-Point private lines as described in Paragraphs 2.02-2.05.

2.25 Typical examples of Telephone Company terminations on customer-provided communications channels are illustrated in Fig. 15.

PBX Tandem Tie Trunk Networks

2.26 When a customer has several PBXs in different locations (or in different cities), it is usually possible to connect the PBXs with tie trunks in tandem to build up a switched network known as a ***PBX Tandem Tie Trunk Network.*** The advantage of a tandem network is to give any station at a given PBX access to all stations at the other PBXs in the network while minimizing the total number of tie trunks required.

2.27 Mixtures of both customer-provided and Telephone Company-provided facilities and PBXs can be used in tandem networks, as well as mixtures of PBX types, key systems, or other types of terminal equipment. When a connection involves several PBXs, problems in transmission and signaling are likely to occur. As a general rule, no more than five PBXs (three tandem switching points) should be involved in a single built-up connection.

2.28 The type of PBX and its position in the network are important, particularly when dial operation is to be used on the network. Two types of dial PBXs need to be considered: the step-by-step type and the common control type. Difficulties arise when the two types are mixed

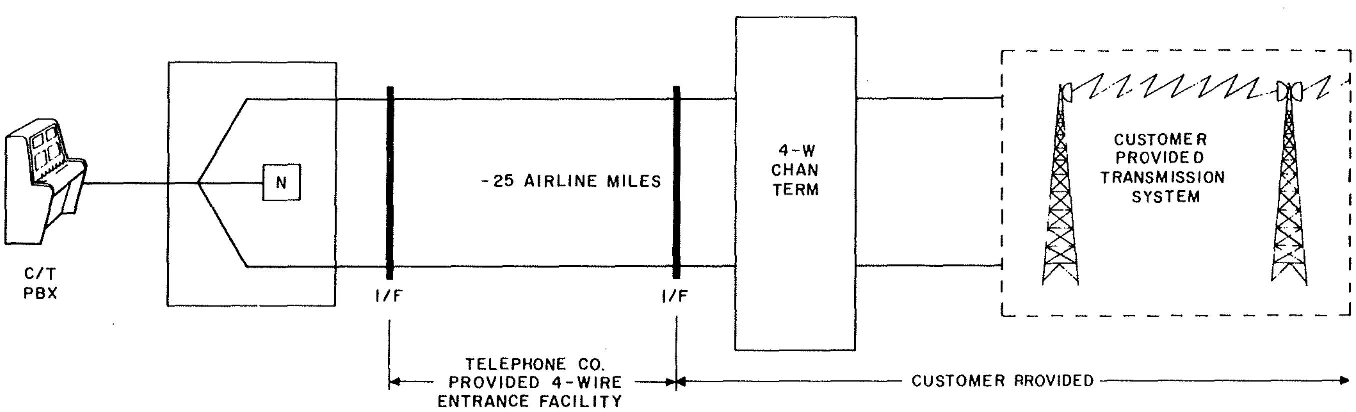


Fig. 14—Typical Entrance Facility

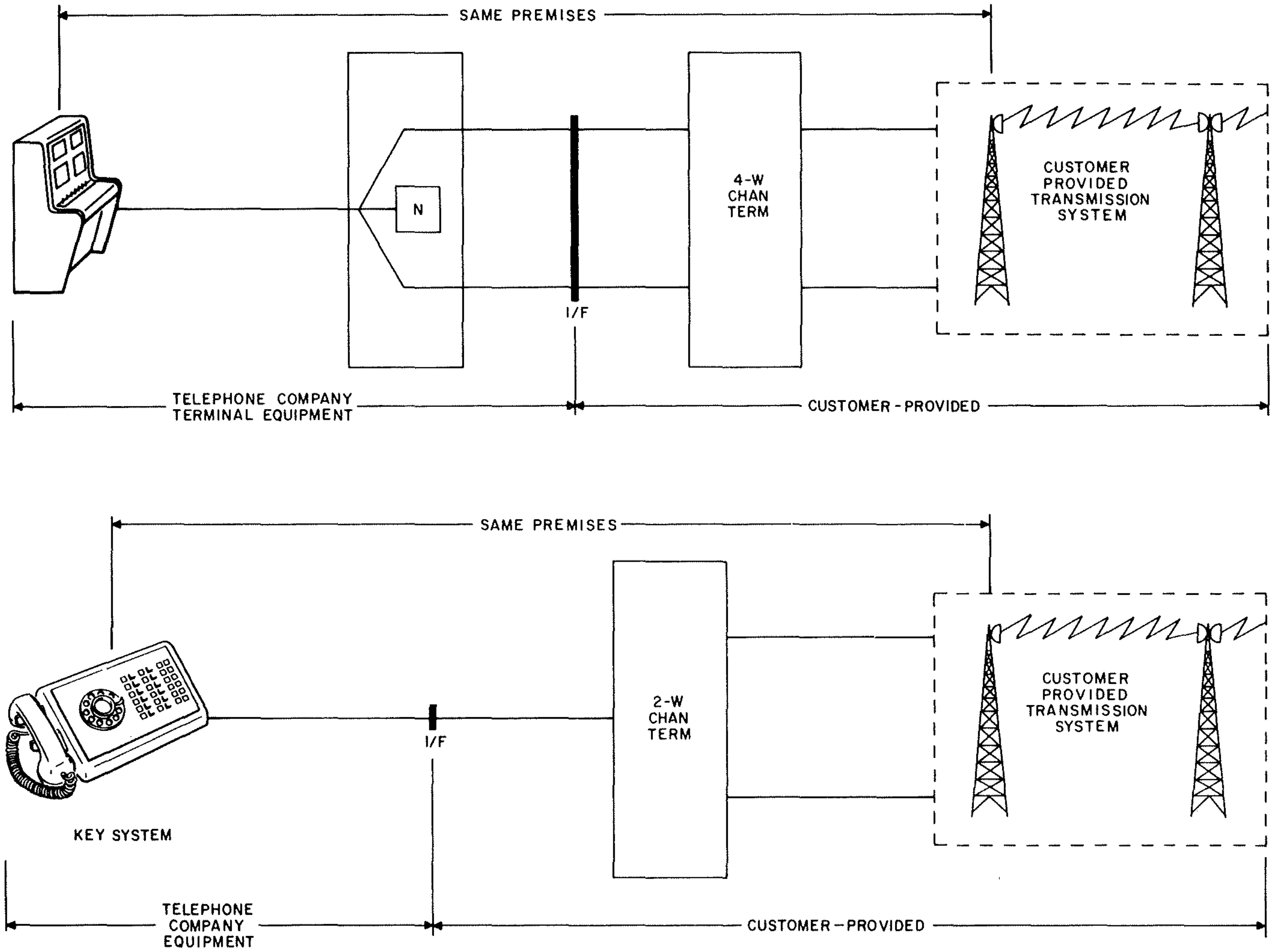


Fig. 15—Terminations of Customer-Provided Communications Systems (Channels) in Telephone Company PBX or Station Equipment

on a dial tandem network, due to the differences in timing sequences in their operation. The problem is discussed in Paragraphs 5.18-5.20 of this Technical Reference.

2.29 The PBXs and tie trunks in a tandem tie trunk network are specially designated according to their position and function on the network. The following sections define these names with respect to the tandem network shown in Fig. 16. The switchable pads associated with the tie trunks shown in Fig. 16 are present to provide adequate echo margin on terminating connections. They are switched out to reduce the loss on built-up connections. Their application is discussed in Paragraphs 6.46-6.55.

Network PBXS (See Fig. 16)

2.30 ***Main PBX*** - A PBX which does not tandem switch tie trunks. A main PBX may or may not be part of a PBX tandem tie trunk network.

2.31 ***Satellite PBX*** - an adjunct to a main PBX used by customers who have a large number of stations on a second premises, usually in the same local calling area as the Main PBX. The Satellite PBX has the same directory number as the main PBX and all incoming calls are routed from the Main PBX via tie trunks. The Satellite may have outgoing trunks to a central office, or may make outgoing calls via the main PBX.

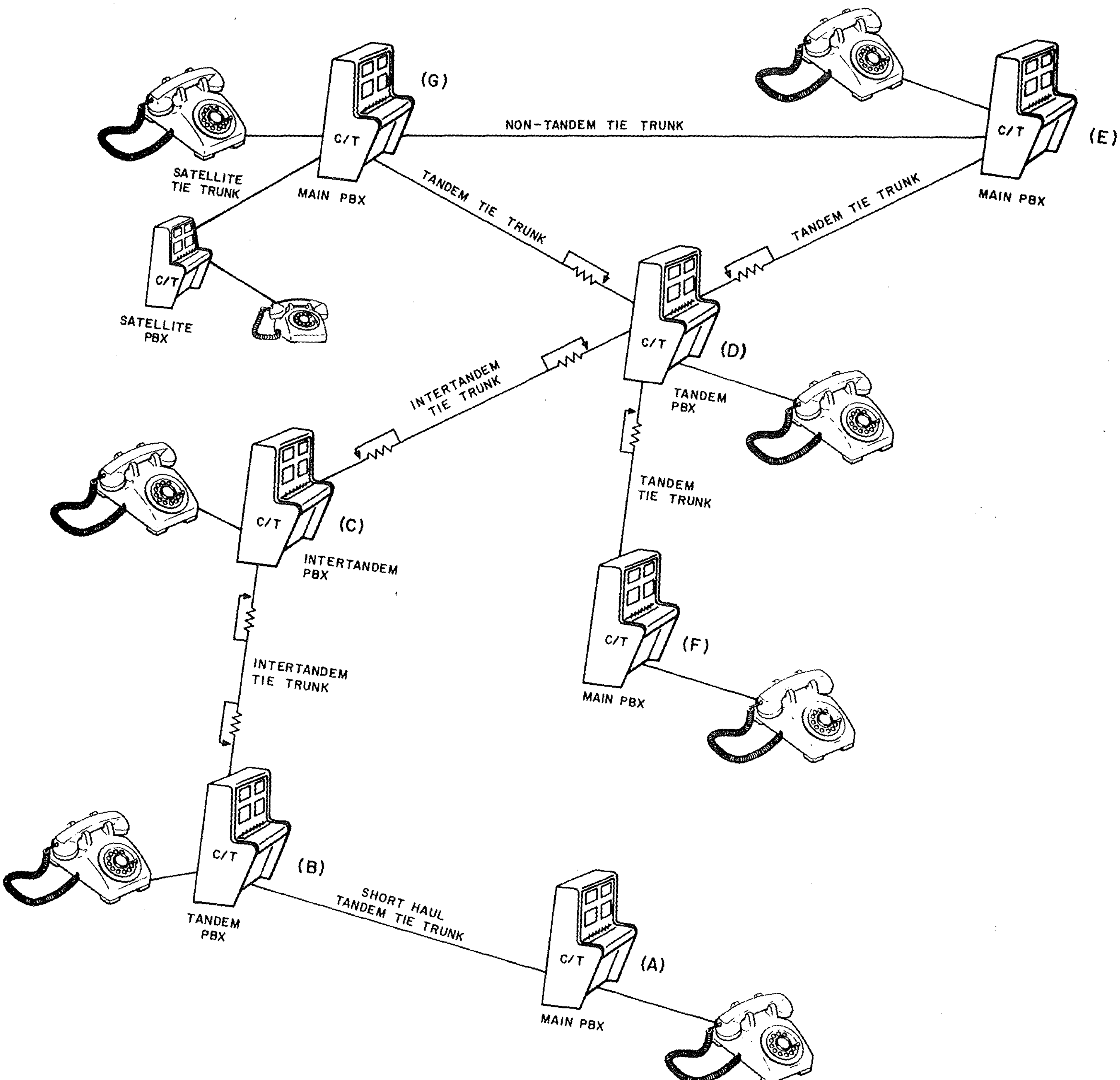


Fig. 16—PBX Tandem Network

2.32 *Tandem PBX* - a PBX which switches together tie trunks from other PBXs.

2.33 *Intertandem PBX* - a PBX which switches together tie trunks from tandem PBXs.

TANDEM NETWORK TRUNKS (See Fig. 16)

2.34 *Tandem Tie Trunks* - Tandem Tie Trunks are used between main PBXs and tandem PBXs which may be connected together in a customer's PBX tie trunk network.

2.35 *Intertandem Tie Trunk* - In larger PBX tie trunk networks some tandem tie trunks may be connected to other tie trunks at both ends simultaneously. Tie trunks which may be connected in this manner are referred to as Intertandem Tie Trunks.

2.36 *Nontandem Tie Trunks* - Tie trunks used between two PBXs which cannot be connected to other tie trunks at either end.

2.37 All of the above trunks are primarily intended to provide connections between PBX stations at both ends, but may also be connected to central office trunks, FX trunks, and WATS trunks at one end. The transmission quality on these types of calls is not guaranteed. Built up connections involving central office trunks, FX trunks or WATS trunks at both ends of any tie trunk connection cannot be expected to provide good transmission.

3. DESCRIPTION OF INTERFACE OPTIONS

3.01 To serve the various private lines described in the preceding section, the Telephone Company will offer certain options to the customer at the interface between the customer-provided and Telephone Company-provided facilities or equipment. The engineering considerations which the customer should consider in choosing from the various interface options are discussed in Section 6. Technical References describing these voice connecting arrangements are available from the Engineering Director-Customer Telephone Systems, American Telephone and Telegraph Company, 195 Broadway, N.Y., N.Y., 10007.

Interface Options With Telephone Company- Provided Facilities

3.02 This Section describes the interface options and facility makeup rules that will be available where Telephone Company-provided private lines are interconnected to customer-provided PBX or station terminal equipment. These interface options can be broken down into the four types described below and shown in Fig. 17.

Type I - A 2-wire transmission interface with the channel signaling provided by the Telephone Company.

Type II - A 2-wire transmission interface without Telephone Company channel signaling. In this option, the customer is expected to provide any channel signaling that is required, using inband signaling techniques.

Type III - A 4-wire transmission interface with the channel signaling provided by the Telephone Company.

Type IV - A 4-wire transmission interface without Telephone Company channel signaling. In this option the customer is expected to provide any channel signaling that is required, using inband signaling techniques.

3.03 For each option a Telephone Company-provided connecting arrangement is required in accordance with the effective date of the Tariff as mentioned in the Introduction. This connecting arrangement contains a transmission coupler plus a line signaling circuit for those options with Telephone Company-provided channel signaling.

3.04 The options available for a particular type of private line employing customer-provided terminal equipment at one or both ends will depend on:

(a) The type of private line involved, ie, tie trunk, FX trunk, etc

(b) The type of supervision and signaling required for the private line

(c) The ownership of the terminal equipment at the distant end of the private line, ie, Telephone Company-or customer-provided terminals

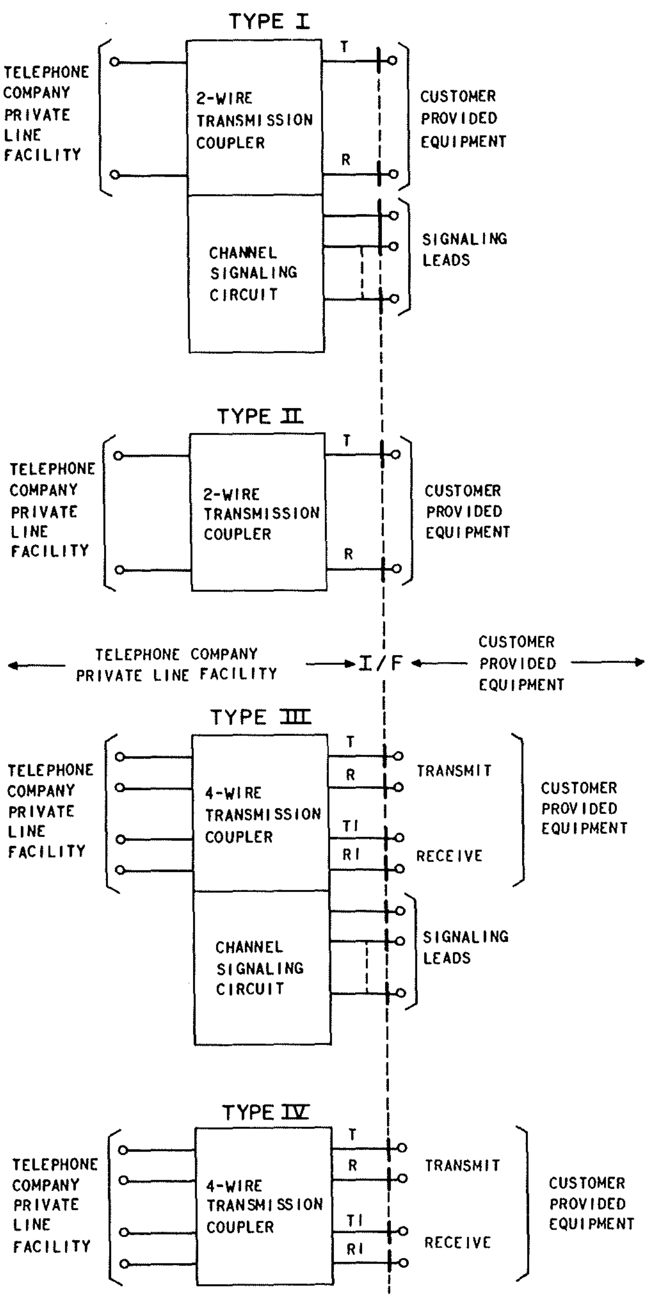


Fig. 17—Interface Options

(d) The availability of Telephone Company facilities and equipment to serve a particular customer location.

3.05 The following are general voice transmission facility makeup rules that the Telephone Company will employ for use with the 2-wire and 4-wire interface options. Broad rules for the facility makeup are provided to cover those cases where the customer may want a 4-wire interface option at one end of a private line and a 2-wire interface option at the distant end.

(a) ***2-Wire Interface at Both Ends:*** The Telephone Company may supply any combination of 2- or 4-wire, voice, or carrier-derived faciltities. This may even include 4-wire facilities out to the customer's premises, where it will be converted to 2-wire at the interface by a Telephone Company-supplied 4-wire terminating set.

(b) ***4-Wire Interfaces at Both Ends:***

(1) The Telephone Company will supply 4-wire facilities (voice or carrier-derived) from interface to interface. However, the customer may incur additional channel charges in accordance with Telephone Company Tariffs.

(c) ***4-Wire Interface at One End 2-Wire at the Other:***

(1) ***Intercity private lines*** - Usually the Telephone Company will provide 4-wire facilities from the 4-wire interface end to the Telephone Company toll center which serves the distant city end. However, where transmission considerations permit, any combination of 2-wire or 4-wire facilities (voice or carrier-derived) may be provided. The local channel from the toll center to the 2-wire interface at the customer premises may be any combination of 2- or 4-wire facilities.

(2) ***Intraexchange or intracity private lines*** - Operation with a 4-wire interface at one end and a 2-wire interface at the other on these private lines is not recommended. If the customer does order an intraexchange or intracity private line this way, the Telephone Company will place the 4-wire terminating set required to convert the 4-wire facilities to 2-wire at its convenience. (This includes the customer's premises where the 4-wire interface is ordered).

3.06 Typical applications using the four interface options on a PBX tie trunk at a customer-provided dial or manual PBX are shown in Fig. 18. The trunk circuit associated with a customer-provided PBX switching machine and/or attendant position converts the PBX and/or switchboard signaling into signaling suitable for use with the customer-provided inband signaling unit, or with the Telephone Company-provided channel signaling circuit. The trunk circuit also connects the 2-wire voice path switched through the PBX or the attendant position to the 2-wire port of the terminating set or to the 2-wire transmission coupler. For station terminations, the PBX tie trunk circuit would be replaced by a station line circuit. The line circuit performs the same functions as the PBX trunk and also provides the talking battery for the station.

3.07 For the type III and IV options, the function of the terminating set is to convert the PBX 2-wire voice path into a 4-wire voice transmission path for use with 4-wire facilities. Variable loss pads are provided to adjust the levels applied to the facilities and to adjust the overall circuit loss. The customer-provided inband signaling units in type II and IV options convert the dc signaling from trunk and station line circuits into signals suitable for end-to-end inband signaling over 4-wire transmission facilities. In some cases, the customer may want to use equipment units that combine some or all of the functions of the trunk or line circuit, the terminating set, the pads, and the signaling unit.

3.08 The connecting arrangements provide the transformers, pads, and amplifiers necessary to couple the signal to the Telephone Company facility at the interface. In order to prevent the power of signals applied to the Telephone Company facilities from inadvertently exceeding the protective criteria given in Par. 4.02, the connecting arrangements may also contain protective signal limiting devices. The presence of the protective signal limiter, however, does not release the customer from the responsibilities of meeting the protective criteria.

3.09 For type I and II options, Fig. 18 indicates the Telephone Company-provided facility leaving the customer's premises as a 2-wire facility. In actual practice, with a type I or II option interface, the Telephone Company, at its discretion, may use either a 2-wire or a 4-wire facility out to the customer's location. In the case where the customer requests a 2-wire interface option, a 4-wire facility, if provided, will be converted to 2-wire on the Telephone Company side of the interface using a 4-wire terminating set.

Interface Arrangements With Customer-Provided Systems (Channels)

3.10 Where the customer chooses to provide his own communication channels to his premises,* the Telephone Company will provide interface options to connect these channels to Telephone Company-provided PBXs. It will also provide interconnections with Telephone Company-provided terminal equipment if the terminal equipment is part of another Telephone Company service already provided to the customer at that location.

3.11 Since the Telephone Company is not providing the private line channels in these cases, private line Tariffs are not applicable. Figure 19 shows some typical arrangements that might be provided with various combinations of customer and Telephone Company-provided equipment. A number of connecting arrangements will be available and will be covered in local Exchange Tariffs for the connection of customer-provided channels with Telephone Company PBXs. The connecting arrangements will consist of a 2- or a 4-wire transmission coupler plus a signaling applique in those cases where dc signaling is used across the interface.

* Not involving an Entrance Facility (see Par. 2.22 and 2.23-2.25.

4. VOICE GRADE PRIVATE LINE TRANSMISSION PARAMETERS AND CHARACTERISTICS

4.01 This Section provides transmission information about Telephone Company-provided voice grade private line facilities. It includes the Telephone Company nominal design objectives, interface requirements, and expected performance variations on these facilities. The facility transmission parameters are summarized in Table D at the end of the Section.

Transmission Level Points

4.02 In order to specify the signal power levels at various points along the private line facility, a common test reference level should be used by both the Telephone Company and the customer. Therefore, to provide a common reference, the station terminal or the PBX switch in the outgoing (transmitting) direction at each end of a private line will be designated as the 0 Transmission Level Point (TLP) for that direction of transmission.

