

## **Systems Reference Library**

### **Planning and Installation of a Data Communications System Using IBM Line Adapters**

This reference manual contains information on planning and installing data communications systems that use integrated IBM Line Adapters (modems). A brief introduction to data communication and the general purposes and functions of line adapters are presented. Included is technical information applicable to an in-plant, limited distance, user-installed data communications system, and to local facilities of common carriers. Specifications and requirements are provided for each type of IBM Line Adapter, including those intended for limited distance use only, and those designed to operate over unlimited distance, common-carrier lines. Also included is a glossary of terms used in this publication.

For a description of the Switched Network, Automatic Answering, and Automatic Call Origination features of the 1200 Bit-per-Second Integrated Modem, this manual refers to Systems manual *IBM 3872 User's Guide, GA27-3058*.

## Preface

This reference manual contains information, for systems engineers and installation planning engineers, on planning and installing data communications systems that use integrated Line Adapters or Integrated Modems. It includes a brief introduction to data communications and to the purposes and functions of line adapters. Technical information presented includes: specifications for in-plant, limited distance, user-installed systems, specifications and requirements for common-carrier local and unlimited distance facilities, and specifications and requirements for each type of IBM Line Adapter. Prior knowledge of data communications systems is helpful, but not essential.

This manual is organized in chapters, presenting general information in the first three chapters. Chapter 4 gives the specifications of individual line adapters and communications facilities. Descriptions of communications facilities in Chapter 4 include only pertinent specifications. Expanded descriptions of communications facilities can be obtained as follows:

Bell System Data Communications Technical Reference  
PUB41004 *Transmission Specifications for Voice  
Grade Private Line Data Channels* and  
PUB41005 *Data Communications Using the Switched  
Telecommunications Network*, obtainable from:

American Telephone and Telegraph Co.  
Supervisor - Information Distribution Center  
195 Broadway, Room 208  
New York, N. Y. 10007 (USA)

CCITT Recommendation M.102, obtainable from:

International Telecommunication Union  
Geneva, Switzerland

or

United Nations Bookstore  
United Nations Plaza  
New York, N. Y. 10017 (USA)

Chapter 5 contains line-length tables; a glossary of terms used in this publication is included in the Appendixes.

The Limited Distance, Leased Line, and Shared Line Adapters are subdivided into types, with each type having one application and no options. The 1200 Bit-per-Second Integrated Modem has special features and options to equip it for various applications. Therefore, the description of the 1200 bps modem in Chapter 4 includes features and options. Reference is made to Systems manual *IBM 3872 Modem User's Guide*, GA27-3058, for a description of certain features.

### *Sixth Edition (June 1974)*

This is a major revision of, and obsoletes, GA24-3435-4, incorporating changes issued in Technical Newsletter GN27-3117, dated April 6, 1973. This revision also adds information on the Switched Network Backup feature for 1200 bps Integrated Modems.

A change, addition, or deletion to the text or an illustration is indicated by a vertical line to the left of the change.

Changes are continually made to the information herein; before using this publication in connection with the operation of IBM systems. Consult the latest *IBM Teleprocessing/Data Collection Bibliography*, GA24-3089, and associated Technical Newsletters for the editions that are applicable and current.

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## **Planning and Installation of a Data Communications System Using IBM Line Adapters**

This Technical Newsletter provides replacement pages for the subject publication. Pages to be inserted and/or removed are:

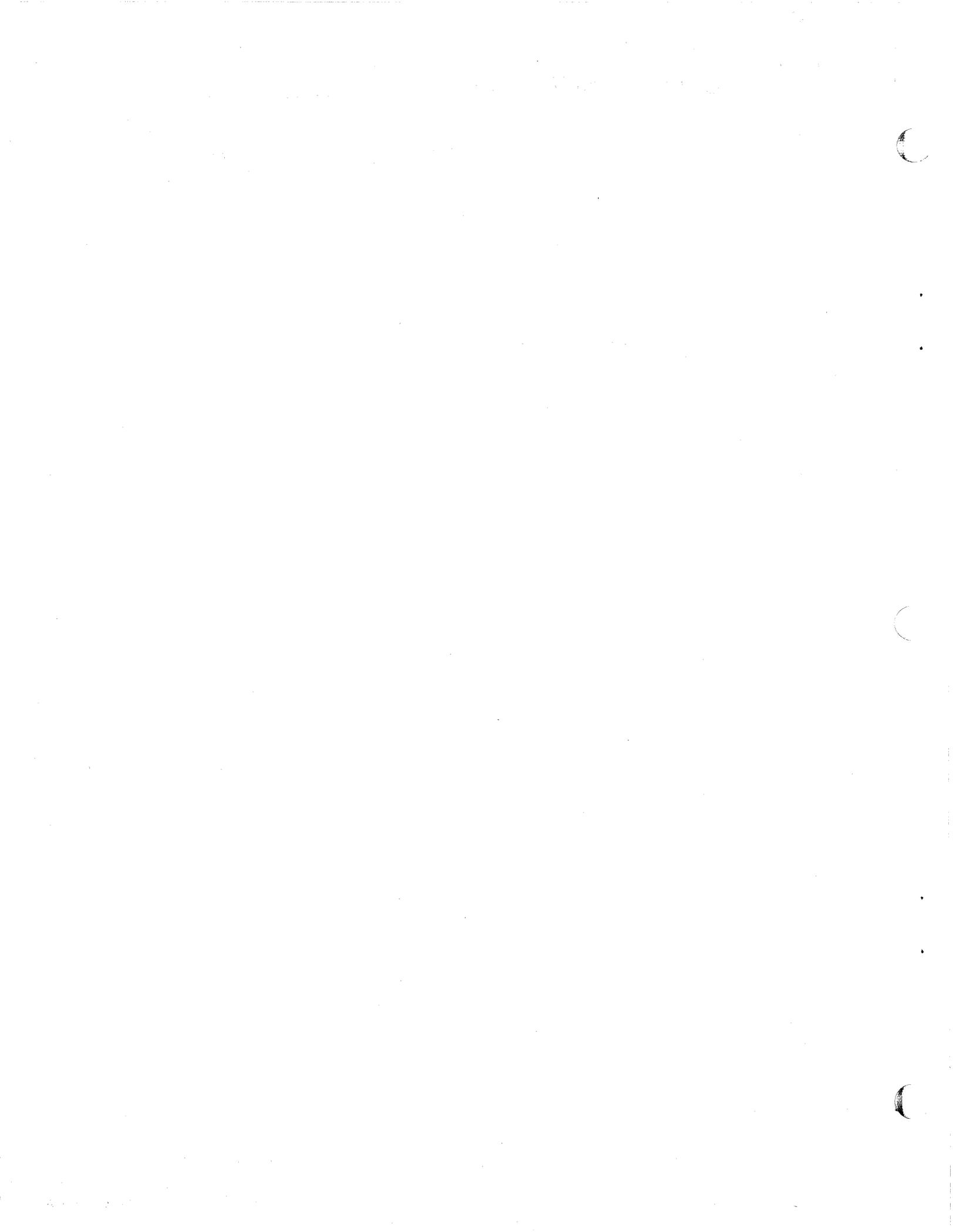
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### **Summary of Amendments**

This Technical Newsletter adds information on World Trade modems and modem features. Also minor changes are made throughout the manual.

*Note:* Please file this cover letter at the back of the manual to provide a record of changes.



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## GENERAL INFORMATION

### Importance of Data Communications

Data communications is currently playing an increasingly important role in the total systems concept of data processing. Distance is no longer a limiting factor to either data collection and dissemination or to the usual input/output functions of data processing systems. Modern techniques allow transmission of data over virtually unlimited distances. Equipment provided by IBM and other manufacturers, together with services made available by communications common carriers in the United States and by Postal Telephone and Telegraph (PTT) administrations in World Trade countries, is rapidly making data communications commonplace.

Data communications is defined as the transmission of information over distances beyond those usually associated with the input/output units of a data processing system. Thus, with a few exceptions, distances from a few hundred feet to thousands of miles are within the scope of this definition. However, numerous types of equipment and facilities are required to transmit data over such wide variations in distance.

### Scope of This Manual

Long distance transmission of data usually requires the facilities of communications common carriers or equivalent privately owned communication networks. A detailed explanation of all types of line facilities and equipment used by common carriers is beyond the scope of this publication. Only IBM Line Adapters used on in-plant or limited distance facilities (customer installed or common-carrier installed) and common-carrier long-haul facilities are considered in this manual.

The subject of data communications is necessarily quite technical. In this publication, complex subject matter is simplified wherever feasible, but the reader should recognize that the need for technical accuracy is a limiting factor to such simplification.

By its nature, human speech is redundant and has many well-defined patterns. For example, the voice of a friend in a roomful of people, can easily be recognized and his words understood, although many people may be talking at once. Data transmission is less redundant and is affected more adversely than voice by certain characteristics of the transmission facilities, such as delay distortion.

This manual discusses such problems of data communications. This introduction emphasizes that, while there are difficulties, proper installation of data communications systems will result in effective operations.

### Why a Modem (Line Adapter) Is Needed

A modem is a device whose primary function is the modulation and demodulation of data signals. An IBM Line Adapter provides these modem functions as part of the circuits of an IBM machine. In this manual, the term "modem" includes IBM Line Adapters and modems (also called "data sets") provided by other suppliers.

Figure 1 shows the binary data bits 1 1 0 1 0 represented as a set of mark and space (on and off) signals. A simple telegraph set using a key, battery, and sounder is capable of transmitting and receiving this data over a short distance at low speed. As distance and speed increase, such equipment cannot function satisfactorily, because the transmitted signal deteriorates with distance. Over long distances, the distortion is so great that the receiving equipment cannot distinguish a binary 0 from a 1.

Commercial telegraph equipment can operate over longer distances and, with regenerative repeater stations, over indefinite distances. But even with such equipment, the speed of data transmission is still limited. At high rates of transmission,

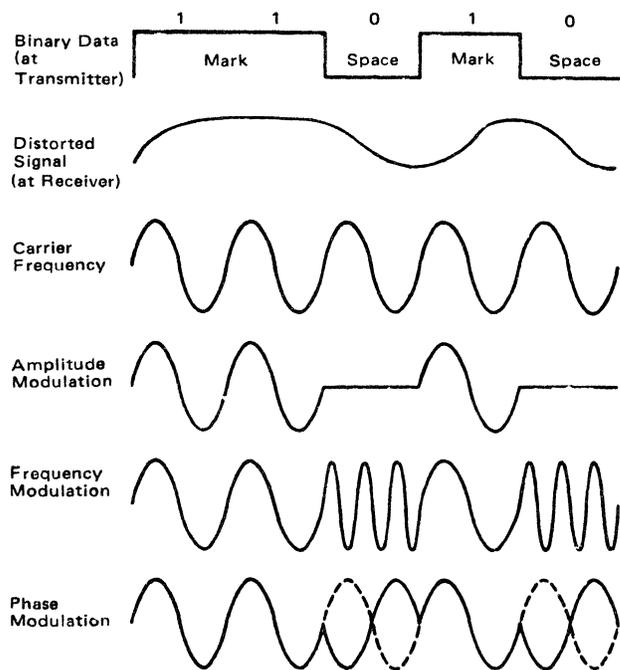


Figure 1. Comparison of Direct Data Transmission and Modulation of a Carrier Frequency

not only is signal distortion present but the electromechanical equipment used cannot respond to the rapid transitions between mark and space signals.

Despite its limitations, commercial telegraph equipment performs many useful functions. However, as data transmission requirements become more demanding, the need for more sophisticated equipment is apparent.

Voice-grade communication channels are designed to transmit ac signals having no average dc component nor any very low frequency components. Data signals often contain such low frequency components, which are not readily passed by voice channels. Therefore, modems are used to provide modulation techniques capable of passing low frequency ac or dc signals for data transmission.

### Modulation Techniques

The on and off (mark and space) signals (shown at the top of Figure 1), as such, can be transmitted only over limited distances. If these signals are used to modulate a carrier frequency, transmission distances can be increased considerably.

Several methods of modulation are currently used. For example, commercial radio stations employ either amplitude modulation (AM) or frequency modulation (FM). Television stations use both forms of modulation, amplitude for the picture and frequency for the sound. Another method is phase modulation, which is often used for data transmission rates higher than those of the IBM Line Adapters discussed in this manual.

The IBM Line Adapters discussed here employ frequency shift keying (FSK), a form of frequency modulation in which only two carrier frequencies are alternately transmitted. For example, a frequency of 1000 Hz can represent a mark signal; 2200 Hz, a space signal. The transmitting line adapter shifts between these two frequencies as mark and space signals are transmitted. The receiving line adapter reverses the process, demodulating or converting the incoming frequencies to the original mark and space signals.

### Transmission Impairments

“Perfect” transmission implies that a signal is transmitted over a line or through some transmission medium and arrives, unchanged, at the receiving device a short time later. A digital data signal being transmitted, although at any instant considered a single tone or frequency as in an FSK modem, can actually be resolved into several component frequencies, all being transmitted simultaneously.

If some of the component frequencies are attenuated more than others or are delayed by the transmission medium longer than other frequencies, or if some unwanted signals are introduced, the signal is changed--transmission is impaired. Attenuation or amplitude distortion, delay distortion, and noise have been described just above and are examples of transmission impairments. Transmission impairments occur in all actual transmission systems to some degree.

Impairments limit transmission speed because they affect higher-speed signals more severely than lower-speed signals. Maximum speed of data transmission, however, is basically limited by the frequency bandwidth available to the system. Transmission impairments are described in the following text, in more detail, under “Planning a Limited Distance Communications System” and “Planning an Unlimited Distance Communications System.”

## PLANNING A DATA COMMUNICATIONS SYSTEM

Effective performance of any data communications system depends largely on *careful, advance* planning. Among the factors that should be considered are:

- Present and anticipated functional requirements.
- Selection of the proper IBM equipment to fulfill these needs.
- Determination of available facilities, other than IBM equipment.
- Additional facilities that must be installed.
- Allowance for future system growth.

### Functional Requirements

Each data communications system has different functional requirements. It may be a simple point-to-point operation within one building. It may be a multipoint operation among several buildings in the same area or in the same city. If many messages must be handled, often simultaneously, a large realtime data communication and processing system employing multiple long distance communications lines may be required. Careful analysis of each user's needs, by the customer and the IBM system specialist, results in the best system for each application.

### Physical Facilities

IBM offers many types of data communications equipment, each designed to meet a specific need. Chapter 4 describes the IBM Line Adapters available for use with various IBM equipment.

In addition to functional specifications, physical factors must be considered in planning a data communications system and selecting specific components. For example, maximum lengths of transmission line (for limited distance line adapters) and the number of points (drops) to be connected can be significant factors in arriving at a proposed system configuration.

A limited distance communications system, described in Chapter 2, is generally considered for distances of up to 8.25 miles (13.1 km) and is sometimes referred to as an “in-plant” system. The communications line for limited distance may be customer-owned or installed, existing common-carrier installed, or newly installed by a common carrier--the latter two cases being called “special assemblies” by common carriers.

An unlimited distance communications system, described in Chapter 3, often uses lines leased from, and maintained by, common carriers. They provide a communication service among points in the system, as required by the customer's configuration. Thus, this service may include circuits that may be changed, at any time, at the discretion of the common carrier.

#### **Future Expansion**

Many data transmission systems are expanded after their original installation. This expansion may include the addi-

tion of communications facilities to new locations, the addition of new remote terminals to existing lines, or the installation of entirely new facilities. The cost of installing transmission lines usually far exceeds the cost of materials (such as wire, conduit, and junction boxes). For this reason alone, spare facilities for future growth should be provided. The additional cost will be more than repaid when the system is expanded. Furthermore, such spare facilities can be useful for line testing, fault location, and for rapid replacement of bad lines. In some cases, it may be desirable to use a spare line for voice communications.



### BASIC CONSIDERATIONS

A limited distance communications system, in this manual, is one for distances of up to 8.25 miles (13.1 km), and it is sometimes referred to as an "in-plant" system. (See Chapter 4, "Types of IBM Line Adapters," and Figure 29 for information on distance ratings of IBM Line Adapters.)

The communications line may be either customer owned or common-carrier owned. Ownership of existing lines may be a determining factor in selecting the equipment to be used with the system. Certain basic restrictions apply to these two types of lines:

- Common-carrier lines are usually required where it is necessary to cross a public right-of-way. In some European countries, this restriction also applies to real estate property lines.
- Common carriers normally do not allow connection of customer owned lines to their lines.
- IBM Limited Distance Line Adapters may be used with either customer or common-carrier owned lines, but if common-carrier owned, the lines must not be connected to the common carrier's public exchange service and must be nonloaded, with no repeat coils or repeaters.
- IBM Leased Line and Shared Line Adapters, though designed primarily for use on leased, relatively long-haul facilities, can be used for a limited distance system, using either customer or common-carrier owned, in-plant facilities. The principal reason for using an unlimited distance type of IBM Line Adapter is for an out-of-plant location which is a part of the system. Such a system should then be considered an unlimited distance system, as described in Chapter 3.
- IBM line adapters and common-carrier data sets cannot be mixed on an individual channel.
- IBM line adapters cannot be mixed on a limited distance channel. (Example: Mixing Types 1 and 2 Limited Distance Line Adapters or mixing Limited Distance Line Adapters with Leased Line Adapters.)

### Signal Attenuation

On limited distance lines, the distortion experienced with direct transmission of signals is virtually eliminated with frequency-shift keying. When no amplification is used, which is the case with limited distance systems, the maximum transmission distance is limited by another factor, signal attenuation. As distance increases, the transmitted signal becomes weaker, until its amplitude falls below the threshold of the receiving line adapter.

Attenuation is measured in decibels and is determined primarily by the quality of wire or cable used. But it is

also affected by the electrical loading of the transmission line (the loading is a function of the number of branch or radial lines used and the number of line adapters connected to these lines.) The line-length tables in Chapter 5 are for IBM Limited Distance Line Adapters and were calculated with maximum allowable signal attenuation as the determining factor.

### Crosstalk and Noise in Physical Lines

Crosstalk and electrical noise are also important factors that affect the operation of a data communications line. Crosstalk is the presence of unwanted signals on a line, produced by signals on other lines adjacent to it, such as in the same cable. Common carriers specify a maximum signal level to be used on their lines, to limit crosstalk to adjacent lines.

Crosstalk is a subdivision of noise and is usually discussed separately, because it can be recognized easily and its causes are well understood. Noise is a more general term; it is used to describe the sum of all unwanted signals on a line. It includes all sources, both internal and external to the line.

Crosstalk and noise are undesirable because they interfere with desired signals and may be detected by the receiving line adapter as actual data signals if no desired signal is on the line. The quality of cable used for transmission line is the most significant factor in reducing crosstalk. Proper shielding of the cable and routing it away from certain types of electrical equipment are usually effective in reducing electrical noise to a tolerable level.

Other factors that should be considered in the installation of an in-plant data communications system are discussed later in this chapter. However, it is apparent that the selection of high-quality wire and cable facilities and careful installation are most important.

### Line Facilities

At many sites, lines may be already available for use in a data communications system. Installed wiring, owned either by the customer or by a common carrier, may be quite acceptable. The common carrier may furnish such facilities as a "special assembly." Line testing (performed by IBM for existing customer owned lines) is required, to determine whether or not existing wiring can perform satisfactorily.

For many systems, additional wiring must be installed; existing wiring was usually installed for other purposes, such as for a telephone or an intercom system. While previously installed wiring must be accepted "as is," in most cases new wiring can be installed to meet system requirements. Thus, it is important to plan such wiring well in advance of actual installation, making allowance for unforeseen circumstances.

*Note: In common-carrier language, a "main line" is the line from a main station (as distinguished from an extension station) on a customer's premises to the local telephone exchange.*

### SYSTEM CONFIGURATIONS

Data communication over limited distances, with either customer-installed wiring or local common-carrier wiring, can use one of three basic system configurations: a simple point-to-point line, a main line with multipoint branches or side legs, or a radial configuration. Figure 2 shows the schematics of these configurations.

Each remote terminal location can be represented by an IBM Line Adapter because the line adapter controls all characteristics of the signal on the communications line. Each type of configuration has certain limitations. The type of line adapter used, the maximum line lengths, the number of branch or radial lines, and the number of line adapters on each line are all interdependent. The inter-dependency of these factors may tend to limit the selection of a system configuration.

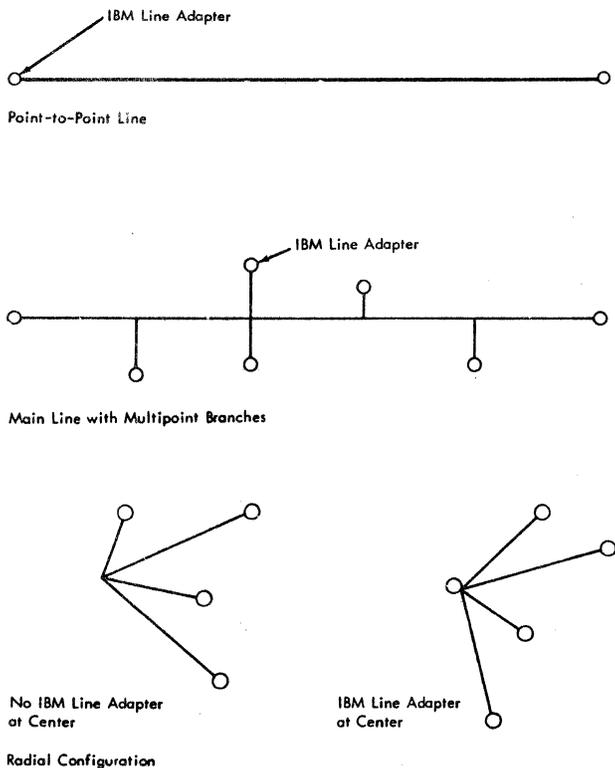


Figure 2. Data Communications System Configuration

### A Typical Limited Distance System

Figure 3 shows, in simplified form, a typical limited distance data communications system using IBM Line Adapters. A number of remote terminals are connected to the central processing unit of a computer through a transmission control unit. Three types of limited-distance communications line configurations are illustrated: a point-to-point main line, a multipoint main line with branch lines, and a group of radial lines. Any one of these configurations can be used in a data communications system.

Each remote terminal contains an IBM Line Adapter that connects the terminal to a communications line. The transmission control unit contains a number of line adapters, one for each communications line connected to it. For the radial configuration, the radial lines connect to a junction box that, in turn, is connected to a line adapter in the transmission control unit. Certain limitations are imposed on each type of communications line configuration. These include the maximum line lengths, the maximum number of branch or radial lines, and the maximum number of line adapters connected to a line.

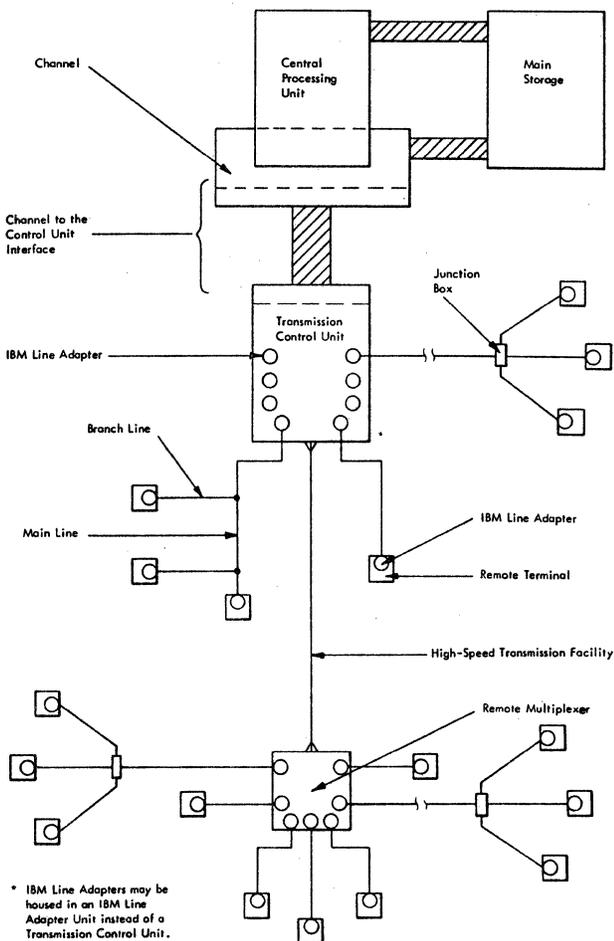
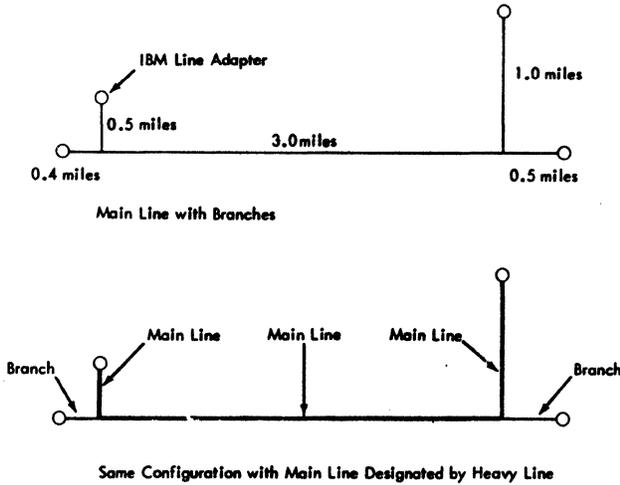


Figure 3. Simplified Schematic of a Data Communications System

### Definition of a Main Line

For a multipoint facility with branches, the main line is defined by the two most widely separated line adapters. Figure 4 illustrates this principle. When another branch is added to a main line, it may be necessary to redefine the main line. For example, Figure 5 shows how an added branch can become part of a new main line, while a section of the former main line becomes a branch.



Metric Conversion Table	
Miles	Kilometers
0.2	0.3
0.3	0.5
0.4	0.6
0.5	0.8
1.0	1.6
2.0	3.2
3.0	4.8
5.2	8.4

Figure 4. Definition of a Main Line

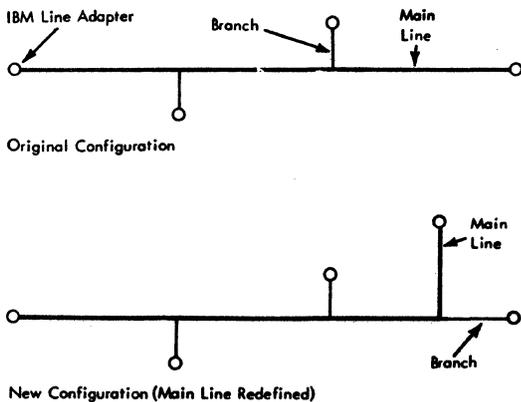


Figure 5. Redefinition of a Main Line

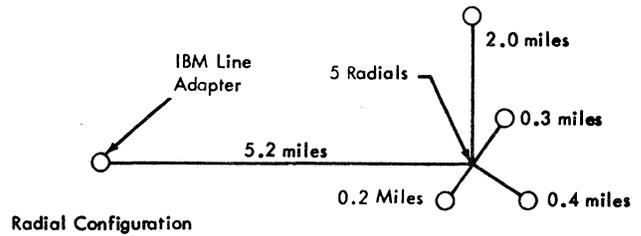
### Radial Configuration

The radial configurations shown in Figure 2 differ only in the use of a line adapter at the center of the configuration. The central line adapter can be considered to be connected to a radial of zero length. Note that a radial configuration is actually a special case of a main line with branches. The two most widely separated line adapters define the main line, and the remaining line adapters are connected to branch lines attached at a common point on the main line. Figure 6 illustrates this principle, showing a configuration of five radial lines, redefined as a main line with three branches.

Radial configurations cannot be used with all types of line adapters. The Limited Distance Line Adapter Type 1 can be used only in systems capable of being served by a main line with branch lines up to 50 feet (15 meters) in length.

### Some Exceptions

Branch lines cannot be connected to other branch lines or to radial lines. In a system using the Limited Distance Line Adapter Type 1, branch lines cannot be longer than 50 feet



Radial Configuration

Same System Considered as Main Line with Branches Configuration

Metric Conversion Table	
Miles	Kilometers
0.2	0.3
0.3	0.5
0.4	0.6
0.5	0.8
1.0	1.6
2.0	3.2
3.0	4.8
5.2	8.4

Figure 6. Main Line Equivalent of a Radial Configuration

(15 m). However, in a system using the Limited Distance Line Adapter Type 2A or 2B, a branch line less than 200 feet (61 m) long can be considered to be of zero length. Therefore, such a line does not violate the general rule; it is considered to be the same as adding another line adapter to an existing branch or radial line. Normally, up to three zero-length lines are allowed per branch.

For unlimited distance data communications (described in Chapter 3) over common-carrier, leased private lines and radio links using amplifier or repeater stations, system configurations need not concern the user. The communications lines are designed and installed by common carriers to meet their specifications and user requirements.

### TYPES OF WIRE AND CABLE

Three types of wire and cable are recommended for customer-installed data communications lines. Listed in order of desirability, these are:

- Outside-type telephone exchange-area cable
- Inside-type telephone cable

*Note:* If it is a new installation, (1) conduit is recommended for shielding, or (2) if conduit cannot be used, outside-type cable with its own integral shield should be used.

- Shielded, single twisted-pair (audio or sound system cable).

See "Wire and Cable Specifications" following in this chapter for a detailed description of wire.

The relative desirabilities of these types of wire and cable are determined primarily by their maximum signal attenuation and susceptibility to crosstalk and noise. These factors are, in turn, functions of the quality of materials and techniques employed in manufacture. Because the user has no control over manufacturing, he should select the best quality of wire and cable consistent with each specific application.