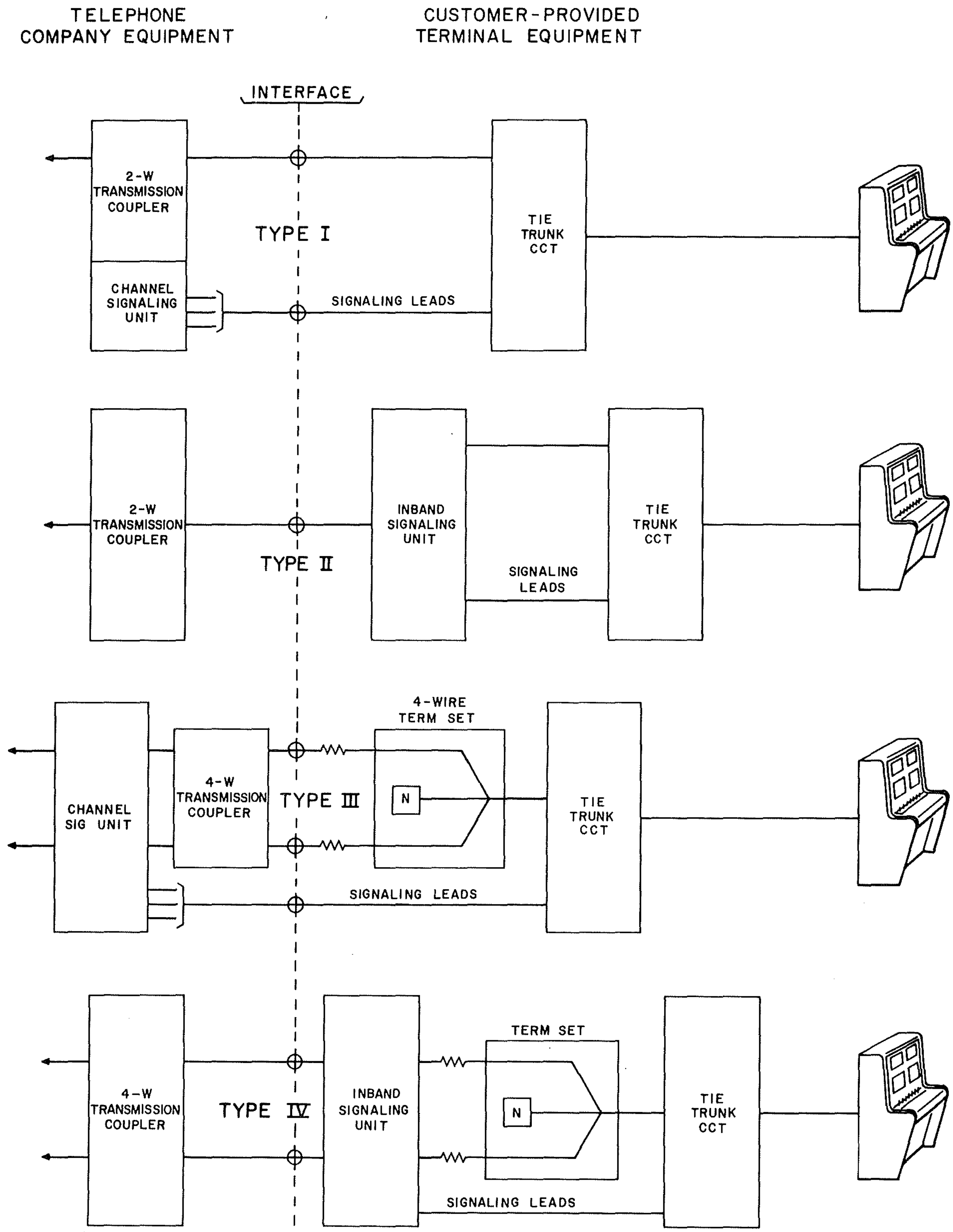


Fig. 18—Typical Interface Applications

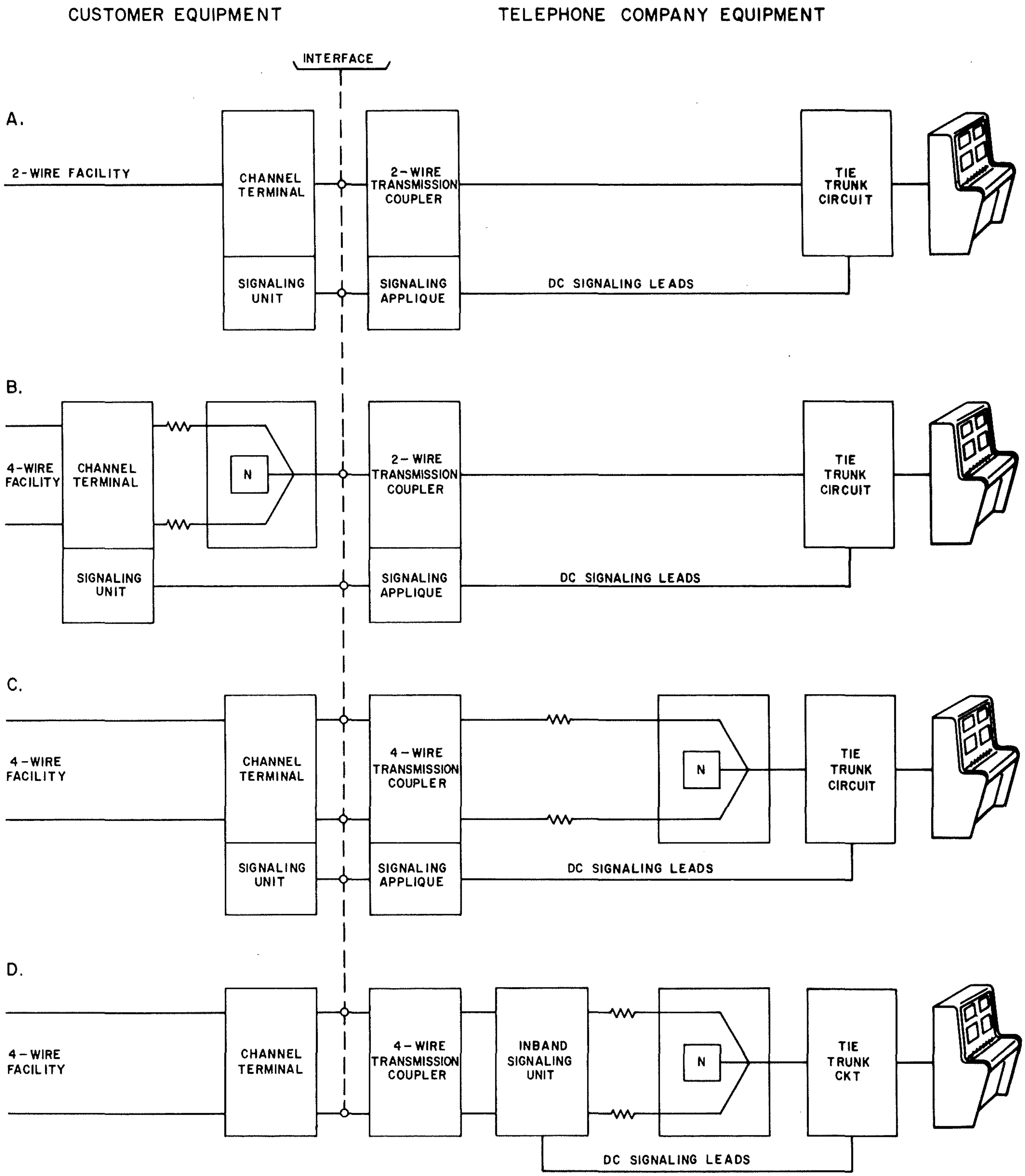


Fig. 19—Typical Interface Arrangements With Customer-Provided Channels

All other level points on either the Telephone Company-provided or the customer-provided portion of the overall circuit should be referred to the 0 TLP by the difference in the nominal loss (−) or gain (+) in dB between them at 1000 Hz. Actual allowable signal powers in dBm at typical TLPs are given in Table B.

Loss

4.03 The nominal 1000 Hz loss of these private line facilities in each direction of transmission will be lined up to within ±1.0 dB of the design loss as given in Par. 6.14-6.17. However, additional variations of both a short-and a long-term nature should be expected. The short-term variations may be caused by dynamic regulation of carrier systems or maintenance activities. These variations, which may be noted during a measurement interval, do not occur periodically or at uniform or rapid rates. The variation in circuit loss due to short-term variations will normally not exceed ±3 dB.

4.04 Long-term loss variations may be caused by temperature changes, amplifier drift, and the like. These variations will be corrected periodically by the Telephone Company during routine measurements, and should not exceed ±4 dB.

Signal Levels

4.05 Since private line channels utilize Telephone Company facilities in common with other services, it is necessary, in order to prevent excessive noise and crosstalk, that the power of the signal applied to Telephone Company lines be limited. Because each private line service is individually engineered, a single value limit for all applications cannot be specified. Therefore, in accordance with FCC Tariff 260, the power of the signal which may be applied by the customer-provided terminal equipment or communications channels to the Telephone Company interfaces located on the customer's premises will be specified by the Telephone Company for each application, to be consistent with the signal power allowed on the telecommunications network. For private line facilities, these values are:

(a) The power of the signal at the interfaces should not exceed 13 dB below one milliwatt, referenced to the 0 TLP, when averaged over any 3-second interval.

(b) To protect other services from interference at frequencies which are above the band of the service provided, it is necessary that the signal power, which is applied by the customer-provided terminal equipment or communications channel to the Telephone Company lines located on the customer premises, not exceed the following limits:

(1) The power in the band from 3995 Hz to 4005 Hz shall not exceed 18 dB below the power of the signal, as specified in (a).

(2) The power in the band from 4000 Hz to 10,000 Hz shall not exceed 16 dB below one milliwatt.

(3) The power in the band from 10,000 Hz to 25,000 Hz shall not exceed 24 dB below one milliwatt.

(4) The power in the band from 25,000 Hz to 40,000 Hz shall not exceed 36 dB below one milliwatt.

TABLE B

MAXIMUM ACCEPTABLE CUSTOMER SIGNAL POWER AT INTERFACE

SIGNAL POWER (In dBm)

INTERFACE TLP	INBAND 3-SECOND AVERAGE	OUT-OF-BAND 3995 TO 4005 Hz	4-10 kHz	10-25 kHz	25-40 kHz	ABOVE 40 kHz
0 TLP	−13	−31	−16	−24	−36	−50
−16 TLP	−29	−47	−32	−40	−52	−66
+ 7 TLP	− 6	−24	− 9	−17	−29	−43

(5) The power in the band above 40,000 Hz shall not exceed 50 dB below one milliwatt.

(c) Where there is connection to a local or toll central office line, to prevent the interruption or disconnection of a call or interference with network control signaling, it is necessary that the signal applied by the customer-provided terminal equipment or communications system to the Telephone Company interface located on the customer premises at no time have energy solely in the 2450 to 2750 Hz band. If signal power is in the 2450 to 2750 Hz band, it must not exceed the power present at the same time in the 800 to 2450 Hz band.

4.06 The inband signal requirements in (a) are intended to limit the average loading per channel to a long-term average power of −16 dBm at the 0 TLP. However, to take advantage of the statistical nature of speech and the activity factors of the channels, the maximum allowable inband signal the customer can use was increased to −13 dBm at 0 TLP average over any three second interval. This value is consistent with other Tariffs where the actual value specified is −12 dBm, average over any three second interval at the local Telephone Company central office switch. The local central office is nominally a +1 TLP with respect to the broadband carrier systems in the intertoll portion of the telecommunications network. Therefore this is equivalent to specifying −13 dBm, averaged over any 3-second interval at the 0 TLP for these channels. A measurement technique to determine a 3-second average for the inband signal power is given in Appendix A.

4.07 The out-of-band limits in (b) are intended to prevent crosstalk and other interference into other services having wider bandwidths, such as program circuits and carrier systems, which may use pairs in the same cable. The power limitations given apply at the input to the physical cable pairs at the customer premises which, for these services, will also be designated by the Telephone Company to be at 0 TLP.

4.08 The restrictions in (c) are intended to prevent interference with 2600 Hz single-frequency (SF) inband signaling systems that may be present in the telecommunications network. They are not intended to prevent the use of the customer-provided 2600 Hz inband signaling system over these private line facilities. The basic problem is that signal energy solely in the 2450 to 2750 Hz band may cause calls which are connected to a central office line to be prematurely disconnected. Energy solely in this band may also cause unintentional operation of a customer-provided inband signaling system, resulting in premature disconnect.

4.09 To refer the above limits to typical transmission level points that will be used at the interfaces as discussed in Part 6, Table B gives the maximum allowable signal powers at the 0, −16, and +7 TLPs.

4.10 If connection of these private line facilities to the telecommunications network is contemplated, the restrictions given in (c) apply to the signal power in the bands from 800 to 2450 Hz and 2450 Hz to 2750 Hz.

Impedance

4.11 The voice transmission pairs at the Telephone Company interfaces will have a nominal impedance of 600 ohms which will be balanced to ground. It is expected that a customer will meet the Telephone Company on the same basis. Also, the voice transmission paths are not designed for dc continuity. Care must be taken that customer-provided equipment does ***not*** present direct current in excess of 1 Ma to the voice transmission pair(s) at the interface, as damage to equipment and test sets may result.

Attenuation Distortion

4.12 Attenuation distortion is the departure from uniform response of the channel referenced to 1000 Hz at the frequency of concern. The attenuation distortion of these private line facilities is expected to be less than −2 dB to +8 dB in the band from 500 to 2500 Hz and −3 dB to +12 dB in the band from 300 to 3000 Hz. A "+" means more loss, and a "-" means less loss than the loss at 1000 Hz.

Bandwidth

4.13 The bandwidth (defined as the 10 dB down points relative to 1000 Hz) of these private line facilities will extend from approximately 300 to 3000 Hz. The bandwidth may be wider in some cases and, therefore, it should not be counted on to prevent singing at either higher or lower frequencies.

Message Circuit Noise

4.14 Message circuit noise has been called "background," "steady state," "white," and "gaussian" noise. Although these terms are generally used to describe the same effect, they are not technically identical. Message circuit noise is the noise level on a circuit, as indicated on a noise measuring set similar to the Western Electric 3-type Noise Measuring Set using a C-Message weighting filter. The resulting reading is in dBrnC.

4.15 The average noise power from these private line facilities on a terminated basis is normally no greater than the value given in Table C.

During noise measurements, the private line facility should be isolated from other noise sources by terminating its distant end in 600 ohms at the interface.

TABLE C

NOISE PARAMETERS

CIRCUIT LENGTH (MILES)	NOISE (dBrnC) +7 TLP	0 TLP
0-50	38	31
51-100	41	34
101-400	44	37
401-1000	48	41
1001-1500	50	43
1501-2500	52	45
2501-4000	54	47

Frequency Error

4.16 In single sideband carrier systems operating in a suppressed carrier mode, the carrier is reinserted locally. The difference in frequency between the modulating and the demodulating carriers causes the frequency of a received signal to differ from the frequency of the transmitted signal. This frequency difference on private line facilities is expected to be no greater than ± 5 Hz. Frequency error is also referred to as frequency shift or frequency offset.

Other Transmission Parameters

4.17 The preceding paragraphs discussed the major transmission parameters which affect the voice transmission performance of private line facilities. (As mentioned in the Introduction, the description of private line offering in this Reference is limited to voice applications.) Limits on other transmission parameters, such as envelope delay distortion, impulse noise, phase jitter, etc., which may affect data transmission are not specified. A discussion of these parameters and their effects on data transmission appears in Reference No. 11 in Part 11.

5. SIGNALING CONSIDERATIONS

5.01 The basic purpose of these private line facilities is to provide a voice communication path between stations and/or switching terminals which they serve. However, before the private line can be utilized for voice communications, certain information must be transmitted between the terminals to establish the connection. When the call is completed, additional information is needed to return the equipment to its idle state. The transfer of this information between the terminals at the ends of a channel is called ***signaling.***

5.02 Using a PBX tie trunk as an example, the following types of signals must be transmitted:

(a) CONTROL (supervision forward)

Used to sieze, hold, or release the tie trunk and distant terminal equipment in the originating-to- terminating direction of the call

(b) STATUS (supervision backward)

Indicates to the originating terminal whether the far end is idle, busy, etc

(c) ADDRESS (dialing)

The digital information corresponding to the called telephone number

(d) AUDIBLE TONES

Provides call progress information to the user, eg, distant end being rung, distant end busy, etc.

TABLE D

SUMMARY OF TRANSMISSION PARAMETERS

1000 Hz Loss:

Facility Design loss is dependent on circuit length and/or interface option choices.

At Installation: Lined up to Facility Design Value ±1 dB.

Short-Term Fluctuations: ±3 dB.

Long-Term Variation: Facility Design Value ±4 dB.

Customer's Maximum Signal Power: (See Table B)

Inband: 13 dB below 1 milliwatt (—13 dBm) at a 0 TLP averaged over any 3-second interval.

Above Band Roll-off: At 0 TLP —

3,995 to 4,005 Hz:	—31 dBm (18 dB below —13 dBm)
4,000 to 10,000 Hz:	—16 dBm
10,000 to 25,000 Hz:	—24 dBm
25,000 to 40,000 Hz:	—36 dBm
Above 40,000 Hz:	—50 dBm

Single Frequency Signaling System Guard Band:

2,450 Hz to 2,750 Hz.

Customer signals at an interface with the Telephone Company telecommunications network shall never transmit signal energy solely in the 2,450 to 2,750 Hz band. Energy in the 2,450 Hz to 2,750 Hz band shall never exceed the level of energy in the 800 Hz to 2,450 Hz band.

Nominal Impedance at the Interface:

600 Ohms

TABLE D (Cont)

Attenuation Distortion:

Relative to the loss at 1,000 Hz:

—2 dB to +8 dB between 500 and 2,500 Hz.
—3 dB to +12 dB between 300 Hz and 3,000 Hz.
("—" means less loss, "+" means more loss)

Bandwidth:

Approximately 300 Hz to 3,000 Hz.

Circuit Noise:

As indicated on a Western Electric Co. type 3 Noise Meter at a 0 TLP:

Circuit Length:	0-50	Miles	31 dBrnC
	51-100	Miles	34 dBrnC
	101-400	Miles	37 dBrnC
	401-1,000	Miles	41 dBrnC
	1,001-1,500	Miles	43 dBrnC
	1,501-2,500	Miles	45 dBrnC
	2,501-4,000	Miles	47 dBrnC

Frequency Error:

±5 Hz

5.03 The signaling functions for private line applications can be broken down into those associated with the PBX or terminal equipment. The channel signaling involves the transmission and reception of the signaling information over the private line facility itself. The terminal signaling functions involve converting the channel signaling information into a form suitable for use by the PBX or terminal equipment, and vice versa.

Channel Signaling Techniques

5.04 Many types of signaling systems such as dc, inband, and out-of-band signaling can be used to transmit channel signaling information between the terminals of a private line facility. The private line channel itself may use several different types of transmission facilities to derive the overall channel. For example, it may consist of a combination of amplitude, frequency, or pulse code modulated carrier system plus 2-or 4-wire voice frequency cable facilities.

5.05 Each of these portions of the overall channel may use a different type of channel signaling technique and in no event is an end-to-end dc metallic path guaranteed. In no case will be customer be allowed to directly connect any form of dc channel signaling to the Telephone Company voice private line facilities.

5.06 In those cases where the customer supplies the PBX or terminal equipment at both ends of a private line and where he orders a type II or IV interface (subject to the restrictions in Table F, he may provide any inband (300 to 3000 Hz) type of channel signaling that he chooses. The signal level for the signaling tones, however, must meet the signal level requirements given in Par. 4.05. Note that the restrictions on energy in the 2450 to 2750 Hz band do not apply to signals transmitted between two SF units operating over a private line as long as the SF sets do not transmit tones beyond the ends of the private line during unguarded intervals.

5.07 Also, in certain cases where the customer provides one of the terminals and the Telephone Company the other, the channel signaling can be jointly provided by the two parties using compatible single-frequency inband signaling units. The rules for these applications are detailed in Par. 5.21-5.24.

5.08 At customer-provided terminals, in order to allow the customer to use dc-type terminal signaling circuits, the Telephone Company has a series of connecting arrangements available which convert the customer terminal signaling into Telephone Company-provided channel signaling.

5.09 In order to minimize the amount of coordination required between the customer and the Telephone Company, the Telephone Company has a standard connecting arrangement available with E-and M-type dc signaling leads. This standard channel signaling unit will be used for type I and III interface options on all private lines except those foreign exchange private lines covered in Par. 2.15-2.21. These foreign exchange-type private lines will require the central office station or trunk type connecting arrangements.

5.10 Manufacturers desiring information about these connecting arrangements should contact the Engineering Director - Customer Telephone System.* In ***all*** cases, it is expected that the manufacturers of customer-provided PBX and terminal equipment will supply their users with the information on the proper connecting arrangements required for use with their equipment. This information must be supplied to the Telephone Company by the ***user*** with his request for service. It is not feasible for the Telephone Company to keep track of all the various types and models of non-Telephone Company-manufactured communications equipment.

*American Telephone and Telegraph Company, 195 Broadway, New York, New York 10007.

Terminal Signaling

5.11 Because it includes all the important considerations, terminal signaling will be discussed in terms of the requirements for terminal signaling on PBX tie trunk. The terminal signaling for a PBX tie trunk is performed by a circuit usually referred to as the PBX tie trunk circuit or equipment. This tie trunk interfaces between the PBX machine or PBX switchboard (console) and the channel signaling equipment.

5.12 Three types of tie trunk operation are in general use. The types are distinguished by their method of terminal signaling as follows:

(a) Dial Repeating Trunk Circuits - These trunks transmit both supervisory and dial pulse signals, and enable a station user to dial completely through the network without assistance from a PBX attendant. It is necessary that all dial PBXs in the network be compatible if tandem operation is contemplated. This is discussed in Par. 5.18-5.20. Dial trunks can be used in tandem with nondial types; but the intervention of a PBX attendant is necessary at any manual PBX and at the juncture with nondial trunks. Where the customer chooses to use Telephone Company channel signaling, his tie trunk circuit must be compatible with the Telephone Company E and M lead channel signaling unit as specified in the applicable Technical Reference (see Par. 5.04-5.10). In these cases the customer will be responsible for any incoming pulse correction required.

(b) Automatic Tie Trunk Circuits - These tie trunk circuits are equipped so that the seizure (either by an attendant cord or by dial selection) at one end automatically alerts the attendant at the other end without the need of a separate ringing signal. Automatic trunks will not transmit dial pulses, and the services of a PBX attendant are required at one or both ends. Where Telephone Company channel signaling is used, the customer's tie trunk, when seized, must generate an automatic seizure signal on the M lead of the channel signaling unit. The distant end, when it recognizes the seizure on its E lead, should return a steady off-hook signal over its M lead when answered by the attendant. An automatic disconnect signal is returned to the opposite end when either end opens its M lead.

(c) Ringdown Tie Trunk Circuits - These trunks require the application of a burst of ringing signal (normally 20 Hz current) either manually by the attendant or by dial selection to alert the attendant at the distant end. Ringdown trunks do not transmit either dial or supervisory (disconnect) signals. Where Telephone Company channel signaling is used, the ringing signal from the attendant (approximately 2 sec. long) must be detected at the sending end and converted into a M lead signal to the channel signaling unit. (Note that the customer's ringing signal cannot be coupled directly to the line because of the inband and out-of-band power limitations given in Par. 4.05-4.10 and the need for dc isolation). Similarly, at the far end, the customer's tie trunk must detect a momentary signal on the E lead as a request for service and alert the far-end attendant.

5.13 Tie trunks normally have the same mode of operation in both directions, but some mixtures of types can be made. For example, a tie trunk connecting a manual PBX and a dial PBX may have dial operation toward the dial PBX and automatic operation toward the manual PBX. This permits the manual PBX attendant to dial extensions or tie trunks without assistance from the dial PBX attendant, and also allows station users at the dial PBX to signal the manual PBX attendant without assistance from the dial PBX attendant.

5.14 Tie trunks can be arranged for one-way operation if desired. One-way operation is usually a traffic control expedient to ensure outgoing service during heavy traffic periods when all trunks would probably be seized from the far end were it not for the one-way outgoing restriction.

5.15 All three types of tie trunk circuits should be arranged to provide idle circuit terminations of approximately 600 ohms in series with +2.16 mF toward the private line facility when the tie trunk is idle. The idle circuit termination should provide a minimum return loss of 10 dB for all frequencies in the band from 200 to 3200 Hz.

Audible Tones

5.16 Other forms of signaling are the audible tone signals, such as dial tone, busy tone, recorder, and audible ringing indications. These are used on communications circuits to keep the user informed of call progress. To avoid confusing the user, the various signals should be mutually distinctive and each specific signal should be as uniform as possible with respect to sound character and level on all calls.

5.17 As a guide for those manufacturing PBX and terminal equipment, Table E gives the Telephone Company objectives for audible signals in ***new*** PBXs. In supplying these objectives it is not intended or implied that all existing Telephone Company-provided PBXs or terminal equipment meet these objectives.

TABLE E

RECOMMENDED AUDIBLE TONE LEVELS FOR CUSTOMER EQUIPMENT

		TO CUSTOMER STATION OR INTRA-PBX CIRCUIT			OVER TRUNK OR LINE TO DISTANT END		
AUDIBLE TONES	PAIRS OF FREQUENCIES USED	INDIV. FREQ. dBm	COMB. FREQ. dBrn		INDIV. FREQ. dBm	COMB. FREQ. dBrn	
			Flat	C Msg		Flat	C Msg
Busy, Reorder Audible Ring Dial Tone	480+620 Hz	−27	66	60	−21	72	66
	440+480 Hz	−22	71	62	−16	77	68
	350+440 Hz	−16	77	66	−16	77	66

Notes:

1. All levels are referenced to the 0 TLP.
2. Frequency tolerance: ±0.5%
3. Tone level variation: ±1.5 dB
4. Noise from tone sources: At least 40 dB below the C-message tone level.
5. Interruption rates:
   - Busy: 60 interruptions/minute
   - Reorder: 120 interruptions/minute
   - Audible ring: 1 second ON, 3 seconds OFF.
6. The values given for Audible Ring should be reduced by 3 dB if the Audible Ring and 20 Hz ringing are superimposed.
7. The levels given in dBrn are based on the measurements being made with 600-ohm terminations, using a Western Electric Company 3-type noise measuring set or equivalent.

Dial Tandem Network Considerations

5.18 When a connection involves several dial PBXs switched together in tandem, the way in which various types of PBXs handle their dialing information becomes an important consideration. The Telephone Company uses two basic techniques in handling the dial signals in their PBXs. Most of the older PBXs use a "step-by-step" or direct control technique, while most of the new PBXs use a "common control" technique.

5.19 The step-by-step PBXs use the train of dial pulse making up the called station number or tie trunk code to directly drive a series of electro-mechanical stepping switches to set up the connection through the PBX. Thus the call progresses through a step-by-step PBX on a real time basis as the dial pulses are received; therefore, a tandem PBX network made up exclusively of step-by-step PBXs does not present any major signaling compatibility problems.

5.20 The common control PBXs (including Bell System Centrex-CO and Centrex-CU Systems) as used in tandem PBX networks operate in one of two basic modes:

(a) ***Register only***

Register only PBXs can receive dial pulses only after a register is attached. For tandem calls they store in their register only the routing information pertinent to the specific switching system of which they are an integral part. After they receive a number which the register recognizes as a trunk routing code, the signaling path is cut through to the desired trunk and succesive dialed digits are transmitted out over the trunk to the next PBX.

(b) ***Register-Sender***

Register-Sender systems also can receive dial pulses only after a register is attached. When a register is attached, however, it stays attached until all the dialed digits are received. After the incoming dialing is completed, a trunk toward the desired destination is selected based upon routing digits received by the register. A sender is then attached to the trunk to outpulse the remaining digits stored in the register.

Both types of common control PBXs present a similar timing problem in tandem network operation: that is, the time required for the PBX to attach its register to a trunk which has been seized by the opposite end. This time is a function of the traffic usage of the PBX at that particular time, with 2 to 3 seconds being a typical delay.

Several techniques have been developed in various common control systems to signal the calling end to hold up its outpulsing until the register can be attached. These include the use of wink start and delay dial pulses, the operation of which are described in detail in reference 10. At present, however, few telephone company common control PBXs and none of its step-by-step PBXs provide this type of operation.

As an alternative, most Telephone Company common control PBXs can be arranged to use register cut-through operation in combination with a second dial tone. With this type of operation, the calling party is instructed (by his telephone dialing instructions) on tandem calls to dial only the routing code for the distant PBX. After dialing this code (usually 3 digits), he is instructed to wait for a second dial tone which is returned from the distant PBX after the register has been attached. This sequence can be repeated again and again to reach a third or fourth PBX after waiting for a new dial tone after each access code; however, this type of operation is highly subject to user error, and is very inefficient. Therefore, most existing Telephone Company-provided PBX tandem networks use step-by-step PBXs wherever possible to avoid timing compatibility problems.

The following is an example of the problems that can arise when PBX types are indiscriminately mixed in a tandem tie trunk network: Consider a network that contains one of each of the three basic PBX types; register-sender (without cut-through features), direct control, and register-only. Consider a call originated from the Register-Sender PBX (A) which tandem switches through the direct control PBX (B) to a station in a register-only type of PBX (C) without any provision for second dial tone. The dialed number for this call consists of six digits. The first digit is an access code for the trunk to PBX (B). The second digit is the access code for the trunk from PBX (B) to PBX (C), while the last four digits are those of the called station number at PBX (C). The call proceeds as follows:

Step 1: When a PBX (A) station goes off-hook, the marker (which serves as a central control unit for the PBX) connects a register to the station line. The station then receives dial tone.

Step 2: The station dials 6 digits which are stored in the PBX (A) register. When the register senses that dialing is complete, it signals the marker.

Step 3: The marker examines the number stored in the register. The marker is programmed to direct calls through the PBX by number.

Since the first digit is a trunk access code, the marker establishes a path to the appropriate trunk. A sender is attached to the trunk; and the numbers stored in the register, less the trunk access code, are made available to the sender by the marker.

Step 4: The sender in PBX (A) outpulses 5 digits toward PBX (B).

Step 5: PBX (B) recognizes the first digit as a trunk access code for a trunk to PBX (C), and switches to the trunk. Because PBX (B) operates on a real time, direct control basis, it uses the first digit in selecting the trunk. The remaining four digits are passed through PBX (B) over the trunk toward PBX (C).

At this point the call fails because PBX (B), the step-by-step PBX, can not generate a stop-dial signal. For want of the stop-dial signal, the sender at PBX (A) continues outpulsing without waiting for a register to be attached to the trunk at the PBX (C). Consequently, one or more of the last four digits will be lost or mutilated between the second and third PBXs, resulting in a dialing failure in PBX (C). A call in the opposite direction would also fail because of register timing problems.

Because of incompatibilities of this type between different PBXs, the customer is cautioned that he must understand the timing requirements and logic sequence of all the PBXs in his network for proper tandem operation. In addition, dialing failures can result in an existing tandem tie trunk network if a common control type PBX is added to the network which does not provide the delayed dialing, second dial tone and/or cut-through features which are required by the particular configuaration of the existing network PBXs.

Signaling Coordination

5.21 For those private lines where the customer provides the PBX or terminal equipment at both ends, it is the customer's option as to who provides the channel signaling. If he chooses Telephone Company-provided channel signaling, the Telephone Company will be responsible for installing and testing the channel signaling units between the interfaces. The Telephone Company will not be responsible for any end-to-end testing through the customer's equipment.

5.22 When the PBX or station equipment at one location is provided by the customer and at the other by the Telephone Company (joint operation), each will be responsible for the provision of the terminal signaling at his end. Note that in the case of foreign exchange private lines or CCSA access lines, the Telephone Company end will terminate in Telephone Company central office equipment.

5.23 Joint operation will require close coordination between the customer and the Telephone Company. First, agreement must be reached on the type of station or trunk signaling to be used (eg, dial repeating, automatic, or manual ringdown). Then coordination will be required to ensure that the signals generated by the station line, PBX trunk equipment or central office equipment at the two terminals is compatible. The Telephone Company will supply specific information on these signals for the terminals it provides.

5.24 The rules for the provision of channel signaling with joint operation are given below:

(a) The Telephone Company will provide the channel signaling at all locations where the customer requests it.

(b) The Telephone Company must provide all the channel signaling units at locations where it provides both the PBX or terminal equipment and the private line facilities.

(c) The Telephone Company must provide the channel signaling in all applications where the private line is directly connected into a Telephone Company telecommunications network central office, Centrex or a CCSA switching center. This includes all the foreign exchange private line services described in Par. 2.15-2.21, and the CCSA access line services described in Par. 2.14. This results from the Tariff requirement that the Telephone Company must provide the network control signaling on these services.

(d) Single Frequency (SF) inband channel signaling (2600 Hz) may be provided jointly under the following restrictions:

(1) It is not a private line service covered by item (3) above.

(2) The customer chooses a type IV interface option at his location, and both parties agree. The Telephone Company will only agree to this type of joint operation if it would normally assign SF signaling equipment to some portion of the private line if it were providing the channel signaling at both ends.

(3) The customer's SF equipment is compatible with the telephone company requirement given in Appendix A.

(4) Each party will be responsible for the "on-line" testing of his SF equipment.

6. OVERALL PRIVATE LINE DESIGN CONSIDERATIONS

6.01 The purpose of this section is to provide information and suggestions to the customer in the following area:

(1) Background information and recommendations are provided to assist the customer in choosing from available interface options.

(2) A discussion of the transmission design considerations used by the Telephone Company when designing similar services.

(3) Specific information on the design loss objectives the Telephone Company recommends for the available options.

(4) Other coordination information affecting the design of private lines (eg, recommended rules for echo suppressor application).

(5) Information concerning electrical protection.

6.02 These design considerations are summarized for all the private line services in a series of tables at the end of Part 6. Overall coordination between the customer and the Telephone Company is summarized in Part 9.

6.03 The design considerations for a private line can be separated into three categories: 1) the overall parameters employed in private line design. 2) determination of losses for specific applications. 3) allocation of losses over the various facilities which comprise the overall circuit.

6.04 Because it presents the most stringent design requirements, a 4-wire long haul* PBX tie trunk in a tandem tie trunk network is used in the following discussion to illustrate the overall design considerations. However, most of the same general considerations apply to other types of private lines. Two-point private lines with 4-wire station equipment present some special design considerations which are discussed in Par. 6.34-6.39.

* A long haul circuit is one that has more than six milliseconds of round trip delay.

DESIGN PARAMETERS

6.05 The selection of the optimum design loss for a tie trunk requires a compromise between the receive volume performance and the susceptibility of the design to the other transmission impairments such as noise, instability, overload, echo, etc. One approach would be to assign all tie trunks a relatively high fixed loss (about 10 dB), as the Telephone Company presently does for some point-to-point non-switched 2-wire private lines. For tie trunks, this would have the advantage both of supplying acceptable received volume performance for calls between on premises stations at the two PBX locations, and of being high enough to provide adequate margin against the transmission impairments.

6.06 The problem with a high fixed-loss approach is that many of today's tie trunks are used for other purposes besides intercommunicating between two PBXs. A tie trunk can also be involved in two general types of built up (tandem switched) connections. The first type involves calls over a tandem tie trunk network where the tie trunk only serves as one link in the call to a distant PBX (Fig. 24). A second type of built up connection involves a call which is first tandem switched over one or more tie trunks and then switched at the distant PBX over the PBX-central office trunk to the telecommunications network. In each of these connections the loss of each trunk in the connection adds to the overall loss, thus making a 10 dB per trunk fixed loss design unacceptable. Therefore, to provide the best performance where built up connections are required, the Telephone Company uses the following two techniques:

(1) Design each tie trunk to have only the minimum loss required to reduce the transmission impairments (echo, noise etc.) to an acceptable level, and

(2) Use a pad switching technique at the PBXs to reduce the loss on connections which involve several trunks. A description of how the pad switching works is given in Par. 6.46-6.48.

6.07 Because these techniques are a compromise between a loss low enough to provide adequate received volume performance on built up connections and a loss high enough to reduce the susceptibility of the design to the other transmission impairments, there will be some connections where the transmission performance will be marginal. This is especially true for calls over tie trunks which are switched into the telecommunication network. The reason for this is that it essentially switches two networks in tandem, each of which is designed to provide a compromise between adequate received volumes and sufficient margin against transmission impairments on its own network. For this reason the transmission performance on tie trunk calls which are switched to the telecommunications network cannot be guaranteed.

6.08 The considerations that went into determining the minimum loss required to control the transmission impairments that are encountered on tie trunks and other private lines will be discussed next. The two major transmission impairments that control the minimum allowable loss are instability and echo. Using the minimum loss required for these impairments, compensation can be made for the other transmission impairments such as overall circuit noise, overload, and crosstalk by employing proper facility selection and correct allocation of the required losses throughout the trunk. Usually, the only adjustable circuit parameter that the user of the transmission equipment is required to specify is the overall loss. Other parameters such as the individual equipment bandwidth, noise, and overload performance should be designed into the various equipment units by their manufacturers, using communication industry standards.

6.09 Telephone Company experience with long haul trunks has shown that, for a single trunk, a fixed overall loss of 4 dB provides adequate protection against instability (singing) and hollowness (near singing) during the ***talking*** mode. This assumes that the circuits are initially lined up to the ± 1 dB objective given in Par. 4.03, and that periodic routine maintenance testing is done on the trunk to keep it within the maintenance objectives. The frequency with which these periodic tests are required varies with the type of transmission facilities involved.

6.10 Additional stability protection, in the form of an idle circuit termination (ICT), is required when the tie trunk is in the ***idle*** or unconnected mode. ICTs are necessary because the terminating impedances at both ends of the tie trunk are removed when the previous call disconnects and the trunk is idle. These terminating impedances are not present again until the trunk is reseized. Since the seizure and release of the tie trunk is accomplished in the trunk circuits at the PBX locations, it will be the responsibility of the party providing the PBX to also provide the ICT.

6.11 Over and above the fixed 4 dB loss required for stability, most long haul circuits require additional loss to protect them against annoying effects of talker echo. Subjective tests have shown that the degree of annoyance for given echo depends on: 1) how much the echo signal is delayed in time in the round trip through the trunk before the echo returns and is heard by the talker, and 2) how much loss the returning echo signal encounters (echo path loss) before it is heard by the talker.

6.12 The circuit components that control the magnitude and delay of the echo path for a typical long haul tie trunk connection are shown in Fig. 20. The round trip delay in the echo path is determined almost entirely by the delay in the trunk since the PBX station loops are usually very short with respect to the length of the trunks. The echo path loss, however, has three main components:

1) the talker's loop, including the transmitting and receiving efficiencies of the telephone set, 2) the trunk loss, and 3) the return loss presented by the listener's loop. At PBXs, because the station loops are normally short (low loss), both items 1) and 3) are fixed by the telephone set characteristics. At the talker's end the echo path loss is controlled by the telephone set's transmitting (accoustic to electrical conversion) efficiency in one direction and by its receiving efficiency in the return direction. Also, again for short PBX station loops, the listener's loop ***return loss*** is controlled by how well the listener's telephone set impedance characteristic matches the balancing network in the 4-wire terminating set. Since items 1 and 3 are fixed, if different echo path losses are required for different values of delay, then the only variable parameter is the tie trunk loss.

6.13 The next several paragraphs describe how the Telephone Company selects the circuit loss objectives for proper echo protection. A more detailed discussion of echo problems, including the required loss versus the delay in the echo path to

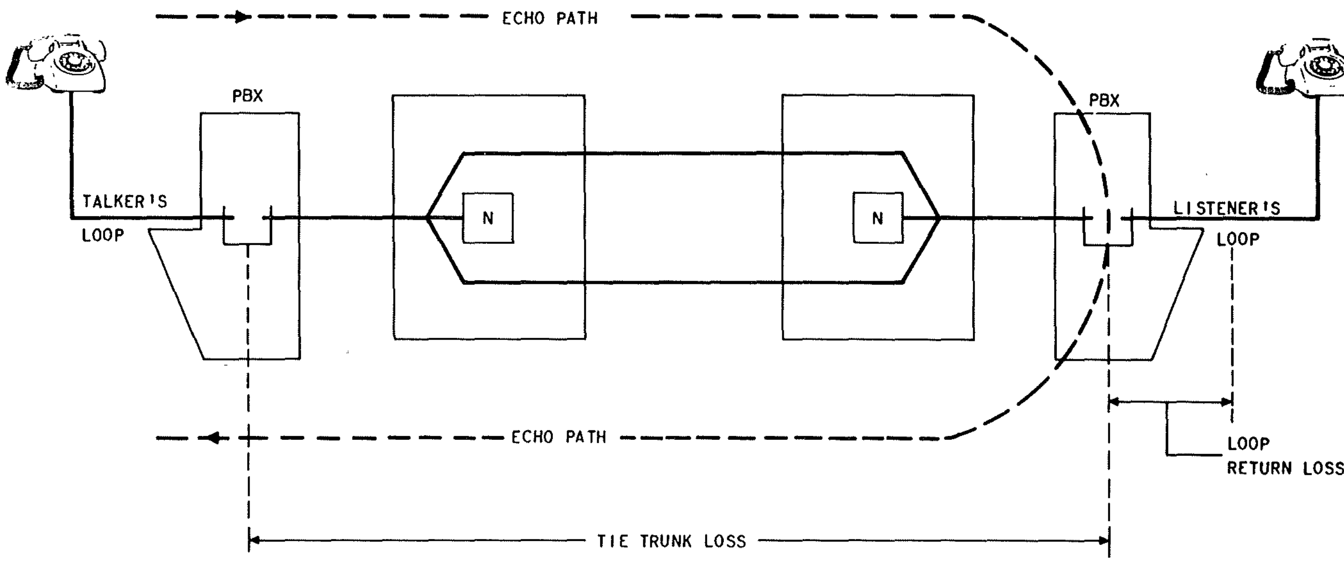


Fig. 20—Echo Path Losses

provide satisfactory echo performance, is given in Part 11, Reference 8.

SELECTION OF THE LOSS

6.14 In order to provide adequate echo protection on long haul circuits, the Telephone Company has developed a variable loss component which is added along with the fixed 4 dB loss to the overall circuit loss. This variable loss component, expressed in dB, is known as the via net loss (VNL) of the circuit; and is a function of the round trip delay of the trunk. For typical Telephone Company circuits furnished by means of carrier systems, the VNL is equal to 0.4 dB + (0.0015 dB/mile x one-way circuit miles), eg, a 400-mile circuit would have a VNL of 1.0 dB. The 0.0015 dB/mile factor represents a loss proportional to the average delay per mile (one way) of the carrier line plus its terminal equipment (approximately 7.5 micro-sec./mile). The 0.4 dB is added to the VNL to compensate partially for a possible buildup of negative variations in the overall connection when the tie trunk is connected in tandem to other tie trunks or to the telecommunications network.

6.15 Because physical voice band cable facilities introduce a much higher delay per mile (approximately 85.0 microsec/mile), these facilities have VNL factors which are much higher (0.017 dB/mile) than the VNL factor for carrier systems. Since a typical tie trunk may contain a mixture of voice-band and carrier facilities, the overall circuit VNL cannot be determined by using a single VNL factor for the total circuit mileage.

6.16 The overall 1 kHz design loss for a tie trunk (and other private lines) is given in Table F. The receive circuit loss adjustment is the responsibility of the party supplying or controlling the terminating equipment at the PBX location. For example, consider the typical interface applications in Fig. 18. For the Type I and Type II interfaces where the Telephone Company provided the equipment at the PBX, the loss values of Table F will be used to select the overall loss of the tie trunk. In Type III and Type IV interfaces, where the customer provides the equipment at the PBX, Table F will be used by the Telephone Company to recommend a design loss to the customer at his PBX. No values less than the minimum 4.0 dB fixed loss should be used by the customer on long haul circuits, however, since these circuits may become unstable in the talking mode and cause interference to other services provided by the Telephone Company.

6.17 The design loss values given in Table F assume that the customer-provided PBX or stations meet the return loss balance objectives specified in Table J. Where the singing point or the echo return loss is less than the minimum values in Table J, additional loss may be inserted by the customer as a temporary expedient until the balance condition can be corrected.

ECHO SUPPRESSORS

6.18 Long haul tie trunks with high round trip delays present a special design problem. As the circuit delay and thus the VNL design loss of these circuits is increased, a point is reached where the received volume performance may become marginal on some built up connections within the tandem tie trunk network itself . At this point the Telephone Company design rules recommend that the VNL of the circuit be reduced to zero (eg, VNL + 4 = 4 dB) and an echo suppressor be inserted in the 4-wire portion of the long haul circuit to provide the required echo protection.

6.19 An echo suppressor is a device which uses voice-switching to open the return or echo path back to the talker when speech is present in the direct path from the talker to the listener (Figure 20).

6.20 While a correctly applied echo suppressor does prevent transmission impairments due to talker echo, it also inserts some transmission impairments of its own to the circuit. One of these is speech clipping caused by momentary echo suppressor switching which may occur when one party interrupts or breaks-in on the other. A second type of impairment occurs when both parties try to talk at once. This momentarily opens the echo suppressors in both directions and allows some echo to be heard. Because these impairments tend to add up when more than one circuit equipped with echo suppressors is switched in tandem, both the Telephone Company private line networks and telecommunication network are designed wherever possible to allow only one echo suppressor equipped trunk in a given switched connection.

6.21 The recommended echo suppressor rules are summarizedin Table G. They call for a "full" or "split" suppressor depending on the amount of delay in the circuit. A full echo suppressor provides echo protection in both directions of transmission and is usually installed as close to the center of the circuit as possible. Because a split echo suppressor only protects one direction of transmission, two split suppressors are required to equip a given circuit. The optimum location for each of the split suppressors on a circuit is as far as practicable from the end of the circuit for which it provides talker echo protection.

6.22 The basic difference between the full and split operation is in an adjustment on the echo suppressor called the hangover-time adjustment. Hangover is the amount of time the echo suppressor must keep its switch closed after the talker stops talking or pauses in order to allow for the delay (end delay) the echo encounters in traveling from the echo suppressor to the listener's end and back to the suppressor.

6.23 The normal hangover adjustment on a full echo suppressor will provide satisfactory performance up to the limits specified in Table G. While it is physically possible that the range of application for the full suppressor could be increased by increasing the hangover adjustment, subjective tests have shown that higher hangover-time adjustments result in higher incidence of speech clipping during break-in. The split suppressor, by being located close to the listener's end, reduces the end delay and hence the required hangover time. A more complete discussion of the operation of echo suppressors can be found in Part 11, Reference 8.

6.24 Normally the Telephone Company will supply the echo suppressor(s) on all private lines where they are required. An important exception to this is a private line where the customer uses either a Type II or Type IV option (Fig. 17) with customer-provided 2-wire or 4-wire full duplex type inband signaling.* These signaling units are not compatible with echo suppressors, since the echo suppressor opens one direction of transmission when speech or signaling tones are present in the opposite direction. Therefore, when a customer chooses a Type IV option with full duplex inband signaling on a circuit long enough to require echo suppressors, he will have to provide the echo suppressor (s) at his terminal locations.

* Most dial type inband signaling units require full duplex operation independent signaling paths in both directions of transmission.

6.25 Note that a Type II option (Fig. 17) with customer-provided 2-wire full duplex inband signaling cannot be equipped with either Telephone Company-provided or customer-provided echo suppressors because:

1. The customer cannot provide the echo suppressor with a 2-wire interface because the echo suppressor requires the two directions of transmission to be separated (ie, 4-wire operation), and

2. The Telephone Company cannot provide the echo suppressor since it would disrupt the duplex nature of the customer's inband signaling.