### Primary Constants of a Communications Line

Four primary constants and one derived secondary constant are commonly used to describe the electrical characteristics of a communications line. These constants are stated for a specified line length, temperature, and signal frequency, usually one mile (1.6 km) at 68°F (20°C) and 1000 Hz. Figure 7 shows an equivalent circuit for a communications line to clarify the meaning of these primary constants:

- R: Resistance in ohms per loop mile (two miles of wire or the resistance of a pair of wires one mile long and shorted together at the far end)
- G: Conductance in siemens (reciprocal of ohms) per mile, between two wires of a pair
- L: Inductance in henries per mile
- C: Capacitance in farads per mile, between two wires of a pair

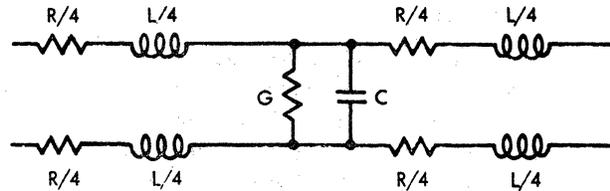


Figure 7. Equivalent Circuit for a Communications Line

For practical purposes, the units used to express these constants are often modified. Thus, G is expressed in microsiemens (one-millionth siemen), L in millihenries (one-thousandth henry), and C in microfarads (one-millionth farad). However, these modified units are not consistent for calculations in which they are used. Conversion to ohms, siemens, henries, and farads must always be made before substituting numeric values, in any equations or formulas.

An equivalent circuit is not an exact representation of the physical circuit. For example, Figure 7 shows the communications line primary constants in lumped form, although they are actually distributed along the line in the form of an infinite number of values. However, for the purposes of this manual, an equivalent circuit is satisfactory.

### Attenuation Constant

The primary constants of a transmission line are used to calculate the secondary constant  $\alpha$  that specifies signal attenuation per mile.

$$\text{Where: } \alpha = \sqrt{\pi fRC}$$

- $\alpha$  is attenuation in nepers\* per mile.
- f is signal frequency (usually 1000 Hz).
- R is resistance in ohms per loop mile.
- C is capacitance in farads per mile.

\*Nepers can be converted to decibels by multiplying by 8.686.

*Note:* If R and C are per loop kilometer and per kilometer, respectively, then  $\alpha$  will be in nepers per kilometer.

The conductance G and inductance L have been omitted from the formula for attenuation constant  $\alpha$ . Their effect is negligible at voice frequencies, and they usually are not specified, except for the highest grade of cable, such as that used for television transmission.

### Wire and Cable Specifications

Figures 8 through 10 give specifications for recommended types of wire and cable, to allow substitution of equivalent types when necessary, although such substitution should be made with caution.

Deviations from established specifications are to be expected and can actually improve transmission characteristics. For example, if resistance, capacitance, or con-

ductance is lower than specified, or if inductance is higher than specified, a lower value for attenuation constant  $\alpha$  results. This allows increased communications line lengths or more line adapters, or both.

A higher value for  $\alpha$  than specified for an approved type of wire or cable must be accompanied by a reduction in calculated or tabulated maximum line lengths, according to the formula:

$$\text{New line length} = 0.75 L_t \frac{\alpha_t}{\text{actual } \alpha}$$

Where:

$L_t$  = line length in table

$\alpha_t$  = attenuation constant used in table (see constants in Appendix A)

$\alpha$  = attenuation constant for wire being considered

Where: the actual  $\alpha$  cannot be more than 1.3 times  $\alpha_t$

<ol style="list-style-type: none"> <li>Multiple twisted pairs assembled to minimize crosstalk.</li> <li>Conductor material: solid annealed copper</li> <li>Conductor sizes: 22, 24, or 26 AWG (gauge)</li> <li>Conductor insulation: color-coded polyethylene</li> <li>Shield: aluminum or copper</li> <li>Sheath or jacket: heavy polyethylene</li> <li>Primary and secondary constants per mile at 68°F (20°C) and 1000 Hz for each wire gauge:</li> </ol>			
	<u>22AWG</u>	<u>24 AWG</u>	<u>26AWG</u>
R (ohms):	171	274	440
G (microsiemens):	2.0	2.0	2.0
L min. (millihenries):	0.75	0.75	0.75
C (microfarads):	.083	.083	.083
$\alpha$ nominal (decibels):	1.80	2.32	2.86
Specifications conform to U. S. Department of Agriculture Rural Electrification Administration Specification PE-22			

Figure 8. Specifications for Outside-Type Telephone Exchange-Area Cable

<ol style="list-style-type: none"> <li>Multiple twisted pairs assembled to minimize crosstalk.</li> <li>Conductor material: solid annealed copper</li> <li>Conductor sizes: 22 or 24 AWG (gauge) *</li> <li>Conductor insulation: color-coded polyvinyl chloride</li> <li>Shield: none (should be run in metal conduit)</li> <li>Sheath or jacket : polyvinyl chloride</li> <li>Primary and secondary constants per mile at 68° F (20°C) and 1000 Hz for each wire gauge:</li> </ol>		
	<u>22 AWG</u>	<u>24 AWG</u>
R (ohms):	171	274
C (microfarads):	0.136	0.136
$\alpha$ (decibels):	2.36	2.97
* 26-gauge inside type telephone cable has not been included because it is not generally an "off-the-shelf" item from domestic cable manufacturers.		

Figure 9. Specifications for Inside-Type Telephone Cable

<ol style="list-style-type: none"> <li>Conductor material: solid or stranded annealed copper.</li> <li>Conductor sizes: 22AWG (gauge) or larger*</li> <li>Conductor insulation: not specified - must satisfy local electrical codes.</li> <li>Shield: tinned copper braid, tinned copper tape, or foil with drain wire.</li> <li>Jacket: not specified - must satisfy local electrical codes.</li> <li>Drain wire (if used): solid or stranded bare or tinned copper.</li> <li>Primary and secondary constants per mile at 68°F (20°C) and 1000 Hz for 22AWG:</li> </ol>	
R (ohms):	200.
C (microfarads):	0.3
$\alpha$ (decibels):	3.77
Note: No industry standard has been established for these specifications * 24- and 26-gauge wire are not recommended for use in a data communications system.	

Figure 10. Specifications for Shielded Single Twisted-Pair Wire (Audio or Sound System Cable)

## INSTALLATION CONSIDERATIONS

Selecting the best system or communications line configuration for a specific application depends upon a number of factors:

- The number of terminals required and the location of each is determined by functional requirements, limited only by maximum communications line lengths and electrical loading allowed for the specific equipment and facilities used.
- The choice of a main line with branches or a radial configuration depends upon which system offers the best transmission characteristics, once terminal locations have been established. When existing wiring is used, the physical cable layout may well determine the configuration.
- The use of point-to-point or multipoint lines depends primarily upon anticipated message traffic. Transmission distances between terminal locations and the reliability required are also important.
- Physical impediments (such as building locations or the need for crossing right-of-way) influence the facilities used, including the need for common-carrier provided facilities.
- The presence of previously installed wiring, or conduit in which new wiring can be run, can reduce the cost of installation, but this may restrict the installation to a specific configuration. The use of any existing facilities depends upon testing by IBM to ensure their suitability.
- Communications lines should be routed away from equipment and its associated wiring, which is prone to producing electrical noise. Examples of such equipment include fluorescent lights, arc welders, diathermy machines, and induction-heating devices. The effects of noise are reduced by shielding the cable (or for unshielded cable, running it in a conduit) and by proper system grounding.

## Simulating a Line Adapter

When planning a data communications system, provision should be made for future expansion. Wiring installed to remote terminals planned for future installation should be tested at the same time as the wiring intended for immediate use. This requires that each terminal location be equip-

ped with an IBM Line Adapter or its equivalent. Figure 11 shows the configuration of an initial system and planned additions to the system.

Line adapters that are not to be installed initially can be simulated by a resistor whose size depends upon the particular line adapter used. Such a resistor is frequently described as a dummy load. The value of resistance used for a dummy load for a given type of unlimited distance line adapter is given in Chapter 4.

If the additional wiring is to remain in the circuit during actual use of the system, this resistor must also be left connected. This ensures that transmission conditions present during the testing period are maintained during operation of the system.

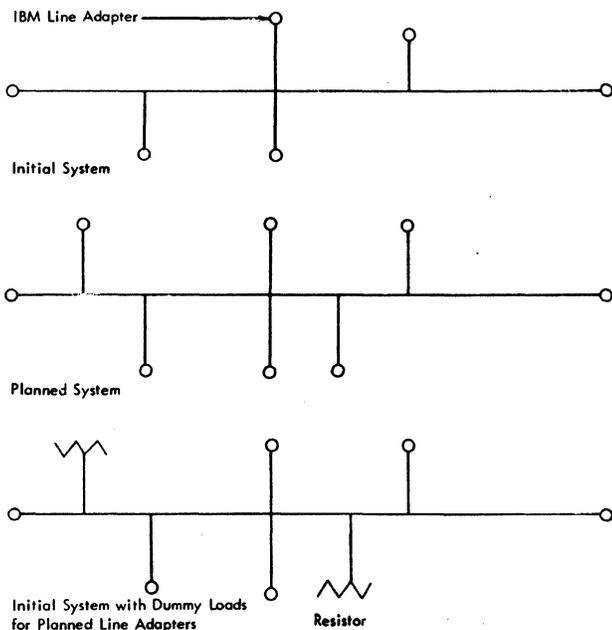


Figure 11. Simulating a Line Adapter with a Dummy Load

### Line Termination

Line termination (equalization with resistance and inductance) can be required at selected points in a data communications system. The need for such termination and the exact values of the resistance and inductance used depends upon the type of configuration (main line with branches or radial) and the type of line adapter.

In some IBM communication terminals, this equalizing network is incorporated within the equipment. Other terminals use a wall-mounted line-terminator box, such as that shown in Figure 12. When planning a system that requires line-terminator boxes, provide for mounting the boxes at remote terminal locations, and include those intended for future use.

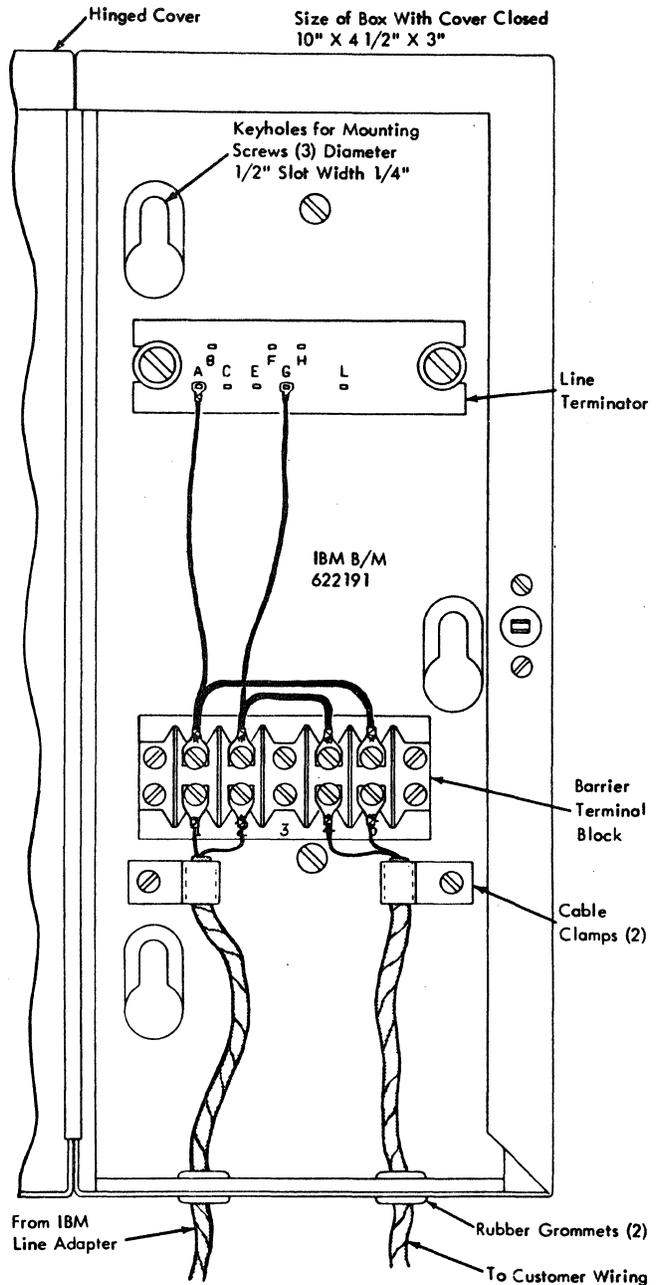


Figure 12. Line Terminator Box

### Crosstalk

Crosstalk between pairs of wire in a multipair cable can have serious effects on data communications. Crosstalk is largely determined by the capacitance between pairs of wire in a cable. Higher capacitance increases crosstalk susceptibility. Crosstalk effects should be negligible if the recommended type of cable is used, but even with recommended cable, certain restrictions apply to other types of signals in the

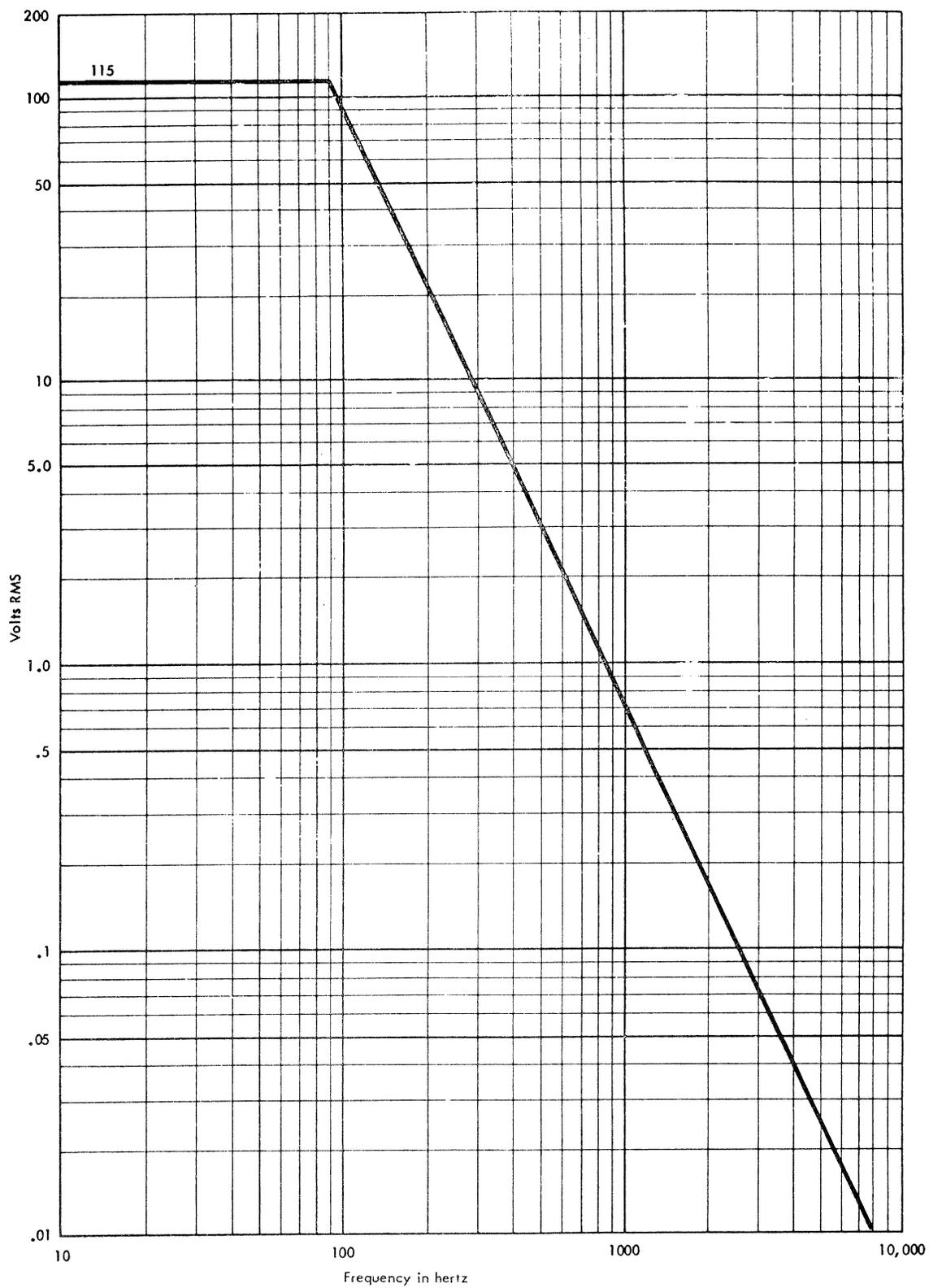


Figure 13. Maximum Single-Frequency Voltage Permissible in Multipair Cable

same cable. These restrictions are similar to those established by common carriers:

- All pairs of wire in a cable should be balanced to ground. That is, neither conductor of the pair should be grounded nor should ground (earth or shield) be used as part of the signal circuit.
- The maximum allowable current in any pair of wires is 0.35 amperes (rms).
- Figure 13 shows the maximum single-frequency rms voltage allowed on any pair of wires. These values should be reduced to 20% for any unbalanced circuits.
- Complex (multiple-frequency) signals should not have a time rate-of-change exceeding  $5.0 \times 10^3$  volts per second ( $1.0 \times 10^3$  for unbalanced circuits).

The time rate-of-change of a single-frequency signal is easily calculated, but multiple-frequency signals are more likely to cause crosstalk. For example, direct-current pulses produced by certain electrical equipment contain multiple high-frequency components. Special equipment is required to measure the time rate-of-change of such signals.

When other than recommended types of cable are used, susceptibility to crosstalk can be determined only by testing, usually under actual installation conditions. Unsatisfactory results from such tests can entail considerable additional expense. For this reason alone, only recommended types of cable should be used.

#### Calculation of Maximum Line Lengths

When planning a data communications system, the lengths of main lines, branches, and radials must not exceed the maximum allowable lengths specified in the length tables. These tables are derived by calculations that take into account the type and number of line adapters in the system, the types of wire and cable used, the configuration, and the number of branch and radial lines. Four sample calculations illustrate use of the length tables.

Figure 14 shows a main line with branches, using IBM Limited Distance Line Adapter Type 1.

- **Description of System**  
*Line Adapters:* Limited Distance Line Adapter Type 1  
*Number of Line Adapters:* Seven (one at each end of main line and one on each branch line)  
*Main Line:* 22-gauge, inside-type telephone cables  
*Branch Lines:* Five (each 50 feet or 15 meters long, maximum allowable)
- Using the length table (Figure 40), the maximum aggregate length of the main line and branch lines is 2.25 miles (3.62 km).
- Deduct the aggregate length of the five branch lines, 250 Feet (0.13 km).

The maximum allowable length of the main line is 2.20 miles (3.49 km).

Figure 15 shows a main line with branches using IBM Limited Distance Line Adapter Type 2.

- **Description of System**

*Line Adapters:* Limited Distance Line Adapter Type 2

*Number of Line Adapters:* Nine (one at each end of main line and one, two, or three on each branch line)

*Main Line:* 24-gauge, inside-type telephone cable

*Branch Lines:* Four of single twisted-pair

- Assume that all branches are the same length as longest branch; for example, 0.2 miles (0.3 km).
- Assume the same number of line adapters on all branches and at the ends of the main line as the largest number of line adapters at any one point (in this example, three).
- Using the key to tables (Figure 41), refer to Table III-B-2 (Figure 44).

The maximum length of the main line is 3.0 miles (4.8 km).

*Note:* When using the Limited Distance Line Adapter Type 2, it is not necessary to subtract the side lengths from the main line length.

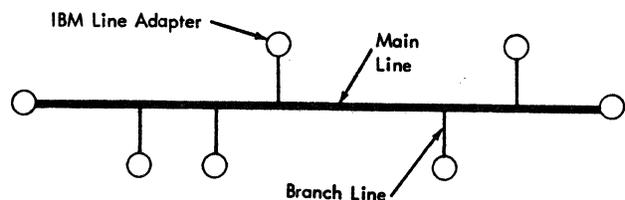


Figure 14. Main Line with Branches, for Sample Calculations Using IBM Limited Distance Line Adapter Type 1

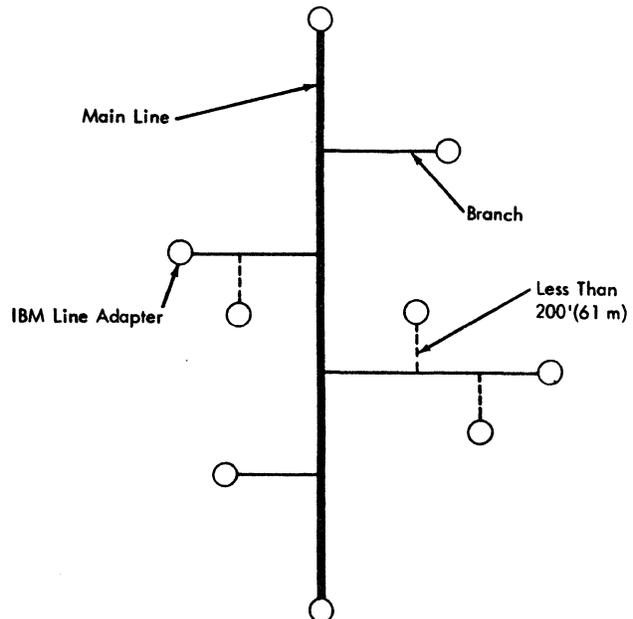


Figure 15. Main Line with Branches, for Sample Calculations Using IBM Limited Distance Line Adapter Type 2

Figure 16 shows a radial configuration, using IBM Limited Distance Line Adapter Type 2.

- **Description of System**

*Line Adapters:* Limited Distance Line Adapter Type 2

*Number of Line Adapters:* Ten (one, two, or three on each radial)

*Radials:* Six of 22-gauge, outside-type telephone exchange-area cable

- Assume the same number of line adapters on each radial as the largest number of line adapters on any radial (in this example, three).
- Using the key to tables (Figure 41) refer to Table IV-A-1 (Figure 45). The average length of all radials cannot exceed 2.75 miles (4.4 km). The maximum length of any radial is 4.0 miles (6.4 km), which is the maximum average length for two radials.

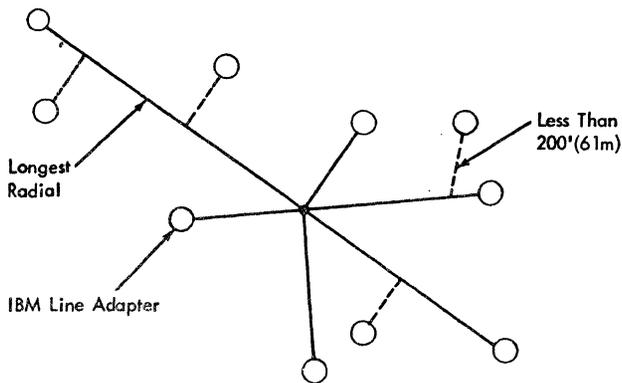


Figure 16. Radial Configuration, for Sample Calculation Using IBM Limited Distance Line Adapter Type 2

Figure 17 shows a main line with branches, using IBM Limited Distance Line Adapter Type 2 on loaded lines.

- **Description of System**

*Line Adapters:* Limited Distance Line Adapter Type 2

*Number of Line Adapters:* Six (distributed on branch lines)

*Main Line:* 24-gauge, outside-type loaded telephone exchange-area cable

*Branch Lines:* Three (two on one end of the main line and one at the opposite end)

- Assume the same number of line adapters on each branch line as the largest number of line adapters on any branch (in this example, three).
- Using the length table for loaded lines (Figure 46), note that the maximum length of the main line is 3.5 miles (5.6 km).

No tables are shown for 26-gauge, inside-type telephone cable or for 24- and 26-gauge, single twisted-pair wire.

These are not recommended for use in a data communications system. The 26-gauge, inside-type telephone cable is not included, since it is not usually a domestic "off-the-shelf" item. The 24- and 26-gauge, single twisted-pair is not recommended, because its high attenuation would seriously limit line lengths.

The length tables for the IBM Limited Distance Line Adapter Type 2 allow for certain simplifications and approximations.

- The values in the tables allow for a safety factor. Therefore, the length of each branch in a main line system can be assumed to be equal to the average length of all branches, rather than to the length of the longest branch, as in a previous example.
- For the same reason, the number of line adapters on each branch or radial can be assumed to be equal to the average number of line adapters, rounded to the next higher number.
- If these modified rules still do not permit the proposed system to meet the line-length limits, a better grade facility or larger gauge of line should be used, or the system should be split into two separate systems.

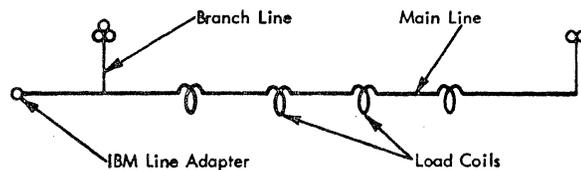


Figure 17. Main Line with Branches, for Sample Calculation Using IBM Limited Distance Line Adapter Type 2 on Loaded Line

### Testing Existing Lines

Previously installed wiring should be tested before it is used in a system. The duration of the tests should be sufficient to ensure experience with all line operating conditions that would be encountered in the future. Arrangements may be made to have existing user-owned facilities for limited distance systems tested by IBM, or the user may perform the tests. Common-carrier-provided, in-plant and out-of-plant facilities are the responsibility of, and should be tested by, the common carrier. If existing wiring is to be used with newly installed wiring, completion tests should be performed, as described at the end of this chapter.

A successful test of existing wiring is indicative of future satisfactory operation only if conditions at the time of the test are maintained. If electrical equipment is added or if the power wiring is changed or if new signals are added to multipair cable, a previous test can no longer be considered valid.

## INSTALLATION STANDARDS

Proper installation of a data communications system (both inside and outside of buildings) requires adherence to certain minimum standards, which are different for domestic installations and World Trade installations. In the United States, these standards are frequently specified in local building and electrical codes. In World Trade countries, each country has its own codes.

The National Electrical Code (specifically, Articles 725 and 800) may be used where local codes do not take precedence. IBM Line Adapters meet the requirements of a class 2, low-voltage signal circuit as defined in Article 725. Maximum possible voltage is well under 15 volts ac rms on transmission lines connected to the line adapter, and no direct current is produced. The line-adapter transformer satisfies the requirement for a current-limiting device. When the 1200 bps Integrated Modem has the ACO and/or AA feature (see Chapter 4), transformer current-limiting occurs in the data coupler.

National distributors of telephone equipment can provide all necessary installation equipment and supplies. Some items may be obtained from regular electrical equipment suppliers.

### Inside Installation

For installation inside buildings, provide adequate clearance where cables cross passageways or other locations in which physical damage is possible. Use of conduit is also recommended for additional physical protection. Cables should not be run in areas exposed to excessive heat or moisture.

Avoid running lines parallel to, or near, power system wiring. Devices such as rectifiers, arc welding machines, and diathermy machines produce electrical noise that can interfere with transmission of data. Therefore, cables should not be run near such equipment.

Junction boxes and terminal boxes should be used where accessibility to wiring is desired. These should be located at a height above the floor that is convenient to maintenance personnel.

Shields on cables and single-pair wiring should be effectively grounded at junction and terminal boxes. (See "System Grounding" under "Installation Standards", following in this chapter.)

Article 725 of the National Electrical Code specifies that "conductors (communication lines) in a vertical run in a shaft or partition shall have a fire-resistant covering capable of preventing the carrying of fire from floor to floor, except where conductors are encased in tubing or other outer covering of non-combustible material, or are located in a fireproof shaft having fire stops at each floor." Figures 18 and 19 show the use of metal conduit to meet this requirement.

Figure 20 shows the use of non-metallic jacket for individual conductor insulation. A non-metallic jacket should meet the

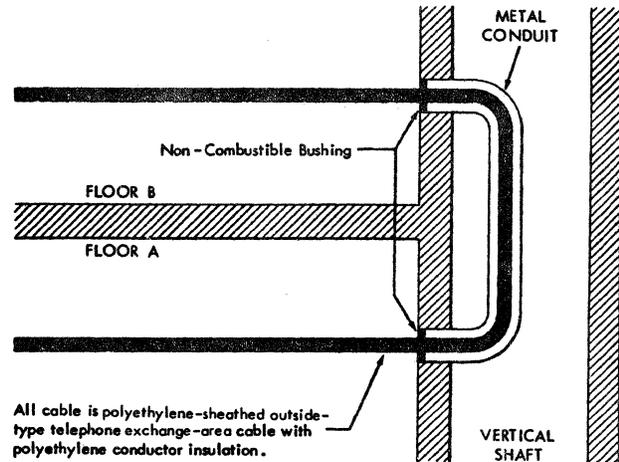


Figure 18. Metal Conduit, Used for Vertical Run Between Floors

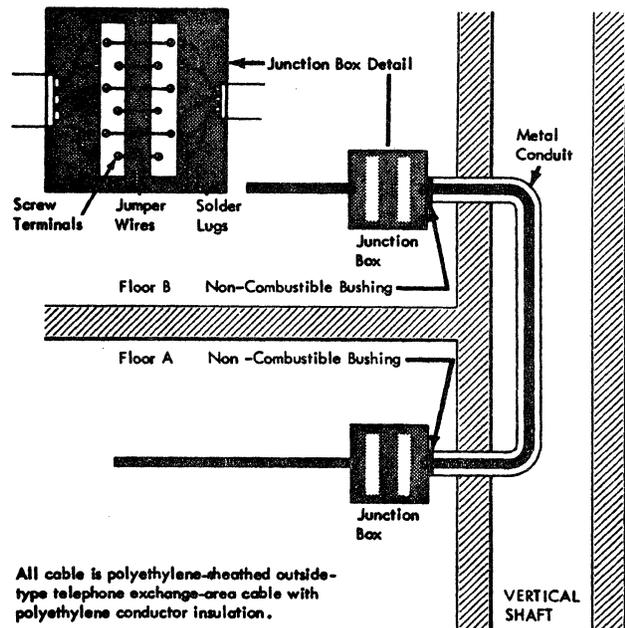


Figure 19. Metal Conduit, Used for Vertical Run Between Junction Boxes

Underwriter's Laboratories *vertical flame test*. Cable suppliers should certify that their product has met this test.

### Outside Installation

#### Cables and Poles

For outside installation of data communications lines, outside-type telephone exchange-area cable is recommended. If placed serially on pole supports, the cable must be supported between poles by separate cable, called a messenger cable, or a cable with an integral messenger must be used. If run underground, the cable must be in conduit of ceramic

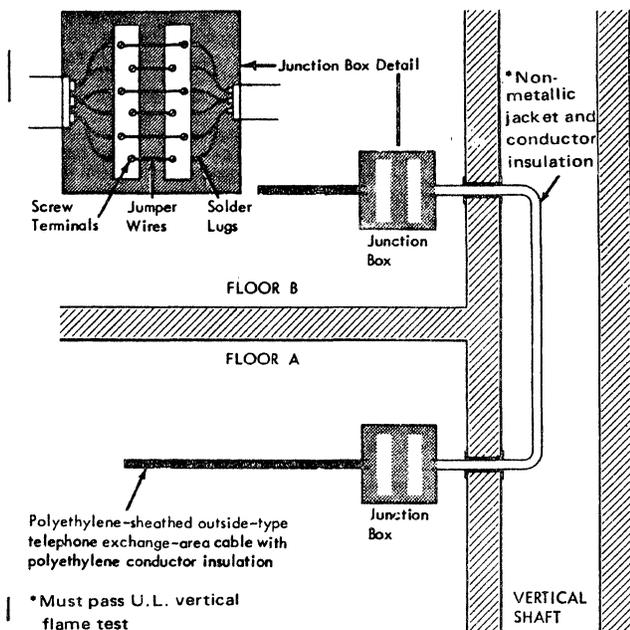


Figure 20. Non-metallic-Jacketed Cable used for Vertical Run Between Junction Boxes

or other suitable material, or have special sheathing suitable for direct burial in the ground.

Where a cable crosses above a roadway, adequate clearance should be provided. A generally accepted minimum clearance is 18 feet (5.5 m). Underground cables should be well below the frost line. Their routes should be clearly marked, especially in areas where excavation is likely. Where cables enter buildings, be careful to prevent water leakage.

Physical contact between communications wiring and power lines *must* be prevented. Article 800 of the National Electrical Code outlines methods to be followed to prevent such contact.

#### Lightning Protection

Article 800 also describes devices required at building entrances to protect against high-voltage surges on both aerial and underground cable. Such protection *must* be provided to protect terminal equipment from damage, if lightning hits directly or near outside wiring. Surge protectors may be of the carbon-air-gap or gas-filled-arrester type; both are available from commercial suppliers. Figure 21 illustrates such a device for a single wire of a cable.

- For single-pair cable, a Western Electric Protector 123A1A or 106C (or equivalent) is recommended. With the 123A1A, a 2- to 6-foot (0.61-1.83 meters) length of 26-gauge wire should be spliced in series, with each of the two conductors to serve as a fuse. These lengths of wire should be in cable sheathing and not near any buildings. With the 106C protector,

a short piece of 30-gauge wire can be substituted for each of the two fuses normally used with this device.

- For multipair cables, a Cook Electric Company Type 3800 Protector (or equivalent) is recommended. This device is available in sections for 10, 20, 21, 50, 51, and 101 cable pairs. It contains a built-in heat coil for each conductor, to provide fuse protection.
- The protector should be located as close as possible to the point of entry of the cable into the building.
- The fuse should protect the 0.003-inch (0.0762 mm) carbon air gap of the protector. See Figure 21.
- Shields on cables and single-pair wiring should be effectively grounded at, or near, building entrances. (See "System Grounding", following.)

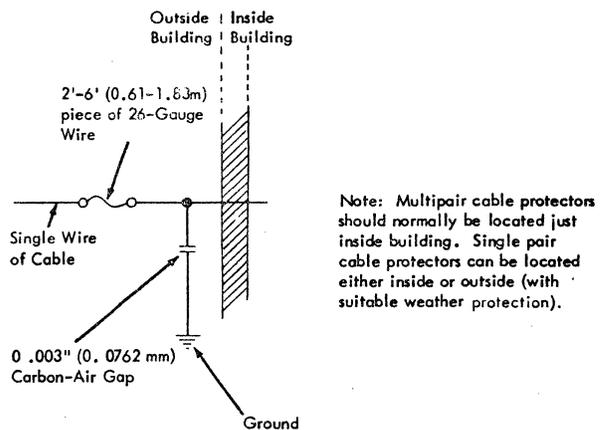


Figure 21. Fuse and Carbon-Air Gap Protection for a Single Wire of a Cable

#### System Grounding

Article 800 of the National Electrical Code states that "Effectively grounded means permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient current-carrying capacity to prevent the building up of voltages which may result in undue hazard to connected equipment or to persons."

Large electrical systems often are subjected to uncontrollable environmental factors. For this reason, it is not possible to specify a method of grounding that will be satisfactory in every situation. Figure 22 shows a suggested method of grounding cable shields at junction boxes. Figure 23 shows grounding at a terminal box, including connections to IBM equipment. Grounding harnesses specifically designed for grounding metallic shields of outside-type exchange cable can be purchased from communications equipment suppliers.

These recommendations are intended to apply to installations of new cable to achieve a well-performing, safe communications system. As explained previously, existing wire is acceptable if it meets the IBM line test; it may be unshielded.

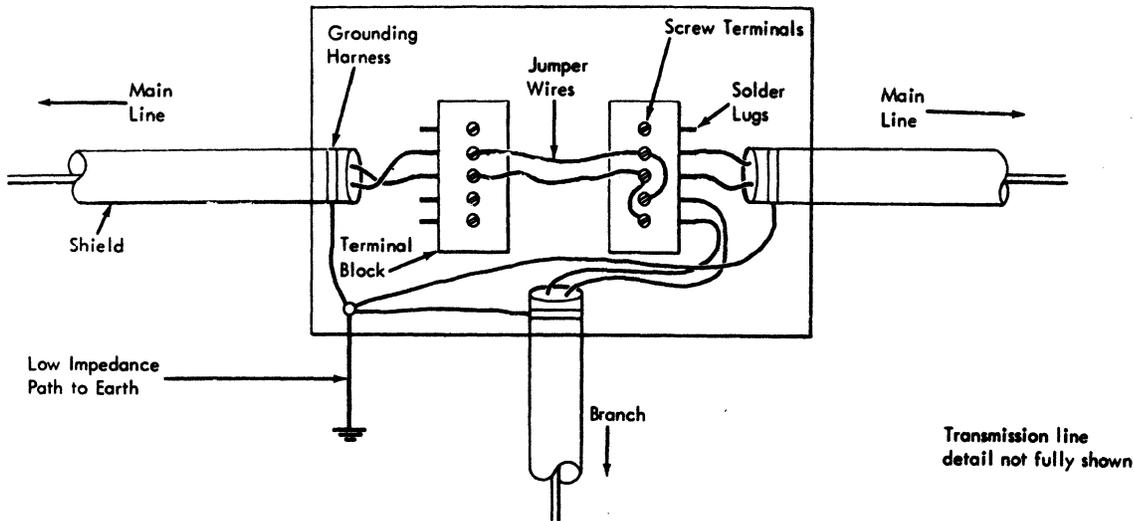


Figure 22. Grounding at a Junction Box

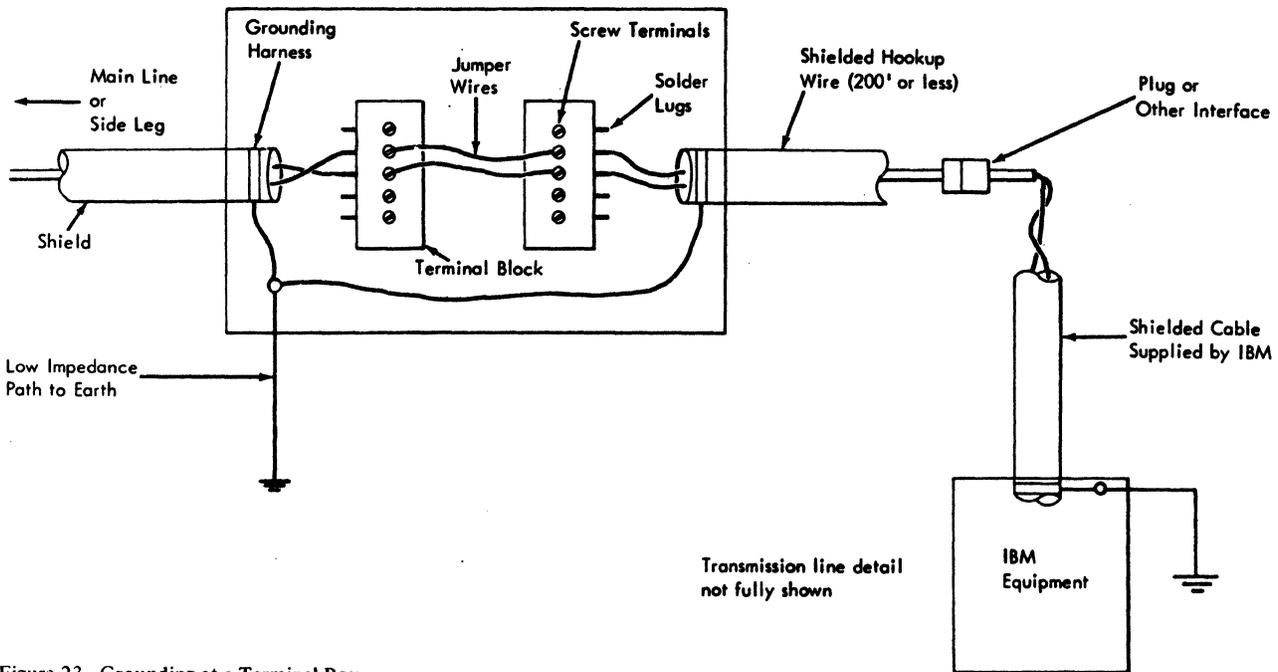


Figure 23. Grounding at a Terminal Box

The methods of grounding illustrated should be used as a starting point. In most cases, these methods are satisfactory. If line noise is still present after making the recommended ground connections, try systematic removal of ground connections, one at a time (both with, and without, replacement of the previously removed connection). In some cases, additional ground connections may prove effective.

Avoid a complete ground loop between any two line adapters in a system. Where two sections of a communi-

cations line are connected by a plug or other interface and the shield is bridged across this connection, be careful not to create a ground loop.

#### Junctions, Terminals, and Splices

Make the junction and terminal connections of cable and wiring in metal boxes that can be locked. Use standard telephone-type terminal blocks inside these boxes, to make necessary connections. As shown in Figures 22 and 23,

direct connections to main line, branches, and radials occur at solder lugs on the terminal blocks. Cross connections can then be made between terminal blocks, using the screw terminals.

Cable splices should be airtight and watertight. Individual conductors should be twisted together and soldered and an insulating sleeve placed over each joint. Place a protective cover over the entire cable splice. Communications equipment distributors have special kits for splicing cables.

#### **Completion Tests**

Contracts for installation of customer-owned wire and cable should stipulate that completion tests be made to ensure that there are no faults, high-resistance connections, or circuits unbalances. These tests are performed by the installing agency, not by IBM.

Tests for the following types of faults should be included in the completion tests.

- Open circuits in individual conductors or shields
- Short circuits between conductors of the same pair
- Grounds on individual conductors, either between a conductor and shield or between a conductor and some grounded object
- Crosses or short circuits between a conductor or one pair and one or more conductors of another pair
- Unterminated stubs (Eliminate them.)

The resistance of individual pairs should not exceed the maximum values specified for various sizes of recommended wire and cable. (See the "Types of Wire and Cable", preceding in this chapter.) Any dc resistance unbalance between conductors of the same pair should not exceed 10 percent. (A 10 percent unbalance is slightly greater than that expected of the cable itself.)



## Chapter 3. Planning an Unlimited Distance Communications System

The IBM Leased and Shared Line Adapters and the 1200 bps Integrated Modem are designed for use on voice-grade communications channels. This type of communications channel is usually supplied by a common carrier; however, channels available in privately owned communications systems that meet the specifications for each IBM Line Adapter are also satisfactory. (See the chapter, "Types of IBM Line Adapters," for detailed line specifications.)

This chapter, which outlines the selection of an IBM Line Adapter and common-carrier facilities, contains background information to all IBM Line Adapters.

At locations served by four-wire local channels, ask the common carrier to provide a key (Western Electric Company Type 6017 or equivalent) to enable the transmit local channel to be looped to the receive local channel (toward the common-carrier central office), to facilitate trouble location.

Call IBM physical installation planners to check for special installation considerations.

### LEASED-PRIVATE-LINE DATA CHANNELS

Communication paths are referred to as channels, lines, or line facilities. The aggregation of channels, terminal equipment, and equipment at intermediate points in the path is customarily called a circuit.

Components of a leased private-line channel are identified as either inter-exchange (inter-city) channels or local channels (local loops). Inter-exchange channels are those channels between common-carrier switching offices. Local channels are the portion of a circuit between the customer's premises where the "customer station equipment" is located and the common-carrier central office where the inter-exchange channels terminate.

Most *inter-exchange channels* are derived from communications company carrier systems. These systems permit one or two transmission lines such as open wire or cable pairs, coaxial cables, or radio channels to provide from as few as four voice-grade channels to as many as thousands of voice-grade channels. Almost all individual voice-grade channels obtained from these systems are capable of full-duplex transmission. These facilities are usually found on the longer inter-exchange channels, but this may not necessarily be the case with "short-haul" facilities. It is also possible to have four-wire and two-wire voice-grade channels consisting of physical cable or open wire pairs, but these physical circuits are becoming less prevalent.

*Local channels* are usually physical cable pairs. Newly developed short-haul multiplexing systems may, however, be used for portions of long local channels.

The auxiliary equipment used with the line facilities to make up a complete private line circuit is called central office or customer station equipment, depending on its location. Sometimes a given type of equipment is found both in central offices and at customer locations.

### Central Office Equipment

*Amplifiers:* See "Repeater" below.

*Echo Suppressors:* Used to prevent echoes on two-wire voice circuits having long propagation delays and relatively low net loss. (Echo is not objectionable if it occurs immediately or is sufficiently attenuated.) Echo suppressors effectively insert a high loss in one direction of transmission while permitting normal low-loss transmission in the other. They are not generally needed on four-wire facilities. (See "Echo Effects" and "Use of Echo Suppressors", following in this chapter.)

*Equalizers:* Channel-conditioning equipment provided to compensate for attenuation and envelope delay distortion. (See "Equalization" under "Transmission Considerations and Impairments", in this chapter.)

*Hybrids* (four-wire terminating sets): Used to couple four-wire inter-exchange channels to two-wire local channels.

*Four-way, Four-wire bridge:* A device, usually located in central offices, used to connect one or two intermediate drops to the main transmission path. These devices are also used at central offices, at the ends of circuits, to serve two or three different drops on separate local channels. Six-way, four-wire bridges permit additional drops. Bridges are connected in tandem when a greater number of drops are required.

*Repeater:* An amplifier used to compensate for the losses on line facilities or the losses resulting from going through four wire bridges or other communications equipment, or both.

*Pads:* Resistance networks used to adjust signal levels.

*Ringers:* Devices used for signaling over leased line circuits. Normally relatively high frequency ac signals are sent over the inter-exchange channel, while 20-Hz ac or dc, is used on local channels. Ringing is controlled by the customer, using pushbuttons, keys, or dials.

*Signaling Equipment:* Ringers, single-frequency signaling equipment, or other equipment used in signaling.

*Relays:* Electrically operated switching devices that may be used: (1) to connect two or more leased line circuits together, or (2) to remove echo suppressors from alternate voice-data

circuits when used for data, or (3) to disconnect ringers or signaling equipment under certain conditions. These relays are normally controlled by a manually operated key at the customer station, through a dc path to the central office.

### Customer Station Equipment

While some communications equipment is found only at the customer's premises, it is also possible to find central office type equipment (described above) such as pads, relays, hybrids, and some signaling equipment at the customer's premises. In addition, items described in the following paragraphs may also be found.

*Key Equipment* (such as Type 1A key equipment): Push-buttons, lights, and relays used to switch a given telephone instrument to different circuits.

*Key*: A switch, ordinarily a toggle or lever variety, used to control central office relays or to switch from one mode of operation to another (such as from voice to data mode, on alternate voice-data circuits).

*Repeat Coils*: Transformers used to: (1) isolate local channels from customer station (or central office) equipment, (2) match line and terminating equipment impedances, and/or (3) provide a ground return (simplex) path to the central office for dc signaling or operating central office relays.

*Local Battery Telephone Sets*: Telephone sets that contain their own batteries or power supply are used on private line voice circuits because the central office battery used in local dial service is not normally applied to leased line local channels.

*Data Coupler* (also called "data access arrangement", or DAA): A common-carrier device that may be provided to couple the common-carrier channel to a non-common-carrier modem. The data coupler provides dc isolation and limits the power that may be transmitted to the channel.

## TRANSMISSION CONSIDERATIONS AND IMPAIRMENTS

Data communications may be impaired by attenuation, distortion, or delay between the transmitter and the receiver. Noise (signals received that were not transmitted) may make the transmitted signal unintelligible to the receiver. Echo on voice lines, if strong enough and sufficiently delayed in returning, will also impair data communications. Irregular characteristics of a line result in varying distortion and delay (called "jitter") that can be troublesome when variations are large.

### Distortion and Jitter

#### Start-Stop Distortion

In systems using start-stop synchronization alone, character synchronization (character framing) and bit sampling are both achieved by use of the start bit. Distortion is said to be

present when, within a given character, one or more mark-to-space or space-to-mark transitions occur earlier or later than they should, with respect to the beginning of the start bit of that character.

The magnitude of the difference between the ideal and actual time intervals, measured from the beginning of the start bit to any transition within the same character, divided by a nominal bit time interval, is the quantitative measure of distortion. See Figure 24A. It is usually quoted as a percentage and may be peak or average; since peak and average distortion may be appreciably different, they should be identified, when used. Because errors are more probable at times of peak distortion, peak distortion is a better indication of the quality of the received signal than is average distortion.

#### Isochronous Distortion

In *isochronous* transmission systems: (1) the bits in each character are of uniform time length, and (2) any interval between characters consists of an integral number (including 0) of such uniform bit time lengths. These systems may or may not be start-stop systems; usually they are not. When no stop and start bits are present, character synchronization is achieved by periodic transmission of special control characters. Bit synchronization is achieved by continuously comparing receiver sample pulses to received data transitions and adjusting the sample instants. This is synchronous sampling.

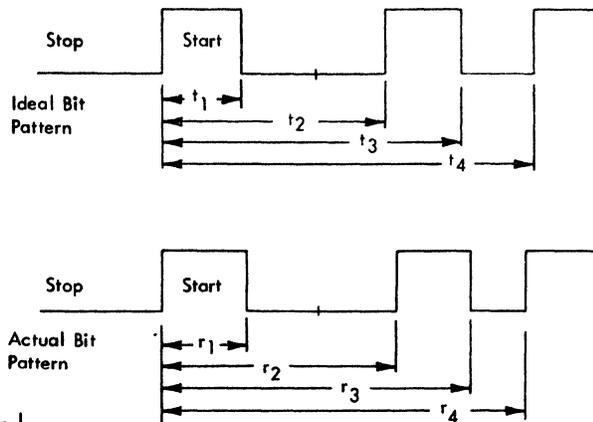
For isochronous transmission systems using synchronous sampling, distortion is called isochronous distortion. It is quantitatively defined as a ratio: the ratio of the difference between the time interval ( $T_A$ ) separating two actual receive data transitions and the ideal interval ( $T_I$ ) separating the same two transitions to the nominal or ideal bit time length (B). See Figure 24B. The two transitions need not necessarily be consecutive.

#### Jitter

In digital data communications systems, changes from marks to spaces (1's to 0's), and vice versa, should occur at precise instants. Because of transmission impairments and the modulation-demodulation process, these mark-to-space and space-to-mark transitions occur early or late, in a random manner. As seen on an oscilloscope, the band of on-time, early, and late transitions is called jitter. Figure 25 illustrates jitter. Jitter can be quantitatively defined in two ways, as illustrated in Figure 25. Definition 2 is the preferred definition and is numerically equal to peak distortion.

#### Attenuation Distortion

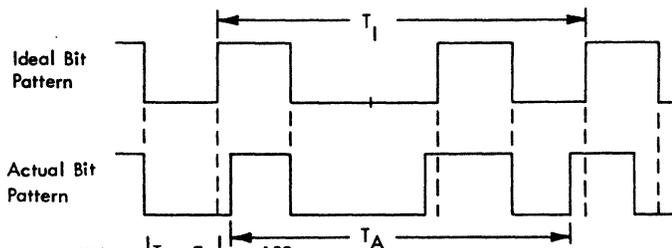
Unequal attenuation of the different component frequencies of a signal is called attenuation distortion (or amplitude distortion). In a voice transmission, attenuation distortion alters the quality of the signal and, in extreme amounts,



$$\% \text{ Distortion} = \frac{|t_n - r_n|}{B} \times 100$$

Where:  $t_n$  = an ideal time interval between any  $n^{\text{th}}$  transition within a character and the beginning of the start bit of the same character  
 $r_n$  = actual time interval between the same  $n^{\text{th}}$  transition and the start of the same character  
 $B$  = ideal or nominal bit length in time

#### A. Distortion in Start-Stop Systems



$$\text{Isochronous Distortion (\%)} = \frac{|T_I - T_A|}{B} \times 100$$

Where:  $T_I$  = ideal interval separating two data transitions  
 $T_A$  = actual interval separating the same two data transitions  
 $B$  = ideal or nominal bit length in time

#### B. Isochronous Distortion

Figure 24. Distortion of a Digital Signal

might make it difficult to recognize a well-known voice. In data transmission, attenuation distortion gives rise to jitter and distortion of the received data signal, thereby increasing the likelihood of errors. Unconditioned common-carrier voice-grade lines are usually acceptable in attenuation distortion for voice transmission and for low-speed data transmission on point-to-point circuits.

#### Envelope Delay Distortion

Envelope delay distortion, often called delay distortion, applies to the phenomenon in which different frequency components of a signal take unequal lengths of time to

traverse the transmission path. Phase distortion (a non-linear phase shift-frequency characteristic) is the same as envelope delay distortion. The human ear is insensitive to the delay distortion normally found on voice-grade channels, but data transmission can be quite susceptible to delay distortion. The effect of delay distortion is the same as for attenuation distortion. The lengths of digital data signal elements are altered, thereby increasing the likelihood of errors.

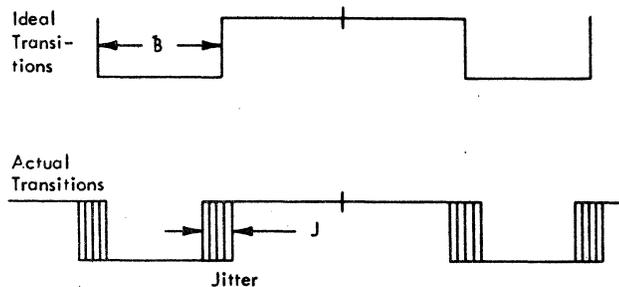
At transmission speeds of up to 700-900 bps, delay distortion (as found on most voice-grade channels) is not excessive for point-to-point circuits. On multipoint circuits,

however, it may be necessary to use conditioned channels. See "Speed Considerations" under "Choice of Line Adapter and Grade of Line" following in this chapter.

### Equalization

The effects of attenuation distortion and envelope delay distortion can be counteracted to a degree that permits faster signaling speeds on a channel. This counteraction process is called equalization. Equalization consists of adding passive, or combinations of active and passive, circuit elements to the transmission path, to make the attenuation and/or envelope delay distortion versus frequency characteristics more nearly constant.

Channel conditioning charges quoted in common-carrier tariffs are charges made primarily for equalizing the channels.



#### Alternative Methods of Calculating Jitter

1. Percent Jitter =  $\pm \frac{J}{2B} \times 100$
2. Percent Jitter =  $\frac{J}{B} \times 100$   
(Preferred definition)

Where:

J = Width of jitter band

B = Nominal bit length

Figure 25. Jitter

### Noise

Crosstalk effects, as defined in Chapter 2, are considered a component of noise. Noise on common-carrier lines is usually categorized into two kinds: (1) average background or "white" noise (sometimes called message circuit noise), and (2) impulse noise.

Average background noise, as the name implies, is normally a relatively steady, low-level, unintelligible noise. Impulse noise is usually of random, infrequent occurrence and is characterized by short duration and relatively high amplitude peaks. Impulse noise is considered to be at a higher level than average background noise because, if it were not

at a higher level, it would be indistinguishable from the average noise. Average background noise is the accumulation of all low-level noise and crosstalk from whatever source. Impulse noise may be caused by central office switching transients, automatic carrier system line switching, or powerful external noise sources. Leased common-carrier channels that bypass central office switching equipment usually experience less impulse and background noise than common-carrier switched facilities.

Average background noise is usually proportional to circuit length; it is seldom a problem to data transmission unless it becomes abnormally high because of line trouble or extremely long distance. This would also be troublesome to voice communications. Impulse noise, however, has a higher amplitude level and can be more troublesome to data transmission. Because impulse noise varies in amplitude, wave shape, duration, frequency of occurrence, and phase with respect to the signal, its effect is difficult to assess and is not normally specified for line adapters and data sets. See "Speed Considerations" under "Choice of Line Adapter and Grade of Line", following in this chapter.

### Propagation Delay

In air, electrical signals travel at a speed of approximately 186,000 miles per second ( $3 \times 10^8$  meters). On common-carrier voice-grade channels, the speed is less. Propagation speed is slower on wire facilities than on radio channels. Even voice channels derived from carrier systems operating on broadband radio channels are slowed down in passing through the filters and other equipment in the carrier system. Some local channels are inductively loaded and have propagation speeds of as low as 12,000 miles (19,300 km) per second. All frequencies in the voice band are delayed; some are delayed more than others (delay distortion).

The propagation delay corresponds to the minimum delay experienced by any frequency in the band. Propagation delay (as compared to delay distortion) is usually of no consequence except in calculating turnaround time and throughput in data communications systems, or in creating echo effects.

Since most long distance circuits are channels derived from relatively high-speed carrier systems, a figure of one millisecond per 150 miles (242 km), which is 150,000 miles (242,000 km) per second propagation speed, can be used for rough planning purposes, for circuits over 200 miles (322 km) in length. In addition, a constant delay term of 12 milliseconds must be added to the per-mile delay calculation, to account for low-speed end sections or unusually long sections of low-speed facilities on the longer circuits.

For circuits under 200 miles (322 km) in length, lower-speed facilities make up a larger proportion of the total circuit than they do for the longer circuits. For this reason, the average propagation speed is slower on the shorter circuits. For circuits under 200 miles (322 km) in length, use a delay of one millisecond per 15 miles (24.2 km).

No constant delay need be added for the short circuits, because a low-enough propagation speed has been chosen to make an added delay constant unnecessary. The following table shows propagation delays and constants.

Circuit Length	Propagation Delay	Added Constant Delay
Over 200 miles (322 km)	1 ms per 150 miles (242 km)	12 ms
Less than 200 miles (322 km)	1 ms per 15 miles (24.2 km)	0 ms

*Example:* What is the propagation delay for a 450-mile (725 km) circuit?

$$\text{Delay} = 450/150 + 12 = 15 \text{ milliseconds}$$

*Note:* Propagation time, as calculated above, is in one direction. Double the one-way delay in calculating the turnaround delay.

### Echo Effects

Echo on transmission lines is usually a phenomenon associated with so-called two-wire channels or lines. These channels normally consist of four-wire inter-exchange channels and two-wire local channels, with hybrid circuits at the four-wire, two-wire junctions. Theoretically, hybrid circuits have infinite losses from four-wire receive to transmit sides. Actually, the loss is finite and depends upon the precision of the hybrid circuit elements and the degree to which the associated line-balancing network actually simulates the two-wire line. (The balance between the network and the two-wire line must be adequate at all frequencies in the band-pass, or the circuit may oscillate or "sing".)

Hybrid unbalances at the far end of the circuit and impedance mismatches in the two-wire portion of the line allow energy to be returned to a speaker and sound like an echo. The longer it takes the echo to return (round trip propagation delay) and the larger the amplitude of the echo, the more annoying it is to the talker. Circuits with short propagation delays or low echo levels, or both, may not be objectionable from an echo standpoint.

First "listener" echo is the echo that makes one and one-half round trips on the channel: from the speaker to the listener end, back to speaker end, and then again back to the listener. First-listener-echo, if of high-enough intensity, can affect data communications systems.

### Use of Echo Suppressors

Echo suppressors may be present on facilities used for long-distance telephone calls made over the nationwide switched network. They are not on every circuit, however; normally they are found only on those whose length and (low) net loss require that echo suppressors be used or on circuits between certain classes of switching centers.

On leased, private-line voice channels, echo suppressors are less frequently used. On leased *data only* channels, echo suppressors are not required.

Data sets and line adapters send continuously, without pauses, so that echos do not get back to a line adapter receiver during a message. On two-wire circuits where echoes are most common, the business machines normally do not "listen" while they are transmitting. However, when a business machine has completed transmitting on a two-wire line with a data set or an IBM two-wire line adapter, it begins listening. Echoes of its own transmission, possibly interpreted as data, could cause system slowdown. Therefore, two-wire line adapters and data sets are normally designed with an "echo clamp" or "squelch", which is applied, momentarily, after transmission ceases and until danger of echo is past. Four-wire "data only" circuits, do not normally present echo problems.