6.26 If the customer chooses an inband signaling system with option II or IV which is compatible (not full duplex) with echo supressor operation, the Telephone Company will provide the echo suppressors for the circuits which require them. The customer must inform the Telephone Company his 2-wire or 4-wire inband signaling circuits do not require full duplex operation when making his service request.

6.27 Echo suppressors will not normally be provided on 2-wire nonswitched point-to-point private lines. The Telephone Company will design these circuits to have a 10 dB loss which is equivalent to a VNL of 6 dB or about 4000 miles of carrier circuit. In those rare cases where the calculated VNL exceeds 6 dB, the Telephone Company will allow the circuit loss to increase by the calculated value rather than introduce an echo suppressor with its inherent voice switched impairments. This technique is not recommended for circuits which can be tandem switched to other circuits since the additional loss may make the received volume performance on these switched connections marginal.

6.28 The provision of echo suppressors on tandem tie trunk networks made up of both Telephone Company- and customer-provided private line facilities will have to be negotiated on a case by case basis.

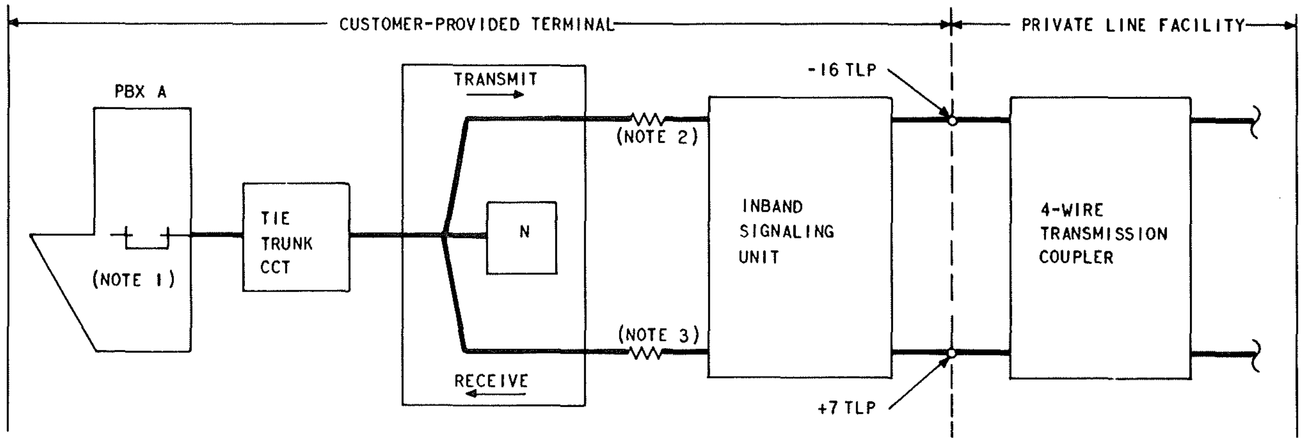
ALLOCATION OF OVERALL LOSS

6.29 This section discusses loss allocations the Customer should consider when he chooses a Type III or Type IV (Fig. 17) interface with standard transmission level points with reference to the line, ie, input (transmit) −16 TLP and output (receive) + 7 TLP. Note that the channel itself provides 23 dB of gain between the two 4-wire interfaces when operating from a −16 to a + 7 TLP.

6.30 After determining what the overall loss should be, there remains the final consideration of how this loss required to overcome the 23 dB channel gain should be allocated throughout the circuit. The best allocation of loss requires a compromise between the overload and the noise performance on the transmission channel. The assignment of level points is in keeping with communication industry standards (see Section 11, Reference 7). These standards provide for optimum transmission performance, flexible equipment installation, and maintenance needs. The transmission channel, shown in Fig. 21, consists of customer-provided terminal equipment and Telephone Company-provided private line facility. The far end of the tie trunk circuit (PBX B) would be terminated in a similar equipment arrangement.

6.31 In Fig. 21, input to the private line facility (PBX A transmitting) is designated as the −16 Transmission Level Point (TLP) relative to the originating PBX (A) switch (0 TLP). This means that there should be 16 dB of loss between the PBX switch (0 TLP) and the private line input (−16 TLP). This loss includes the loss of the PBX tie trunk circuitry, the PBX office cabling, the terminating set, and the SF unit. The remainder of the required 16 dB loss is made up by the selection of the proper value for the transmit pad. The insertion of 16 dB of loss between the 0 TLP and the input of a transmission channel provides for overload protection and maintains the desired signal-to-noise relationship.

6.32 The output of the private line facility (PBX A receive) is designated as the +7 TLP



NOTES:
1. OUTGOING SIDE OF PBX SWITCH IS:
   (A) 0 TLP FOR TRANSMITTING DIRECTION,
   (B) RECEIVE LEVEL POINT (CIRCUIT DESIGN LOSS) FOR RECEIVING DIRECTION.
2. ADJUST FOR DESIRED TRANSMITTING LEVEL AT INPUT TO INTERFACE.
3. ADJUST TO PROVIDE OVERALL CIRCUIT LOSS (FROM TABLE F) AT THE PBX RECEIVE LEVEL POINT.

Fig. 21—Loss Allocation

relative to the distant PBX (B) 0 TLP. This indicates that a net gain of 7 dB exists between the PBX (B) 0 TLP and the output of the private line facility at PBX A interface. The required adjustment for the overall circuit loss, as recommended by the Telephone Company using the values in Table F is made between the +7 TLP and PBX A switch. This includes any losses in the SF units, tie trunk circuit, PBX office cabling, and terminating set which are present. The remainder of the required loss should be made up by the proper selection of the receiving pad loss.

6.33 Since each amplifier section in a transmission channel contributes some noise to the circuit, any loss adjustment for the receive signal should be made after all the gain devices. After allowing for the 23 dB of channel gain, the above loss allocation puts all the net circuit loss as given in Table F after any noise that is generated in the communications channel facilities. This will provide the listener with the highest signal to noise performance and the most protection against noise in the absence of signal that is consistent with the overload performance at the transmitting (−16 TLP) end of the channel.

FOUR-WIRE STATION CONSIDERATIONS

6.34 An exception to the design considerations presented in the preceding section is the 4-wire long haul point-to-point private line. On these private lines, the two directions of transmission are separated except for some low level coupling in the reverse direction through the station sidetone circuit. A sidetone circuit is usually provided as part of a 4-wire station set so that a talker feels the set is working since he can hear himself talking. This circuit should have a high reverse loss (greater than 40 dB) in the direction from the station receiver to the station transmitter; otherwise, it will provide a path for echo back to the far end when the far end is talking. With 4-wire stations assuming a station sidetone circuit with a high reverse loss because the two directions of transmission are separated, these circuits normally do not have either echo or stability limitations. Their loss can then be chosen as a compromise between the received volume performance and noise performance in the absence of speech.

6.35 Another factor that affects the choice of loss for 4-wire circuits is the efficiency of the 4-wire station. Most Telephone Company-provided

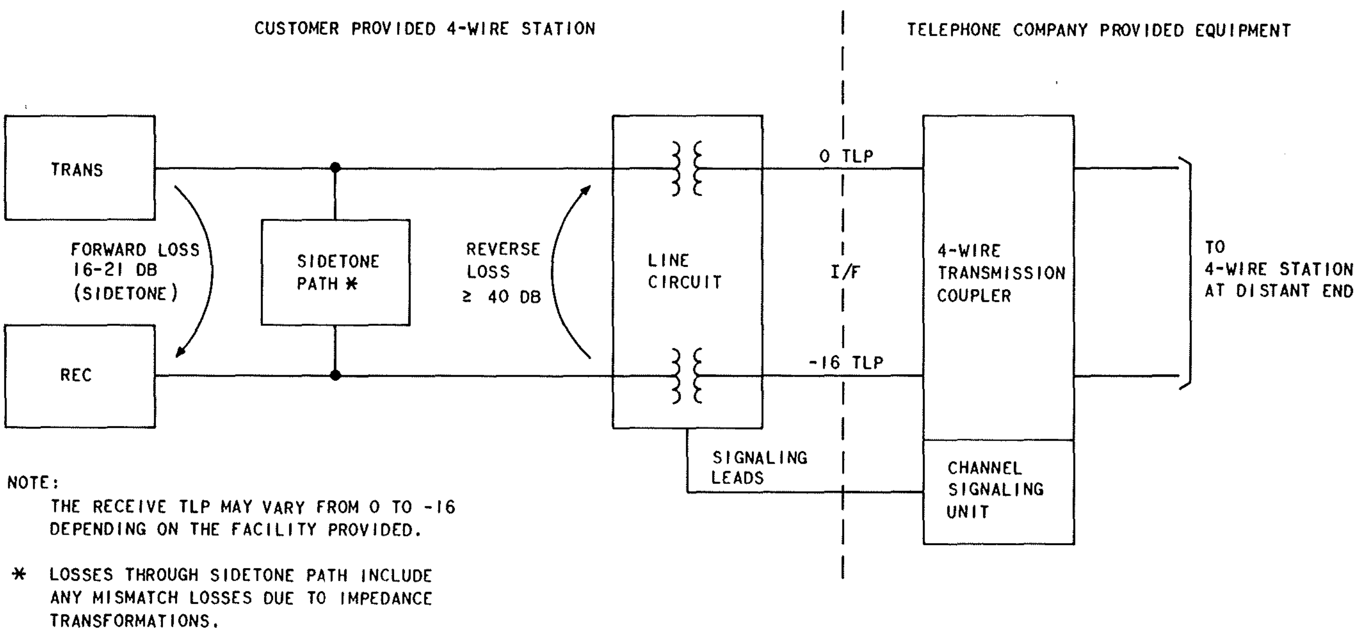


Fig. 22—Typical Station Interface Arrangement for Long Haul, 4-Wire Point-to-Point Private Line

4-wire stations have the same transmitting efficiency as the Telephone Company 2-wire stations but have receiving efficiences that are about 6 dB higher than the 2-wire stations. For this reason the Telephone Company uses a 16 dB set-to-set loss design for point-to-point circuits equipped with 4-wire stations, as compared to 10 dB when 2-wire point-to-point stations are used.

6.36 In allocating the end-to-end loss on 4-wire long haul point-to-point circuits, because the Telephone Company's 4-wire stations have the same transmitting effiency as its 2-wire stations, the transmitting terminal at a 4-wire station is designated a 0 TLP. This makes the 4-wire receiving station terminal a −16 TLP. The level of the talker's voice, coupled though the forward direction of the sidetone path, should be approximately equal to the incoming signals in the receive direction (−16 TLP at the input to the station receiving terminal).

6.37 For long haul point-to-point circuits to be used with 4-wire station equipment, the Telephone Company will provide an interface (with Type III or Type IV) with a 0 TLP input and a −16 TLP output as shown in Fig. 22. These levels normally eliminate the need for customer-provided pads.

6.38 In using the above loss allocation, the customer should check to make sure that internal pads have not been added in the receiving port of his 4-wire station to make its efficiency equal to a 2-wire station. Also, in some 4-wire stations, the transmitter may be directly coupled through a transformer to the station terminal. This normally increases the transmitting efficiency of the station approximately 4 dB. In this case, the 4-wire station transmitting terminal should be assigned a +4 TLP (ie, 4 dB of loss between it and the 0 TLP) in order to meet the signal power limitations given in Par. 4.05. The receiving station terminal in these cases should remain a −16 TLP to give an end-to-end loss of 20 dB. In these cases the customer should coordinate with the Telephone Company on the provision of the 4 dB pad.

6.39 When point-to-point 4-wire private lines are short haul, the received noise usually associated with the long haul facilities is not present. For these short haul circuits, no pads or gain devices will be used and the receiving TLP will be just equal the facility loss where the facility loss is less than or equal to 16 dB.

TERMINATIONS OF CUSTOMER-PROVIDED COMMUNICATIONS SYSTEMS (CHANNELS) IN TELEPHONE COMPANY PBX OR STATION EQUIPMENT

6.40 Where the customer provides his own private line channels onto his premises, the Telephone Company will provide interface arrangements to connect these channels to Telephone Company-provided PBXs or terminal equipment (see Par. 3.10 and 3.11) on those premises. Some general considerations in the selection of the proper interface arrangements for tie trunks and other private lines are given below.

6.41 Figure 23 shows some possible interface arrangements. As indicated in the figure, the interface may be either 2-wire or 4-wire and the channel signaling may be provided by the customer or the Telephone Company. When the customer-provided channel facility is 2-wire then a 2-wire interface arrangement (Fig. 23A) should be used.

6.42 When the customer-provided channel facility is 4-wire, as shown in Fig. 23B, C, and D, either a 2-wire or a 4-wire interface may be requested by the customer. The criteria the customer should consider in choosing between a 2 or 4-wire interface is whether or not there is a requirement for tandem switching the channel to other tie trunks at the PBX. If tandem switching is not required, then either a 2 or 4-wire arrangement may be used. When an arrangement for tandem switching ***is*** required, a 4-wire interface is recommended because of the high degree of return loss balance required (see Par. 7.06(d))for this type of operation. With a 4-wire interface, the Telephone Company will provide the 4-wire terminating set, and will assume the responsibility for including the customer's channel in the balance testing of the PBX.

6.43 Note that if the customer decides to provide a 2-wire interface arrangement (Fig. 23B), and there is a tandem switching requirement, it will not be possible for the Telephone Company personnel to include the customer-provided channel when balancing the PBX. Telephone Company administrative practices do not contemplate that Telephone Company personnel will make tests on customer-provided equipment. The required balance testing techniques are discussed in Appendix B.

6.44 Where 4-wire interface arrangements are used with customer-provided 4-wire channels, the customer will be required to specify the desired overall circuit loss to be used, so that proper pads may be provided on the Telephone Company side of the interface. It is recommended that the design loss limits shown in Table F based on the VNL of the customer-provided facilities be used.

6.45 When 2-wire interface arrangement is used (Fig. 23A or B) the loss through the 2-wire transmission coupler plus that of the PBX tie trunk circuit, will add about 1 dB to the overall circuit loss.

PAD SWITCHING FOR TANDEM TIE TRUNK NETWORKS

6.46 As discussed in Par. 6.14-6.17 long haul tandem tie trunks are designed to have an overall loss of VNL + 4 dB which is the minimum loss per trunk needed for echo protection on a call which terminates to PBX stations at both ends.

6.47 When long haul tie trunk circuits are tandem switched, the end to end overall loss required is still VNL + 4 dB. Here, the VNL is the sum of the VNLs of each of the trunks included in the tandem connection. It is suggested that no more than four tie trunks (not including satellite tie trunks) be switched in tandem. This is to avoid the build up of transmission and signaling impairments as well as the need for complex dialing instructions.

6.48 In order to make the required adjustments in the overall loss or tandem connections, switchable 2 dB pads are used. This pad switching technique is described in the following section using

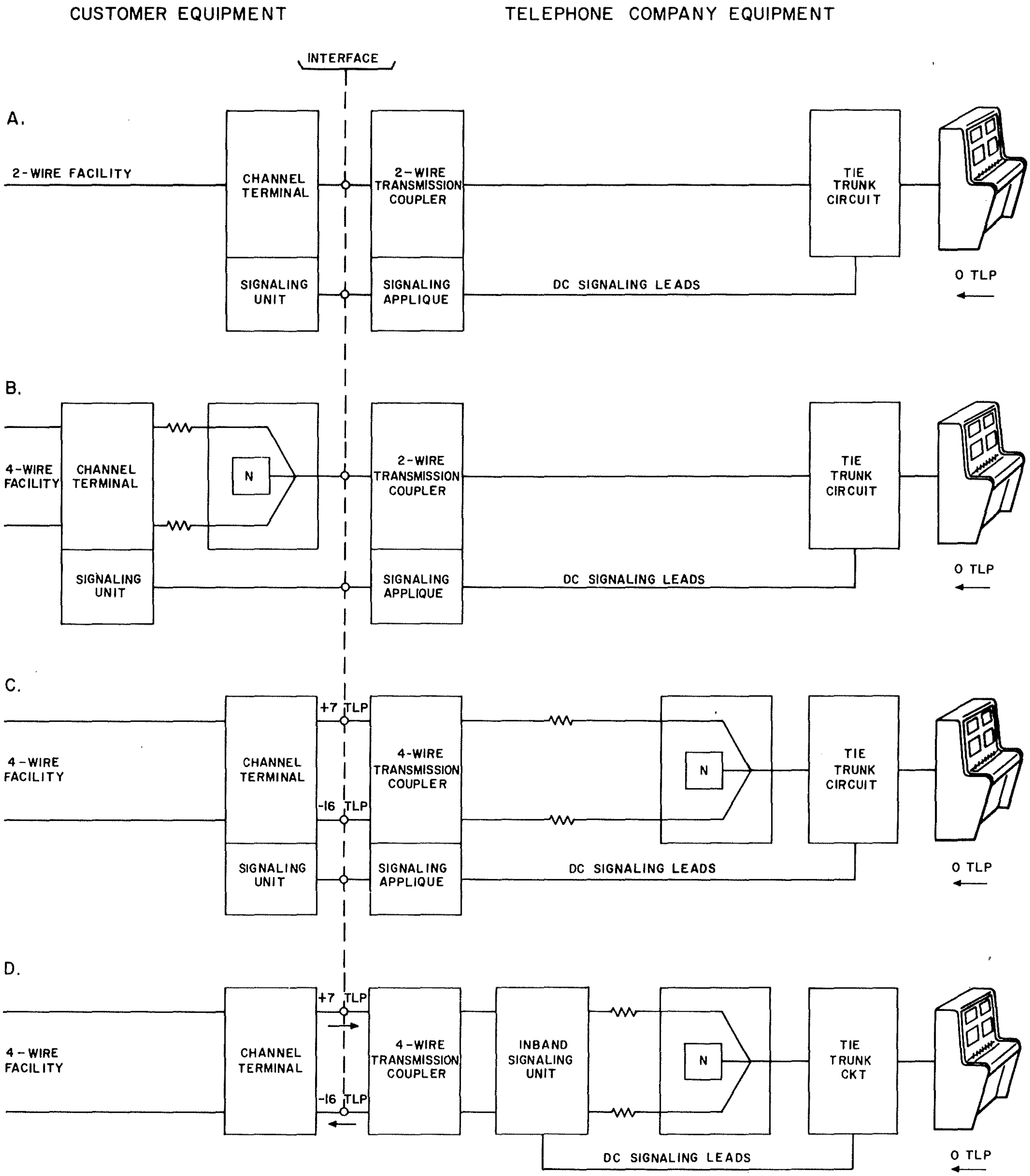


Fig. 23—Typical Interface Arrangements With Customer-Provided Channels

the tandem network shown in Figure 24 as an example. In the example a call that originates at a station on PBX A will be switched in turn to stations at PBXs B, C, D, and E.

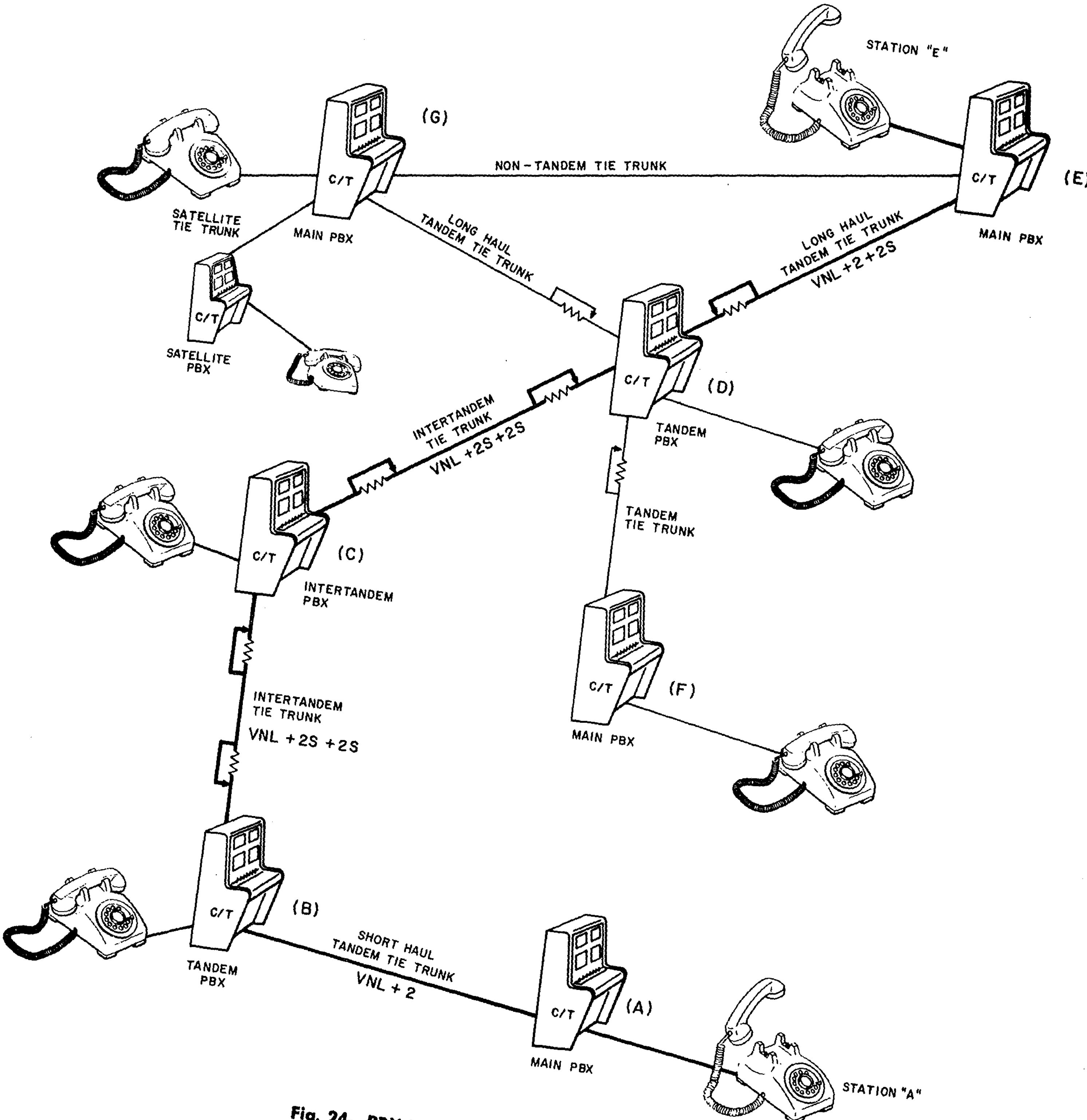


Fig. 24—PBX Tandem Tie Trunk Network

Call from PBX A to PBX B

6.49 Figure 24 shows that the tie trunk which connects PBX A to PBX B is a short haul (absolute round trip delay less than 6 milliseconds) tie trunk. Thus, as described in Par. 6.14-6.17 and Table F, this trunk should have a design loss of VNL + 2 dB and as shown in the figure it is not equipped with any switchable pads. If tandem tie trunk connections are not required at PBX B, then no special return loss measurements are required on the tie trunk to PBX A.

Call from PBX A to PBX C

6.50 For a call from a station at PBX A to a station at PBX C, PBX B acts as a tandem PBX. Thus, if the trunk from PBX A to B meets the terminal balance requirements given in Table J, Section 7, the pad at PBX B in the B to C intertandem tie trunk should be switched out. At PBX C, since it is acting as a terminating or main PBX for this call, the 2 dB (2S) pad at its end of the B to C tie trunk is left in. The overall trunk loss from PBX A to PBX C therefore is (VNL+2) + (VNL+2S) or "VNL" + 4 dB.