First-listener echo can cause trouble if the intensity is high enough to interfere with the direct signal. Listener echo could also cause trouble on point-to-point circuits at the end of a transmission if the receiving business machine does not know when to stop listening to the line; but this is not normally the case. As previously stated, multipoint circuits are usually four-wire and present no echo problems.

Alternate voice/data, leased, two-wire circuits may require echo suppressors for satisfactory voice transmission. The echo suppressor must be conditioned to permit transmission in one direction and to block transmission (and the echo path) in the other. The presence of ordinary voice triggers the echo suppressor automatically, but line adapters and data sets must send tone in one direction for a timed interval, to accomplish the same result.

A built-in delay in the line adapter (of sufficient time to condition the echo suppressor) signals the business machine that keying may begin. Therefore, single-channel line adapters may operate in half-duplex mode with echo suppressors.

If echo suppressors are not used, the echo clamp or squelch circuits in the line adapter will handle echoes on two-wire channels. Echo clamp and squelch on two-wire channels need not be disabled when echo suppressors are used, because the echo suppressor conditioning interval (clear-to-send delay) overlaps the echo clamp or squelch period.

Multichannel line adapters such as the IBM Shared Line Adapter and data sets capable of independent simultaneous transmission in two directions on two-wire lines obviously cannot have echo suppressors present. The echo suppressor would lock up in one direction and thereby block transmission in the other. Modems used for data communications

over the switched telephone (DDD) network use frequencies in a particular band to automatically disable echo suppressors.

Multichannel data sets and line adapters used on leased lines rely on the removal of echo suppressors from the data transmission circuit.

Duplex channels, which provide for data communications in both directions simultaneously, cannot have echo suppressors present during transmission.

### Compandors

The term "compandor" is a contraction of the words "compressor" and "expander". Compandors are devices used on certain types of telephone carrier systems to improve the signal-to-noise ratio present in the communications system. At the transmit end, the lower signal levels are increased (*compressed* in level range). This increases the signal-to-noise ratio on the line. At the receive end, the signals are decreased back to their original levels. The signals are thus *expanded* to their original form.

This compression-expansion process explains the name compandor. Compandor action requires a short conditioning interval. Normal line adapter request-to-send/clear-to-send delays are sufficient to stabilize compandors.

### Clamp Action

When a two-wire line adapter is not transmitting, it normally monitors the communications channel. Four-wire data set or line adapter receivers always monitor the line. If no signal is present, the line adapter may respond to line noise signals. Since this is not desirable and noise levels are usually low when compared to desired signal levels, line adapters and data sets have well-established "clamp" thresholds.

These thresholds imply that the desired signal must be above some established level before the receiver will respond to it. Therefore, the modem will ignore most noise but will respond to the desired signal. The signal must be above the threshold level for a given length of time before the receiver will respond.

During the time the line signal is below the threshold and until a time delay elapses after the signal appears above the threshold, the modem holds its receive-data lead to some predetermined state, usually the "mark" (1) state. Modems with a carrier-detected lead usually obtain this lead from the threshold or "clamp" circuitry.

Clamp action is sometimes called mark-hold or space-hold. When the signal level falls below clamp threshold, the clamp is applied to the receive-data lead. Some modems apply the clamp immediately, to prevent noise from tripping the receiver; others wait a timed interval before applying the clamp so that short line dropouts will not cause the clamp to be applied. High noise levels can, of course, interfere with clamp action by preventing its application or causing the modem to unclamp. It may also add to transient effects such as carrier turn-off and turn-on transients, which will give spurious receive-data outputs.

### Spurious Outputs—"Glitches"

Spurious outputs, or glitches, are unwanted space bits occurring at times when the modem receive-data lead should be in its mark state.

It is not feasible to make modems glitch-free under all conditions. Therefore, business machines and data communications systems should either be made inherently insensitive to glitches or have logic circuitry that ignores their effects.

### THROUGHPUT CONSIDERATIONS

In calculating system throughput, consider propagation delay, request-to-send/clear-to-send delay, and built-in system delays. Unclamp delays, echo clamp, or squelch are usually overlapped by the request-to-send/clear-to-send delay. Some modems contain options that shorten or disable these timing delays. The systems engineer must (1) be aware of the possible delays and timing options in the modem he wishes to use, and (2) make sure that the correct options are specified. There are different delays between the various IBM Line Adapters, and differences in delays between the two-wire and four-wire versions of some IBM Line Adapters. The IBM 1200 Bit-per-Second Integrated Modem (due to variable applications) offers optional request-to-send/clear-to-send delays.

Spurious outputs or glitches can be brought about in half-duplex systems by attempting to speed up system throughput. If the line is not left dead (signal-free) long enough between transmissions, the modem will not have sufficient time to apply clamp. Under these conditions, carrier turn-on transients can cause glitches. If the line is kept dead between transmissions for a time somewhat longer than the interval for applying the clamp, after the signal disappears (as given for IBM Line Adapters in Chapter 4), the glitches do not occur. If the control station of a duplex multipoint system keeps carrier on at all times, glitches are minimized; there are no turn-on transients on the control station's transmit side. On the control station's receive side, there are no glitches if replies from tributary stations are always preceded by a control station transmission long enough to allow the control station receiver to apply the clamp (because it is not receiving carrier).

### CHOICE OF LINE ADAPTER AND GRADE OF LINE

#### Speed Considerations

The choice of grade of line cannot be made independent of other considerations. The entire communications system consists of the line facilities and the modems. The performance of the system depends on both.

Modems are usually rated at various signaling speeds (baud or bits-per-second rates) over specific grades of lines. The logical approach is to determine which modem meets your signaling speed requirements and then lease the grade of line recommended for that modem.

At the lower bit rates, signaling speed on a channel is normally controlled by the channel bandwidth, amplitude distortion, and envelope delay distortion.

Conventional unconditioned, private-line, voice-grade channels (for example, common-carrier Type 3002 channels) may vary considerably in these three characteristics. When a channel with a definite data transmission capability is required, it is necessary to specify one of the grades of data communications channels identified by clearly defined characteristics. For a chart of common-carrier channel characteristics, see Figure 63 in Appendix C.

The *IBM Shared Line Adapter* is rated at speeds of from 0 to 134.5 bits per second on channels meeting the specifications listed for that line adapter in Figure 29.

Unconditioned, common-carrier Type 3002 channels, or equivalent, are satisfactory for point-to-point circuits. On multipoint circuits, unconditioned Type 3002 (or equivalent) channels are satisfactory for systems within up to three exchange areas and involving distances not exceeding approximately 50 miles. For systems exceeding these limits, common-carrier Type 3002 channels with type C1 Conditioning (or equivalent channels) should be specified.

The *IBM Leased Line Adapter* is rated at speeds of from 0 to 600 bits per second, on channels meeting the specifications listed for that line adapter in Figure 29. Common-carrier Type 3002 channels (or equivalent) are usually satisfactory for point-to-point circuits, over the entire speed range. For multipoint circuits operating at 134.5 bps and using the *IBM Leased Line Adapter*, the signaling speed is low enough for the unconditioned channels to be satisfactory.

For multipoint circuits operating at 600 bps using the *IBM Leased Line Adapter*, common-carrier Type 3002 (or equivalent) channels are satisfactory for systems within up to three exchange areas and involving distances not exceeding approximately 50 miles. For 600-bps multipoint systems exceeding these limits, common-carrier Type 3002 channels with type C1 Conditioning (or equivalent channels) should be specified.

Faster signaling speeds require more complex modems and often may require more precisely conditioned (equalized) communications lines. These higher-speed modems usually have higher rentals, and higher additional charges apply for the more precise channel-conditioning arrangements.

The *IBM 1200 Bit-per-Second Integrated Modem* is rated at speeds of from 0 to 1200 bits per second on suitable channels (Figure 29). Channel requirements differ with the use of this line adapter depending upon the transmitting rate, and whether it is a dedicated (leased or privately owned), point-to-point or multipoint configuration, or public switched network operation.

Most IBM systems utilizing binary synchronous communications\* offer the optional special feature of 1200 bps with synchronous clock. The *IBM 1200 Bit-per-Second Integrated Modem* may be used with these systems on the channels shown in Figure 29.

#### Choice of Half-Duplex or Duplex

A *half-duplex* communications channel is one capable of transmitting in both directions, but in only one direction at a given time. (Half-duplex operation is also described as nonsimultaneous two-way data transmission.)

A *duplex* communications channel is one capable of *simultaneous* transmission in both directions. Tariffs now refer to "duplex" channels rather than "full-duplex" channels, the term used in previous tariffs. The terms are synonymous.

Two-wire channels are usually capable of only half-duplex operation. However, some lower-speed modems can provide duplex capability on a two-wire channel by frequency multiplexing—using different frequencies for the two different directions of transmission.

Four-wire channels are capable of duplex point-to-point operation. (See "Multipoint Circuits" following.)

If simultaneous signals are to be transmitted on a four-wire multipoint circuit, a separate bridge is required at each intermediate dropping point, for each direction of transmission. This arrangement imposes the restriction that only one transmitter in the system (the control station transmitter) can be heard by all remaining receivers and that transmitters of the remaining stations can be heard only by the control station receiver.

Figure 26 illustrates multipoint bridging, where one transmitter and the remaining receivers are connected to one side of the four-wire line. On the other side, one receiver (the control station receiver) is associated with all the other transmitters. This arrangement increases throughput and is advantageous in a centralized multipoint system where all transmission is between the single control station and each of the individual tributary stations. See "Alternate Master Stations", following in this chapter, for a discussion of alternate control station operation.

Most IBM teleprocessing systems or terminals can only transmit or only receive data at any one time and, therefore, are half-duplex in operation. Because of various considerations, however, some of these systems require four-wire facilities, even in point-to-point circuits. Examples are the *IBM 1050* system, the *IBM 2741 Communications Terminal* with the Interrupt feature and the *IBM 1030 System* using the *IBM Leased Line Adapter*.

At other times, half-duplex systems may wish to keep carrier on at all times at the control station, to eliminate

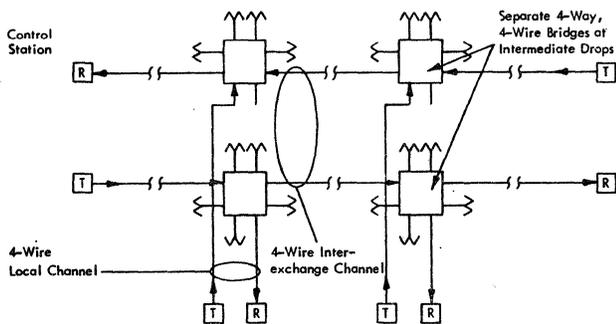
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\*See *General Information--Binary Synchronous Communications*, GA27-3004-2 (or later edition).

delays (such as clamp circuit delays) in multipoint circuits. In the latter case, duplex facilities and four-wire split bridges (Figure 26) are required.

In cases where four-wire facilities are required, duplex channel charges may apply. Check the local common-carrier marketing representatives to determine which rate applies.

With a multipoint half-duplex system that drops carrier between transmission at both control and tributary stations, four-wire, end-to-end facilities should be specified for IBM Line Adapters, but at intermediate dropping points, only single bridges are required. (A system that has the 2741 Interrupt feature requires duplex facilities and split bridges.)



**Notes:**

1. Control station/tributary station operation is necessary.
2. Tributary stations can hear only the control station, not each other.
3. The control station can keep carrier on at all times.
4. Only one tributary station may have carrier on at any one time.
5. Minimum turnaround time provides optimum throughput.

Figure 26. Multipoint Four-Wire Duplex System with Simultaneous Signals in Both Directions

**POINT-TO-POINT CIRCUITS**

Point-to-point (two-point) circuits for half-duplex teleprocessing systems normally require only two-wire channels. Although only two-wire channels are required, if four-wire channels are provided, they can be used.

Certain IBM half-duplex systems require four-wire channels for point-to-point circuits, and four-wire channels should be specified. Duplex, point-to-point systems require four-wire facilities. While it should not be necessary to specify both duplex and four-wire facilities, to do so may prevent an occasional misinterpretation. An exception is modems that use different frequencies in the two directions of transmission, such as the IBM 3976 Model 1 or Model 2 Modem. On point-to-point circuits, this modem can operate in duplex mode on two-wire channels.

IBM two-wire and four-wire line adapters used on leased common-carrier lines have different feature codes, to distinguish their differences. Where, from a transmission

standpoint, two-wire facilities may be acceptable on a point-to-point circuit, four-wire facilities may be preferable because of the shorter turnaround time at both modems.

If the system is point-to-point, half-duplex, the common carrier may provide either two-wire or four-wire channel facilities. The common-carrier engineering representative should be contacted for a decision so that the proper IBM Line Adapter feature code will be ordered.

If the requirements of the customer application do not permit the long clear-to-send delay of the two-wire versions of the Leased Line and the Shared Line Adapters, the four-wire version should be used. The four-wire adapters have a short clear-to-send delay, which reduces turnaround time. If the four-wire version is used, four-wire, end-to-end line facilities must be specified to the common carrier.

*Note:* If a system uses IBM Shared Line Adapters, and there are three or more stations on the circuit, the communications facility is multipoint, even though individual stations operate point-to-point on separate subchannels. A multipoint communications facility requires four-wire, end-to-end facilities, as described under "Multipoint Circuits", following.

**MULTIPOINT CIRCUITS**

Multipoint leased circuits offer certain operating advantages over exchange (dial-up) facilities and permit connecting more than two terminals to the same channel. The IBM Shared Line Adapter permits simultaneous transmission on as many as four independent transmission paths on a leased, common-carrier or privately owned, voice-grade channel. With the IBM Shared Line Adapter, one can have up to four point-to-point, 134.5 bps systems combined on one multipoint circuit. See the following chapter, "Types of IBM Line Adapters," for specific line configurations possible with the various line adapters.

IBM specifies that four-wire, end-to-end facilities and duplex bridging configurations (two separate four-way, four-wire bridges at each drop) be used with its line adapters on multipoint circuits. The number of points possible on a multipoint circuit is a function of the grade of line and the configuration of the system from the standpoint of bridge location.

The number of drops on a multipoint network is limited by the total circuit mileage. Normally, systems with ten or fewer service points and less than 4,000 circuit miles may be safely proposed, without consulting the common carrier. In most cases involving more than ten points, or more than 4,000 circuit miles, this will be permissible, but the customer should consult his local common-carrier representative early in the installation planning.

*Note:* With the IBM Shared Line Adapter, the ten-point limit applies to the number of local channels, not ten IBM terminals. With all four subchannels present at each point,

this restriction would allow 40 IBM terminals in the system. Shared line adapter multipoint and point-to-point circuits are defined under "IBM Shared Line Adapter" in Chapter 4.

Traffic throughput must also be considered in setting up multipoint systems. Although a single multipoint circuit may be feasible from transmission considerations, traffic may overload it.

Also, in multipoint circuits, do not overlook the question of outages. Trouble in any part of the circuit can affect the entire circuit.

### ALTERNATE VOICE AND DATA CIRCUITS

Many data circuits are alternately used for voice. This sometimes enables a circuit to be "proven-in" economically where either data or voice traffic alone may not justify it. Alternate voice communication is extremely useful. At times it may even be necessary, for operator coordination of batch-type traffic. Although it is also very useful in troubleshooting "online" data communications systems, voice communication requires that the whole data processing system be "down."

On alternate-use circuits, the common carrier provides keys (switches) to switch from data to voice communications, and vice versa, at each terminal location. Such switching is normally done manually at each location, but it must be coordinated among the various locations.

Various kinds of signaling can be used on alternate-use channels. In earlier data communications systems, signaling equipment necessary on alternate-use channels has sometimes been actuated by data signals, resulting in disruption of the data. This problem is well-known to common-carrier personnel. If it occurs, the situation can be remedied by disconnecting the signaling equipment from the line while the channel is being used for data communications or by other means available to the common carrier.

The dc voltages required for voice operation should be isolated from the IBM Line Adapters.

### ALTERNATE MASTER STATIONS

In multipoint systems using line control, it may be necessary or desirable to have an alternate master station. In systems where the master station drops carrier between transmissions, where single bridges are used and where each station is on a separate local channel, there is no difficulty in changing to an alternate master, since each station can talk to, and hear from, every other station. (If the master and alternate master share the same local channel, switching is required.)

In systems where the master station keeps carrier on at all times and where separate bridges are used at intermediate points in the two directions of transmissions, there are restrictions to alternate master station operation. Usually it is not practical to have alternate master stations, unless the regular and alternate master stations are served from the same two bridges at the same location.

Figure 27 shows the general switching arrangement where the regular and alternate master stations are served from the same bridges. The switching arrangement can be located at the common-carrier central office or at the customer premises.

Figure 28A shows an arrangement where the alternate master is served from different bridges than the regular master and, presumably, in a different exchange area. The regular master station is in control. Figure 28B shows the same system with the alternate master station in control. In this example, it would be necessary to make switches at three different locations. Such an arrangement is difficult to troubleshoot and requires additional facilities. Switch-control paths are necessary between points requiring switching unless switching is manually coordinated at all points. Such systems as that shown in Figure 28 are not recommended by IBM.

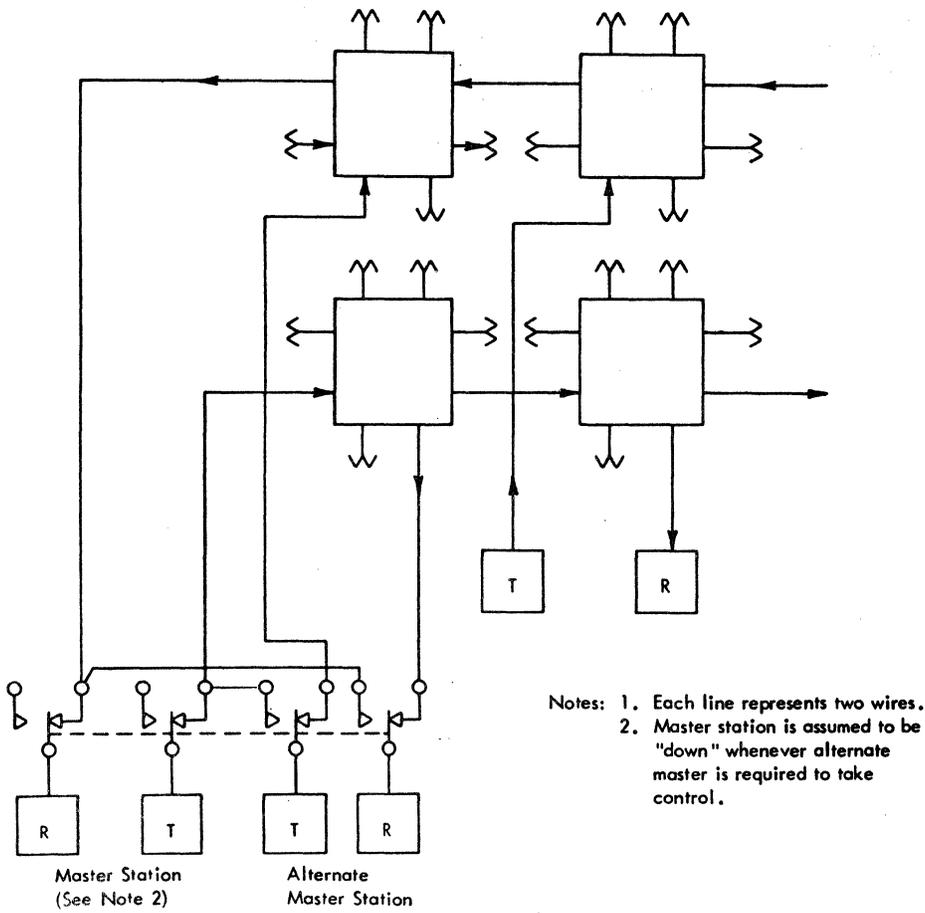
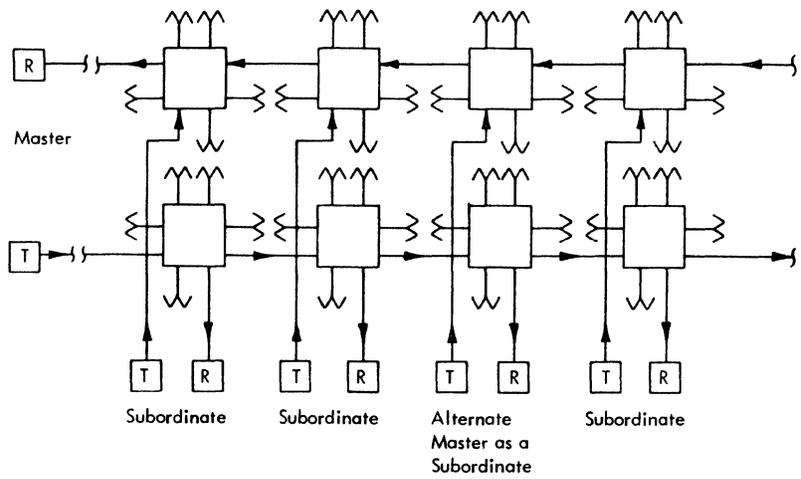
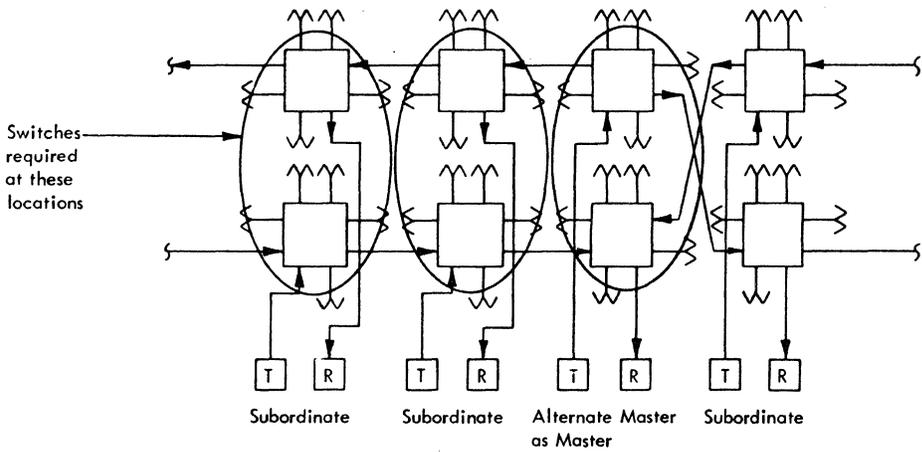


Figure 27. Regular and Alternate Master Station Served from the Same Bridges



A. Regular Master Station in Control



B. Alternate Master Station in Control

Figure 28. Regular and Alternate Master Station Served from Different Bridges



IBM Line Adapters (modems) are used on customer-installed communications lines and on common-carrier channels. Where multiplexers are used as a part of the system, various channels and modems may be found. Although a mixture of channels containing IBM Line Adapters and non-IBM modems may be used. Compatibility cannot be assured between IBM Line Adapters and any other manufacturers modem that are used on the same channel.

The five major types of IBM Line Adapters (Modems) are:

- *Limited Distance Line Adapter Type 1:* for use on either two- or four-wire lines up to 4.75 miles (7.65 km) long
- *Limited Distance Line Adapter Type 2:* for use on two-wire lines up to 8.25 miles (13.1 km) long
- *Leased Line Adapter:* for use on leased, common-carrier (or equivalent privately owned), two- or four-wire lines
- *Shared Line Adapter:* to provide up to four narrow-band subchannels over a common-carrier (or equivalent privately owned) two- or four-wire line
- *1200 Bit-per-Second Integrated Modem:* for duplex (four-wire) or half-duplex (two- or four-wire) use on dedicated (leased, common-carrier or equivalent privately owned) lines or for half-duplex (two-wire) use on the public switched network in the USA and Canada

These line adapters are further categorized to distinguish their allowable bit rates and also their use on either two- or four-wire transmission lines. Figure 29 lists IBM Line Adapters, with their various characteristics and requirements.

### IBM LIMITED DISTANCE LINE ADAPTER TYPE 1

The Limited Distance Line Adapter Type 1 is used in point-to-point and multipoint systems with 134.5 bps IBM equipment. Two versions of this line adapter are available: Type 1A for two-wire, half-duplex systems; and Type 1B for four-wire, half-duplex or duplex systems.

The recommended system configuration is a main line with branches, such as that shown in Figure 14. Up to 12 line adapters, each connected to a separate branch line, are allowed. Branch lines cannot be connected to other branch lines, and the length of any branch line must not be greater than 50 feet (15.2 m). Maximum transmission distances (aggregate length of main line and its branch lines) depend upon the number of line adapters in a system and the type of wire or cable used (see Chapter 5).

When leased common-carrier communications lines are used with this line adapter for in-plant systems, nonloaded lines with no amplifiers, no repeat coils, and no repeaters

should be specified. Additional technical information, usually required by common carriers, includes:

*Signaling Speed:* 0-134.5 bps

*Type of Line:*

Non-loaded, direct metallic lines

Amplifiers, repeat coils, or other equipment not allowed

Unterminated bridge taps not allowed. Terminated

bridge taps, if used, must be terminated in dummy loads. Bridge-tap length must not exceed permissible length for side leg. Bridge tap and termination then count as a regular side leg and a line adapter.

*Method of Modulation:* Frequency-shift keying (FSK)

*Line Frequencies:* Mark-1170 Hz; Space-1830 Hz

*Transmit Signal Level:* -8 dBm (0.876 volt, peak-to-peak)

*Minimum Receive Level:* -15.5 dBm (0.370 volt, peak-to-peak)

*Noise Rejection:* -32.8 dBm (0.050 volt, peak-to-peak)

*Input/output Impedance (Type 1A):* 3000 ohms\*

*Input Impedance (Type 1B Receive Line):* 3000 ohms\*

*Output Impedance (Type 1B Transmit Line):* 5000 ohms\*

### IBM LIMITED DISTANCE LINE ADAPTER TYPE 2

The Limited Distance Line Adapter Type 2 is used in two-wire, point-to-point and multipoint systems. Three versions are available: (1) Type 2A1 for two-wire, half-duplex systems that operate at 134.5 bps, (2) Type 2A2, which is a version of the 2A1, having arate of 600 bps, and (3) Type 2B, used with newer systems that operate at speeds of up to 600 bps.

The Type 2 line adapter allows increased system flexibility and complexity, compared to the Type 1 Limited Distance Line Adapter. Both main line and radial configurations can be used (Figure 15 and 16). Up to 36 line adapters can be connected in the same system, depending upon the capabilities of the terminal. Increased main branch and radial line lengths can be used. Branch lines up to 0.2 miles (0.3 km) or 0.5 miles (0.8 km) long can be used, depending upon the type of cable used. Line adapters may be located up to 200 cable feet (61 meters) from the main branches or radials, thus allowing a normal branch-on-branch capability of as many as three line adapters.

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\*Use these values of input/output impedance when dummy loads are required. (See "Simulating a Line Adapter" in the chapter "Planning a Limited Distance Communications System.")

Line Adapter (Modem) (9)	Type	Max. Miles (km)	RTS to CTS (ms)	Adapter Termination	Max Bit Rate	Transmit Level	Receiver Sensitivity	Average Noise Tolerance	Not Multi-point	Line	Mark Freq. (Hz) (9)	Space Freq. (Hz) (9)	Input Impedence (ohms)	Output Impedence (ohms)	Termination Resistance								
Limited Distance	1A	4.75 (7.65 km)	25 to 66	Two-wire	134.5 600	-8dBm (8)	-15.5 dBm	-32.8 dBm		See Chapter 2	1170	1830	3000	3000 or 5000	As required (See Chapter 2)								
	1B			Four-wire (1,1)																			
	2A1	8.25 (13.1 km)	8.3 to 14.8	Two-wire																			
	2A2			Two-wire																			
Leased Line	1A	None	200 ±55	Two-wire	600	0dBm (8)	-27 dBm (8)	-42 dBm	X	(2,5)	1400	2000	600	600									
	1B			Four-wire (1,11)																			
Shared Line (3)	1A			200 ±55	20 to ±5						Two-wire	134.5	-14dBm for each channel -8dBm composite (8,3)	-38 dBm		-42 dBm	X	(2,5)	820 1230 1640 2050	990 1400 1810 2200	600	600	
	1B										Four-wire (1,11)												
1200 bps (12)	Leased Line	None	200 -275	Two-wire	1200	0dBm (8)	-33 or -43 dBm	-42 dBm	X	(5,7)	1300	2100	600	600									
	Switched Network (10)			20 -40												Four-wire (1,11)							
				200 -275												Two-wire							

Notes:

- Two separate four-way, four-wire bridges are required at each drop of a multipoint circuit if continuous carrier is to be maintained on the line from the control station, or if a machine feature such as the IBM 2741 Interrupt feature is to be used. The effective operation is duplex. (Refer to the requirements given in the manual for each machine type.)
- Point-to-point systems, at bit rates of 600 bps or less, require a common-carrier Type 3002 Channel, or equivalent privately owned facilities.
- An agreement must be reached with the common carrier that the communications channel will be designed for a -8dBm transmit level, for IBM Shared Line Adapter installations.
- An "over 300 bps" loop to the local exchange and a data accrss arrangement (DAA) are required for attachment to a telephone company switched telecommunications network.
- Refer to Figure 63 in Appendix C for common-carrier channel specifications.
- A multipoint circuit less than 50 miles long and not exceeding three exchange areas (bridging point), or any point-to-point circuit, requires a common carrier Type 3002 channel or equivalent privately owned facilities (no conditioning required). A multipoint circuit greater than 50 miles long or with more than three exchange areas (bridging points) requires a common-carrier Type 3002 Channel with C1 Conditioning or equivalent privately owned facilities.
- On leased lines at the designed bit rates, the 1200 bps Integrated Modem requires a common-carrier, Type 3002 channel without conditioning. On the switched network, no modem equalization is required for bit-synchronous transmissions up to 1200 bps.
- Adjustable.
- The modulation technique for all line adapters in this table is frequency shift keying (FSK).
- The Automatic Call Orination and/or Automatic Answering special features are available. Refer to "Special Feature Descriptions" in Part 3 of Systems manual IBM 3872 Modem User's Guide, GA27-3058.
- A four-wire line adapter is capable of duplex or half-duplex operation; common-carrier facilities and the controls of the using terminal determine which operation is applicable. (Four-wire common-carrier facilities may be duplex or half-duplex, according to the specification of the customer.)
- The Local Loop Test special feature is available for verification of line adapter functions, independent of the communications line.