6.51 In situations like this, if the customer has a requirement for tandem switching, and his PBX machine has the ability to do pad switching, he should indicate this to the Telephone Company when placing the order for the A to B trunk. This way the Telephone Company will supply a 2-wire facility that meets the terminal return loss balance requirements in Table J. Since this requires special engineering and equipment, the Telephone Company will only supply these terminal balanced facilities at locations where the customer indicates he intends to provide pad switching in other long haul tie trunks at that location.

6.52 In the following example calls it will be assumed that the PBX A to B trunk does meet balance requirements and that PBX B switches out the pad in the PBX B to C trunk.

Call from PBX A to PBX D

6.53 For a call from a station at PBX A to a station at PBX D, PBXs B and C act as Tandem PBXs and should switch their 2dB (2S) pads out. For this call PBX D acts as a Main PBX and should leave in the 2 dB pad at its end of the C to D trunk. The end to end trunk loss is VNL + 2 (A to B) + VNL (B to C) + VNL + 2 (C to D) for an overall trunk loss of "VNL" + 4.

Call from PBX A to PBX E

6.54 For a call from a station at PBX A to a station at PBX E, PBXs B and D act as Tandem PBXs (pads switched out), PBX C acts as an Intertandem PBX (pads out) and PBX E acts as a Main or terminating PBX. Again the overall trunk loss is "VNL" + 4 dB end to end. This call is illustrated in Fig. 24.

6.55 For this type of operation terminal balance requirements given in Table J must be met by all the trunks involved at PBXs B and D while the through balance requirements must be met by the trunks switched at PBX C.

CALLS TO THE TELECOMMUNICATIONS NETWORK

6.56 Tandem connection from tie trunks to local PBX central office trunks and to foreign exchange PBX trunks are permitted. However, no guarantee of transmission performance for these connections is made. Normally, tandem or intertandem trunks connecting to these central office trunks are operated with the 2 dB switch pad ***in,*** and in this case, terminal balance on central office trunks is not required. Transmission performance can be improved on connections to Central Office trunks by operating with the 2 dB switchable pad ***out.*** However, the central office facility should meet the terminal balance objectives for short haul tie trunks as discussed in Par. 7.02-7.06. At the customer's request, the Telephone Company will usually provide central office trunk facilities (when equipment and facilities are available) which will meet these terminal balance objectives at the interface. A consideration before requesting balanced central office facilities is that there will often be several central office trunks for each tie trunk. It may be possible to balance only a few central office trunks and switch the pad out where the PBX making these tandem connections can be arranged to select only the balanced central office trunk on outgoing tie trunk calls to the telecommunications network. This type of selection is not possible for calls incoming from the telecommunication network since the final destination of the call is not known until the PBX attendant answers the incoming central office trunk call.

ELECTRICAL PROTECTION CONSIDERATIONS

FOREIGN AND SURGE VOLTAGE PROTECTION

6.57 Where telephone lines are exposed to lightning, power circuit contact, or induction, protective devices are installed at the central office and on subscriber premises that provide a path to ground for foreign voltages that exceed about 600 volts peak. Since the customer's equipment is connected to the telephone line through the connecting arrangement, the customer's equipment is protected from longitudinal surges by transformer isolation or other means. The maximum surge between conductors (tip and ring) that the customer's equipment should encounter due to foreign potential is 30 volts.

6.58 The customer is responsible for providing protection, internal to his equipment and facilities, against foreign and surge voltages from his equipment and facilities being applied to the connecting arrangement. The foreign potential on the transmission leads should be limited to 30 volts. The surge potential on the transmission leads should be limited to 30 volts. The surge potential on other conductors should be limited to 600 volt peak between conductors or from one conductor to ground.

VOLTAGE LIMITATIONS (Signaling leads)

6.59 When it is necessary for the customer to apply an operational voltage to facilities interconnected with telephone facilities, certain voltage limitations should be observed. (This discussion applies to signaling leads only, since transmission paths are not designed to pass dc; and the application of dc in excess of 1 Ma. could damage components). These limitations are for the purpose of providing adequate protection to personnel and plant facilities. Unless otherwise specified, steady-state voltages applied by customer-provided equipment to conductors connected to the connecting arrangement should not exceed the following:

	dc	ac(RMS)
Maximum voltage, any conductor to ground	135	50
Maximum voltage, conductor to conductor	135 270*	50 100*

* Permitted only if voltage source is center-tapped to ground.

The power supplies and wiring methods used in the customer-provided equipment should meet the provisions of the National Electric Code (NEC), Article 725, for Class 2 remote control and signal circuits.

GROUNDING

6.60 In general, it is desirable that circuits in the customer's equipment which connect to the connecting arrangement have some path to ground. A direct or resistive ground on one side of the power supply would be an example of such a path. This practice avoids the possibility of the entire circuit involved being at an indeterminate potential with respect to ground. Such a potential, perhaps as a result of electrostatic induction, could result in an insulation breakdown in the arrangement. It is expected that the customer's equipment, if powered from commercial power, will be grounded in accordance with applicable electrical codes (NEC). Self-powered or passive customer's equipment need not be grounded. One side of the customer's ringing generator supply, when provided, should be grounded.

6.61 The Connecting Arrangement is generally provided with a common signal ground (a cold water pipe or other ground approved by the NEC) which will be bonded to the electric power ground and telephone protector ground, where present. As an example, a good ground may be obtained with a proper connection to a metallic cold water pipe, using a single No. 6 AWG copper conductor. The other end should be connected to the ground return terminal of the customer's equipment. Proper attention should be given to providing the lowest possible resistance connection at each end of the circuit. It is imperative that this ground be connected at the same location to the water piping system used as the telephone protector or signal ground. This connecting conductor should be short, straight and, if possible, a continuous piece of wire. This lead shall not be fused.

7. INSTALLATION AND TRANSMISSION TESTING CONSIDERATIONS

7.01 This section provides general installation considerations required for Telephone Company-provided equipment at customer terminal

TABLE F

1000 HZ DESIGN LOSS OBJECTIVES

TYPE OF SERVICE	SHORT HAUL LOSS (dB)		LONG HAUL LOSS (dB)†	
NON-SWITCHED PRIVATE LINES	OBJECTIVE	MAXIMUM	OBJECTIVE	MAXIMUM
2-wire point-to-point	0-10	10	0-10	10
4-wire point-to-point	0-16	16	0-16	16
SWITCHED PRIVATE LINES CAPABLE OF SWITCHED ACCESS TO THE TELECOMMUNICATIONS NETWORK				
PBX Non Tandem Tie Trunks	0-3	5	VNL+4	*
PBX Tandem Tie Trunks**	VNL+2	3	VNL+2+2S	*
PBX Inter-Tandem Tie Trunks**	VNL+2S+2S	VNL+2S+2S	VNL+2S+2S	*
CCSA Access Line	VNL+2	VNL+2	VNL+2	*
PBX Off-Premises Station Lines	0-3	5	VNL+4	6
FOREIGN EXCHANGE (FX) PRIVATE LINES				
FX Line	0-5	8	VNL+4	8
FX Secretarial Line	0-5	8	VNL+4	8
FX Off-Premises Extension	0-5	8	VNL+4	8
Long Distance Line or Trunk	VNL+4	8	VNL+4	8
FX PBX Trunk	0-3	5	VNL+4	6

*Maximum design loss subject to echo limitations (See paragraphs 6.16-6.27 and Table G).

**Design losses include switch pads (2S=2dB switch pad) where present.

†A long haul private line has a 1000 Hz round trip delay greater than 6 milliseconds by definition.

TABLE G

ECHO SUPPRESSOR APPLICATION RULES

TYPE OF SERVICE	FULL ECHO SUPPRESSOR REQUIRED WHEN CALCULATED VNL GREATER THAN:	SPLIT ECHO SUPPRESSOR REQUIRED WHEN CALCULATED VNL GREATER THAN:	NOTES
NONSWITCHED POINT-TO-POINT PRIVATE LINES			
Echo Suppressors are not provided for these private lines.	—	—	—
SWITCHED PRIVATE LINES CAPABLE OF SWITCHED ACCESS TO THE TELECOMMUNICATIONS NETWORK			
PBX Long Haul Tie Trunks	3.5 dB	4 dB	1, 2
PBX Long Haul Off-Premises Station Lines	3.5 dB	4 dB	2
CCSA Access Line-Provided by TELCO where required at SS-3 Office	—	—	
FOREIGN EXCHANGE PRIVATE LINES			
PBX Long Haul Foreign Exchange Trunk	3.5 dB	4 dB	2
All other Foreign Exchange Private Lines	3.5 dB	4 dB	2

NOTES:

1. If any possible connection in a tandem tie trunk network has a combined VNL which is greater than 4.5 dB, the longest trunk in the connection should be equipped with echo suppressor (s).
2. When echo suppressors are used on a trunk, the VNL for that trunk is reduced to zero.

TABLE H

GUIDELINES FOR SELECTING INTERFACE OPTIONS (PER SECTIONS 5 AND 6)

TYPE OF SERVICE	LONG HAUL OR SHORT HAUL	INTERFACE OPTIONS I	II	III	IV	NOTES
NON-SWITCHED TWO-POINT PRIVATE LINES						
2-wire	both	R	R	NR	NR	
4-wire	both	NA	NA	R	R	
SWITCHED PRIVATE LINES CAPABLE OF SWITCHED ACCESS TO THE TELECOMMUNICATIONS NETWORK						
PBX Tandem Tie Trunk (both ends)	short	R	R	NR	NR	
PBX Non-Tandem Tie Trunk	both	R	R	NR	NR	
Tandem Tie Trunk (Non-Tandem PBX End)	long	R	R	NR	NR	
PBX Tandem Tie Trunk (Tandem PBX End)	long	NA	NA	R	R	
PBX Intertandem Tie Trunk (both ends)	both	NA	NA	R	R	
PBX Off-Premises Station Line (both ends)	both	R	R	NR	NR	
CCSA Access Line (PBX End)	both	NR	NA	R	NA	
FOREIGN EXCHANGE FX PRIVATE LINES						
FX Line	both	R	NA	NR	NA	
FX Secretarial Service	both	R	NA	NR	NA	
Long Distance Line or Trunk	both	R	NA	NR	NA	
PBX FX Trunk	both	R	NA	NR	NA	
FX Off-Premises Extension Line	both	R	NA	NR	NA	

R — Recommended Interface Option.
NR — Not recommended but may be provided.
NA — Not applicable because of Tariff restriction, signaling or circuit incompatibility.

locations. The more important of these considerations are:

Installation

(a) Space

Space should be provided by the customer for the installation of Telephone Company-provided private line equipment, including connecting arrangements. This space should be located in a safe work area which has a clean, dry, well ventilated, noncorrosive, nonexplosive atmosphere. The area should be accessible to Telephone Company craftsmen for maintenance and repair purposes.

(b) Mounting

The equipment will be either relay rack mounted or enclosed in a cabinet. The mounting arrangement depends largely on the location available for mounting the equipment and on the size of the installation. Normally, the Telephone Company provides the mounting for its equipment; in some cases, however, the mounting of Telephone Company-provided equipment on customer-provided relay racks may be acceptable.

(c) Power

The equipment associated with most private lines will require an ac power supply on the customer's premises. The ac source supplied should be a continous 117 volt 60 Hz from a dedicated nonswitched outlet. The Telephone Company equipment will work properly if the voltage range is between 105 and 129 volts ac and the frequency deviation does not exceed ± 0.1 Hz. If a receptacle is provided, it must accept a U-blade ground type plug and present an effective valid earth ground to the ground pin. The capacity of the power source will depend on the size of the installation, and will be specified by the Telephone Company in conjunction with the service inquiry reply in discussed in Part 9.

(d) Location of Interface

The Telephone Company will install the equipment which it provides at the customer location. The transmission and signaling pairs will be wired to the interface and identified.

The actual location of the interface between the customer and the Telephone Company should be a comprise between the location of the connecting arrangement and the location of the customer-provided equipment. The cabling loss between the connecting arrangement and the customer-provided equipment should be minimized for all applications. This loss is particularly important where the customer provides an inband signaling system because the operational margin on this system may be reduced. Therefore, with Type II and Type IV options, it is recommended that the length of cabling from the interface to the connecting arrangement or from the interface to the customer-provided inband signaling unit be limited to approximately 25 feet.

The location of the interface is also important because the transmit and receive transmission paths (ie, Type III or Type IV interfaces) should be in separate cable sheaths or wiring runs. This separation is essential to limit crosstalk from the receive path of one circuit to the transmit paths of other circuits which can occur because of the 23 dB level difference (ie, −16 TLP transmitting and +7 TLP receiving) between the transmit and receive paths. Also, any dc signaling leads required between inband signaling units and associated trunk or line circuits should be segregated from the transmission paths to prevent the coupling of signaling transients or noise into the transmission paths.

The physical connection point supplied by the Telephone Company at the interface may be:

(1) distributing frame terminal strips

(2) cable terminals, or

(3) connecting blocks.

The selection of one of the above will be dependent on the size of the installation and location of the interface.

Transmission Testing Considerations

7.02 At the completion of the installation, the Telephone Company personnel will perform certain transmission tests on those portions of the private line which it provides. In those cases where the customer selects a Type III or Type IV (4-wire +7 TLP, −16 TLP) interface it is suggested he make the tests described in the following paragraphs in order to line up his portion of the circuit. These test measurements will also act as bench marks which can be used for comparison in the event of trouble on the circuit.

7.03 As a general rule, during transmission tests, the customer's portion of the circuit under test should be isolated from the Telephone Company's private line by opening the transmission path toward the Telephone Company equipment at the interface. This will prevent false readings caused by bridged impedances. The level of any test signals applied at the test access point should not exceed the values given in Table B referred to the appropriate TLP.

7.04 Although the criteria given in Table B allow a maximum customer signal level of −13 dBm referred to 0 TLP, a slightly lower test signal level of −15 dBm at 0 TLP is suggested during tests. (−15 dBm at 0 TLP is equivalent to −8 dBm at +7 TLP or −31 dBm at −16 TLP). This will reduce the possibility of reaction with any signal-limiting devices which may be present in the protective connecting arrangement, or the possibility of the test signals interfering with other services provided by the customer at this location.

7.05 Using a PBX tie trunk as an example, the following is a description of initial line transmission tests recommended for the customer-provided portion of the circuit when the customer uses a Type III or Type IV interface option.

7.06 The test equipment characteristics recommended for making these tests is summarized in Appendix B, Par. 6.01-6.03 of this Technical Reference.

(a) Loss Measurements for Customer-Provided Terminal Equipment

The customer should make 1000 Hz insertion loss measurements on his terminal equipment in both directions of transmission to insure proper lineup of each circuit. Examples which illustrate the test procedures are given in Fig. 25 (measurement of Transmitting Loss) and 26 (Measurement of Receiving Loss). These examples assume that a customer-provided dial PBX with 600-ohm terminal equipment is used. Because loss in fixed components can be relatively closely controlled, it is recommended that the measured transmit and receive loss of the equipment be within ±0.25 dB of the design values at lineup.

(b) Frequency Response Measurements

The customer should make frequency response measurements on his terminal equipment in both directions of transmission to insure that his equipment does not have excessive roll-off. If the roll-off is not controlled for each circuit, roll-off on tandem connections may accumulate to the point where intelligibility of received speech is impaired. These measurements are made with the same equipment setup as in (a) above and the oscillator frequency is varied over the band of interest. With Type III and Type IV interface options, the roll-off of the customer's terminal equipment relative to 1000 Hz should be no greater than the suggested limits in Table I.

(c) Message Circuit Noise Measurements

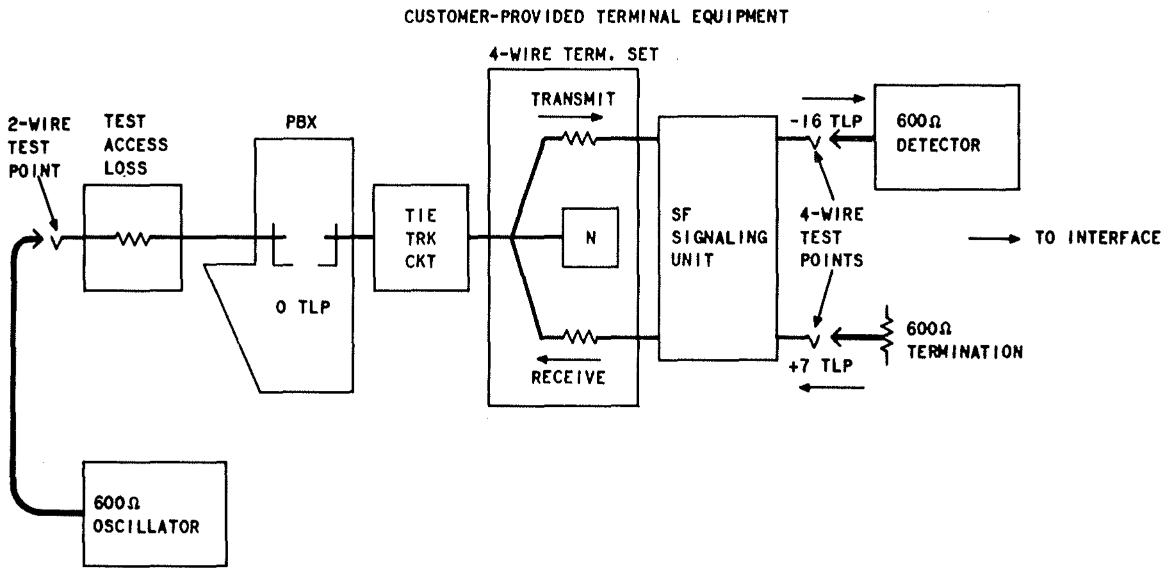
It is suggested that the customer make a noise measurement on his terminal equipment. The noise measurement should be made at the O TLP with the transmitting and receiving pairs terminated with 600 ohms at the interface. It is expected that the message circuit noise of customer-provided terminal equipment at the O TLP should not exceed 20 dBrnC.

(d) Return Loss Balance Tests

Return loss balance tests are designed to check the degree of balance between a 4-wire tie trunk and other tie trunks, PBX stations, or other terminations to which it can connect. The balance measurement objectives are summarized in Table J.

The terminal balance tests to on-premises stations should be made to a representative sample of stations covering the range of loop lengths. Each off-premises station line should be tested and should meet the minimum objectives for station lines in Table J. All short haul 2-wire tie trunks should be tested for terminal balance.

Terminal balance tests to station equipment on point-to-point 2-wire private lines are not normally made. However, it is expected that customer-provided 2-wire station equipment will

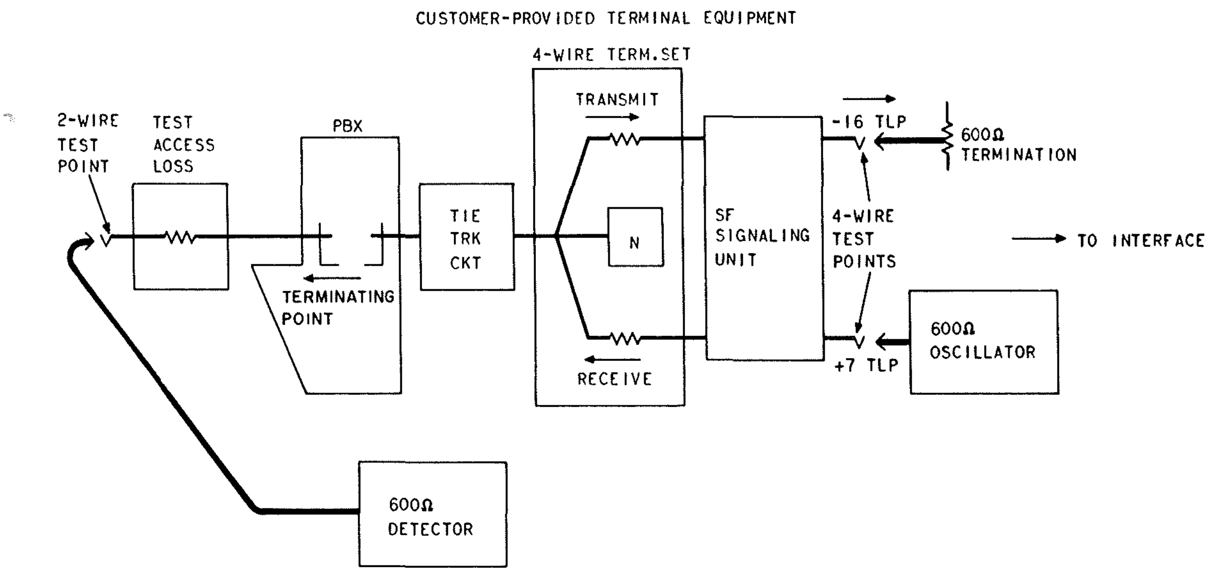


METHOD OF MEASURING TRANSMITTING LOSS:

1. ESTABLISH THE TEST CONDITION AS SHOWN AND CHECK THE EQUIPMENT TO INSURE THAT IT IS IN THE NORMAL OPERATING MODE.
2. SET THE OSCILLATOR TO DELIVER -15 DBM AT THE 0 TLP* AT 1000 HZ (I.E. COMPENSATE FOR ANY TEST ACCESS LOSS BY INCREASING THE OUTPUT OF THE OSCILLATOR ABOVE -15 DBM BY THE AMOUNT OF THE TEST ACCESS LOSS.)
3. CONNECT THE TEST EQUIPMENT AS SHOWN AND TERMINATE THE RECEIVING LEG IN 600Ω AT THE 4-WIRE TEST POINT.
4. THE DETECTOR READING (AT THE -16 TLP) SHOULD BE -31 DBM. THE TRANSMITTING PAD SHOULD BE ADJUSTED SO THAT THE DETECTOR READING IS -31 DBM ±0.25 AT INITIAL LINE-UP.

* 0 TLP IS THE TRANSMISSION LEVEL POINT AT THE OUTGOING SIDE OF THE PBX SWITCH.

Fig. 25—Typical Measurement of Transmitting Loss



METHOD OF MEASURING RECEIVING LOSS

1. ESTABLISH THE TEST CONDITION AS SHOWN AND CHECK THE EQUIPMENT TO INSURE THAT IT IS IN THE NORMAL OPERATING MODE.
2. SET THE OSCILLATOR TO DELIVER -8 DBM AT THE +7 TLP AT 1000 HZ (i.e. -15 DBM REFERRED TO 0 TLP).
3. CONNECT THE TEST EQUIPMENT AS SHOWN AND TERMINATE THE TRANSMITTING LEG IN 600Ω AT THE 4-WIRE TEST POINT.
4. THE DETECTOR READING (IN DBM) AT THE TERMINATING POINT * SHOULD BE THE DESIGN LOSS OF THE CIRCUIT MINUS 15 DB. THE DETECTOR READING (IN DBM) AT THE 2-WIRE TEST POINT SHOULD BE THE DESIGN LOSS OF THE CIRCUIT MINUS 15 DB MINUS ANY TEST ACCESS LOSS FROM THE TERMINATING POINT TO THE 2-WIRE TEST POINT. THE RECEIVING PAD SHOULD BE ADJUSTED SO THAT THE DETECTOR READING IS ±0.25 DB OF THE DESIGN VALUE ABOVE AT INITIAL LINE-UP.

* THE TERMINATING POINT IS THE POINT ON THE RECEIVING SIDE OF THE PBX SWITCH.