Figure 29. Line Adapter Characteristics and Communications Facilities Specifications

Maximum transmission distances depend upon: (1) the number of branch or radial lines, (2) the number of line adapters in a system, and (3) the types of wire or cable used (see Chapter 5).

When leased common-carrier communications channels are used, the transmit signal level must be reduced to -8 dBm, which reduces maximum allowable transmission distances by 40 percent.

Loaded lines can be used, but only for two special configurations and with certain limitations (Figure 46).

Technical information usually required by common carriers includes:

For Type 2A

**Signaling Speed:** (2A1) 0-134.5 bps  
(2A2) 0-600 bps

**Type of Line:**

Nonloaded, direct metallic two-wire lines  
Amplifiers, repeat coils, or other equipment not allowed

Unterminated bridge taps not allowed. If bridge taps are present, they must be terminated in dummy loads. (Type 2A Limited Distance Line Adapter dummy load is 8200 ohms.) Bridge-tap length must not exceed permissible length for side leg or radial. Bridge tap and termination then count as regular side leg or radial and a line adapter.

**Method of Modulation:** Frequency-shift keying (FSK)

**Line Frequencies:** Mark-1000 Hz; Space-2200 Hz

**Transmit Signal Level:** 0 dBm (2.2 volts, peak-to-peak).

It can be adjusted downward to either -6 dBm or -8 dBm.

**Minimum Receive Level:** -27 dBm (0.104 volt, peak-to-peak)

**Average Background Noise Allowable:** -52 dBm (36 dBm measured on a Western Electric Type 3A Noise set, or equivalent).

**Impulse Noise:** Should be kept to a minimum, to avoid degrading performance. (See "Noise" under "Transmission Considerations and Impairments" in the chapter "Planning an Unlimited Distance Communications System.")

**Input/Output Impedance:** Approximately 600 ohms or 8200 ohms (depending upon circuit configuration), balanced to ground.

**Timing Considerations:**

1. Request-to-send/clear-to-send delay: 8.3 to 14.8 milliseconds
2. Length of time signal must be present above threshold level before receiver unclamps: less than five milliseconds
3. Interval to apply clamp after signal disappears: less than five milliseconds
4. Signal propagation time through a transmitter and a receiver, not including line propagation time: less than three milliseconds

5. Echo clamp interval: none. Echo is not a problem on in-plant systems using nonloaded lines.

**Restrictions:**

1. No dc current must be introduced into the line adapter.
2. Allow 4 seconds warm-up time after turning on power.

**Line Configurations:** See "Planning a Limited Distance Communications System."

Type 2B

**Signaling Speed:** 0 to 600 bps

**Type of Line:**

Nonloaded direct metallic two-wire lines. Loaded lines can be used for only two special configurations with certain limitations (Figure 46). "IBM Leased Line Adapter," following in this chapter, describes a line adapter without this limitation.

Amplifiers, repeat coils, or other equipment are not allowed. Unterminated bridge taps are not allowed. If bridge taps are present, they must be terminated in dummy loads. The Type 2B Limited Distance Adapter dummy load is 5000 phms. Bridge-tap length must not exceed permissible length for a side leg or radial. Bridge tap and termination then count as a regular side leg or radial and a line adapter.

**Method of Modulation:** Frequency-shift keying (FSK)

**Line Frequencies:** Mark-1000 Hz; Space-2200 Hz

**Transmit Signal Level:** 0 dBm (2.2 volts, peak-to-peak).

It can be adjusted downward to either -6 dBm or -8 dBm.

**Minimum Receive Level:** -27 dBm (0.104 volt, peak-to-peak). It can be adjusted upward to -21 dBm.

**Average Background Noise Allowable:** -42 dBm (46 dBm on a Western Electric Type 3A Noise Set, or equivalent). For a -21 dBm receiver sensitivity, -36 dBm of noise can be tolerated.

**Impulse Noise:** Should be kept to a minimum so as not to degrade performance. (See "Noise" under "Transmission Considerations and Impairments", in Chapter 3.)

**Input/Output Impedance:** 600 ohms, or 5000 ohms (depending upon the circuit configuration), balanced to ground

**Timing Considerations:**

1. Request-to-send/clear-to-send delay: 8.2 to 16.7 milliseconds
2. Length of time signal must be present above threshold level before receiver unclamps: 3.2 to 6.28 milliseconds
3. Interval to apply clamp after signal disappears: less than five milliseconds
4. Signal propagation time through a transmitter and receiver, not including line propagation time: less than three milliseconds.

5. Echo clamp interval: none. Echo is not a problem on in-plant systems using nonloaded lines.

**Restrictions:**

1. No dc current must be introduced into the line adapter.
2. Allow four seconds warm-up time after turning on power.

**Line Configurations:** See the chapter, "Planning a Limited Distance Communications System."

### IBM LEASED LINE ADAPTER

The IBM Leased Line Adapter is used in point-to-point and multipoint systems over leased common-carrier (or equivalent privately owned) lines. Two versions of this line adapter are available: Type 1A for two-wire, half-duplex systems, and Type 1B for four-wire half-duplex or duplex systems.

This line adapter performs the same general functions as a common-carrier data set. Transmission speeds of up to 600 bps are specified. (See "Choice of Line Adapter and Grade of Line" in the chapter, "Planning an Unlimited Distance Communications System.")

Common carriers may use echo suppressors on very long, individual, two-wire voice circuits and on circuits between certain classes of switching centers in the DDD (direct distance dialing) network. Echo suppression is not usually required for data transmission; and in some cases, it may be undesirable. As a general rule, echo suppression should not be used in systems employing the IBM Leased Line Adapter. The two-wire version of this line adapter is equipped with an echo clamp circuit. As explained in Chapter 3, echo is not usually a problem on four-wire circuits

Additional technical information, usually required by common carriers, includes:

**Signaling Speed:** 0 to 600 bps

**Type of Line:** See "Speed Considerations" under "Choice of Line Adapter and Grade of Line" in Chapter 3.

**Method of Modulation:** Frequency-shift keying (FSK)

**Line Frequencies:** Mark-1400 Hz, Space-2000 Hz.

**Transmit Signal Level:** -8 dBm (0.876 volt, peak-to-peak). Can be adjusted upward to -6 dBm or 0 dBm, with common-carrier approval.

**Minimum Receive Level:** -32 dBm (0.055 volt, peak-to-peak). Can be adjusted upward to -27 dBm. This sensitivity allows for the effects of transmission line impairments and circuit net loss variations on the nominal received signal level of -16 dBm.

**Average Background Noise Allowable:** -42 dBm (for -32 dBm receiver sensitivity) or -36 dBm (for -26 dBm receiver sensitivity). The -42 dBm and -36 dBm correspond, respectively, to 46 dBrnc (54 dBrnc 0) and 52 dBrnc (60 dBrnc 0), as measured on a Western Electric Type 3A Noise Set, or equivalent.

**Impulse Noise:** Should be kept to a minimum so as to not degrade performance. (See "Noise" under "Transmission Considerations and Impairments" in

the chapter "Planning an Unlimited Distance Communications System.")

**Input/Output Impedance:** 600 ohms, balanced to ground

**Attenuation Distortion Allowable (Compared to Attenuation at 1000 Hz):**

-2 dB to +6 dB in the range of from 350 Hz to 2000 Hz

-3 dB to +8 dB in the range of from 2000 Hz to 2500 Hz

**Envelope Delay Distortion Allowable:** One millisecond maximum between 1000 Hz and 2400 Hz

**Timing Considerations:**

1. Request-to-send/clear-to-send delay:

Type 1A (two-wire): 200 ± 55 milliseconds (requires 15 milliseconds recovery time).

**Note:** On very short lines, 20 milliseconds' clear-to-send time can be used with Type 1A, if round trip line propagation time is less than 7 milliseconds and first talker echo (echo from the transmitting modem) is below receiver threshold.

Type 1B (four-wire): 20 ± 5 milliseconds (requires 2 milliseconds recovery time)

2. Length of time signal must be present above the threshold level before the receiver unclamps: 6.8 to 13.4 milliseconds
3. Interval to apply clamp after signal disappears: less than 8 milliseconds
4. Signal propagation time through a transmitter and a receiver, not including line propagation time: less than 3 milliseconds
5. Echo clamp interval (Type 1A, 200 ms clear-to-send): 113 to 145 milliseconds.

**Restrictions:**

1. No dc current must be introduced into the line adapter.
2. Four seconds warm-up time after turning on power.

**Line Configurations:**

1. The two-wire version is normally used in point-to-point, half-duplex applications.
2. The four-wire version is normally used for other than half-duplex, point-to-point.
3. See the chapter, "Planning an Unlimited Distance Communications System," for figures and details.

**Connection to Common-Carrier Facilities:**

The cable connecting the IBM terminal to the common-carrier line normally terminates in a standard telephone type 283B, four-prong plug. The pin assignments for two-wire and four-wire local channels are shown in Figure 30. This plug mates with a telephone type 404B (surface mount) or 493B (flush mount) jack (or equivalent) provided by the customer or common carrier. Multiple line connections, such as at a multiplexer, may require termination arrangements other than telephone type 404B jacks. These situations require coordination with common-carrier representatives.

## IBM SHARED LINE ADAPTER

The IBM Shared Line Adapter is used in point-to-point and multipoint systems over leased common-carrier (or equivalent privately owned) lines. Two versions of this line adapter are available: Type 1A for two-wire half-duplex systems, and Type 1B for four-wire half-duplex or duplex systems.

This line adapter performs the same general functions as a common-carrier data set. It provides one to four narrow-band subchannels on a common-carrier voice-grade channel or equivalent. A transmission speed of up to 134.5 bps is specified.

Note that echo suppression must never be used in systems employing the IBM Shared Line Adapter. See "Use of Echo Suppressors" in the chapter, "Planning an Unlimited Distance Communications System."

*Note:* An agreement on -8 dBm transmit level must be reached with the common carrier, for installations of the IBM Shared Line Adapter.

Additional technical information usually required by common-carriers, includes:

*Signaling Speed:* 0 to 134.5 bps

*Type of Line:* See "Speed Considerations" in Chapter 3.

*Method of Modulation:* Frequency-shift keying (FSK).

*Line Frequencies:*

Subchannel	Mark	Space
1	820 Hz	990 Hz
2	1230 Hz	1400 Hz
3	1640 Hz	1810 Hz
4	2050 Hz	2220 Hz

*Transmit Signal Level (per Subchannel at Line Side of Channel Filter):* -14 dBm (0.438 volt, peak-to-peak).

Can be adjusted upward to -11 dBm or -8 dBm. See *Note* under "Minimum Receive Level," following.

*Minimum Receive Level (per Subchannel at Line Side of Channel Filter):* -38 dBm (0.0276 volt, peak-to-peak).

This sensitivity allows for the effects of transmission line impairments and circuit net loss variations on the nominal received signal level of -22 dBm.

*Note:* The values for transmit signal level and minimum receive level are stated on a "per subchannel" basis. These values are not easily measured. The total signal level achieved by four subchannels, each producing equal signal levels, is 6 dB higher than the level of each subchannel.

*Average Background Noise Allowable:* -42 dBm, measured over the entire bandpass of transmission line. (This corresponds to 46 dBm or 54 dBm O.) Noise rejection is measured across the entire bandpass of the communications channel. Therefore, on a "per subchannel" basis, the value given can be reduced by 6 dB.

*Impulse Noise:* Should be kept to a minimum so as to not degrade performance. (See "Noise" under "Transmission Considerations and Impairments" in Chapter 3.)

*Input/Output Impedance:* 600 ohms, balanced to ground  
*Attenuation Distortion Allowable (Compared to Attenuation at 1000 Hz):*

-2 dB + 6 dB in the range of from 350 Hz to 2000 Hz

-3 dB to + 8 dB in the range of from 2000 Hz to 2500 Hz

*Envelope Delay Distortion Allowable:* 1 millisecond maximum between 1000 Hz and 2400 Hz

*Timing Considerations:*

1. Request-to-send/clear-to-send delay: Type 1A (two-wire): 200 ± 55 milliseconds (requires 15 milliseconds recovery time). Type 1B (four-wire): 20 ± 5 milliseconds (requires 2 milliseconds recovery time)
2. Length of time signal must be present above the threshold level before the receiver unclamps: 6.8 to 13.4 milliseconds.
3. Interval to apply clamp after signal disappears: less than 8 milliseconds.

*Note:* Because of the slow signal decay at the receive filter terminals, the interval to apply the clamp, as measured from the time the signal starts to decay at the receive filter terminals, can be much longer. Intervals of up to 20 milliseconds may be observed.

4. Signal propagation time through a transmitter and a receiver, including line filters, not including line propagation time: less than 15 milliseconds. Excluding line filters and line propagation time, the delay is less than 3 milliseconds.
5. Echo clamp interval (Type 1A, two-wire versions only): 113 to 145 milliseconds

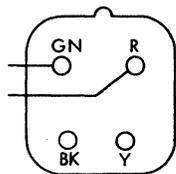
*Restrictions:*

1. No dc current must be introduced into the line adapter.
2. Allow for a 4-second warm-up time after turning on power.
3. Echo suppressors may not be used with the IBM Shared Line Adapter.

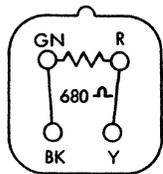
*Connections to Common-Carrier Facilities:* The cable connecting the IBM terminal to the common-carrier line normally ends in a standard telephone type 283B, four-prong plug. The pin assignments for two-wire and four-wire local channels are shown in Figure 30. This plug mates with a type 404-B (surface mount) or 493A (flush mount) jack (or equivalent) provided by the customer or common carrier. Multiple line connections, such as at a multiplexer, may require termination arrangements other than telephone type 404B jacks. These situations require coordination with common-carrier representatives.

Domestic Common-Carrier-Provided Type 404B or 549A Surface Mount, or Type 493A Flush Mount (or Equivalent) Jacks

To 2-Wire Local Channel (loop)



IBM-Provided Type 283B Plug with Terminating Resistor (Shared Line Adapter)

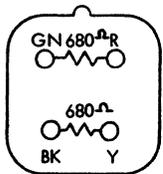
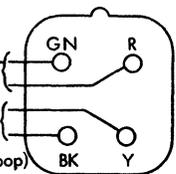


IBM P/N 5151250

A. 2-Wire Terminating Jack and Plug

Domestic Common-Carrier-Provided Type 404B or 549A Surface Mount, or Type 493A Flush Mount (or Equivalent) Jacks

Transmit to local channel (loop)  
Receive from local channel (loop)



IBM P/N 5151251

B. 4-Wire Termination Jack and Plug

Figure 30. Line Termination Jacks and Plugs

**Line Configurations:**

1. The IBM Shared Line Adapter can operate over two-wire or four-wire channels.
2. The system consisting of the transmission line and all the line adapters of the same subchannel make up a separate transmission system. Therefore, up to four different transmission systems are possible within a given point-to-point or multipoint leased-line circuit. As described in detail below, there is considerable flexibility in arranging the drops and subchannels.
3. On a given local channel (two- or four-wire), four subchannels are available, each using separate frequencies. All four subchannels, or any combination of them, may be present. Only one terminal may use the same subchannel on a local channel. See Figure 31.
4. In multipoint circuits, subchannels may be dropped at an intermediate point on the same four-wire local channel (Figure 32).
5. For installation of Shared Line Adapters, common carriers generally terminate their local channels using one of three methods, depending upon local practices.

One method used by the common carrier provides the local channel with one jack for each Shared Line Adapter feature and an additional jack for the terminating impedance.

A second method used by the common carrier provides only a single jack for the local channel ter-

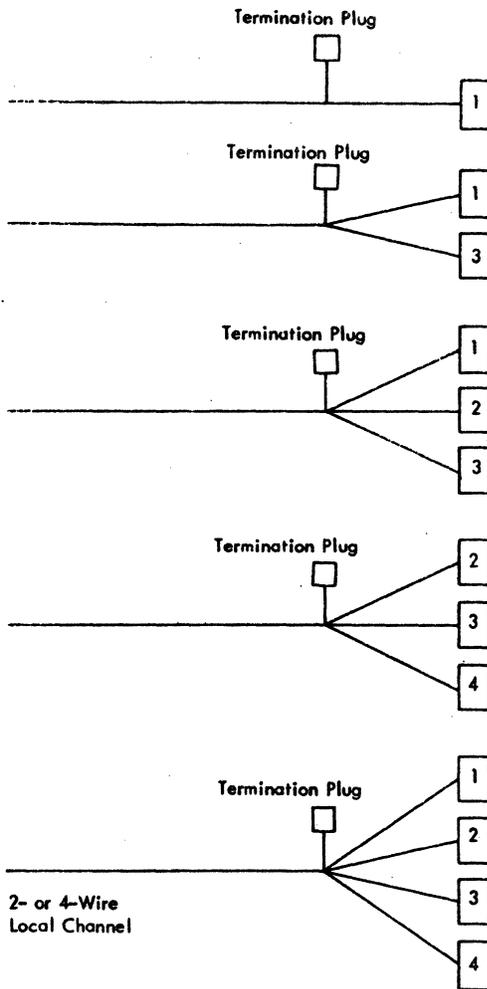


Figure 31. Representative Distributions of Subchannels on a Local Channel

mination; an IBM Shared Line Adapter 4/1 Terminator plugged into the jack then enables the attachment of up to four Shared Line Adapter features.

A third method is optional for World Trade applications; it is one in which the common carrier terminates the local channel at a terminal strip which has, fastened to it, the skinned-and-tinned cables from the Shared Line Adapter features. These three methods are detailed in the following paragraphs:

**Method 1:** The common carrier provides multiple 404B-type jacks, wired together in parallel; this arrangement contains one jack for each Shared Line Adapter feature on the local channel and one jack-located at the fan-out point-for the terminating impedance. Figures 33 and 34 illustrate this method. When it is plugged, the terminating

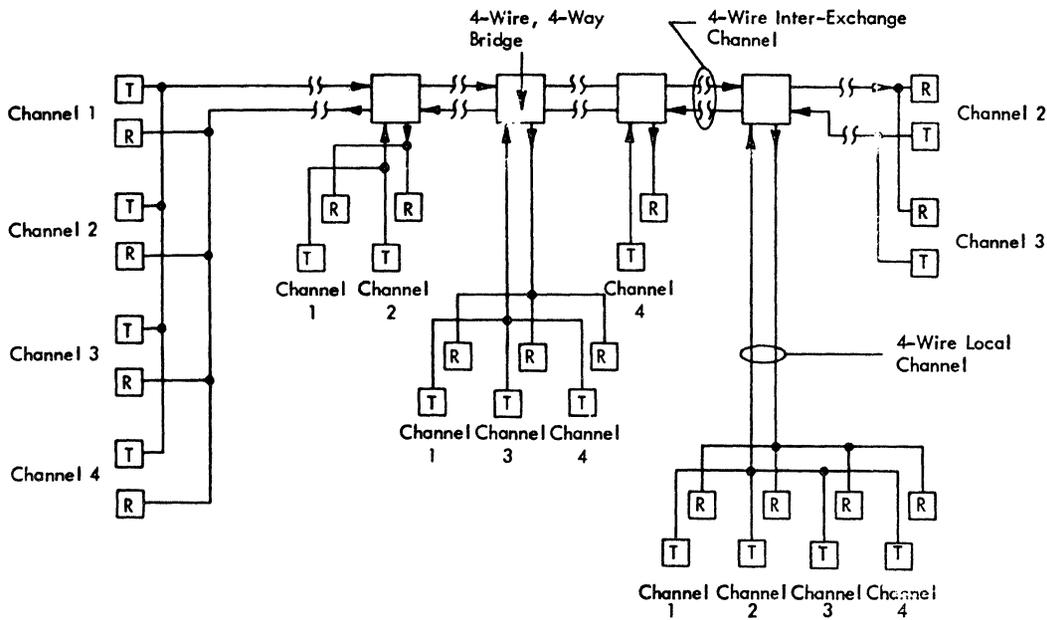


Figure 32. Multipoint Channel, Showing Flexibility of IBM Shared Line Adapter Subchannels

impedance allows terminals to be disconnected from the line without risk of disrupting transmission that is in progress on the line. The termination impedance is provided by IBM with the

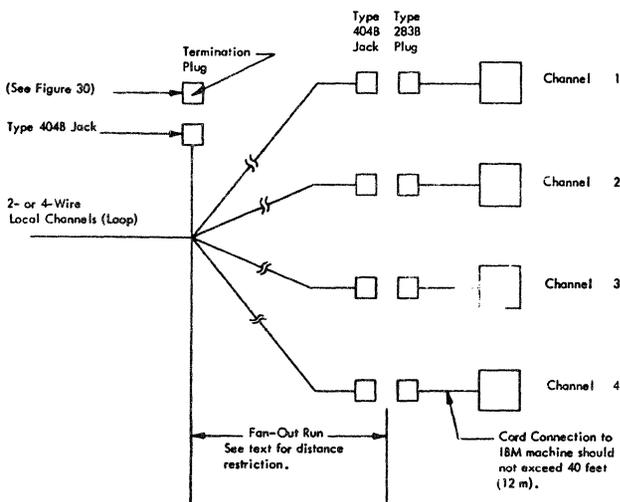


Figure 33. Fan-Out Run for IBM Shared Line Adapter

2711 subchannel 1 and with each terminal having the Shared Line Adapter feature.

*Method 2:* The common carrier provides a single 404B-type jack termination per local channel. At the 2711, a fan-out box--the Shared Line Adapter 4/1 Terminator--is used to attach up to four different subchannels to the single jack. The 4/1 terminator receptacle contains the line terminating impedance (see Figure 35); the line, therefore, remains terminated, even if the line adapter cable is unplugged for servicing.

*Method 3:* This is a World Trade option in which the common carrier terminates the local channel at a PTT - or customer-provided terminal strip. Skinned-and-tinned cables, available as an option with the Shared Line Adapter feature on the 2711, are screw-connected to the terminal strip. The terminating impedances are provided with the 2711 subchannel 1 for field attachment across each pair of wires on the local channel (see Figure 36).

6. Fan-out run cable lengths: The length of cable between the fan-out point (where the termination plug is located) and each IBM terminal depends on the resistance (gauge) and capacitance of the wire. See

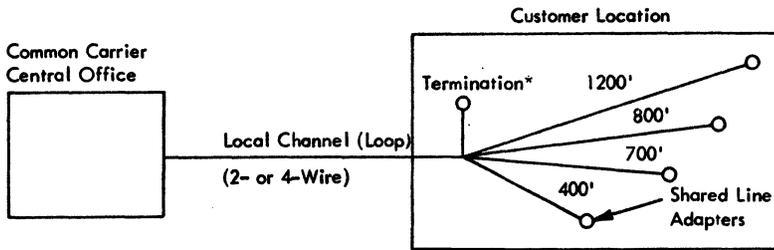
Figure 33 for illustration of cable lengths. Multi-pair inside-type phone cable lengths are:

Gauge	Maximum Length of Fan-out Run	Maximum Length of Fan-out Run	
		Feet	Meters
22 gauge capacitance per mile (1.6 km) of 0.137 $\mu$ F or less	900	275	
24 gauge capacitance per mile (1.6 km) 0.136 $\mu$ F or less	900	275	
22 gauge high-capacitance cable up to 0.3 $\mu$ F per mile or 1.6 km or 56 pF per foot (0.305 m)	400	122	

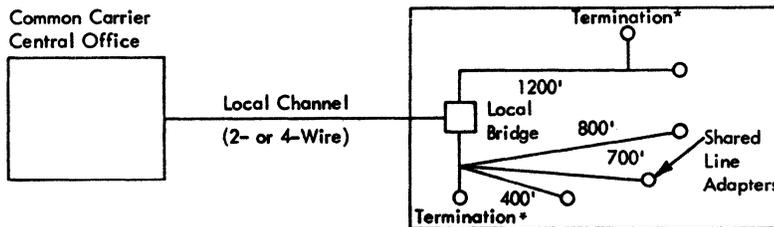
*Note 1:* It should not be necessary to ascertain the fan-out length unless a building is over 40 stories high and/or covers a wide area (such as a large industrial plant complex) since the 900-foot (275 meters) restriction is not normally exceeded.

*Note 2:* If the fan-out cable length to a shared line adapter exceeds the limits above, that adapter must be served from a separate bridge leg. Use either a local bridge or central-office bridge. Local bridges may be either the two-wire variety (see Figure 20 on Bell Telephone Laboratories (AT & T) drawing No. SD-55647-01, or equivalent) or the four-wire variety (see Figure 11 or 23 of the same drawing, or equivalent). Each separate bridge leg must have its own separate 283B plug, with its own 680-ohm termination (Figure 34).

- Other special requirements: If any one of these separate subsystems of line adapters, of the same subchannel number, has carrier on at the master station at all times, then the whole circuit must be four-wire and have two separate bridges at intermediate dropping points—one bridge in each direction of transmission. The requirement restricts the system as follows:

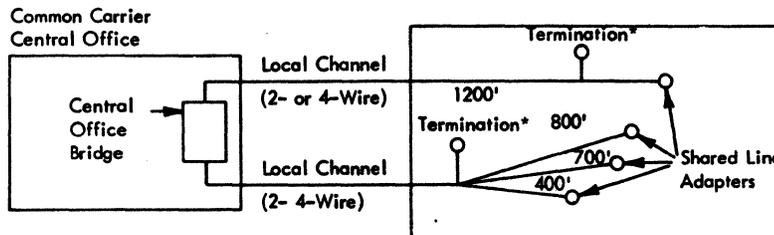


A. Proposed Arrangement - Unsatisfactory



B. Satisfactory Arrangement Using Local Bridge

English	Metric
1200'	368 m
800'	244 m
700'	213 m
400'	122 m



C. Satisfactory Arrangement Using Central Office Bridge

\* To be located within 900 feet of line adapter.

Figure 34. Installation When 900-Foot Fan-Out Length is Exceeded

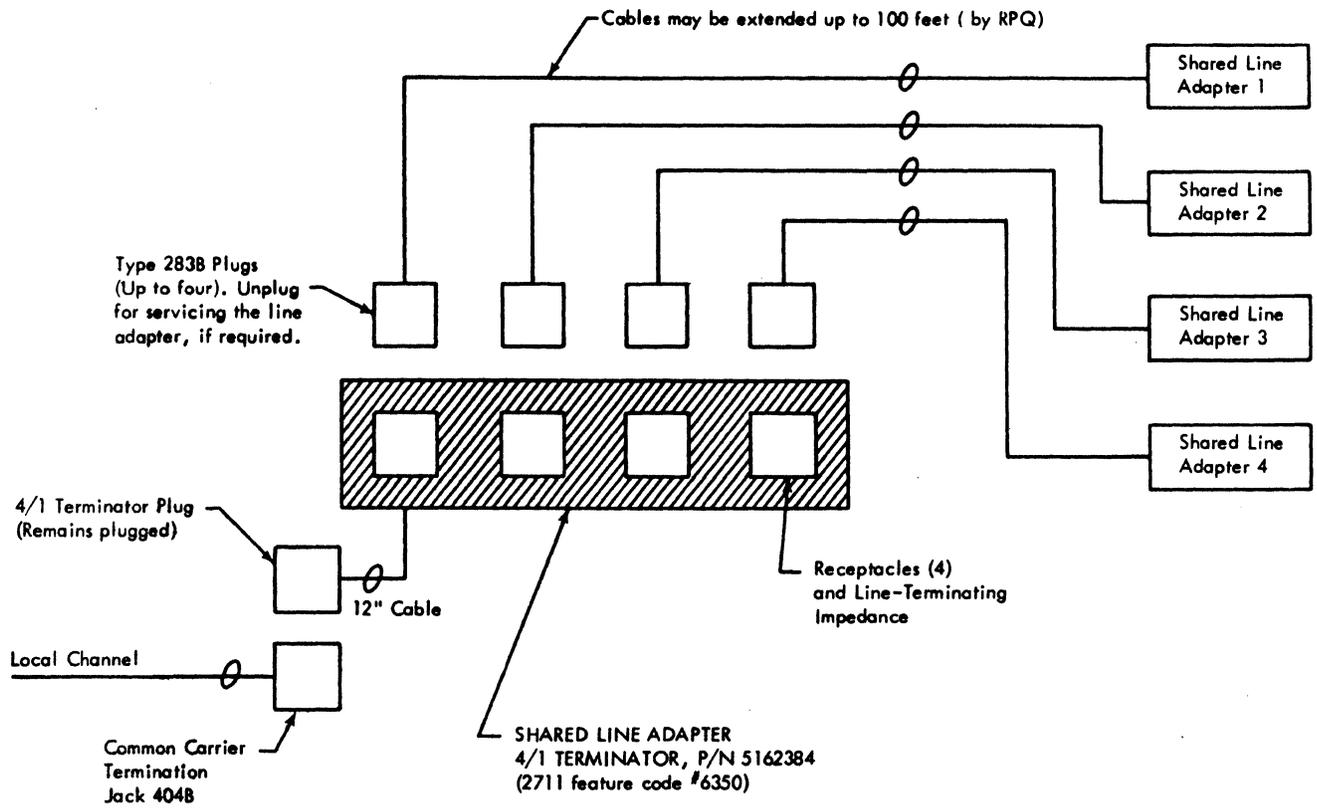


Figure 35. Up to Four Shared Line Adapters Per Local Channel (USA)

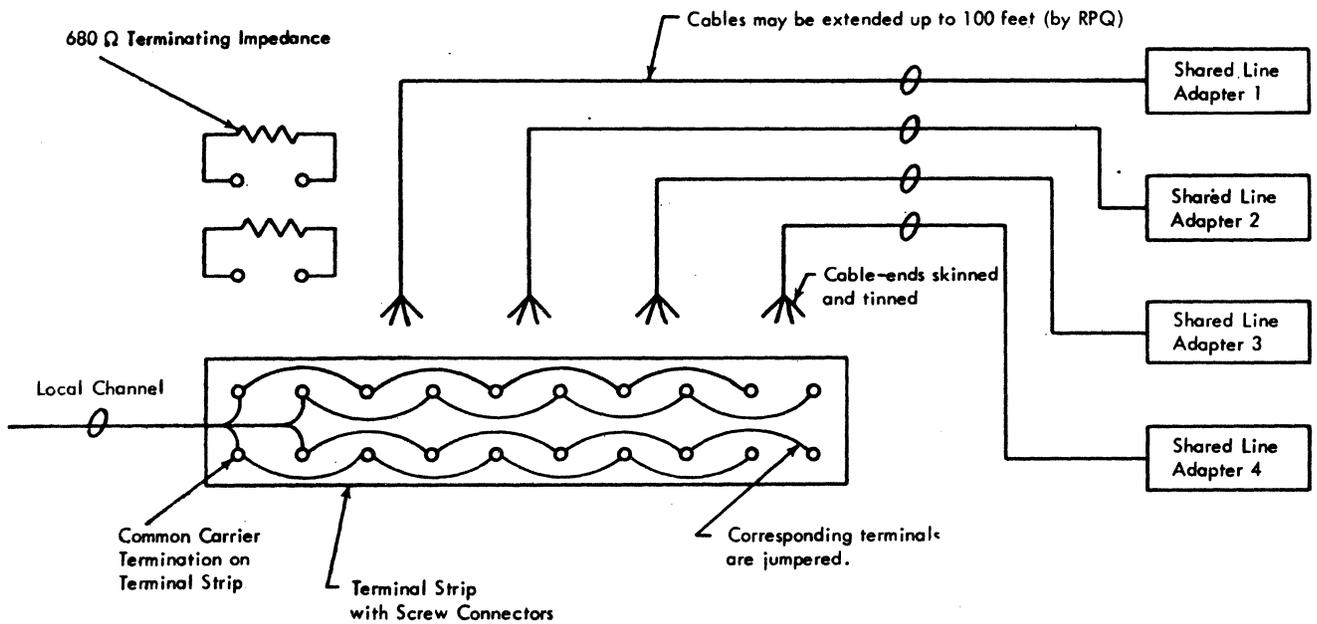


Figure 36. Up to Four Shared Line Adapters Per Local Channel (World Trade)

Master-subordinate station operation (line control) must be used on all subchannel transmission systems.