Fig. 26—Typical Measurement of Receiving Loss

TABLE I

FREQUENCY RESPONSE LIMITS RELATIVE TO 1000 Hz

FREQUENCY (Hz)	LIMITS (dB)
500 to 2500	−0.5 to +0.5
300 to 3000	−0.5 to +1.5

(+ means more loss, − means less loss than the 1000 Hz Loss)

meet the minimum objectives for PBX stations given in Table J. See Par. 6.56 for a discussion of return loss balance considerations for tandem switching of tie trunks to local or foreign exchange PBX CO trunks.

Through balance tests are made at intertandem PBXs on through connections from an intertandem tie trunk to an intertandem tie trunk.

A more complete discussion of terminal and through balance testing can be found in Appendix B.

8. MAINTENANCE CONSIDERATIONS

8.01 In order to reduce the possibility of transmission impairments and out-of-service conditions, it is desirable to perform preventive maintenance on the equipment and on the associated transmission facilities of a communications service. For this reason, the Telephone Company will perform preventive maintenance on the private line facilities and terminal equipment which they provide. To allow for this, the Tariffs generally specify that these facilities must be released by the customer at a mutually agree-upon time for maintenance purposes. The release of the facilities will be required during normal business hours. However, the Telephone Company will cooperate with the customer in order to limit disruption of his service.

8.02 Even when an adequate maintenance program is carried out, there will be occasions when trouble is experienced or suspected on the customer-provided communications equipment. When this occurs, it will be necessary to determine the source or cause through analyzing and through methodical testing of the service. This can only be done by those having knowledge of and responsibility for the equipment involved. This section of the Technical Reference is provided to assist the customer in sectionalizing troubles that may occur in portions of the overall private line which he provides. Additional information on testing of customer-provided communications channels can be found in Reference 12 of Part 11.

Analyzing Trouble

8.03 Generally, telephone users' trouble reports fall into two basic categories: transmission and signaling. Typical examples of these reports are:

(a) Transmission

(1) Static or hum on the line

(2) Noisy

(3) Hollow sounding

(4) Howling noise

(5) Fades

(6) Can't hear - can't be heard (dead line)

(b) Signaling

(1) Doesn't answer

(2) False busy

(3) Disconnect while talking (false disconnect)

(4) No signals

8.04 By obtaining as many details as possible of the trouble condition and by understanding the operation of each section of the circuit, much unnecessary testing is eliminated. For example, a PBX tie trunk reported as hollow sounding (near-singing), may indicate the possibility of inadequate receive loss or of poor terminal balance at the PBX location.

Reporting Trouble

8.05 When trouble is experienced or suspected on a private line with one or both ends employing customer-provided equipment, the customer should first isolate and check (sectionalize) his

TABLE J — BALANCE OBJECTIVES

TYPE OF CONNECTION		CONNECTED CIRCUIT TERMINATION	2 dB SWITCH PAD	TYPE TEST **	AVERAGE OF ALL CIRCUIT MEASUREMENTS	NO CIRCUIT MEASUREMENT LESS THAN
FROM (TEST CIRCUIT)	TO (CONNECTED CKT. TERM.)					
THROUGH BALANCE MEASUREMENT OBJECTIVES						
4-Wire Tie Trunk	4-Wire Tie Trunk	4-Wire Legs Terminated In 600 ohms at the Distant PBX	Out (Pad Out of Both Tie Trunks)	ERL	27.0 dB	23.0 dB
				SP	20.0 dB	16.0 dB
TERMINAL BALANCE MEASUREMENT OBJECTIVES						
A 4-Wire Tie Trunk at the PBX	On Premises or Off Premises* PBX Station Lines	Station Off Hook	IN	ERL	12.0 dB	9.0 dB
				SP	6.0 dB	4.0 dB
	2-Wire Short Haul Tie Trunk	600 ohms + 2.16Mfd at the Distant PBX	OUT†	ERL	18.0 dB	13.0 dB
				SP	10.0 dB	6.0 dB
	PBX Test Balance Termination	600 ohms† 2.16Mfd. at the PBX	In	ERL	—	20.0 dB
				SP	—	14.0 dB

* Because off-premises stations are expected to be few in number, only the objectives in the last column should be applied to each station.

† The 2 dB pad should not be switched out where the loss of the connected facility is less than 2 dB, or where these balance objectives are not met.

** ERL — Echo Return Loss   SP — Singing Point portion(s) of the circuit before reporting the trouble to the Telephone Company. This is to preclude the customer from incurring a Telephone Company maintenance charge if the trouble is in his equipment.

8.06 After the customer has sectionalized the trouble and determined that it is in a Telephone Company-provided private line facility or equipment, it should be reported to the Telephone Company listed "Repair Service" telephone number (unless otherwise indicated). In order to provide speedy handling of the complaint, the following information should be given to the attendant processing the call:

(a) Customer name

(b) Customer address (and equipment location, if different)

(c) Circuit identification number

(d) Description of type of trouble

(e) Pertinent test information

(f) Customer contact for additional information

8.07 The Telephone Company will test the transmission capabilities of its private line facility and equipment and, where necessary, dispatch repair forces to clear the trouble, but will not assume responsibility for locating troubles in the customer's equipment.

9. COORDINATION

9.01 The information in previous sections contains recommendations for transmission design and for the responsibilities of the parties involved. This section presents the key items of coordination necessary to establish and maintain these private line facilities, cross-referencing them to parts of the Technical Reference where there is more detail on the subject.

9.02 When the customer submits a service inquiry for a private line facility, it will help speed the processing of his inquiry, if at the same time, he provides the Telephone Company with the information listed below.

(a) Type of overall communication service, ie, tie trunk, off-premises station lines, etc.

(b) Which interface option is desired, subject to the considerations in Part 3 and 6, and to the availability of Telephone Company facilities and equipment and which connecting arrangement the customer wants.

(c) Quantity of circuits desired:

(1) Present requirements

(2) Projected requirements.

(d) Will the customer locations have maintenance personnel in attendance for trouble location work?

(e) Required receive loss, if not the value given in Table F. (Loss other than that ordinarily provided by the Telephone Company may incur additional charges).

(f) Type of echo suppressor customer will supply (if required). (See Par. 6.18 - 6.28)

(g) Type of inband signaling unit customer will supply (if applicable). (Par. 5.01 - 5.07, and Par. 5.21-5.24).

9.03 In those cases where one PBX or station terminal is provided by the customer and the other by the Telephone Company, there will be signaling compatibility considerations with regard to the terminal equipment selected for the communication service, (ie, a trunk could be dial repeating, automatic, or ringdown, etc.). As described in Par. 5.21 - 5.23 the coordination required to ensure equipment compatibility will be the joint responsibility of the respective engineering representatives.

9.04 Once the customer and the Telephone Company reach agreement on a proposal, agreement should be reached on when the space and other installation items will be available to the Telephone Company. (Part 7).

9.05 The design of the private line will be based on the information supplied by the customer and on the availability of Telephone Company facilities at that time. Any changes the customer makes in design, serving arrangements, service data, allocation of space for Telephone Company equipment, etc., could affect the rates charged and the date for turning over the private line to the customer.

9.06 The recommended coordination of in-service maintenance and trouble reporting procedures is outline in Part 8.

10. GLOSSARY

10.01 The following are definitions of terms used in this Technical Reference. They may, however, differ in letter from the exact wording used in the FCC Tariff.

AML (ACTUAL MEASURED LOSS) - See LOSS

ATTENUATION

Attenuation is a general term used to denote a decrease in magnitude of power from one point to another. It is usually expressed as a ratio or, by extension of the term, in decibels.

CENTRAL OFFICE (LOCAL)

The local (or "Serving") Telephone Company ***Central Office*** is the Telephone Company premises where the customer would normally gain access to the Telecommunications Network.

CENTRAL OFFICE PBX TRUNK - See PBX CENTRAL OFFICE TRUNK

CHANNEL

Channel denotes a path (or paths) for electrical communications between two or more stations or Telephone Company offices furnished by wire, carrier, radio, or a combination thereof.

COMMUNICATIONS SYSTEMS

Communications systems are channels and other facilities which are capable, when not connected to private line services, of communications between customer-provided terminal equipment or Telephone Company-provided stations.

CONNECTING ARRANGEMENT

Connecting Arrangement denotes the equipment provided by the Telephone Company to accomplish the direct electrical connection of customer-provided facilities with the facilities of the Telephone Company, or the direct electrical connection of Telephone Company-provided facilities.

CUSTOMER

Customer denotes the person, firm, or corporation which orders service; and which is responsible for the payment of charges and compliance with Telephone Company regulations.

CUSTOMER-PROVIDED TERMINAL EQUIPMENT

Customer-provided terminal equipment denotes devices, apparatus, and their associated wiring provided by a customer authorized user, or joint user, which do not constitute a communications system.

dBrn, dBrnC, dBrnCO - See NOISE

DECIBEL (dB)

A ***decibel*** is a unit for comparing the relative transmission losses or gains in power of two signals. When expressed in terms of power, decibel (dB) is defined by the equation $dB = 10 \log P_2/P_1$ where P_1 and P_2 are the powers of the two signals compared. Another reference unit of the dB is dBm in which the power is referred to one milliwatt (ie, $P_1 = 1mw$).

See "Noise" for other references.

ECHO

An ***echo*** is a signal which has been reflected or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a signal distinct from that directly transmitted.

ECHO RETURN LOSS (ERL)

Echo return loss (ERL) is the weighted average of the return losses of all frequencies between 500 and 2500 Hz.

ECHO SUPPRESSOR (Voice)

An ***echo suppressor*** is a voice-operated device for connection to a two-way telephone circuit to attenuate echo currents in one direction caused by telephone speech currents in the other direction.

EML (EXPECTED MEASURED LOSS) - See LOSS

ENTRANCE FACILITIES

An ***Entrance Facility*** is a voice grade transmission facility (less than 25 airline miles) provided by the Telephone Company to extend a customer-provided communication channel to his premises. It is referred to as Series 10,000 channels, type 10,001 in Tariff FCC No. 260.

EXCHANGE

The Term ***Exchange*** denotes a unit established by the Telephone Company for the administration of communications service in a specified area which usually embraces a city, town, or village and its environs. It consists of one or more central offices together with the associated plant used in furnishing communication service within that area.

4-WIRE CIRCUIT

A ***4-wire circuit*** is a 2-way circuit using two paths so arranged that the signals are transmitted in one direction by one path and in the other direction by the other path.

NOTE: The transmission paths may or may not employ physical wires.

4-WIRE TERMINATING SET (4-WTS)

A ***4-wire terminating set*** (4-WTS) consists of a form of bridge, usually made up of transformers (hybrid coils), arranged for interconnecting a 4-wire facility to a 2-wire facility.

FOREIGN EXCHANGE CENTRAL OFFICE

A ***foreign exchange central office*** is a central office in an exchange other than the exchange which would normally serve a particular location.

FULL DUPLEX OPERATION

Full duplex operation is that which uses a system capable of transmitting and receiving signals simultaneously in both directions.

IDLE CIRCUIT TERMINATION (ICT)

Idle circuit termination (ICT) is a function performed by a trunk or line equipment in its idle condition to prevent singing of a trunk or line equipped with gain devices. It should be automatically removed when the circuit is in use.

INTERCONNECTION UNIT - See CONNECTING ARRANGEMENT

KEY SERVICE

A ***key system*** is an arrangement to provide access to more than one circuit from one telephone instrument. Usually, more than one instrument will have access to any particular line. The service may terminate private tie lines and off-premises station lines, as well as ordinary subscriber lines. Key service differs from PBX service in that there is no provision for attendant functions.

LINE SIGNALING EQUIPMENT

Line signaling equipment is Telephone Company-provided equipment to accept signaling indications at the interface, convert them to a form suitable for transmission over the private line facility, and deliver the signaling indication to the interface at the distant end.

LOSS (in dB)

ACTUAL MEASURED LOSS (AML)

Actual measured loss (AML) is the measured loss at a specific frequency, normally 1000 Hz, between appropriate test points on a telephone circuit.

EXPECTED MEASURED LOSS (EML)

Expected measured loss (EML) is the calculated loss at a specific frequency, normally 1000 Hz, that is expected to be measured between appropriate test points on a telephone circuit.

INSERTION LOSS

The ***insertion loss*** of a facility is the loss caused by inserting the facility between a source and a load impedance. It is determined by comparing the power in the load impedance when the line is inserted, with the power when the line is removed and the source is directly connected to the load.

NETWORK CONTROL SIGNALING

Network Control Signaling denotes the transmission of signals used in the telecommunications system which perform functions such as supervision (control, status, and charging signals), address signaling (dialing), calling and called number identification, audible tone signals (call progress signals indicating re-order or busy conditions, alerting, coin denominations, coin collect and coin return tones) to control the operation of switching machines in the telecommunications systems.

Network Control Signaling Unit denotes the terminal equipment furnished, installed and maintained by the Telephone Company for the provision of network control signaling.

NOISE

REFERENCE NOISE

Reference noise is the magnitude of circuit noise that will produce a noise measuring set reading equal to that produced by 10 watt of power at 1000 Hz (0 dBm = 90 dBrn).

MESSAGE CIRCUIT NOISE

Message circuit noise is the short term average noise level as measured with a Western Electric Company 3-type noise measuring set or its equivalent.

Noise measurements are designated as follows: (see also "Decibel")

dBrn—dB referred to Reference Noise

dBrnc—dBrn with C-Message weighting network

dBrnCO—dBrnC referred to O TLP

PRIVATE BRANCH EXCHANGE (PBX)

Private Branch Exchange denotes an arrangement of stations and switching equipment for intercommunicating among the stations, which stations may be connected to the telecommunications network or to private line circuits.

PBX CENTRAL OFFICE TRUNK

The ***PBX central office trunk*** provides the connection between a PBX and the Telecommunications Network.

PBX TIE TRUNK

A ***PBX tie trunk*** is a channel directly connecting two private branch exchanges.

RETURN LOSS

The ***return loss*** at the junction of a transmission line and a terminating impedance is the ratio, expressed in dB, of the reflected wave to the incident wave. More broadly, the ***return loss*** is a measure of the dissimilarity between two impedances, expressed by the formula:

$$20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{ dB}$$

where Z_1 and Z_2 are two impedances.

SINGING POINT (SP)

The ***singing point*** of a circuit is the point at which the gain is just sufficient to maintain sustained oscillation.

SYMBOLS (see Fig. 1 and Table A)

TANDEM CONNECTIONS

A ***tandem connection*** is the switching of two circuits in series to extend communications from one point through a connection at a second point to a termination at a third point.

TELECOMMUNICATIONS NETWORK

The ***telecommunications network,*** also called the Public Message Network or the Direct Distance Dialing (DDD) Network, is the assemblage of channel facilities; transmission, signaling, and station equipment; and message switching systems used by the Telephone Company to provide communications services and connections to its customers.

TELEPHONE COMPANY

Telephone Company denotes the American Telephone and Telegraph Company, Long Lines Department, its concurring carriers, and its connecting carriers, either individually or collectively.

TRANSMISSION LEVEL POINT (TLP)

The ***transmission level point*** (TLP) is a point in a transmission system at which the transmission level (expressed in dB) is defined as the nominal or design gain (or loss) at 1000 Hz referenced to an arbitrary point in the system called the ***O transmission level point (O TLP).*** The O TLP (not to be confused with O dBm) is a point chosen for engineering convenience and is not an indication of signal power level.

VIA NET LOSS (VNL)

Via net loss is the name used by the Telephone Company for its circuit design technique wherein the overall loss of a circuit is set in proportion to the circuit delay. The VNL design technique is intended to yield the minimum loss sufficient to give satisfactory control of echos.

VOICE CONNECTING ARRANGEMENT - See CONNECTING ARRANGEMENT

11. REFERENCES

11.01 Some references describing various transmission characteristics of the telecommuncation network are listed below:

(1) Alexander, A.A., Gryb, R.M., Nast, D.W., "Capabilities of the Telephone Network for Data Transmission", Bell System Technical Journal (BSTJ), 39, No. 3, pp. 431-476, May 1960.

(2) Hinderliter, R.G., "Transmission Characteristics of Bell System Subscriber Loop Plant", IEEE Trans. Commun. Elec., 82, pp. 464-470, September 1963.

(3) McAdoo, K.L., "Speech Volumes on Bell System Message Circuits-1960 Survey", BSTJ, 42, No. 5 pp. 1999-2012, Sept. 1963.

(4) Nasell, I., "Some Transmission Characteristics of Bell System Toll Connections", BSTJ, 47, pp. 1001-1018, July-August 1968.

(5) Nasell, I., Ellison, C.R., Jr., Holmstrom, R., " The Transmission Performance of Bell System Intertoll Trunks", BSTJ, 47, pp. 1561-1613, October 1968.

(6) Applicable Intrastate Tariffs.

(7) Appropriate Telegraph Technique and Data Transmission, International Telecommunication Union (CCITT) Books: Red Book, 1961; Blue Book, 1964; White Book, 1969.

(8) Notes on Distance Dialing, A.T.& T., New York, New York 1968.

(9) Notes on Transmission Engineering, United States Independent Telephone Association (USITA), Washington, D.C. June 1967.

(10) Tariff F.C.C. No. 260, Private Line Services, Rates & Regulations, Interstate Services, A.T. & T. Long Lines Department, New York, New York.

(11) Technical Reference, "Transmission Specifications for Voice Grade Private Line Data Channels", A.T.& T. Co. Engineering Department, Data Communications Section, Bell System Data Communications, September 1968.

(12) Technical Reference, "Voice Grade Entrance Facilities for Extending Customer-Provided Communication Channels", A.T.& T. Co. Engineering Department.

(13) Transmission System for Communications (Blue Book), Bell Telephone Laboratories, Inc., Indianapolis, Ind., 1964.

(14) Technical Reference, "Telecommunication Network Structure, Control, Transmission Performance And Service Considerations For Data Operation", A.T.& T. Co. Engineering Department, Data Communications Section, 1970.

Notes

(!) Available through appropriate Federal or State regulatory bodies.

(*) Available through Graybar Electric Company.

APPENDIX A
DESCRIPTION OF INBAND SINGLE FREQUENCY SIGNALING SYSTEM

1. GENERAL

1.01 As discussed in Parts 5 and 6, on certain private lines where the Telephone Company provides the terminal equipment at one end and the Customer provides it at the other, the Telephone Company will meet the Customer on the channel with its inband 2600 Hz single frequency (SF) signaling equipment. This type of operation is possible only where the Customer chooses a Type IV interface at his end. (See Table H).

This appendix gives the operational specifications required for customer-provided SF equipment to work compatibly with Telephone Company SF equipment.

Line Signal States

1.02 The two dc signaling states, ***on-hook*** and ***off-hook,*** shall be represented on the line (channel) by signal tone ***on*** and ***off,*** respectively. Ringing current shall be considered as an ***on- hook*** state.

Line Transmission Level Points

1.03 The signaling equipment shall be connected to the line at -16 dB and $+7$ dB nominal transmission level point (TLP) for transmitting and receiving, respectively, and all power levels in the following sections are specified with respect to either of these points, whichever is appropriate.

2. SIGNAL TONE TRANSMITTER

Signal Tone Frequency

2.01 The transmitted signal tone frequency shall be 2600 ± 5 Hz.

Signal Tone Power

2.02 On each initiation of the ***on-hook*** state the signal tone power into the line shall be -24 ± 1 dBm for the duration of the signal, or a minimum of 300 milliseconds (ms) (whichever is shorter) and a maximum of 550 ms, after which the tone power shall be reduced to -36 ± 1 dBm for the remainder of the ***on-hook*** state.

Extraneous Frequency Components

2.03 The total power of extraneous frequency components accompanying the signal tone shall be at least 35 dB below the fundamental signal power.

Signal Tone Leak

2.04 The level of signal tone leak power into the line shall not exceed -86 dBm during the ***off-hook*** state.

Transmission Voice Path Split

2.05 When signal tone is to be transmitted, the local transmitting voice path shall be split (cut-off) back toward the terminal, if not already split, within the interval from 20 ms before to 5* ms after tone is applied to the line, and shall remain split for a minimum of 350 ms and a maximum of 750 ms.

2.06 When signal tone is to be removed, the local transmitting voice path shall be split back toward the terminal, if not already split, within the interval from 20 ms before to 5 ms after tone is removed from the line, and shall remain split for a minimum of 75 ms and a maximum of 160 ms after the tone is removed.

2.07 When the signaling equipment is receiving and transmitting signal tone simultaneously, the local transmitting voice path split shall be maintained until:

(a) The transmitted tone is terminated, in which case, the split shall be removed in the interval from 75 ms to 160 ms after tone is removed or,

(b) The incoming tone ceases, in which case the split shall be removed in the interval from 350 ms to 750 ms after tone ceases.

*The 5 ms may be relaxed to 15 ms when tone is applied while tone is being received.

2.08 When the signaling equipment is transmitting tone but is not simultaneously receiving signal tone, the local transmitting voice path back toward the terminal shall be split, if not already split, within 250 ms after receipt of incoming tone.

Dial Pulsing

2.09 Dial pulses are sequences of ***on-hook*** pulses which shall be transmitted as corresponding sequences of signal tone pulses at a rate of 10 ± 2 pulse per second. The minimum duration of any signal tone pulse shall be 45 ms, and the minimum interval between pulses in a sequence shall be 25 ms. It may be necessary to employ a transmitting pulse corrector circuit to meet these limits.

Ring Forward Signal

2.10 The ring forward signal is an ***on-hook*** pulse which shall be transmitted as a signal tone pulse with a duration of 65 ms to 135 ms.

Delay Dialing or Wink Start Pulsing Signals

2.11 Delay dialing or wink start-pulsing signals are ***off-hook*** intervals, each of which shall be transmitted as a corresponding tone ***off*** interval at least 140 ms in duration.

3. SIGNAL TONE RECEIVER

General

3.01 The signal tone receiver shall be operationally compatible with any signal tone transmitter which satisfies the specifications in Part 2 of this Appendix. Further, the receiver shall satisfy each and every requirement in the following sections in the presence of 65 dBrnC message circuit noise. For noncompandored trunks this noise figure may be relaxed to 57 dBrnC.

Frequency Limits

3.02 The receiver shall accept as a valid signal tone any single frequency tone within the 2600 ± 15 Hz band.

Sensitivity and Overload Levels

3.03 The receiver shall accept as a valid signal tone any tone within the limits of -20 dBm to $+6$ dBm. The receiver shall reject any tone at or below -30 dBm.

Recognition Times

3.04 The receiver shall accept as valid signals, all signal tone pulses and tone ***off*** intervals which are within the limits specified for dial pulsing, ring forward, and delay dialing (wink) signals in Par. 2.09 - 2.11 of this Appendix.

3.05 The receiver shall reject any tone pulse having a duration of 30 ms or less.

3.06 The receiver shall reject any tone ***off*** interval having a duration of 40 ms or less if the previous valid tone duration was 350 ms or longer.

Immunity to Data or Voice Transmission

3.07 The receiver shall not accept as valid signal tone, nor shall it adversely affect, any tone or data transmissions originating from a customer station (or other source), when these transmissions satisfy the following condition at the station output terminals:

> The total power in the band from 800 Hz to 2450 Hz equals or exceeds the total power present at the same time in the band from 2450 Hz to 2750 Hz.

The receiver design shall tolerate expected deviations from these values which may be caused by attenuation distortion and carrier frequency shift over the total transmission path between the station and receiver.