All master stations must be at the same location on the same local channel.

Master station transmitters and all subordinate station receivers must be on one side of the line; master station receivers and all subordinate station transmitters must be on the other side of the line. (See "Choice of Half-Duplex or Duplex" in Chapter 3.)

## 1200 BIT-PER-SECOND INTEGRATED MODEM

The 1200 Bit-per-Second Integrated Modem is used in point-to-point and multipoint systems over dedicated (leased or privately owned) voice-grade lines. It is also used on the public switched network in the USA and Canada. This adapter performs the same general functions as common-carrier data set equipment. Transmission rate may be up to 1200 bps (bit-synchronous transmission). (See "Choice of Line Adapter and Grade of Line" in the preceding chapter, "Planning an Unlimited Distance Communications System".)

Common carriers may use echo suppressors on very long, individual voice circuits between certain classes of switching centers in the direct distance dialing (DDD) network. Echo suppression usually is not required for data transmission; in some cases, it is undesirable. As a general rule, echo suppression should not be used in dedicated systems using the 1200 Bit-per-Second Integrated Modem. The two-wire half-duplex versions of this adapter are equipped with an echo clamp circuit. As explained in the preceding chapter, echo is not normally a problem on duplex systems.

The basic line adapter (without additional features) operates as a multipoint line adapter. The Automatic Answering or Automatic Call Origination (which includes automatic answering) special features are available for switched network applications.

The special features for the 1200 Bit-per-Second Integrated Modem included:

Local Loop Test, Automatic Answering, and Automatic Call Origination (with automatic answering). The Local Loop Test feature allows verification of line adapter functions, independent of the communications line. The Switched Network Calling and Answering features are the same as those used for the IBM 3872 Modem. Figure 37 illustrates automatic answering; Figures 38 and 39 illustrate automatic call origination. For further information, refer to "Special Feature Descriptions" in Part 3 of Systems manual *IBM 3872 Modem User's Guide*, GA27-3058, as follows:

- Manual switched network configuration. Disregard automatic equalization and specific reference to 3872 usage.
- Switched network with automatic answering. See "Switched Network Feature"; disregard automatic equalization and specific reference to 3872 usage.

- Switched network with automatic call origination. See "Automatic Call Origination on Switched Network Feature"; disregard operator panel controls and specific reference to 3872 usage.

Additional technical details are as follows:

*Signaling Speed:* 0 to 1200 bps

*Type of Line:* See Figure 29.

*Line Parameters:* See Figure 63.

*Method of Modulation:* Frequency-shift keying (FSK)

*Line Frequencies:* Mark-1300 Hz; Space - 2100 Hz

*Transmit Signal Level:* 0 dBm, continuously adjustable to -15 dBm.

*Minimum Receive Level:* -33 dBm or -43 dBm, strapped according to use on leased lines or the switched network, respectively.

*Input/Output Impedance:* 600 ohms, balanced to ground, with an option of 5000 ohms available.

*Timing Considerations:*

1. Request-to-send/clear-to-send delay: four-wire (duplex or half-duplex), dedicated line, nominally 25 milliseconds; two-wire (half-duplex dedicated line or switched network), nominally 250 milliseconds. A 90-millisecond delay is available for short two-wire (half-duplex) dedicated lines.

*Note:* On very short two-wire lines, 25 milliseconds' clear-to-send time can be used, if round trip line propagation time is less than 7 milliseconds and first talker echo (echo from the transmitting modem) is below receiver threshold.

2. Length of time that the received signal must be present above the threshold level before the receiver unclamps: 10.0 to 20.0 milliseconds.
3. Interval for applying clamp after the signal disappears: 5 to 15 milliseconds.
4. Signal propagation time through a transmitter and a receiver: less than 3.2 milliseconds.
5. Received data clamp interval (two-wire, half-duplex only): with the 250-millisecond clear-to-send delay, it is nominally 175 milliseconds; with the optional 90-millisecond clear-to-send delay, it is nominally 60 milliseconds.
6. With automatic call origination, there is an optional 20, 40, or 60-second timeout between dial digits or for the answer tone.
7. With automatic call origination, recognition of dial tone for call origination may be replaced (by strapping) with a 3.2 second "blind dial" delay.

*Restrictions:*

1. No dc current must be introduced by the line into the line adapter.
2. Five seconds warm-up time is needed after turning power on.

*Line Configurations:*

1. Point-to-point, two-wire, half-duplex
2. Point-to-point, four-wire, duplex or half-duplex

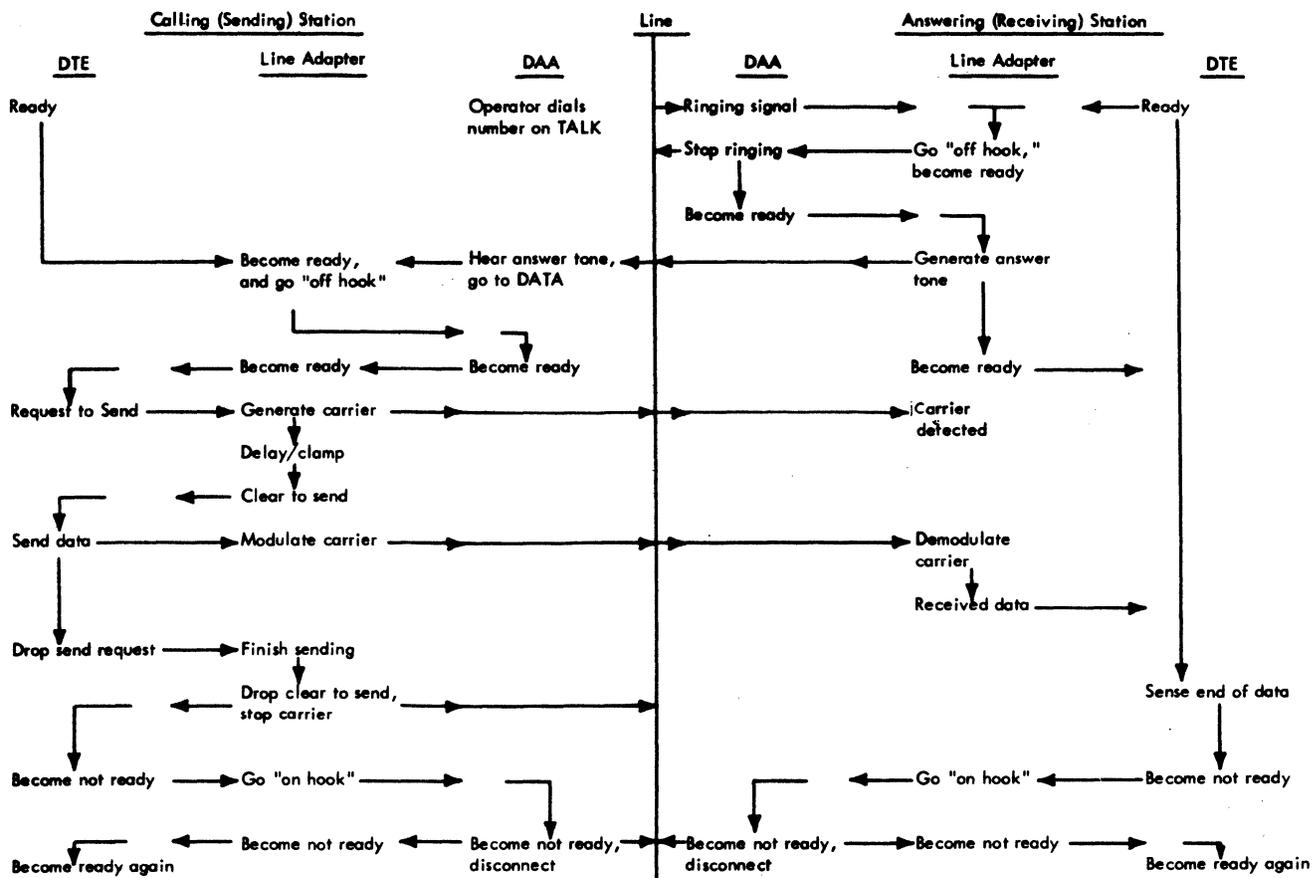


Figure 37. Manual Call, Automatic Answer (Switched Network)

- 3. Multipoint, four-wire, duplex or half-duplex (control or tributary)
- 4. Switched network, two-wire, half-duplex

Note: Refer to Figure 29.

**Customer Responsibilities**

When installing an IBM modem (stand-alone or integrated) it will be the responsibility of the customer to:

1. Assure that the communication facility is for the type and grade over which the modem is designed to operate. The information the customer will require concerning these facilities can be obtained from the IBM sales representative.
2. Assure that the proper coupling/connection devices have been installed to allow the connection of the modem to the communication facility. The information the customer will need to arrange for this follows:
  - A. For connection to a non-switched voice grade line in the United States and Canada, a Western

Digit	Hex
0	'00'
1	'01'
2	'02'
3	'03'
4	'04'
5	'05'
6	'06'
7	'07'
8	'08'
9	'09'
EON*	'0C'
SEP*	'0D'

\* The use of EON (end of number) is a strapping option recommended for reliable operation. When used, these characters are transferred as dial digits. SEP indicates a pause, such as waiting for a second dial tone, in dialing for an outside line. EON indicates that all dial digits have been transferred.

Note:  
 Approximate digit dialing time: 0.9 sec. min. 1.8 sec. max.

Figure 38. Dial Digits with Automatic Call Origination

Electric Type 404B, 493B, or 549A (or equivalent) four prong receptacle must be provided. This receptacle must be wired to the local loop as follows:

- Terminals GN and R must be connected to a two wire local loop or to the transmit pair of a four wire local loop.
- Terminals BK and Y must be connected only to the receive pair of a four wire local loop.

B. For connection to a non-switched voice grade line in all countries except the USA and Canada, a terminal block which will accept spade lugs must be provided.

C. A manual call, manual answer connection to the switched communication facilities in the USA and Canada requires all of these:

- A telephone local loop conditioned for data transmission above 300 bits-per-second,

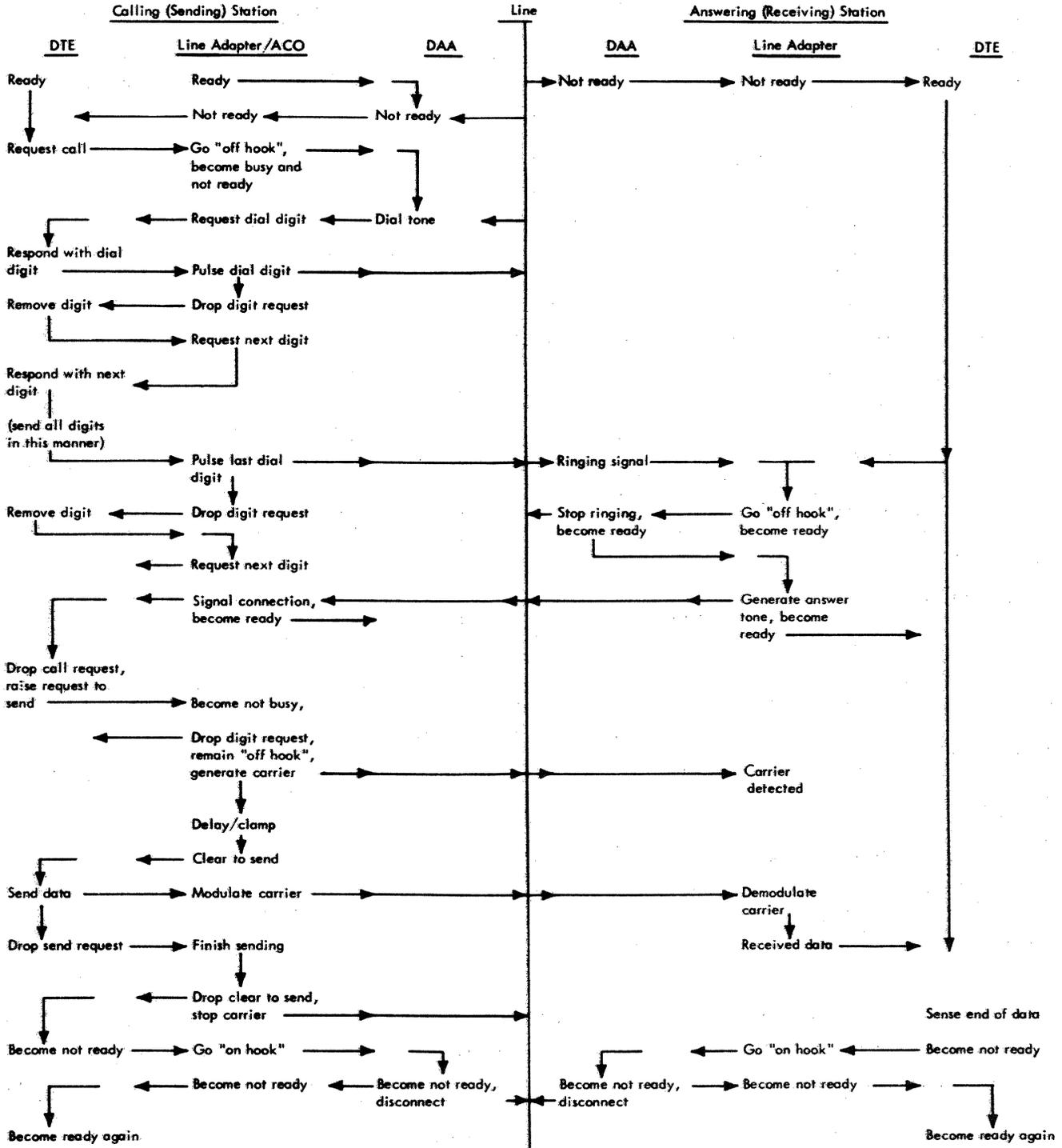


Figure 39. Automatic Call, Automatic Answer (Switched Network)

- A Type CDT Data Access Arrangement (DAA) (Western Electric Type 1000A or common carrier-provided equivalent), and
- A Western Electric Type 404B, 493B, or 549A (or equivalent) four prong receptacle with terminals GN and R connected to the Type CDT DAA.

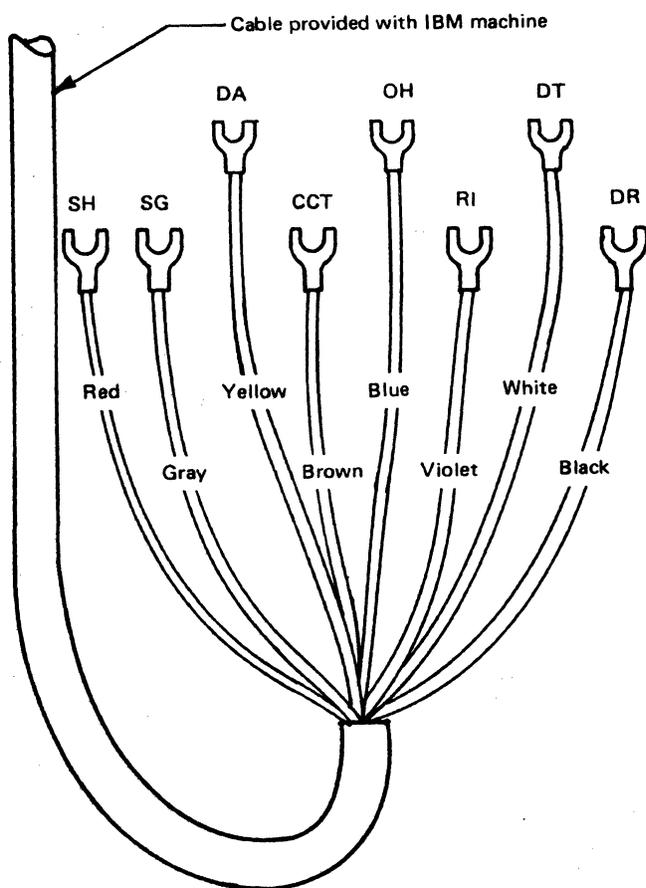
D. An automatic/manual call or automatic/manual answer connection to the switched communi-

cation facilities in the USA and Canada requires both:

- A telephone lical loop conditioned for data transmission above 300 bits-per-second, and
- A Type CBS DAA (Western Electric Type 1001A series 5 or Western Electric Type 1001F or common carrier-provided equivalent) with these options:
  - An appropriate telephone set with an exclusive key or a talk/data switch,
  - Coupler control of the line, and
  - Ring Indicate to the modem or to the modem and the telephone set.

In addition, the customer is responsible for having the IBM modem interface cable connected to the Type CBS DAA in accordance with Figure 39.1.

E. For connection to the switched communication facilities in all countries except the USA and Canada, a terminal block which will accept spade lugs must be provided.



- SH - 'switch hook' (red)
- SG - 'signal ground' (gray)
- DA - 'data modem ready' (yellow)
- CCT - 'coupler cut through' (brown)
- OH - 'off hook' (blue)
- RI - 'ring indicator' (violet)
- DT - 'data tip' (white)
- DR - 'data ring' (black)

Figure 39.1. Connection to Data Coupler

**DUPLEX 600 bps INTEGRATED MODEM**

The Duplex 600 bps Integrated Modem is used in point-to-point systems, over nonswitched voice-grade communications lines. There is no provision for its use with multipoint or switched network systems.

Duplex transmission is accomplished with two simplex subchannels transmitting and receiving on two separate frequencies. The operating frequencies are:

Modem 1	Channel A	Transmitter	Mark	900 Hz.
			Space	1300 Hz.
Modem 2	Channel A	Receiver	Mark	900 Hz.
			Space	1300 Hz.
Modem 2	Channel B	Transmitter	Mark	2000 Hz.
			Space	2400 Hz.
Modem 1	Channel B	Receiver	Mark	2000 Hz.
			Space	2400 Hz.

Installation of this modem requires a "modem 1" at one end of the transmission line and a "modem 2" at the other end. See Figure 39.2.

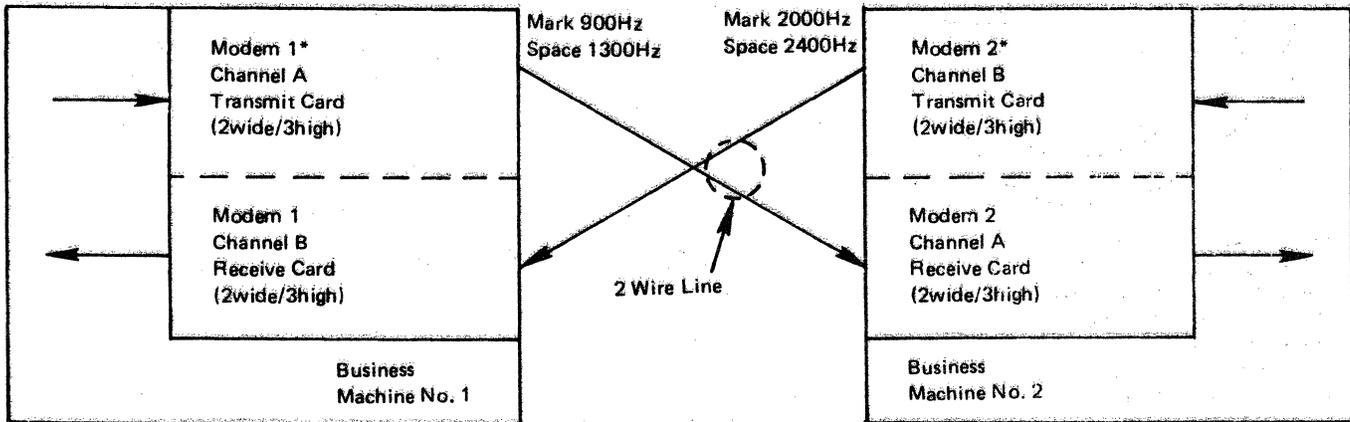
Technical details are:

- Signaling speed: 0 to 600 bps
- Type of Line: Two-wire nonswitched (voice-grade)

- Line Frequencies: Mark - 900 Hz and 2000 Hz  
 Space - 1300 Hz and 2400 Hz
- Method of Modulation: Frequency-shift keying (FSK)
- Transmit Signal Level: 0 to -16 dBm (adjustable)
- Minimum Receive Level: -35 dBm
- Maximum Receive Level: -8 dBm
- Input/Output Impedance: 600 ohms

Timing Considerations: The length of time that the receive signal must be present above the threshold level before the receiver unclamps is 10.0 to 20.0 milliseconds. The interval for applying a clamp to the receiver after the signal falls below the threshold level is 5.0 to 15.0 milliseconds.

- Line Configuration: Point-to-point, two-wire, duplex.
- Connection to Common Carrier Facilities: The host business machine provides a shielded, twisted-pair cable from the modem, terminating in spade lugs.



\* A modem 1 must be paired with a modem 2.

Figure 39.2. Duplex 600 bps Integrated Modem—System Data Flow

Communications lines connecting IBM Limited Distance Line Adapters, Types 1 and 2 can be either user-installed or wiring installed by a common-carrier. For either type of wiring, maximum line lengths are specified in tabular form for each type of line adapter. The use of these tables is described in "Calculation of Maximum Line Lengths" in the chapter, "Planning a Limited Distance Communications System."

Figure 40 shows maximum aggregate lengths for a main line and branch connecting Type 1 Limited Distance Line Adapters. These lengths are given for three types of 22-gauge wire or cable, in systems using from 2 to 12 line adapters.

Figure 41 is a key to the line-length tables shown in Figures 42 to 45. These tables are used with the Type 2 Limited Distance Line Adapter. For a main-line configuration, the maximum length of the main line and of each branch line can be calculated.

Maximum Aggregate Length of Main Line and Branch Lines*						
No. of Line Adapters in System*	Outside-Type Telephone Cable		Inside-Type Telephone Cable		Single Twisted-Pair Wire	
	Miles	Kilo-meters	Miles	Kilo-meters	Miles	Kilo-meters
2	4.75	7.65	4.00	6.44	2.75	4.42
3	4.25	6.84	3.60	5.80	2.60	4.18
4	3.50	5.64	3.25	5.23	2.40	3.86
5	3.00	4.83	2.90	4.67	2.20	3.54
6	2.60	4.18	2.50	4.02	2.00	3.22
7	2.25	3.62	2.25	3.62	1.85	2.98
8	1.90	3.06	1.90	3.06	1.70	2.74
9	1.65	2.66	1.70	2.74	1.55	2.49
10	1.40	2.25	1.50	2.41	1.40	2.25
11	1.30	2.09	1.40	2.25	1.30	2.09
12	1.20	1.93	1.30	2.09	1.20	1.93

\* Only one Line Adapter can be connected to a branch line. Maximum length of each branch line is 50 feet (15.2 meters).

Figure 40. Maximum Transmission Distances for IBM Limited Distance Line Adapter Type 1

For a radial configuration, the maximum value of the average of the lengths of all radial lines and the maximum length of the longest radial can be determined.

The IBM Leased Line Adapter and Shared Line Adapter are intended for use on unlimited distance, leased, common-carrier, private lines. Because such lines are designed and are installed by communications common carriers, line-length tables are not applicable. However, this does not preclude using these line adapters on customer-owned communications facilities that meet common-carrier specifications.

Figure 46 shows allowable system configurations and maximum main-line lengths for the Type 2 Limited-Distance Line Adapter when used on common-carrier lines.

Configuration	Table Group
Main Line: 1 Line Adapter per branch and at ends of main line	I (Figure 42)
Main Line: 2 Line Adapters per branch and at ends of main line	II (Figure 43)
Main Line: 3 Line Adapters per branch and at ends of main line	III (Figure 44)
Radial: maximum of 3 Line Adapters per line	IV (Figure 45)

Main Line or Radials Type of Cable	Branch Lines or Radials Type of Cable	Table Sub-Group
Outside-Type Telephone	Outside-Type Telephone	A
	Inside-Type Telephone	B
	Single Twisted-Pair	B
Inside-Type Telephone	Outside-Type Telephone	B
	Inside-Type Telephone	B
	Single Twisted-Pair	B
Single Twisted-Pair	Outside-Type Telephone	C
	Inside-Type Telephone	C
	Single Twisted-Pair	C

Smallest Gauge Cable in System	Table
22	1
24	2
26	3

Example: Main line with branches. Two line adapters per branch and at ends of main line. Main line of outside-type cable and branches of inside-type telephone cable. Smallest gauge cable in system: 24 (Use Table II-B-2 in Figure 43.)