3.08 On voice calls, the number of times that the receiver may falsely accept voiceband energy as valid signal tone, shall not exceed the following:

(a) An average of once per 1500 call hours for false signals exceeding 150 ms in duration. For older receiver designs, the call hour figure may be lower; however, it shall not be less than 500 call hours when the local signaling transmitter is in the ***off-hook*** (tone ***off***) state.

(b) An average of once per 70 call hours for false signals exceeding 50 ms in duration. For older receiver design, the call hour figure may be lower when the local signaling transmitter is in the ***on-hook*** (tone ***on***) state.

3.09 False splits of the receiving voice path (discussed in Par. 3.11-3.12 of this Appendix, or other actions which may occur as a result of the receiver falsely accepting voiceband energy as valid signal tone, shall not adversely affect the transmission quality on voice calls.

3.10 The receiver shall not release when voice, tone, or data transmissions at levels up to +17 dBm are superimposed on the signal tone.

Receiving Voice Path Split

3.11 The local receiving voice path shall be split toward the switch if not already split, within 20 ms after signal tone appears at the receiver. This shall be a narrowband split with an insertion loss of at least 35 dB over the 2600 $\pm$15 Hz band but not more than 5.0 dB outside the 2600 $\pm$200 Hz band nor more than 0.5 dB outside the 2600 $\pm$400 Hz band. The split shall be maintained for the duration of the incoming signal tone and shall be removed within 300 ms after the signal tone ceases.

3.12 For older receiver designs, a split over the full voiceband (with at least 35 dB insertion loss) may be introduced within 20 ms but this split shall be converted to the narrowband split within 100 ms, after signal tone appears at the receiver.

APPENDIX B
RETURN LOSS BALANCE THEORY AND BALANCE TESTS

1. GENERAL

1.01 The information contained in this Appendix discusses the theory of converting 4-wire transmission paths to 2-wire, using a 4-wire terminating set; and the problems encountered in achieving an acceptable standard of return loss performance at PBX and station terminals. Equipment and the test setups required to make balance tests are described using a 4-wire PBX tie trunk as an example.

2. RETURN LOSS BALANCE THEORY

2.01 Because the voice path through most PBX switching machines is 2-wire, it is necessary to convert the voice paths of a 4-wire private line channel into a 2-wire voice path at the PBX. The device used to accomplish this conversion is called a 4-wire terminating set (term set). Most term sets designed for voice facilities use hybrid transformers to accomplish the actual conversion between the 2-wire and 4-wire voice paths.

2.02 The operation of the hybrid transformers used in a term set can be explained by the Wheatstone bridge concept, as shown in Fig. 27. If Ra = Rb and RL = RN, there is no difference of potential (voltage) across the galvanometer (G), and no current will flow through G. The bridge is balanced. If Ra = Rb but RL does not equal RN, an amount of current determined by the degree of unbalance (or mismatch) between RL and RN will flow through G.

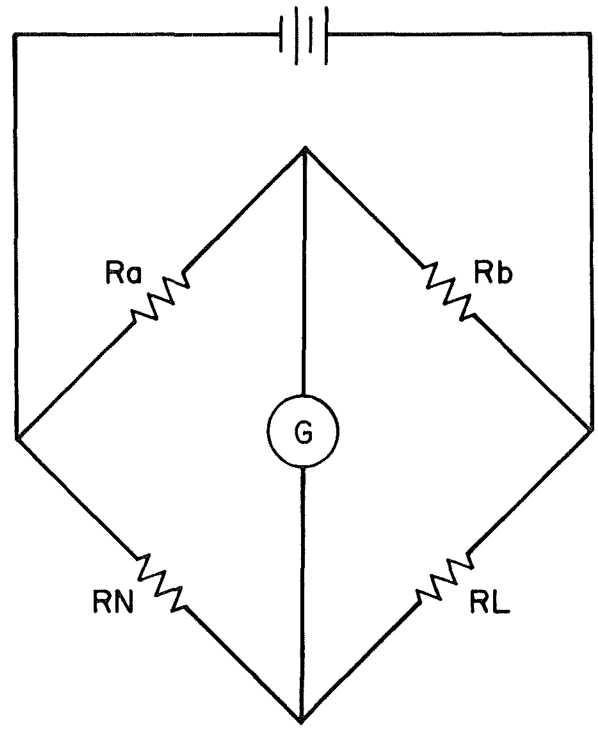


Fig. 27—Wheatstone Bridge

2.03 In Fig. 28, alternating current equipment has been substituted for the direct current equipment of Fig. 27. The battery has been replaced by an oscillator (OSC), the galvanometer with a transmission measuring set (TMS), and the resistances (R) with impedance (Z). The power in this case is transformer coupled to the bridge. If Za = Zb and ZL = ZN, no current will flow through the TMS. If Za = Zb but ZL does not equal ZN, an amount of current determined by the degree of unbalance (or mismatch) between ZL and ZN will flow through the TMS. The rest of the current divides between ZL and ZN, with the division also dependent upon the degree of unbalance.

2.04 Fig. 29 is the same as Fig. 28 but redrawn in hybrid form. ZL and ZN become the

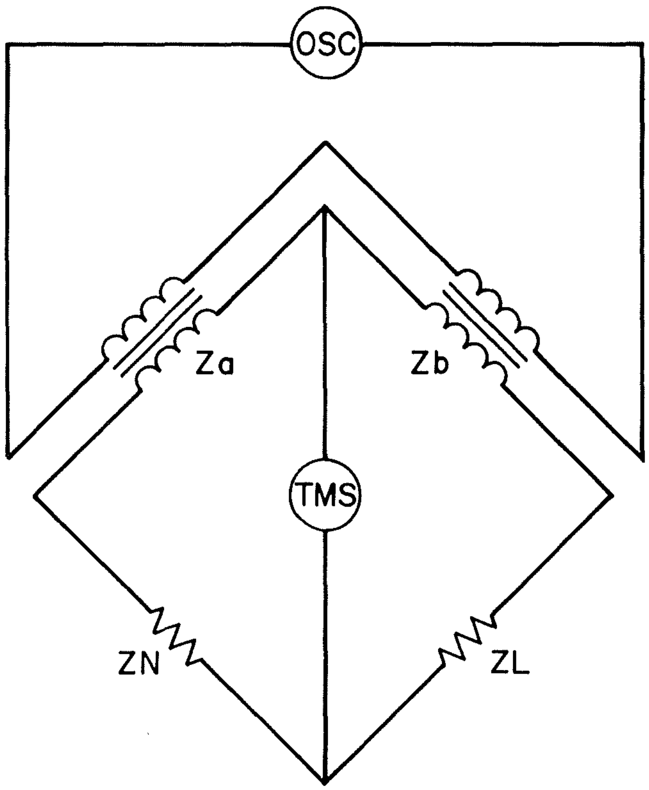


Fig. 28—A.C. Bridge

impedance of the 2-wire line and of the network, respectively.

2.05 The principles discussed can be used to describe the operation of 4-wire terminating sets. Fig. 30 illustrates a simplified arrangement consisting of a hybrid transformer and a balancing network to convert a 4-wire voice path to a 2-wire voice path.

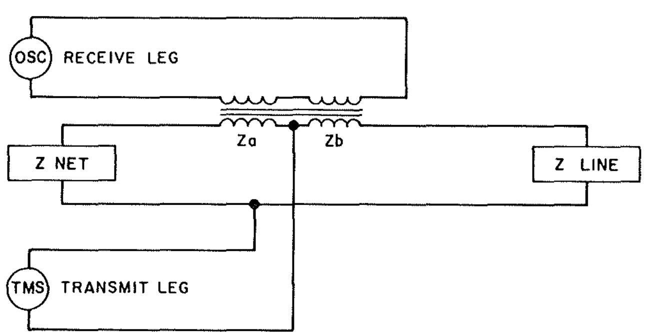


Fig. 29—Hybrid Transformer

2.06 Power entering the hybrid coil over the receive leg divides between the 2-wire line and the balancing network. If the network and the 2-wire line balance each other perfectly (their impedances are identical), the power divides equally between them and no power enters the transmit leg. If the network and the 2-wire line do not balance each other perfectly (their impedances are not identical), an amount of power determined by the degree of unbalance (or mismatch) enters the transmit leg and is returned to the originating end. The purpose of balance tests is to adjust the network impedance to reduce the power returned to the originating end to a minimum.

2.07 Referring to Fig. 30, power received into the hybrid from the 2-wire line divides so that half of it goes into the receive leg where it is dissipated in the output circuit of the amplifier. The other half goes into the transmit leg and is sent over the line to the distant end.

2.08 The impedance of both the 2-wire voice path and the network will vary with frequency. In the practical case, the network and the 2-wire line impedance are not identical, and the degree of balance between the network and the 2-wire line will depend on the frequency of the applied signal and will change as the frequency is varied.

2.09 Under cetain conditions the power reflected at a 4-wire terminating set, due to impedance mismatch between the network and the 2-wire line will cause transmission impairments. If sufficient power in the range of 500 to 2500 Hz is reflected, the talker will hear his own voice repeated to him but delayed in time and this reflection will interfere with his ease of conversation. This effect is called ***talker echo.***

2.10 Power reflected at a single frequency may result in the circuit going into sustained oscillations. This is known as ***singing***, and may occur at any frequency in the voiceband; but usually occurs in the 200 to 500 Hz or 2500 to 3200 Hz ranges.

2.11 It should be noted that talker echo is depedent upon the degree of balance at the distant end of the connection, the round trip facility loss, and on the round trip transmission time (delay) between the talker and the distant end. Singing depends upon the degree of balance at both ends of a circuit, on the facility loss, on the frequency

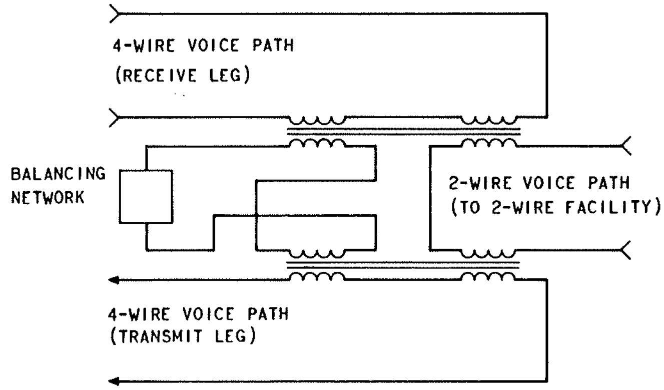


Fig. 30—4-Wire Terminating Set

response, and on the phase relationship between the original and the reflected power.

2.12 To reduce the possibility of transmission impairments, networks are designed to match the impedance of 2-wire lines over the voice frequency range to a degree sufficient to limit the reflected power to acceptable levels. The network is called a balancing network, and the resultant degree of impedance match is called ***balance.***

2.13 The degree of balance is usually expressed in terms of ***return loss*** (in dB) at a specified frequency or band of frequencies. ***Echo return loss*** is a weighted average (on a power basis) of the return losses at all frequencies in the echo range (500 to 2500 Hz). This weighting is accomplished automatically by the networks associated with the testing equipment described in Part 6 of this Appendix. Return loss can be most clearly defined by means of a specific example of how it is measured.

2.14 Referring to Fig. 30, a short is placed across the 2-wire line at the hybrid coil, and a known amount of power from a weighted noise source is sent into the receive leg. Reflected power is measured at the transmit leg. Assume a weighted noise power at a level of 82 dBrn (−8 dBm) sent into the receive leg and the power measured at the transmit leg to be 74.5 dBrn, indicating a total loss of 7.5 dB from the receive leg input to the transmit leg output. This is the loss of the hybrid from the receive leg to the transmit leg, generally referred to as the transhybrid loss, with 0 dB return loss (total reflection of power) at the 2-wire terminals. The actual loss measured will depend on the type of hybrid and on the loss of the receive and transmit pads (if any) in the measuring path.

2.15 To measure the return loss of a 2-wire line, another measurement is taken at the transmit leg (same input power and frequency at the receive leg) with the 2-wire side of the hybrid connected to its 2-wire line and with the distant end terminated in the correct impedance. The level of the power measured at the transmit leg will be lower than with the 2-wire leg shorted, because the network and the 2-wire line with its terminating impedance will absorb most of the power sent in at the receive leg. Assume that the power measured at the transmit leg is now 55.5 dBrn, which indicates that there is 26.5 dB of loss from the receive leg to the transmit leg. Since the losses of hybrid and pads (if any) are common to both tests, the 7.5 dB loss for the 0 dB return loss condition is subtracted from the 26.5 dB, leaving 19.0 dB. This 19.0 dB is the return loss and represents the degree of balance between the 2-wire facility and the balancing network at the frequency of the applied power. Better degrees of balance are indicated by larger values of return loss.

2.16 ***Singing point*** values are another means of expressing the degree of balance between the network and the 2-wire line. However, a different basis is used for evaluating this balance. The singing point is an approximate measure of the stability of a circuit, ie, its freedom from a singing condition.

2.17 It is not enough to obtain a balance that will prevent sustained singing; sufficient balance must be obtained to prevent the circuit from operating in a near-singing condition. This condition results in transmission impairment, readily recognized as hollowness or "rain-barrel" effect, caused by multiple echoes.

2.18 A singing point test is the measure of the degree of balance between the network and the 2-wire line at the critical (or worst) frequency. This critical frequency is usually, but not always, the frequency at which the poorest degree of balance occurs. Although the echo return loss test covers the important voiceband, it will not necessarily indicate poor return losses at single frequencies within this band, and will not indicate inadequate balance within the frequency ranges most susceptible to singing, ie, 200-500 Hz and 2500-3200 Hz. Therefore, both echo return loss and singing point tests are needed to determine the degree of balance over the usable frequency range.

3. BALANCE TESTING CONSIDERATIONS

3.01 The design loss and echo suppressor application rules for tie trunks in tandem networks discussed in Part 6 have been derived in conjunction with terminal and through balance objectives at PBXs in the network. The echo return loss and singing point objectives for terminal and through balance are summarized in Table K.

3.02 These rules may be used as a guide in determining the balance of customer-provided communications services at the PBX or station terminal location. If the transmission design of the terminal is correct and no trouble sources are present, these objectives can be met. The selection of the terminating equipment for the trunks should approximate the nominal impedance of the PBX, switching, or the station terminal equipment. The accuracy of this selection will determine how well the objectives will be met.

3.03 Balance tests are made with the circuit under test connected by a PBX or switching machine to a station or test termination, or connected through the PBX to another circuit. In the following discussion the circuit being tested will be called the ***test circuit.*** The other circuit is the termination to which the test is made, and will be called the ***connected circuit termination.*** If a procedure indicates that the ***connected circuit termination*** is to be a telephone instrument, the telephone transmitter and receiver should be muffled to prevent room noise from overriding the balace test power. Because the reflected power (the power that is being measured) is small, the presence of noise from other sources may also affect the results of the tests. The failure of the tests due to the presence of excessive noise should be treated as a trouble condition which must be cleared before the balance tests are continued.

3.04 There are other transmission irregularities that can result in not meeting balance objectives. The more obvious cases of potential trouble can be found and corrected during the course of a thorough net loss vs frequency line-up of the circuits as described in Section 7 of this Technical Reference. Such tests should be completed prior to attempting the balance tests.

3.05 Some troubles may not become apparent until the actual balance tests are performed. The following is a list of the more common causes for poor balance tests results and may be of use in locating the source of the trouble:

PBX or TRUNK EQUIPMENT—Incorrect ratio repeating coils, repeating coil wired in reverse, undesirable capacitance or inductance across voice path, or a wiring error in voice path circuitry. Poor floor plan layout with scattered trunk equipment and long cable runs may degrade through balance at intertandem PBXs.

4 WIRE TERMINATING SET —Defective hybrid coils, incorrect type or value of balancing network.

LOADED CABLE—Loading irregularities, bridge tap, improper end-section.

NON-LOADED CABLE—Excess bridge tap; cable may require impedance compensation or loading.

3.06 In many cases the Customer-provided test equipment instruction manuals will give adequate information for making these tests. To reduce the chance of interference to other circuits, the transmitted test signals should not exceed the limits established in Par. 7.04 of this reference (ie −15 dBm referred to O TLP). A summary of the characteristics of the test equipment used to make these tests is given in Part 6 of this Appendix.

3.07 The following sections on through balance tests (Part 4) and terminal balance tests (Part 5) of this appendix are presented to assist

TABLE K — BALANCE OBJECTIVES

TYPE OF CONNECTION		CONNECTED CIRCUIT TERMINATION	2 dB SWITCH PAD	TYPE TEST **	AVERAGE OF ALL CIRCUIT MEASUREMENTS	NO CIRCUIT MEASUREMENT LESS THAN
FROM (TEST CIRCUIT)	TO (CONNECTED CKT. TERM.)					
THROUGH BALANCE MEASUREMENT OBJECTIVES						
4-Wire Tie Trunk	4-Wire Tie Trunk	4-Wire Legs Terminated In 600 ohms at the Distant PBX	Out (Pad Out of Both Tie Trunks)	ERL	27.0 dB	23.0 dB
				SP	20.0 dB	16.0 dB
TERMINAL BALANCE MEASUREMENT OBJECTIVES						
A 4-Wire Tie Trunk at the PBX	On Premises or Off Premises* PBX Station Lines	Station Off Hook	IN	ERL	12.0 dB	9.0 dB
				SP	6.0 dB	4.0 dB
	2-Wire Short Haul Tie Trunk	600 ohms + 2.16 Mfd at the Distant PBX	OUT†	ERL	18.0 dB	13.0 dB
				SP	10.0 dB	6.0 dB
	PBX Test Balance Termination	600 ohms† 2.16 Mfd. at the PBX	In	ERL	—	20.0 dB
				SP	—	14.0 dB

* Because off-premises stations are expected to be few in number, only the objectives in the last column should be applied to each station.

† The 2 dB pad should not be switched out where the loss of the connected facility is less than 2 dB, or where these balance objectives are not met.

** ERL — Echo Return Loss   SP — Singing Point the Customer when equipment instructions do not cover the desired test.

4. THROUGH BALANCE TESTS

4.01 Through balance tests should be made at all PBXs in a tandem tie trunk network where intertandem tie trunks can be switched together as discussed in Par. 6.42-6.51 of this Technical Reference.

4.02 Through balance tests consist of adjusting the Network Building Out Capacitor (NBOC) in the terminating set balancing network (the network should already be balanced to the PBX standard impedance), Echo Return Loss tests, and Singing Point tests.

4.03 The purpose of the NBOC adjustment test is to select a value of capacitance which will balance the capacitance of the equipment and wiring that is involved in connections through the PBX. Since there are numerous paths through the PBX for the various connections, a compromise value of capacitance is selected which will provide an adequate balance for any connection. The Echo Return Loss and Singing Point tests are used to determine whether objectives are met, or if further corrective measures are required to meet the objectives.

4.04 The selection of NBOC value is determined by making return loss measurements at 2000 Hz. on representative connection paths through the switching equipment and switchboard. Fig. 31 illustrates the equipment arrangements for these tests. More accurate measurements are obtained by using 2000 Hz. than if a lower frequency is used. The various equipment components (transformers, etc.) have less effect on capacitance values, and the shunt capacity is more easily measured at the higher frequency.

4.05 The NBOC measurements are made by using a test hybrid wired to the PBX switching machine and switchboard. The length of the wiring used with the test hybrid must be the same as the average of the 2-wire sides of all the 4-wire trunks terminated at the PBX. If a separate test hybrid is not available, the tests can be made using a working hybrid temporarily taken out of service. If service hybrids (or spare hybrids) are used, a selection of several such hybrids should be used in the course of the testing to average out any unusually large or small capacitance associated with a particular trunk.

4.06 If a large number of trunks terminate at the PBX, it is not necessary that NBOC tests be made on each trunk. If the number of trunks is five or less, all trunks should be included in the NBOC tests. If there are more than five trunks in the PBX, Table L is recommended for choosing the number of trunks to be tested. The tie trunks tested should be evenly divided among all trunk groups and should contain the longest and shortest paths through the PBX.

4.07 PBXs are usually compact, and should not have large differences in capacitance between the longest and shortest connection paths. Hence, the compromise value of NBOC will closely approximate the value of the capacitance of the equipment and wiring. The through balance objective can usually be met if the capacitance of the longest and shortest through connection paths do not deviate more than ± 0.008 mfd. from the average value. Since 0.008 mfd. is equivalent to approximately 300 feet of ordinary PBX cabling, a difference of 600 feet between the longest and shortest connection paths should be tolerable. It is apparent, however, that care should be taken in floor-planning PBX installations as judicious location of equipment and cable runs will have a considerable effect on through balance.

4.08 If, at a particular PBX, most of the connections which require through balance are handled on a dial basis with only a negligible percentage handled through the switchboard, it will be permissible to base NBOC values on dial connections only. This would be especially advantageous if the capacitance of the switchboard call path is appreciably different from the capacitance of the dial connection path.

4.09 A step-by-step procedure for making the NBOC test is given in Par. 4.12 of this appendix. The compromise NBOC value determined by these tests is then strapped into every 4-wire terminating set in the PBX.

4.10 After the NBOCs of all 4-wire terminating sets have been adjusted to the compromise value, the ERL and SP portions of the through balance tests can be made. While the ERL and SP tests can be made on the same sampling basis as outlined above, it is highly desirable to test as many of the connections as possible to reveal trouble conditions. The objectives for through balance are given in Table K and step-by-step procedure for making the ERL and SP tests are given in Par. 4.13-4.17 of this appendix.

4.11 If, in some large and complex systems, the use of a compromise value of NBOC is not adequate to meet through balance objectives, it may be necessary to employ the precise methods which require Drop Building Out Capacitors (DBOCs). Information on these precise building out techniques may be found in Part 11, Reference 8.

Through Balance - NBOC Adjustment Tests

4.12 Test equipment arrangements are shown in Fig. 31. The figure along with the following step-by-step procedures comprise the necessary testing to determine an NBOC value for PBX 4-wire tie trunks.

TABLE L

RECOMMENDED SAMPLE SIZE FOR NBOC TESTS

TOTAL NUMBER OF 4-WIRE TRUNKS	NUMBER TO BE MEASURED
6 to 10	5
11 to 15	6
16 to 25	7
26 to 50	8
Over 50	18%

Step 1 - Establish connection between the selected test tie trunk and the connected trunk via the PBX switches. If tie trunks to be tested are "manual only", establish connection via switchboard.

Step 2 - Check terminating sets to assure that they are in the normal operating mode, but with NBOCs open (ie, NBOC out of circuit).

Step 3 - Adjust the oscillator for 600-ohm impedance and −8 dBm output at 2000 Hz into 600 ohms. The oscillator is to remain on this adjustment for the remainder of these tests.

Step 4 - Connect test equipment and terminate the connected circuit as shown in Fig. 31.

Step 5 - Increase NBO capacitance in minimum steps (using the decade capacitor or the NBOC adjustments on the terminating set), and adjust the detector attenuator as necessary, to obtain the minimum return power (highest numerical-negative) reading on the detector meter. Record the capacitance value which gives the minimum return power.

Step 6 - Repeat the above test procedure for all trunks selected for the NBOC tests. Where both dial and switchboard switching of these tie trunks is provided, the NBOC tests should be made over both paths.

Step 7 - Determine the numerical average capacitance from all tests and adjust all NBOCs in all 4-wire trunks to this value.

Through Balance ERL and SP Tests

4.13 The test equipment arrangements shown in Fig. 32 and 33 together with the following step-by-step procedures comprise the ncessary testing to determine if the circuits tested meet the through balance requirements of Table K. It is suggested that through balance tests should not be made through the SF unit, but rather at the test access points of the 4-wire terminating sets. The 4-wire test access points can be considered approximately +7 and −16 TLPs for the purpose of these tests.

Singing Point Tests (Fig. 32)

4.14 The singing point test is essentially a high gain amplifier in series with a variable attenuator. High and low pass filters are used to shape the flat amplifier gain to that of the voice band. During the test, the test set is connected between the transmitting and receiving ports of the 4-wire circuit to be tested. The net gain of the test set is then increased by lowering the attenuator until the circuit sings. Because the actual path over which the singing takes place includes the loss through the hybrid, the value

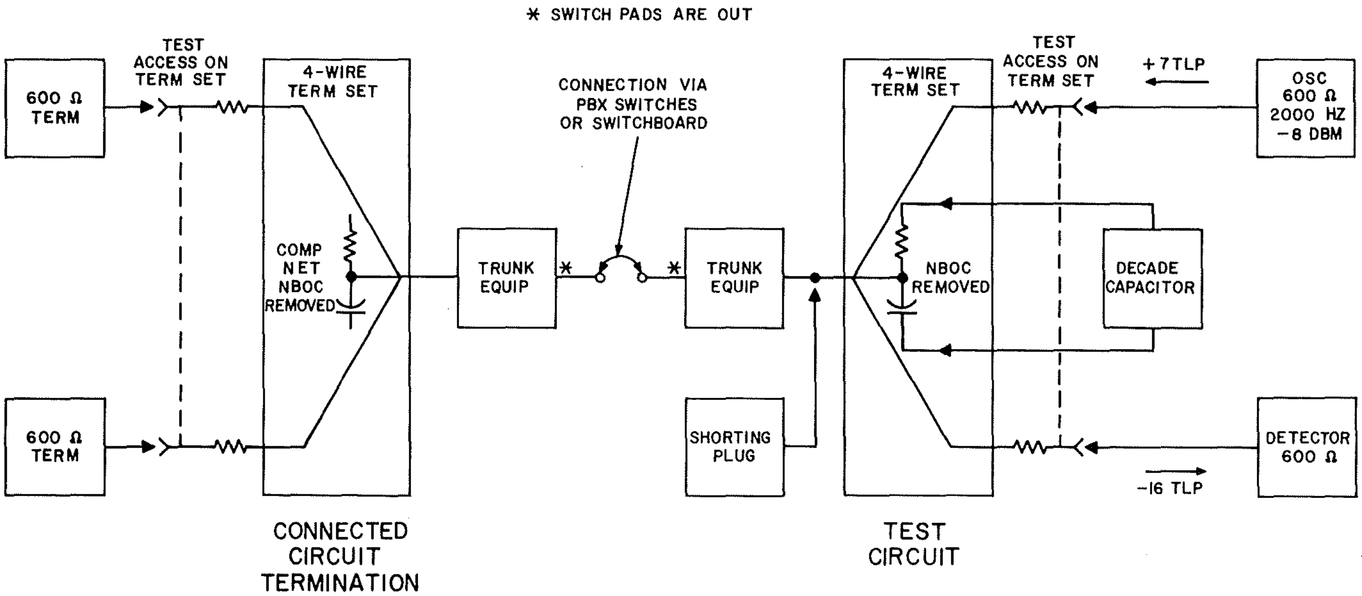


Fig. 31—Typical Through Balance Equipment Arrangements for NBOC Adjustment Tests

read on the test set must be corrected by the loss of the hybrid.

4.15 The use of the following procedure together with the testing arrangement shown in Fig. 32 is recommended when making singing point tests:

Step 1: All wiring options for the 4-wire terminating sets must be completed including connection of the compromise balancing network and NBOCs as determined in Par. 4.12 of this Appendix.

Step 2: Establish the connection between the ***test circuit*** and the ***connected circuit termination.***

Step 3: Connect the singing point test set and filters as shown.

Step 4: While monitoring the singing point test set, increase the setting of the coarse gain attenuator until sustained singing is heard in the monitor, then turn back one step.

Step 5: Increase the setting of the fine gain attenuator until sustained singing is just heard. Note the sum of the two dial settings.

Step 6: Operate reverse poling key and repeat steps 4 and 5. The lower value obtained in Step 5 is the uncorrected singing point in dB.

Step 7: Connect the oscillator and the detector as shown. Short the 2-wire port of the 4-wire terminating set. Adjust the oscillator to send −8 dBm at the point of connection. The detector reading, corrected

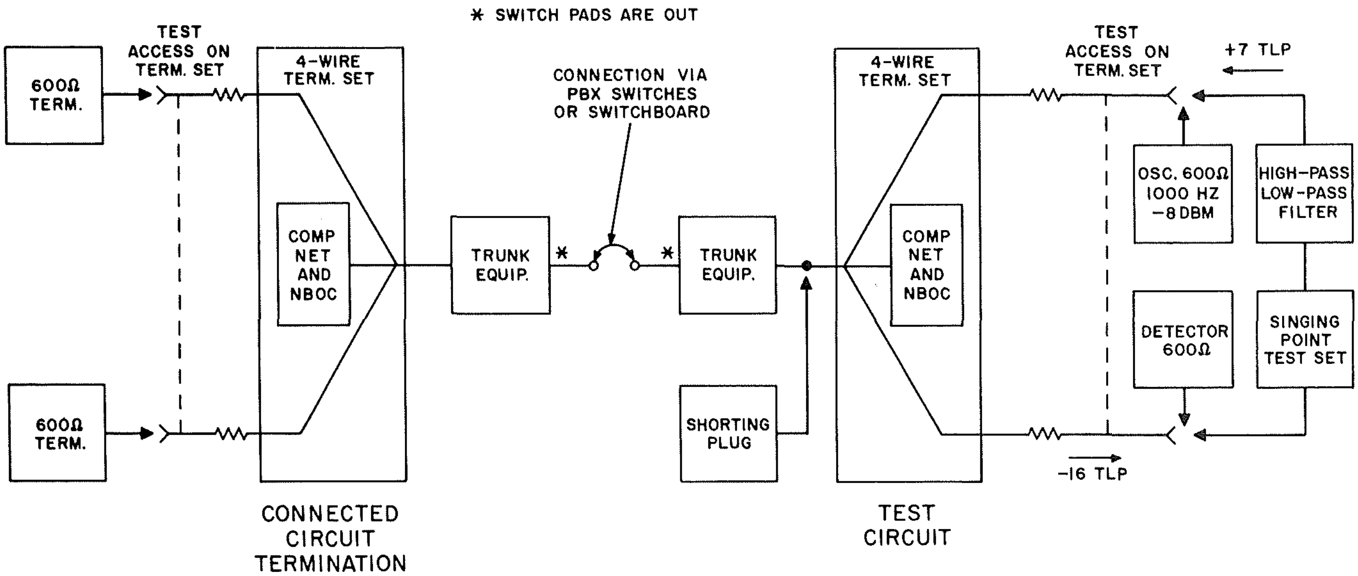


Fig. 32—Typical Through Balance Equipment Arrangements for Singing Point Tests

for the −8 dBm test tone, will be the singing point hybrid correction factor for the circuit under test.

Step 8: Substract the hybrid correction factor (Step 7) from the uncorrected singing point (Step 6). The difference is the singing point for this connection.

Step 9: Repeat the above procedures for all the connections to be tested.

Step 10: Compare the singing points obtained by testing with the through balance objectives in Table K to determine if corrective measures are required.

Echo Return Loss Tests (Fig. 33)

4.16 As in the case of singing point tests, because the echo return loss path includes the loss through the hybrid, the values read on the test set must be corrected by the loss of the hybrid.

4.17 The following procedure, together with the testing arrangement shown in Fig. 33 is suggested when making echo return loss tests:

Step 1: All wiring options for the 4-wire terminating set must be completed including connections of the Compromise Balancing Network and NBOCs as determined in Par. 4.12 of this Appendix.

Step 2: Establish the connection between the ***test circuit*** and the ***connected circuit termination.***

Step 3: Adjust the noise generator for 82 dBrn (−8 dBm) output before connecting to the ***test circuit.***

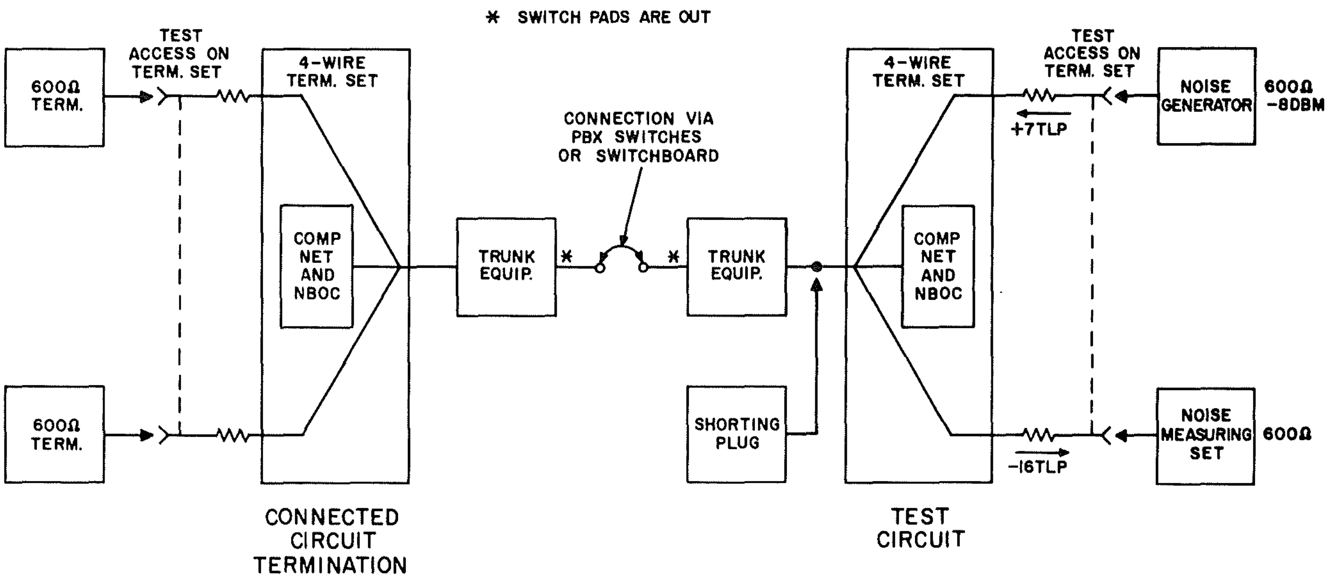


Fig. 33—Typical Through Balance Equipment Arrangements for Echo Return Loss Tests

Step 4: Connect the noise generator and noise measuring set, and terminate in the connected circuit as shown in Fig. 33.

Step 5: Adjust the attenuator associated with the noise measuring set to obtain a reading on the meter. Record this reading, which is the uncorrected echo return loss.

Step 6: Short the 2-wire part of the 4-wire terminating set; repeat Step 5. This noise measuring set reading is the echo return loss hybrid correction factor for the circuit under test.

Step 7: Subtract the uncorrected echo return loss (Step 5) from the hybrid correction factor (Step 6). The difference is the actual Echo Return Loss for this connection.

Step 8: Repeat the above procedures for all the connections to be tested.

Step 9: Compare the Echo Return Loss (Step 7) values obtained by testing with the through balance objectives of Table K to determine if corrective measures are required.

5. TERMINAL BALANCE TESTS

5.01 Terminal balance tests should be made at all PBXs in a tandem tie trunk network which switch 4-wire tie trunks to tandem tie trunks or PBX station lines as discussed in Par. 6.46-6.55 of this Technical Reference. These tests may be made to a representative sample of on-premises PBX stations covering the range of loop lengths. However, all other connections, such as short haul tie trunks or off-premises stations and especially those that are able to switch the 2 dB pad out of the tie trunk, should be tested individually.

5.02 If required, through balance tests should be completed before any terminal balance tests are attempted. The NBOC values determined from the through balance tests are used in all 4-wire terminating sets. At locations where through balance tests are not required and most of the connections are made to short PBX station loops, the best terminal balance will be obtained with the NBOC disconnected. Where it is necessary to use NBOCs to meet terminal balance objectives, the methods outlined for through balance NBOC tests may be used except that connections should be made to representative tie trunk and line terminations.

5.03 The test equipment arrangements shown in Figure 34 and 35 together with the following step-by-step procedures comprise the necessary testing to determine if the circuits tested meet the terminal balance requirements of Table K. It is suggested that terminal balance tests should not be made through the SF unit, but rather at the test access points of the 4-wire terminating set. The 4-wire test access points can be considered approximately +7 and −16 TLPs for the purpose of these tests.

Singing Point Tests (Fig. 34)

5.04 The test procedures for the singing points tests for terminal balance are essentially the same as those previously described for through balance in Par. 4.14 of this appendix. The only difference is that connections from the ***test circuit*** to the ***connected circuit termination*** should be made as illustrated in Figure 34. The results should be compared to the terminal balance objectives given in Table K.

Echo Return Loss Tests (Figure 35)

5.05 The test procedures for the echo return loss tests for terminal balance are essentially the same as those previously discussd for through balance in Par. 4.16-4.17 of this Appendix. The only difference is that connections from the ***test circuit*** to the ***connected circuit termination*** should be made as illustrated in Figure 35. The results should be compared to the terminal balance objectives given in Table K.

6. TEST EQUIPMENT CHARACTERISTICS

6.01 The various types of transmission test equipment used in making loss and balance tests usually have balanced 600-ohm input and/or output impedances which match the impedance seen at the terminating set 2-wire and 4-wire test access points. However, if the terminating equipment has an impedance different from that of the test equipment, it will be necessary to match the impedance before making the loss or balance tests.

6.02 At times it will be necessary to make measurements on circuits requiring a direct current holding bridge for supervision in the 2-wire path through the PBX. When this is necessary, an inductance of at least five henries and a dc resistance of 150 ohms is suggested in the holding bridge. This will make the transmission loss through the bridge negligible at the testing frequencies because of the large inductance and the dc resistance of 150 ohms should not cause marginal supervision in the held circuit. When not internally protected, test instruments can be protected from the dc current by inserting 8 mfd. or larger blocking capacitors in each side of the line between the test circuit and the measuring instruments.

6.03 The following information provides suggested characteristics for the various types of test instruments required:

NOISE GENERATOR (Similar to Western Electric Type 201B)

Frequency range	20 Hz to 20,000 Hz
Output power	0 to −20 dBm
Output impedance	600 ohms balanced
Frequency weighting network	Match frequency characteristics on telephone lines from F1 telephone transmitter (average speech—male talker)

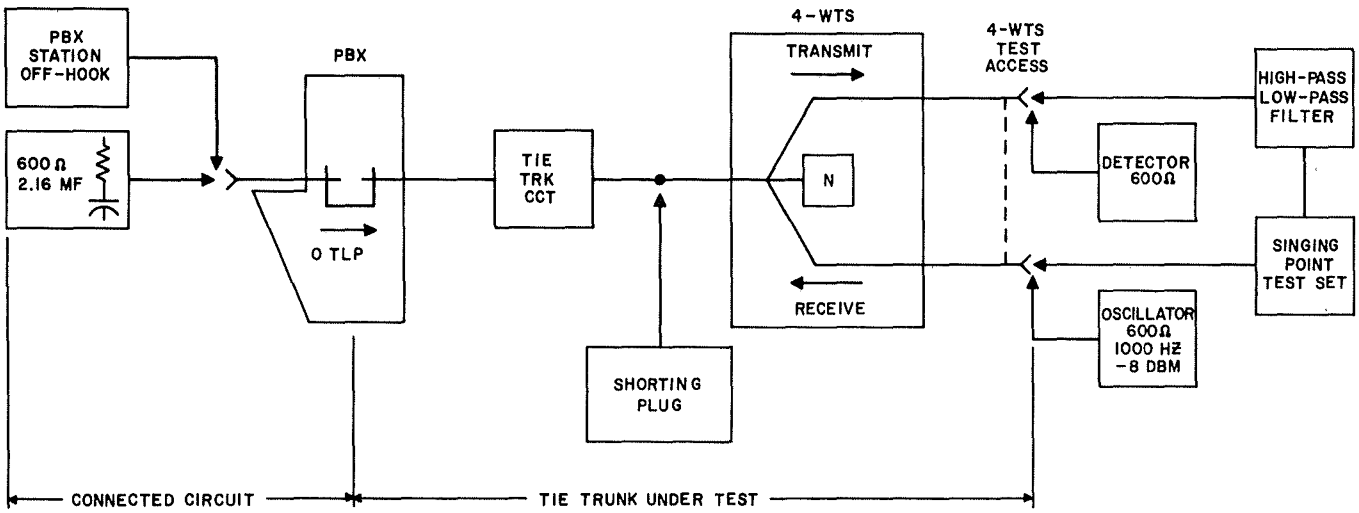


Fig. 34—Terminal Balance—Equipment Arrangements for Singing Point Tests

NOISE MEASURING SET (Similar to Western Electric Type 3)

Reference noise

Range

Input impedance

Frequency weighting network

−90 dBm @ 1000 Hz (ASA standard)

0 to 97 dBrn

600 ohms balanced

C-message and 3 kHz flat

AUDIO DETECTOR (Similar to Western Electric Type 23)

Frequency range

Input impedance

Sensitivity range

Low frequency suppression

200 Hz to 3500 Hz

600 ohms balanced

+10 to −35 dBm

180 Hz, −4.5 dB; 60 Hz, −30 dB

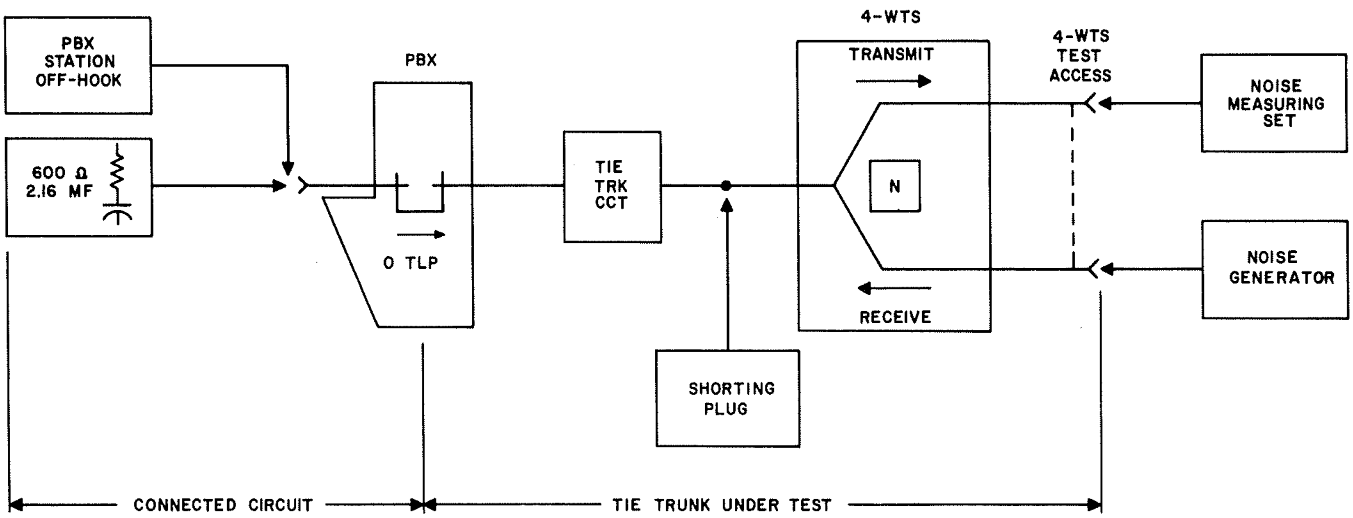


Fig. 35—Terminal Balance—Equipment Arrangements for Echo Return Loss Tests

If the low frequency noise, usually present in battery supplies, is not to interfere with test measurements, it should be 20 dB below the test signal. If additional noise suppression is required, use of a filter having characteristics similar to the one described with the Singing Point Test Set connected at the input to the detector, will provide additional protection.

SINGING POINT TEST SET (Similar to Western Electric Type 2)

Frequency range

Amplification

Input/output impedance

Filters (if not integral part of test set)

200 Hz to 5000 Hz

0 to 60 dB in 1 dB steps (coarse adjustment 10 dB per step)

(fine adjustment 1 dB per step)

600 ohm balanced

Low pass: 3500 Hz limit

High pass: approx. 48 dB @ 180 Hz

approx. 36 dB @ 60 Hz

greater loss than @ 1,000 Hz

AUDIO OSCILLATOR (Similar to Western Electric Type 21A)

Frequency range

Output power

Output impedance

200 Hz to 3500 Hz

0 to −20 dBm

600 ohms balanced

If the low frequency noise, usually present in battery supplies, is not to interfere with test measurements, it should be 20 dB below the test signal. If additional noise suppression is required, use of a filter having characteristics similar to the one described with the Singing Point Test Set connected at the input to the detector, will provide additional protection.

SINGING POINT TEST SET (Similar to Western Electric Type 2)
AUDIO OSCILLATOR (Similar to Western Electric Type 21A

APPENDIX C
METHOD FOR MEASURING INBAND SIGNAL POWER

1. GENERAL

1.01 The following method is suggested for estimating the maximum power averaged over a 3-second interval to determine that the inband criteria given in Par. 4.05 & 4.06 of this Technical Reference are being met. The measurement should be made at the transmitting interface (ie, either O TLP or −16 TLP depending on the option) using a test meter in the bridging mode. For 4-wire options the meter can be bridged directly across the transmitting line. For 2-wire options, the customer-provided equipment should be operated into a 600-ohm load (this assumes that the customer-provided equipment has a 600 ohm impedance) bridged by the test meter. Suggested test meters are a Western Electric 3-type Noise Measuring Set, a Hewlett-Packard Transmission & Noise Measuring Set - Model 3555B, or equivalent.* The controls on each meter should be operated as given in Table M. In almost all cases the speech power averaged over any 3-second interval will not exceed the −13 dBm limit at O TLP (−29 dBm at −16 TLP) if the maximum meter swing does not exceed 80 dBrn 64 dBrn).

*These meters do not have a 3-second averaging time, but ***when used on speech,*** they give a reasonable estimate of a 3-second average.

1.02 The accuracy of this method can be somewhat improved by increasing the size of the damping capacitance in the Western Electric 3A or 3C Noise Measuring Set by 150 micro-farads. To do this, connect the minus side of a 150 microfarad capacitor to either terminal of the NORM/DAMP switch and connect the plus side to ground. This allows the meter to more nearly approximate a 3-second averaging meter. (NOTE: This modification does not necessarily hold for noise meters other than the Western Electric 3A or 3C). With the additional damping, the power averaged over any 3-second interval will not exceed the −13 dBm limit at O TLP (−29 dBm at −16 TLP) if the maximum meter swing does not exceed 78 dBrn(62 dBrn).

TABLE M

CONTROL SETTINGS FOR MEASURING 3-SECOND AVERAGE POWER

WESTERN ELECTRIC 3-TYPE NOISE MEASURING SET		HEWLETT-PACKARD TRANSMISSION & NOISE MEASURING SET — MODEL 3555B	
CONTROL	SETTING	CONTROL	SETTING
FUNCTION (Switch)	BRDG	INPUT (Switch)	NOISE/BRDG
NORM/DAMP (Switch)	DAMP	FUNCTION (Pushbutton)	VF/N_m −600 BAL
WTG (Plug-In Network)	3KC FLAT	NOISE WTG (Switch)	3kHz FLAT
		NORM/DAMP (Switch)	DAMP