Figure 41. Key to Maximum Line Length Tables for Limited Distance Line Adapter Type 2

Table 1-A-1

22 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	8.25	13.3	8.25	13.3	8.0	12.9	8.0	12.9	7.75	12.5	7.75	12.5	7.5	12.1	7.5	12.1	7.25	11.7	7.25	11.7	7.0	11.3		
0.25	.403	-	-	8.0	12.9	7.75	12.5	7.5	12.1	7.25	11.7	7.0	11.3	6.75	10.9	6.25	10.1	6.25	10.1	6.25	10.1	6.0	9.65		
0.50	.805	-	-	8.0	12.9	7.5	12.1	7.25	11.7	6.75	10.9	6.5	10.5	6.25	10.1	6.0	9.65	5.75	9.26	5.5	8.85	5.25	8.45		

Note: AWG = American Wire Gauge

Table 1-A-2

24 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	7.5	12.1	7.5	12.1	7.5	12.1	7.25	11.7	7.0	11.3	7.0	11.3	6.75	10.9	6.75	10.9	6.5	10.5	6.5	10.5	6.25	10.1		
0.25	.403	-	-	7.25	11.7	7.25	11.7	7.0	11.3	6.75	10.9	6.5	10.5	6.25	10.1	6.0	9.65	6.0	9.65	5.75	9.26	5.5	8.85		
0.5	.805	-	-	7.25	11.7	6.75	10.9	6.5	10.5	6.0	9.65	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25		

Table 1-A-3

26 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	6.0	9.65	6.0	9.65	5.75	9.26	5.75	9.26	5.5	8.85	5.5	8.85	5.5	8.85	5.25	8.45	5.25	8.45	5.0	8.05	4.75	7.65		
0.25	.403	-	-	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	5.0	8.05	4.75	7.65	4.5	7.25	4.25	6.85	4.25	6.85	4.0	6.45		
0.50	.805	-	-	5.75	9.26	5.25	8.45	5.0	8.05	4.5	7.25	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	3.0	4.83		

Table 1-B-1

22 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	6.0	9.65	5.75	9.26	5.75	9.26	5.75	9.26	5.5	8.85	5.5	8.85	5.25	8.45	5.25	8.45	5.25	8.45	5.0	8.05	5.0	8.05		
0.1	.161	-	-	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	4.25	6.85	4.25	6.85	4.0	6.45	3.75	6.04		
0.2	.322	-	-	5.5	8.85	5.25	8.45	5.0	8.05	4.5	7.25	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	3.0	4.83		

Table 1-B-2

24 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	4.75	7.65	4.5	7.25	4.5	7.25	4.5	7.25	4.25	6.85	4.25	6.85	4.0	6.45	4.0	6.45	4.0	6.45	4.0	6.45	3.75	6.04		
0.1	.161	-	-	4.5	7.25	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.5	5.63	3.5	5.63	3.0	4.83	2.75	4.42	2.75	4.42		
0.2	.322	-	-	4.25	6.85	4.0	6.45	3.75	6.04	3.25	5.23	3.0	4.83	2.75	4.42	2.5	4.02	2.5	4.02	2.0	3.22	2.0	3.22		

Table 1-C-1

22 AWG Shielded Single Twisted-Pair

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	2.75	4.42	2.65	4.26	2.65	4.26	2.65	4.26	2.65	4.26	2.4	3.86	2.4	3.86	2.4	3.86	2.4	3.86	2.4	3.86	2.4	3.86		
0.2	.322	-	-	2.65	4.26	2.4	3.86	2.15	3.46	2.15	3.46	1.9	3.06	1.9	3.06	1.65	2.65	1.65	2.65	1.4	2.25	1.4	2.25		

Figure 42. Maximum Line Lengths for Limited Distance Line Adapter Type 2 (Main Line with Branches; One Line Adapter per Branch and at Ends of Main Line)

Table II-A-1

22 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	8.25	13.3	8.0	12.9	7.75	12.5	7.5	12.1	7.25	11.7	7.25	11.7	7.0	11.3	6.75	10.9	6.5	10.5	6.5	10.5	6.25	10.1	6.25	10.1
0.25	.402	-		7.75	12.5	7.5	12.1	7.25	11.7	7.0	11.3	6.75	10.9	6.25	10.1	6.0	9.65	5.75	9.26	5.75	9.26	5.5	8.85	5.5	8.85
0.50	.805	-		7.75	12.5	7.25	11.7	6.75	10.9	6.5	10.5	6.0	9.65	5.75	9.26	5.5	8.85	5.5	8.85	5.25	8.45	5.25	8.45	5.25	8.45

Table II-A-2

24 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	7.5	12.1	7.25	11.7	7.0	11.3	6.75	10.9	6.75	10.9	6.5	10.5	6.25	10.1	6.0	9.65	5.75	9.26	5.25	8.45	5.0	8.05	5.0	8.05
0.25	.402	-		7.25	11.7	7.0	11.3	6.5	10.5	6.25	10.1	6.0	9.65	5.5	8.85	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	4.5	7.25
0.5	.805	-		7.0	11.3	6.75	10.9	6.25	10.1	5.75	9.26	5.5	8.85	5.0	8.05	4.75	7.65	4.5	7.25	4.25	6.85	4.0	6.45	4.0	6.45

Table II-A-3

26 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	6.0	9.65	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	4.75	7.65	4.75	7.65	4.25	6.85	4.25	6.85	4.0	6.45	4.0	6.45	4.0	6.45
0.25	.402	-		5.75	9.26	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	3.25	5.23
0.50	.805	-		5.5	8.85	5.0	8.05	4.75	7.65	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.0	4.83	2.75	4.42	2.5	4.02	2.5	4.02

Table II-B-1

22 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	5.75	9.26	5.75	9.26	5.5	8.85	5.5	8.85	5.25	8.45	5.25	8.45	5.0	8.05	4.75	7.65	4.75	7.65	4.5	7.25	4.25	6.85	4.25	6.85
0.1	.161	-		5.75	9.26	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	4.25	6.85	4.0	6.45	4.0	6.45	3.75	6.04	3.5	5.63	3.5	5.63
0.2	.322	-		5.5	8.85	5.0	8.05	4.75	7.65	4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	3.0	4.83	2.75	4.42	2.75	4.42

Table II-B-2

24 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	4.5	7.25	4.5	7.25	4.25	6.85	4.25	6.85	4.0	6.45	4.0	6.45	3.75	6.04	3.5	5.63	3.5	5.63	3.25	5.23	3.25	5.23	3.25	5.23
0.1	.161	-		4.25	6.85	4.0	6.45	3.75	6.04	3.5	5.63	3.5	5.63	3.0	4.83	2.75	4.42	2.75	4.42	2.5	4.02	2.5	4.02	2.5	4.02
0.2	.322	-		4.25	6.85	3.75	6.04	3.5	5.63	3.25	5.23	2.75	4.42	2.5	4.02	2.25	3.62	2.0	3.22	1.75	2.82	1.75	2.82	1.75	2.82

Table II-C-1

22 AWG Shielded Single Twisted-Pair

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	2.75	4.42	2.65	4.26	2.65	4.26	2.65	4.26	2.4	3.86	2.4	3.86	2.4	3.86	2.4	3.86	2.15	3.46	2.15	3.46	2.15	3.46	2.15	3.46
0.2	.322	-		2.65	4.26	2.4	3.86	2.15	3.46	2.15	3.46	1.9	3.06	1.65	2.65	1.4	2.25	1.4	2.25	1.15	1.85	1.15	1.85	1.15	1.85

Figure 43. Maximum Line Lengths for Limited Distance Line Adapter Type 2 (Main Line with Branches; Two Line Adapters per Branch and at Ends of Main Line)

Table III-A-1

22 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	8.0	12.9	7.75	12.5	7.5	12.1	7.25	11.7	7.0	11.3	6.5	10.5	6.25	10.1	6.0	9.65	6.0	9.65	5.75	9.26	5.5	8.85		
0.25	.402	-	-	7.75	12.5	7.25	11.7	7.0	11.3	6.5	10.5	6.25	10.1	5.75	9.26	5.5	8.85	5.5	8.85	5.25	8.45	5.0	8.05		
0.50	.805	-	-	7.5	12.1	7.0	11.3	6.5	10.5	6.25	10.1	5.75	9.26	5.5	8.85	5.25	8.45	5.25	8.45	5.0	8.05	4.75	7.65		

Table III-A-2

24 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	7.25	11.7	7.0	11.3	6.75	10.9	6.5	10.5	6.25	10.1	6.0	9.65	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	4.5	7.25		
0.25	.402	-	-	7.0	11.3	6.75	10.9	6.25	10.1	6.0	9.65	5.75	9.26	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	3.75	6.04		
0.5	.805	-	-	7.0	11.3	6.5	10.5	6.0	9.65	5.5	8.85	5.25	8.45	4.75	7.65	4.5	7.25	4.25	6.85	3.75	6.04	3.5	5.63		

Table III-A-3

26 AWG Outside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	4.75	7.65	4.5	7.25	4.0	6.45	4.0	6.45	3.75	6.04	3.5	5.63	3.0	4.83		
0.25	.402	-	-	5.5	8.85	5.0	8.05	4.75	7.65	4.5	7.25	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	3.25	5.23	2.75	4.42		
0.50	.805	-	-	5.25	8.45	5.0	8.05	4.5	7.25	4.0	6.45	3.75	6.04	3.5	5.63	3.25	5.23	2.75	4.42	2.5	4.02	2.25	3.62		

Table III-B-1

22 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	5.75	9.26	5.75	9.26	5.5	8.85	5.25	8.45	5.0	8.05	5.0	8.05	4.75	7.65	4.5	7.25	4.5	7.25	4.25	6.85	4.0	6.45		
0.1	.161	-	-	5.5	8.85	5.25	8.45	5.0	8.05	4.5	7.25	4.5	7.25	4.0	6.45	3.75	6.04	3.75	6.04	3.5	5.63	3.25	5.23		
0.2	.322	-	-	5.5	8.85	4.75	7.65	4.5	7.25	4.25	6.85	4.0	6.45	3.5	5.63	3.25	5.23	3.0	4.83	2.75	4.42	2.5	4.02		

Table III-B-2

24 AWG Inside-Type Telephone Cable

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	4.5	7.25	4.5	7.25	4.25	6.85	4.0	6.45	3.75	6.04	3.75	6.04	3.5	5.63	3.25	5.23	3.25	5.23	3.0	4.83	3.0	4.83		
0.1	.161	-	-	4.25	6.85	4.0	6.45	3.75	6.04	3.25	5.23	3.25	5.23	3.0	4.83	2.5	4.02	2.5	4.02	2.25	3.62	2.25	3.62		
0.2	.322	-	-	4.25	6.85	3.75	6.04	3.25	5.23	3.0	4.83	2.75	4.42	2.5	4.02	2.25	3.62	2.0	3.22	1.75	2.82	1.75	2.82		

Table III-C-1

22 AWG Shielded Single Twisted-Pair Wire

Branch Length		Maximum Main Line Length																							
		Number of Branches																							
		0		1		2		3		4		5		6		7		8		9		10			
Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km		
0	0	2.75	4.42	2.65	4.26	2.65	4.26	2.4	3.86	2.4	3.86	2.4	3.86	2.4	3.86	2.15	3.46	2.15	3.46	2.15	3.46	2.15	3.46		
0.2	.322	-	-	2.4	3.86	2.4	3.86	2.15	3.46	1.9	3.06	1.9	3.06	1.65	2.65	1.4	2.25	1.4	2.25	1.15	1.85	1.15	1.85		

Figure 44. Maximum Line Lengths for Limited Distance Line Adapter Type 2 (Main Line with Branches; Three Line Adapters per Branch and at Ends of Main Line)

Table IV-A-1

22 AWG Outside-Type Telephone Cable

No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	4.25	6.85	4.0	6.45	3.5	5.63	3.25	5.23	3.0	4.83	2.75	4.42	2.5	4.02	2.25	3.62	2.0	3.22
2	4.0	6.45	4.0	6.45	3.5	5.63	3.25	5.23	2.75	4.42	2.5	4.02	2.25	3.62	2.25	3.62	2.0	3.22
3	4.0	6.45	4.0	6.45	3.5	5.63	3.0	4.83	2.75	4.42	2.5	4.02	2.25	3.62	2.0	3.22	2.0	3.22

Table IV-A-2

24 AWG Outside-Type Telephone Cable

No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	3.5	5.63	3.0	4.83	2.75	4.42	2.25	3.62	2.0	3.22	1.75	2.82	1.75	2.82	1.5	2.42	1.0	1.61
2	3.5	5.63	3.0	4.83	2.75	4.42	2.25	3.62	1.75	2.82	1.75	2.82	1.5	2.42	1.5	2.42	1.0	1.61
3	3.0	4.83	3.0	4.83	2.5	4.02	2.0	3.22	1.75	2.82	1.75	2.82	1.5	2.42	1.0	1.61	1.0	1.61

Table IV-A-3

26 AWG Outside-Type Telephone Cable

No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials*																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	3.0	4.83	2.5	4.02	1.75	2.82	1.75	2.82	1.5	2.42	1.25	2.01	1.0	1.61	.75	1.21	.75	1.21
2	2.75	4.42	2.5	4.02	1.75	2.82	1.75	2.82	1.5	2.42	1.25	2.01	1.0	1.61	.75	1.21	.75	1.21
3	2.75	4.42	2.0	3.22	1.75	2.82	1.5	2.42	1.5	2.42	1.0	1.61	.75	1.21	.75	1.21	.5	.805

Table IV-B-1

22 AWG Inside-Type Telephone Cable

No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	2.75	4.42	2.75	4.42	2.75	4.42	2.5	4.02	2.25	3.62	1.75	2.82	1.75	2.82	1.5	2.42	1.5	2.42
2	2.75	4.42	2.75	4.42	2.75	4.42	2.25	3.62	2.25	3.62	1.75	2.82	1.75	2.82	1.5	2.42	1.5	2.42
3	2.75	4.42	2.75	4.42	2.75	4.42	2.25	3.62	2.0	3.22	1.75	2.82	1.5	2.42	1.5	2.42	1.25	2.01

Table IV-B-2

24 AWG Inside-Type Telephone Cable

No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	2.25	3.62	2.25	3.62	2.0	3.22	1.75	2.82	1.75	2.82	1.5	2.42	1.5	2.42	1.25	2.01	1.25	2.01
2	2.25	3.62	2.25	3.62	2.0	3.22	1.75	2.82	1.5	2.42	1.5	2.42	1.25	2.01	1.25	2.01	1.0	1.61
3	2.25	3.62	2.25	3.62	2.0	3.22	1.75	2.82	1.5	2.42	1.25	2.01	1.25	2.01	1.0	1.61	1.0	1.61

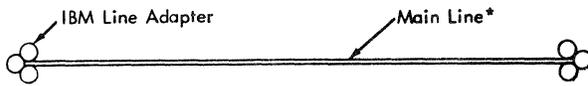
Table IV-C-1

22 AWG Shielded Single Twisted-Pair Wire

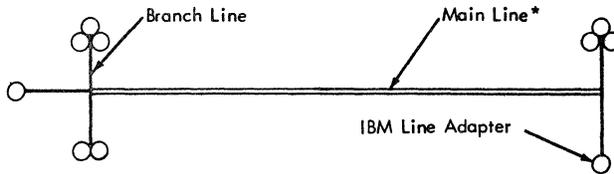
No. of Line Adapters Per Radial	Average Length of all Radials*																	
	Number of Radials																	
	2		3		4		5		6		7		8		9		10	
	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km	Miles	Km
1	1.35	2.17	1.3	2.09	1.1	1.77	.9	1.45	.65	1.05	.65	1.05	.65	1.05	.65	1.05	.65	1.05
2	1.35	2.17	1.3	2.09	1.1	1.77	.9	1.45	.65	1.05	.65	1.05	.65	1.05	.65	1.05	.4	.645
3	1.35	2.17	1.2	1.93	.9	1.45	.9	1.45	.65	1.05	.65	1.05	.65	1.05	.65	1.05	.4	.645

\*In any system, the length of the longest radial cannot exceed the length specified for a two-radial system.

Figure 45. Maximum Line Lengths for Limited Distance Line Adapter Type 2 (Radial Configuration; Maximum of Three Line Adapters per Line)



System A: Loaded main line with up to 3 IBM Line Adapters connected directly at extreme ends of line.



System B: Loaded main line with up to a total of 5 non-loaded branch lines (max. 1/4 mile) at ends of line, but distributed as desired. Max. of 3 Line Adapters per branch line.

Type of System (see schematics) and Number of Line Adapters**	Max. Main Line Length for Outside Cable					
	22-gauge		24-gauge		26-gauge	
	Miles	Kilo-meters	Miles	Kilo-meters	Miles	Kilo-meters
System A - one line adapter at each end	8.25	13.3	7.5	12.1	6.0	9.65
	8.25	13.3	7.5	12.1	6.0	9.65
	8.0	12.9	7.25	11.7	6.0	9.65
System B - one line adapter per branch	5.25	8.45	4.5	7.25	3.0	4.83
	5.25	8.45	4.0	6.45	2.5	4.02
	4.75	7.65	3.5	5.63	2.25	3.62

\* Only outside-type telephone exchange-area cable (22, 24, or 26 gauge) is specified. Entire main line should be loaded, but if not, reduce maximum lengths to 50% of those specified in table.

\*\*When number of Line Adapters at ends of main line (System A) or on each branch line (System B) are unequal, assume number of Line Adapters at each point is same as maximum number of Line Adapters at any point.

Figure 46. System Configurations and Limitations for Use of IBM Limited Distance Line Adapter Type 2 on Loaded Lines

This information is provided to allow the tables in the chapter, "Line Length Tables," to be adapted for use with cables available in World Trade areas. Only shielded single twisted-pair wire, or multiple pair cables, consisting of twisted-pairs, as described in "Types of Wire and Cable" in the chapter "Planning a Limited Distance Communications System," should be used.

The resistance per loop kilometer and per loop mile and the capacitance per kilometer and mile used in calculating each line length in the tables, are given. The derived constant  $\alpha$  (attenuation constant) is given in decibels per kilometer, at 800 Hz, and per mile, at 1000 Hz. To convert to decibels per kilometer at 1000 Hz or decibels per mile at 800 Hz, multiply by the proper conversion factor as given in Appendix B.

If the attenuation constant ( $\alpha$ ) for a cable being considered for use is equal to, or less than, the attenuation constant for one of the tables, then use that table to obtain the line lengths for the cable being considered.

*Note:* The resistance and capacitance for the cable under consideration should be roughly equal to the resistance and capacitance used in calculating the tables. The characteristic impedance

$Z_0 = \sqrt{\frac{R}{2\pi fC}}$   $\angle 45^\circ$  depends upon the ratio of R to C and will have some effect on line lengths, even though the attenuation constants as given by  $\alpha = \sqrt{\pi fRC}$  are equal.

If the attenuation constant ( $\alpha$ ) for a cable pair is greater than the attenuation constant for one of the tables, there are two choices:

1. Find a table for wire whose attenuation constant is greater than the attenuation constant of the wire being considered, or

2. Calculate the new line lengths according to the following formula:

$$\text{New Line Length} = 0.75 L_t \frac{\alpha_t}{\alpha}$$

Where:  $L_t$  = Line length in table

$\alpha$  = Attenuation constant for the wire being considered

$\alpha_t$  = Attenuation constant used for table

To use this formula, the attenuation constant ( $\alpha$ ) for the cable being considered should not exceed the attenuation constant for the table ( $\alpha_t$ ) by more than one third; in other words, the ratio  $\alpha_t/\alpha$  should not be less than 0.75. A further restriction is that one should not try to match attenuation constants between two types of cable—for example, (shielded) outside-type telephone cable and (unshielded) inside-type telephone cable. *Try to match attenuation constants or calculate new line lengths using the preceding formula only if the two cables are of the same general type.*

Figures 47 through 61 give characteristics of cable types found in various World Trade areas. The tables that can be used for each type of cable (Chapter 5) are listed, together with the cable type (outside telephone cable, inside telephone cable, or shielded single twisted-pair), conductor diameter, resistance, capacitance, and attenuation constant. Cables not listed may be used if they are of the proper type (see "Types of Wire and Cable" in Chapter 2); they can be fitted into one of the figures in this Appendix.

In Figure 62 note that the values used in calculating the line length tables are usually nominal values, not maximum. Refer to Figure 41 for the key to table groups and subgroups.

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.91 mm	57.2	0.052 x 10 <sup>-6</sup>	0.75	40 42 43 44 45	Column 3 I-A-1 II-A-1 III-A-1 IV-A-1
0.64 mm	113.0	0.052 x 10 <sup>-6</sup>	1.06	42 43 44 45	I-A-1* II-A-1* III-A-1* IV-A-1*
0.51 mm	180.0	0.052 x 10 <sup>-6</sup>	1.33	42 43 44 45	I-A-2 II-A-2 III-A-2 IV-A-2
0.4 mm	286.0	0.052 x 10 <sup>-6</sup>	1.67	42 43 44 45	I-A-3* II-A-3* III-A-3* IV-A-3*

\* Must reduce length in table by the method given in this Appendix.

Figure 47. Argentina: Outside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.5 mm	182	0.050 x 10 <sup>-6</sup>	1.32	42 43 44 45	I-A-2 II-A-2 III-A-2 IV-A-2
0.4 mm	284	0.050 x 10 <sup>-6</sup>	1.64	42 43 44 45	I-A-3* II-A-3* III-A-3* IV-A-3*

\* Must reduce length in table by the method given in this Appendix.

Figure 48. France: Outside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.6 mm	125	0.07 x 10 <sup>-6</sup>	1.29	40 42 43 44 45	Column 5 I-B-1 II-B-1 III-B-1 IV-B-1
0.5 mm	182	0.07 x 10 <sup>-6</sup>	1.6	42 43 44 45	I-B-2 II-B-2 III-B-2 IV-B-2

Figure 49. France: Inside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.6 mm	140	0.136 x 10 <sup>-6</sup>	1.9	40 42 43 44 45	Column 7 I-C-1 II-C-1 III-C-1 IV-C-1

Figure 50. France: Shielded Single Twisted-Pair

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.8 mm	73.2	0.05 x 10 <sup>-6</sup>	0.83	40 42 43 44 45	Column 3 I-A-1 II-A-1 III-A-1 IV-A-1
0.6 mm	130	0.05 x 10 <sup>-6</sup>	1.11	42 43 44 45	I-A-2 II-A-2 III-A-2 IV-A-2
0.4 mm	300	0.05 x 10 <sup>-6</sup>	1.69	42 43 44 45	I-A-3* II-A-3* III-A-3* IV-A-3*

\* Must reduce length in table by the method given in this Appendix.

Figure 51. Germany: Outside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.8 mm	73.2	0.12 x 10 <sup>-6</sup>	1.3	40 42 43 44 45	Column 5 I-B-1 II-B-1 III-B-1 IV-B-1
0.6 mm	1.30	0.12 x 10 <sup>-6</sup>	1.57	42 43 44 45	I-B-2 II-B-2 III-B-2 IV-B-2

Figure 52. Germany: Inside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.75 mm <sup>2</sup> (area)	49.2	0.12 x 10 <sup>-6</sup>	1.06	40 42 43 44 45	Column 7 I-C-1 II-C-1 III-C-1 IV-C-1

Figure 53. Germany: Shielded Single Twisted-Pair

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.9 mm	56	0.045 × 10 <sup>-6</sup>	0.7	40	Column 3
				42	I-A-1
				43	II-A-1
				44	III-A-1
				45	IV-A-1
0.6 mm	128	0.045 × 10 <sup>-6</sup>	1.05	42	I-A-2
				43	II-A-2
				44	III-A-2
				45	IV-A-2

Figure 54. Italy: Outside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.65 mm	105	0.050 × 10 <sup>-6</sup>	0.98	40	Column 3
				42	I-A-1
				43	II-A-1
				44	III-A-1
				45	IV-A-1
0.5 mm	175	0.050 × 10 <sup>-6</sup>	1.25	42	I-A-2
				43	II-A-2
				44	III-A-2
				45	IV-A-2
				0.4 mm	280
43	II-A-3*				
44	III-A-3*				
45	IV-A-3*				

\* Must reduce lengths in table by the method given in this Appendix.

Figure 57. Japan: Outside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.9 mm	56.8	0.045 × 10 <sup>-6</sup>	0.7	40	Column 5
				42	I-B-1
				43	II-B-1
				44	III-B-1
				45	IV-B-1
0.6 mm	128	0.045 × 10 <sup>-6</sup>	1.1	42	I-B-1
				43	II-B-1
				44	III-B-1
				45	IV-B-1

Figure 55. Italy: Inside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.65 mm	120	0.09 × 10 <sup>-6</sup>	1.34	40	Column 5*
				42	I-B-1*
				43	II-B-1*
				44	III-B-1*
				45	IV-B-1*
0.5 mm	200	0.09 × 10 <sup>-6</sup>	1.6	42	I-B-2
				43	II-B-2
				44	III-B-2
				45	IV-B-2

\* Must reduce lengths in table by the method given in this Appendix.

Figure 58. Japan: Inside-Type Telephone Cable

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.6 mm	134	0.10 × 10 <sup>-6</sup>	1.58	40	Column 7
				42	I-C-1
				43	II-C-1
				44	III-C-1
				45	IV-C-1

Figure 56. Italy: Shielded Single Twisted-Pair

Conductor Diameter	R <sub>2</sub> Ohms per Loop km	C <sub>2</sub> Farads per km	α dB per km at 800 Hz	Figure	Table
0.65 mm	120	0.1 × 10 <sup>-6</sup>	1.79	40	Column 7
				42	I-C-1
				43	II-C-1
				44	III-C-1
				45	IV-C-1

Figure 59. Japan: Shielded Single Twisted-Pair

Cable Size	R <sub>2</sub> Ohms per Loop Mile	C <sub>2</sub> Farads /Mile	dB/Mile at 800 Hz	Figure	Table
10 lb.	183.7	0.11 x 10 <sup>-6</sup>	1.96	42 43 44 45	I-A-2 II-A-2 III-A-2 IV-A-2
6 1/2 lb.	287	0.11 x 10 <sup>-6</sup>	2.45	42 43 44 45	I-A-3 II-A-3 III-A-3 IV-A-3
4 lb.	454	0.11 x 10 <sup>-6</sup>	3.08	42 43 44 45	I-A-3* II-A-3* III-A-3* IV-A-3*

\* Must reduce lengths in table by the method given in this Appendix.

Figure 60. United Kingdom: Outside-Type Telephone Cable

Cable Size	R <sub>2</sub> Ohms per Loop Mile	C <sub>2</sub> Farads /Mile	α dB/Mile at 800 Hz	Figure	Table
9 1/4 lb.	199.3	0.09 x 10 <sup>-6</sup>	1.84	40 42 43 44 45	Column 5 I-B-1 II-B-1 III-B-1 IV-B-1
6 1/2 lb.	287.6	0.09 x 10 <sup>-6</sup>	2.22	42 43 44 45	I-B-2 II-B-2 III-B-2 IV-B-2

Figure 61. United Kingdom: Inside-Type Telephone Cable

Table	Figure	Resistance per Loop		Capacitance x 10 <sup>-6</sup> farad		Attenuation Constant (α)	
		km (R <sub>2</sub> )	mile (R <sub>1</sub> )	per km C <sub>2</sub>	per mile C <sub>1</sub>	dB per km at 800 Hz	dB per mile at 1000 Hz
I-A-1 II-A-1 III-A-1 IV-A-1 Column 3	42 43 44 45 40	106	171	0.0515	0.083	1.00	1.8
I-A-2 II-A-2 III-A-2 IV-A-2	42 43 44 45	170	274	0.0515	0.083	1.29	2.32
I-A-3 II-A-3 III-A-3 IV-A-3	42 43 44 45	273	440	0.0515	0.083	1.59	2.86
I-B-1 II-B-1 III-B-1 IV-B-1 Column 5	42 43 44 45 40	106	171	0.0845	0.136	1.31	2.36
I-B-2 II-B-2 III-B-2 IV-B-2	42 43 44 45	170	274	0.0845	0.136	1.65	2.97
I-C-1 II-C-1 III-C-1 IV-C-1 Column 7	42 43 44 45 40	124	200	0.186	0.3	2.1	3.77

Figure 62. Cable Constants

## Appendix B. English-Metric Conversion Factors

feet = meters x 3.28

meters = feet x 0.305

miles = kilometers x 0.621

kilometers = miles x 1.61

dB at 1000 Hz = dB at 800 Hz x 1.12

dB at 800 Hz = dB at 1000 Hz x 0.893

dB/mile = dB/km x 1.61

dB/km = dB/mile x 0.62

dB/mile at 1000 Hz = dB/km at 800 Hz x 1.8

dB/km at 800 Hz = dB/mile at 1000 Hz x 0.555

$\alpha$  = attenuation constant in dB/mile at 1000 Hz.

$$\alpha = 487 \sqrt{R_1 C_1} \quad \text{where } R_1 = \text{ohms per loop mile}$$
$$C_1 = \text{farads per mile}$$

$\alpha$  = attenuation constant in dB/km at 800 Hz.

$$\alpha = 436 \sqrt{R_2 C_2} \quad \text{where } R_2 = \text{ohms per loop km}$$
$$C_2 = \text{farads per km}$$

$\alpha$  = attenuation constant in dB/mile at 800 Hz.

$$\alpha = 436 \sqrt{R_1 C_1} \quad \text{where } R_1 = \text{ohms per loop mile}$$
$$C_1 = \text{farads per mile}$$

$\alpha$  = attenuation constant in dB/km at 1000 Hz.

$$\alpha = 487 \sqrt{R_2 C_2} \quad \text{where } R_2 = \text{ohms per loop km}$$
$$C_2 = \text{farads per km}$$

C

C

C

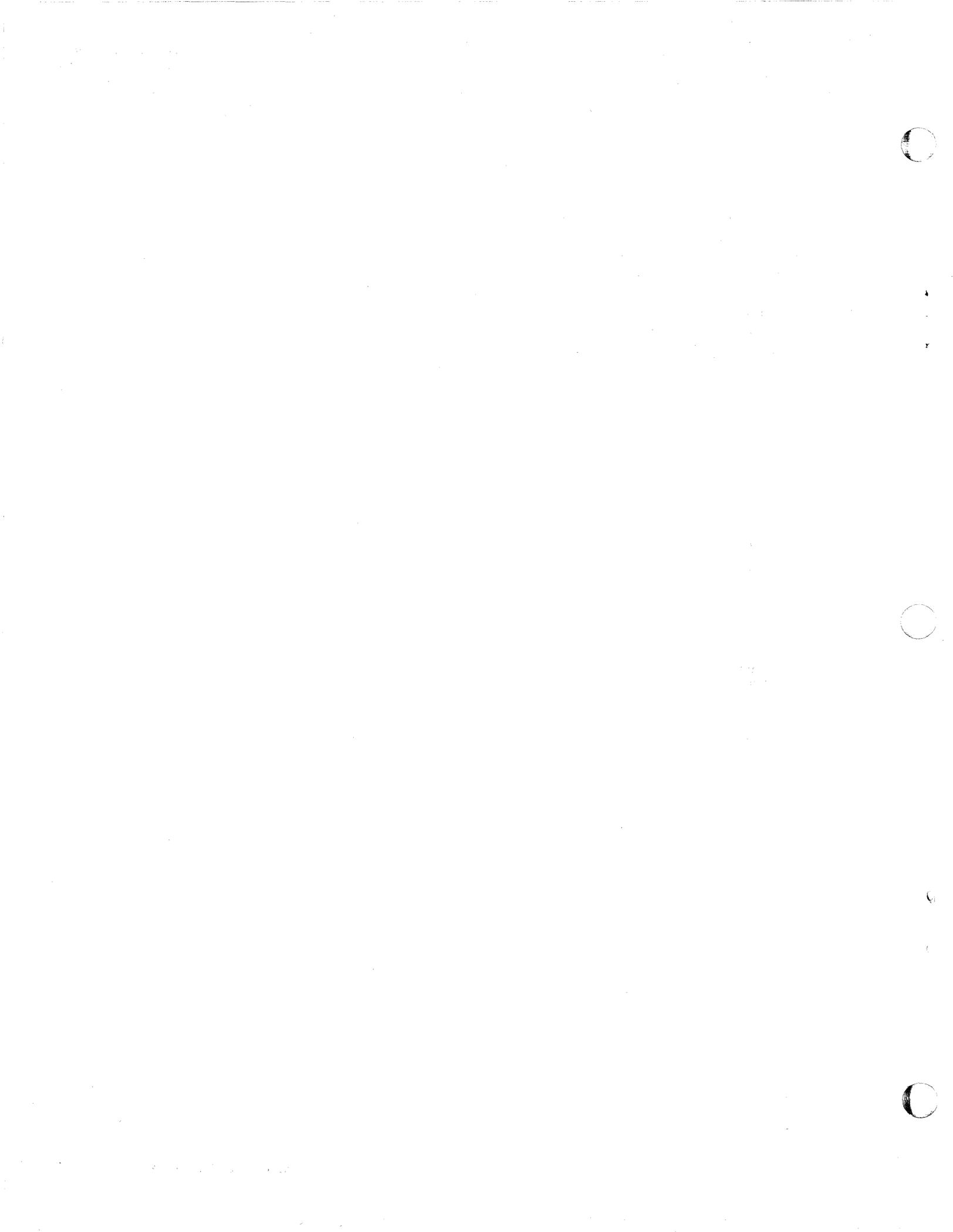
Appendix C. Characteristics of Lines

World Trade Countries		(Note 4)	CCITT Recommendation M.102																													
USA Common Carrier	Type 3002	Type 3002 with C1 Conditioning (Note 3)	Type 3002 with C2 Conditioning	Type 3002 with C4 Conditioning																												
1. Circuit Designation	Alternate Voice/Data or Data Only	Alternate Voice/Data or Data Only	Alternate Voice/Data or Data Only	Alternate Voice/Data or Data Only																												
2. General Characteristics Type of Service Mode of Operation Method of Termination (Note 2)	2-Point or Multipoint Duplex or Half-Duplex 2-Wire or 4-Wire (Note 2)	2-Point or Multipoint Duplex or Half-Duplex 2-Wire or 4-Wire (Note 2)	2-Point or Multipoint Duplex or Half-Duplex 2-Wire or 4-Wire (Note 2)	2-Point or up to 4 Point Duplex or Half-Duplex 2-Wire or 4-Wire (Note 2)																												
3. Attenuation Characteristics Frequency Response (Ref to 1000 Hz)	<table border="1"> <thead> <tr> <th>Freq. Range</th> <th>Var. -in dB</th> </tr> </thead> <tbody> <tr> <td>300-3000</td> <td>-3 to +12</td> </tr> <tr> <td>500-2500</td> <td>-2 to +8</td> </tr> <tr> <td colspan="2">(Note 1)</td> </tr> </tbody> </table>	Freq. Range	Var. -in dB	300-3000	-3 to +12	500-2500	-2 to +8	(Note 1)		<table border="1"> <thead> <tr> <th>Freq. Range</th> <th>Var. -in dB</th> </tr> </thead> <tbody> <tr> <td>300-2700</td> <td>-2 to +6</td> </tr> <tr> <td>1000-2400</td> <td>-1 to +3</td> </tr> <tr> <td>300-3000</td> <td>-3 to +12</td> </tr> </tbody> </table>	Freq. Range	Var. -in dB	300-2700	-2 to +6	1000-2400	-1 to +3	300-3000	-3 to +12	<table border="1"> <thead> <tr> <th>Freq. Range</th> <th>Var. -in dB</th> </tr> </thead> <tbody> <tr> <td>300-3000</td> <td>-2 to +6</td> </tr> <tr> <td>500-2800</td> <td>-1 to +3</td> </tr> </tbody> </table>	Freq. Range	Var. -in dB	300-3000	-2 to +6	500-2800	-1 to +3	<table border="1"> <thead> <tr> <th>Freq. Range</th> <th>Var. -in dB</th> </tr> </thead> <tbody> <tr> <td>300-3200</td> <td>-2 to +6</td> </tr> <tr> <td>500-3000</td> <td>-2 to +3</td> </tr> </tbody> </table>	Freq. Range	Var. -in dB	300-3200	-2 to +6	500-3000	-2 to +3
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300-3000	-2 to +6																															
500-2800	-1 to +3																															
Freq. Range	Var. -in dB																															
300-3200	-2 to +6																															
500-3000	-2 to +3																															
4. Envelope Delay Distortion	Less than 1750 microseconds from 800-2600 Hz.	Less than 1000 microseconds from 1000 to 2400 Hz. Less than 1750 microseconds from 800-2600 Hz.	Less than 500 microseconds 1000-2600 Hz. Less than 1500 microseconds 600-2600 Hz. Less than 3000 microseconds 500-2800 Hz.	Less than 300 microseconds 1000-2600 Hz. Less than 500 microseconds 800-2800 Hz. Less than 1500 microseconds 600-3000 Hz. Less than 3000 microseconds 500-3000 Hz.																												

Notes:

1. These limits, while not specified in the tariffs, are specified in the common-carrier engineering objectives.
2. Four-wire service is always provided by Western Union.
3. USA switched network "over 300 bps" local loop has negligible distortion, so the total effect of most long distance connections approaches that of C2 Conditioning.
4. In or between World Trade countries, a series connection of two channels that meet, or exceed, the requirements of CCITT Recommendation M. 102 will equal, or exceed, the requirements of a 3002 Channel with C1 Conditioning.

Figure 63. Characteristics of Lines



This glossary defines terms used in this publication. No attempt is made to define all data communication terms, nor to define basic electrical terms.

**active circuit element:** A device capable of amplifying a signal.

**addressing:** The means whereby the multiplexer or control station selects the unit or terminal to which it is going to send a message.

**amplifier (repeater):** A device used by common-carrier or privately owned systems to amplify signals, thereby allowing transmission over long distances.

**amplitude:** Signal level, volume (see "decibel" and "dBm").

**amplitude distortion:** Unequal reductions in the amplitudes of signals of different frequency.

**attenuation:** The decrease in amplitude that accompanies propagation or passage through equipment, lines, or space; usually measured in decibels.

**attenuation constant ( $\alpha$ ):** The rated signal attenuation of a specified wire or cable, usually stated in decibels per mile. It is not constant for all frequencies on a given communications channel.

**audio:** Frequencies that can be heard by the human ear (usually 50 to 16,000 cycles per second).

**balanced to ground:** As applied to a two-wire transmission line, both wires have the same impedance to ground.

**band:** A range of frequencies between two defined limits.

**bandwidth:** The difference, expressed in hertz (the number of cycles per second), between the limiting frequencies of a band.

**baud:** The reciprocal of the duration, in seconds, of the shortest signaling element that a channel can accommodate. A rate of one baud is one signal element per second. A bit rate (information rate) is not necessarily equal to the baud, in that a signal element may carry more than one bit of information. For a binary (two-state) channel, the baud and bit rates are equal.

**bias distortion:** This is defined as mark or space intervals that are consistently too long or too short. If an alternate mark/space pattern is transmitted with an equal amount of time between transitions, the receive signal may be said to have marking bias, if the mark interval is longer than the space interval.

**bit:** A contraction of "binary digit", the smallest unit of information. It has two possible states: 1 or 0 (mark or space).

**bit rate:** The speed at which bits are transmitted, usually expressed in bits-per-second (bps).

**branch (branch line, side leg):** A short section of transmission line connected to a main line.

**Broadband Exchange Service (BEX):** An automatic voice/record exchange service using pushbutton addressing and featuring various bandwidths on a selective basis.

**bridge tap:** A length of line, usually not used, connected to a transmission line at some intermediate point. Bridge taps are usually unterminated lengths of cable connected to local channels. Whether terminated or not, these bridge taps can seriously degrade data transmission.

**business machine clocking:** This term identifies the service in which the business machine supplies the time-base oscillator for the bit rate of transmission. This is also referred to by IBM as "internal clocking" and by the common carrier as "external clocking". To avoid confusion, use "non-data-modem clocking" or "business machine clocking".

**cable, coaxial:** A cable consisting of one conductor, usually a small copper tube or wire, within and insulated from, another conductor of larger diameter, usually copper tubing or copper braid.

**calling, selective:** The ability of a transmitting station to direct a call to one or more specifically designated stations.

**camp-on:** A method of holding a call for a line that is in use and of signaling when it becomes free.

**carrier:** A high-frequency current that can be modulated by voice or signaling impulses. A line-adaptor (modem) or data-set line frequency.

**carrier system:** A means of conveying a number of channels over a single path by modulating each channel on a different carrier frequency and demodulating, at the receiving point, to restore the signals to their original form.

**central office equipment:** Common-carrier equipment located in their central offices. Examples are bridges, repeaters, and ringers.

**channel:** A path for electrical transmission between two or more stations or channel terminations. A channel can consist of wire, radio waves, or both. A channel is sometimes inaccurately referred to as a circuit.

**channel, analog:** A channel on which the information transmitted can take any value between the limits defined by the channel. Voice channels are analog channels.

**channel, duplex:** A channel capable of providing simultaneous transmission in both directions.

**channel, four-wire:** A two-way circuit in which the signals simultaneously follow separate and distinct paths, in opposite directions, in the transmission medium.

**channel, half-duplex:** A channel capable of transmitting and receiving signals, but in only one direction at a time.

**channel, simplex:** A channel that permits transmission in only one direction.

**channel, two-wire:** A two-way circuit for transmission in either direction, but not simultaneously, unless frequency-division multiplexing is used, such as in the Western Electric Type 103 data set.

**channel, voice-grade:** A channel that permits transmission of speech.

**channelizing:** The process of dividing one channel into several sub-channels.

**character:** The actual or coded representation of a digit, letter, or special symbol.

**circuit:** A transmission system consisting of local channels, interchange channels, and necessary central office and customer station equipment.

**circuit grade:** The useful bandwidth of a circuit—normally limited by amplitude and/or delay distortion.

**circuit, multidrop:** A circuit connecting several locations, making information transmitted over it available at all locations simultaneously.

**COAM:** Customer owned and maintained—a common-carrier term for non common-carrier equipment connected to the common-carrier lines.

**code:** A system of symbols and rules for use in representing information.

**common carrier:** A company that furnishes communication services to the general public and which is regulated by appropriate state or federal agencies; or the telecommunications administration of a government which provides such services.

**communication:** The transferring of information from one point to another.

**communications, data:** The transmission of data from one point to another.

**companders:** Devices that compress or expand the volume range of the human voice for transmission and expand the signals at the receiving end; a contraction of the words "compressor" and "expander".

**conduit:** Solid or flexible metal tube through which wires or cables are run; provides physical protection and shielding from electrical noise.

**contention:** A condition on a multidrop communications channel in which two or more locations attempt to transmit without central control.

**converter:** A device capable of converting impulses from one mode to another, such as analog to digital or parallel to serial.

**crossstalk:** Unwanted signals on a line, produced by signals on other lines of the same cable or carrier system.

**customer station equipment:** Common-carrier equipment located on the customer's premises. Examples are telephone sets, bells, key equipment, and data sets.

**data, analog:** A physical representation of information which bears an exact relationship to the original information. The electrical signals on a telephone channel are analog representations of the original voice.

**data, digital:** Information represented by a code consisting of a sequence of discrete elements.

**Data Phone\*:** Both a service and equipment trademark of the Bell System. As service, it indicates the use of the Bell System message network for the transmission of data. As an equipment trademark, it identifies the data sets designed and manufactured for Data Phone service.

**data set:** See "data modem" (not to be confused with the computer programming term "data set"). Data set is also a common-carrier term for a data modem.

**data modem:** A modulation/demodulation device designed to provide compatibility between digital input/output equipment and communications facilities. See "line adapter."

**data modem clocking:** This term identifies the service in which the data modem (common carrier) supplies the time-base oscillator for the bit rate of transmission. This is also referred to by IBM as "external clocking" and, by the common carrier, as "internal clocking." To avoid confusion, use "data modem clocking" and "business machine clocking."

**data terminal subset:** A Western Union term for data modem.

**decibel (dB):** A unit for expressing the relative power of two signals,  $P_1$  and  $P_2$ .

$$\text{dB} = 10 \log_{10} P_1/P_2$$

Current (I) or voltage (V) can be used to measure the two signals, but all measurements must be made with the same value of impedance. Then:

$$\text{dB} = 20 \log_{10} I_1/I_2 = 20 \log_{10} V_1/V_2$$

**dBm:** Same as decibel, but comparison is to an absolute value of power, 1 milliwatt. Then:

$$\text{dBm} = 10 \log_{10} P/0.001$$

**delay distortion (envelope delay):** An effect in which signals of different frequency take unequal times to travel the length of a transmission line.

**demodulation:** The process of retrieving an original from a modulated carrier wave. For FSK modulation, the demodulation process consists of the conversion of mark and space signal frequencies to

binary on-and-off signals by receiver circuits of a line adapter. This technique is used to make communications signals compatible with business machines signals.

**dial-up:** The service by which a dial telephone can be used to initiate and effect a station-to-station telephone call.

**distortion:** Modification of a data pulse wave form or voice signal in such a way that the received signal is different from the transmitted signal.

**drop:** A terminal or customer station on a leased-line circuit.

**dummy load:** A resistor that simulates a line adapter connected to a communications line.

**duplex:** Describes a communications line, usually requiring four wires, on which signals can be transmitted and received simultaneously. (See "Simultaneous and Nonsimultaneous Transmission.")

**echo suppressor:** A device attached to a line to prevent a reflected signal from returning to the transmitter.

**effectively grounded:** "Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient current-carrying capacity to prevent the building up of voltages which may result in undue hazard to connected equipment or to persons." (Reference: Article 800 of the National Electrical Code)

**electrical loading:** The effect of current drawn by equipment connected to a communications line. It is not to be confused with inductive loading used to reduce attenuation on physical cable pairs. (See "loaded line.")

**end of message:** The specific character (EOM) or set of characters that indicates the termination of a message.

**envelope delay distortion:** Same as "delay distortion."

**equalization:** Use of passive, or active and passive, circuit elements to make attenuation and/or delays equal, for signals of different frequency.

**exchange, central office:** The place where a communications common carrier locates the equipment that connects incoming subscriber lines and circuits.

**exchange, dial:** An exchange where all subscribers originate their calls by dialing.

**exchange, manual:** An exchange where calls are completed by an operator.

**exchange, private automatic (PAX):** A dial exchange that provides private telephone service to an organization.

**exchange, private automatic branch (PABX):** A private automatic exchange that provides for the transmission of calls to and from the public telephone networks.

**exchange, private branch (PBX):** A manual or dial exchange, connected to the public telephone network located on a customer's premises and operated by his employees.

**exchange service:** A service permitting connection of any two customers' telephones, through switching equipment.

**external clocking:** A term used by IBM to identify the service in which the data modem supplies the time-base oscillator for the bit rate transmission. See "data modem clocking" and "business machine clocking."

**facsimile (FAX):** Transmission of graphic material such as pictures, maps, and diagrams, by wire. The image is scanned at the transmitter and reconstructed at the receiving station.

**Foreign Exchange Service:** A service that connects a customer's telephone to a telephone company central office not normally serving the customer's location.

**four-wire circuit:** See "Duplex".

**frequency:** The number of hertz (cycles per second) of a signal.

**frequency shift keying:** A form of frequency modulation in which only two frequencies are transmitted, mark and space.

\*Trademark of American Telephone & Telegraph Company

**gauge (gage):** For transmission lines, the size of wire used—the higher the gauge number, the smaller the wire.

**ground:** See “effectively grounded.”

**ground loop:** A complete electrical circuit that includes earth ground—undesirable for a communications line.

**half duplex:** Describes a communications line on which signals can be transmitted or received, but not simultaneously.

**hard copy:** A machine-printed document, such as a message, order, or invoice.

**header:** The first part of a message: It contains all necessary information for directing the message to its destination(s).

**hertz:** A measure of frequency period in cycles per second, abbreviated “Hz”.

**impedance:** The total opposition of a circuit to the flow of alternating current—a function of resistance, inductance, capacitance, and frequency.

**in-plant system:** A data-handling system confined to one building or to a number of buildings in one locality with no wires crossing a public right of way.

**inter-exchange channel:** A transmission path between exchanges which are usually located in different cities.

**interface:** A common boundary—for example, a physical connection between two systems or two devices.

**internal clocking:** This term is used by IBM to identify the service in which the business machine supplies the time-base oscillator for the bit rate of transmission. (See “data modem clocking” and “business machine clocking.”)

**jitter:** The phenomenon of received data transitions, (mark-to-space and space-to-mark) occurring early and late and changing in a random manner.

**key:** A device performing a switching function, such as a toggle switch.

**key-controlled:** Controlled by a key or switch usually located on the customer’s premises.

**leased line:** A transmission channel leased from a common carrier for exclusive use. Note that a *specific* line may or may not be leased. The common carrier agrees only to furnish communication service between specific points. The common carrier may alternate from one line to another at his discretion. The line may or may not contain a radio link. The path between the specified points is not defined and may vary at any time.

**line:** Commonly used in referring to telephone communications channels consisting of two or more copper wires strung between any two given points.

**line adapter (modem):** A device for transmitting and receiving data. Data is transmitted by converting the two different voltage levels of binary signals to mark and space frequencies. Data is received by reconvert mark and space frequencies to the original binary signals. (See “data modem.”)

**line, in-house:** A privately owned or leased line that does not cross a public right of way. (See “in-plant system.”)

**line termination:** A passive element used to terminate a line; it should be equal to the characteristic impedance of the line. In this manual, for the IBM Limited Distance Line Adapters, Type 2, the term refers to the resistive and inductive terminations which actually have equalizing functions as well.

**loaded line:** A communications line with inductance added in series with each conductor, at spaced intervals. Loading reduces attenuation within the voice band and makes the attenuation more nearly constant with frequency within the voice band.

**loading coil:** Inductance for loading a line. See “loaded line.”

**local channel:** See “loop, local.”

**loop, local:** A channel connecting a subscriber to a central office exchange; usually a metallic circuit.

**main line:** A communications line connecting the two most widely separated points in a system.

**mark:** The binary-1 state of a two-state system; one of the two frequencies used by a frequency-shift keying (FSK) line adapter.

**message:** A transmitted series of words or symbols intended to convey information. As used in message switching, a message consists of header, test, and an end-of-message symbol.

**message, multiple-address:** A message for delivery to more than one destination.

**message, single-address:** A message for delivery to one destination only.

**message switching:** Passing messages through a communications control system to transfer the message from one circuit to another.

**microwave:** An electromagnetic wave in the super-high-frequency radio spectrum, ranging from 1,000 to 300,000 megacycles per second.

**modem:** The contraction of “modulator”-“demodulator”. (See “line adapter” and “data modem”.)

**modulation:** The process by which some characteristic of one signal (wave) is varied in accordance with another signal (wave). For FSK modulation, the modulation process consists of conversion of the two different voltage levels of binary signals to mark and space frequencies by the transmitter circuits of a line adapter.

**multidrop:** See “circuit, multidrop.”

**multiplexing:** Any means whereby two or more signals (or the output of two or more system elements) share the same physical transmission facility, circuit element, or system component.

**multiport:** A system using three or more line adapters.

**neper:** A unit for expressing the relative power of two signals,  $P_1$  and  $P_2$ .

$$\text{nepers} = \log_e \sqrt{P_1/P_2}$$

$$1 \text{ neper} = 8.686 \text{ decibels}$$

**net loss:** As applied to a leased or private line circuit, the overall attenuation between drops or stations; usually expressed in decibels.

**network:** A series of points connected by communications channels.

**network, leased-line, or private-wire:** A series of points connected by telegraph or telephone channels and reserved for the exclusive use of one customer. (See “leased line.”)

**network, private-line telegraph:** A series of points connected by telegraph-grade channels and reserved for the exclusive use of one customer.

**noise:** Unwanted signals on a line, from any source.

**non-data-modem clocking:** See “business machine clocking.”

**nonloaded (cable pairs):** Physical cable pairs that have not had inductive load coils connected to them.

**nonsimultaneous transmission:** Transmission of information in both directions, but not at the same time.

**offline system:** A system in which human operations are required between the original recording functions and the ultimate data processing function. This includes conversion operations as well as the necessary loading and unloading operations incident to data-gathering systems.

**online system:** A system that eliminates the need for human intervention between source recording and the ultimate processing by a computer.

**passive circuit element:** Circuit elements that cannot amplify, such as resistors, capacitors, and inductors.

**peak jitter:** Maximum jitter excursions. (See “jitter.”)

**plant (used by telephone industry):** All the physical facilities—lines, equipment, and buildings—used to provide service.

**plant department:** The organization and personnel charged with maintaining the common-carrier plant.

**point-to-point:** A system using only two line adapters.

**point-to-point transmission:** Transmission of data directly between two points, with no intermediate drops.

**polling:** The action whereby the multiplexer or control station says effectively to the terminal, "Do you have anything for me?"

**priority indicators:** Groups of characters used in the header of a message to define the order of transmitting messages over a communications channel.

**processing, batch:** A method of processing in which a number of similar input items are accumulated and grouped.

**radial configuration:** A multipoint system in which all lines radiate from a common point.

**record:** A group of related facts or fields of information treated as a unit.

**realtime data communication:** The transmission of data from the originating terminal to the terminal designated to receive the information, without a time delay caused by a store-and-forward operation.

**repeat coil:** An audio-frequency transformer—usually used for isolation or impedance transformation purposes or to derive a simplex or ground return path.

**repeater:** A device to amplify communications signals.

**ringer:** A device that applies a signal to the circuit to actuate the telephone bell.

**routing:** The assignment of the communications path by which a message or telephone call will reach its destination.

**routing, message:** The function of selecting the route, or alternate route if required, by which a message will proceed to its destination; sometimes used in place of message switching.

**routing indicator:** An address or group of characters in the header of a message that defines the final circuit or terminal of the message destination.

**service, extended area:** An exchange service, without toll charges, that extends over a geographical area in which there is a community of interest in return for a higher exchange service rate.

**service, private-line (wire):** A channel or circuit furnished a subscriber for his exclusive use; also the total service or act of providing and maintaining private-line circuits.

**shield:** A metallic covering over insulated wire or cable to reduce the possibility of noise or an extraneous signal being induced in the wire or cable from an external field.

**side leg:** See "branch".

**simplex circuit:** (1) A ground return transmission path, or (2) a circuit that permits transmission in only one direction. See "single."

**simultaneous transmission:** Transmission of information in both directions at the same time. (See "duplex.")

**single:** A telegraph service term for a circuit that permits transmission in only one direction.

**space:** The binary-0 state of a two-state system; one of the two frequencies used by a frequency-shift keying (FSK) line adapter.

**store and forward:** The interruption of data flow from the originating terminal to the designated receiver by storing the information enroute, in physical media (such as punched card or tape), and forwarding it at a later time. (See "switching" and "message".)

**STR:** An abbreviation of "synchronous transmitter-receiver". This is the transmitter-receiver section of the 1009, 1013, 7702, Autodin, and other medium-speed IBM transmission control equipment.

**stunt box:** A device in a teletypewriter used to control nonprinting and other control functions of a telegraph terminal.

**subset:** See "line adapter" and "data modem."

**switched line:** A transmission line made up of a number of shorter transmission lines connected through switching networks, usually provided by a common carrier.

**switching center:** A location at which incoming data from one circuit is transferred to the proper outgoing circuit.

**switching, circuit or line:** A switching technique where the connection is made between the calling party and the called party before starting communication (for example, telephone switching).

**switching, message:** The technique of receiving a message, storing it until the proper outgoing circuit is available, and then retransmitting it.

**tariff:** The published rate for a particular approved commercial service of a common carrier.

**teleprinter:** Name used by Western Union to refer to its telegraph terminal equipment.

**Teletype\*:** A system for transmitting messages to a distant location, employing keyboard or paper tape sending and printer receiving.

**teletypewriter:** Equipment used to transmit and/or receive a typed record.

**Teletypewriter Exchange Service (TWX):** Provides direct-dial, point-to-point connections, using input/output equipment such as page printers, keyboards, paper tape readers, and paper tape punches.

**Telex:** An international automatic teletypewriter exchange service; the domestic service is provided by Western Union.

**Telpak:** Telpak service makes available wideband communication channels of various sizes, suitable for large-volume, point-to-point transmission of data, voice, teletypewriter, facsimile, or other services for a flat rate, regardless of usage. Telpak can be used as a single large channel or a group of smaller channels. For example, a Telpak "A" channel may be divided into 12 voice-grade channels.

**terminal, job-oriented:** A specially designed terminal for receiving source data in an environment associated with the job to be performed, and transmitting it to and from the system of which it is a part.

**terminal subset:** As used in this manual, a synonym for line adapter, data set, and data modem. A term often used by Western Union to describe its modulator-demodulator unit.

**terminal unit:** Communication-channel equipment that can be used for either input or output.

**text:** The part of the message that contains the information to be conveyed.

**tie line:** A leased communications channel or circuit terminating in a private branch exchange (PBX) at each end.

**toll:** Charge for making a connection beyond an exchange boundary.

**traffic:** The information passed on a circuit. Also called "load."

**transmission:** The electrical transfer of a signal, message, or other form of intelligence from one location to another.

**trunk:** A channel connecting switching centers or exchanges.

**turnaround time:** The amount of time required to reverse the flow of data in a half-duplex communications system, nominally 200 milliseconds on two-wire channels. In four-wire half-duplex systems, turn-around time can be much shorter than 200 milliseconds.

**voice band:** The band of frequencies necessary to adequately represent the human voice. It is commonly considered to range from about 300 Hz to 3300 Hz, although a narrower bandwidth will still transmit intelligible speech.

**voice-grade channel:** A communications channel capable of passing human speech.

**way station:** A telegraph term for one of the stations on a multipoint circuit.

**Wide Area Telephone Service (WATS):** A service arranged for subscribers who make many outgoing long distance calls to many points. Monthly charges are based on the size of the area in which the calls are placed, not on the number or length of calls. Under the WATS arrangement, the United States is divided into six zones. The subscriber is billed a flat rate, according to the zones to be called on a fulltime or measured time basis. This can be an advantageous arrangement for data communications over the DDD switched network.

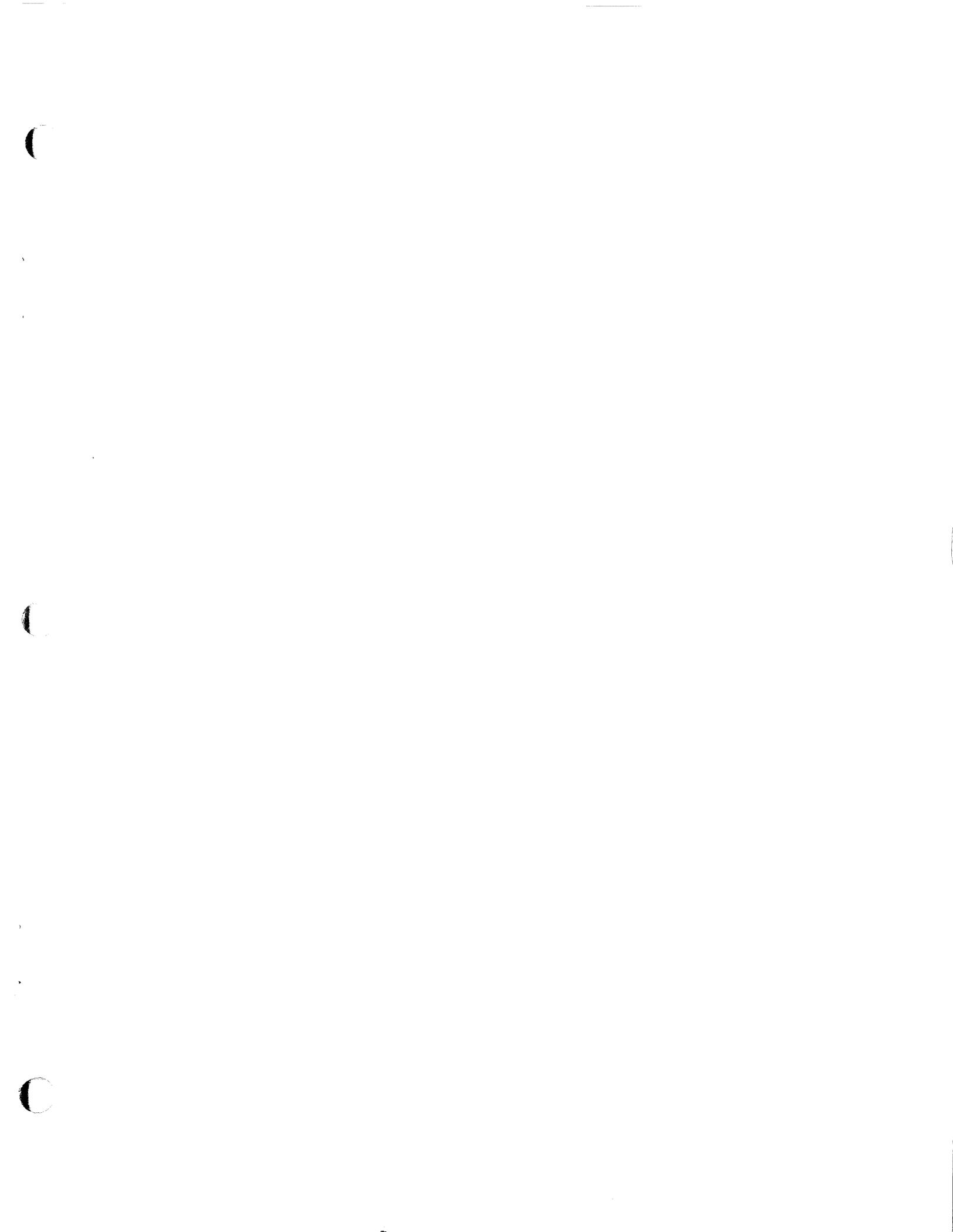
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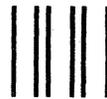
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