POWER SYSTEM COMMUNICATIONS:

# PLANT COMMUNICATIONS

**REA BULLETIN 66-7**

RURAL ELECTRIFICATION ADMINISTRATION • U.S. DEPARTMENT OF AGRICULTURE

DECEMBER 1978

## FOREWORD

REA Bulletin 66-7, "Power System Communications: Plant Communications," is one of a series of REA bulletins dedicated to power systems communications. This publication is the first of its kind to specifically deal with rural electric cooperatives' design and implementation requirements for this particular communications transmission media and is an excellent reference guide for fundamental engineering considerations. The subject area covers systems engineering, design considerations, equipment and facilities, operating parameters, performance analyses, and operations and maintenance.

The step-by-step presentation of the material in this bulletin should be of great benefit to all cooperative engineers and engineering firms and particularly helpful to relatively inexperienced engineers beginning their careers in power systems communications.

RICHARD F. RICHTER
Assistant Administrator - Electric

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# POWER SYSTEM COMMUNICATIONS: PLANT COMMUNICATIONS

POWER SUPPLY AND ENGINEERING STANDARDS DIVISION
RURAL ELECTRIFICATION ADMINISTRATION
U.S. DEPARTMENT OF AGRICULTURE

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## I. GENERAL

### A. Introduction

Plant communications systems are an essential part of any power communications system. Power generating and control centers require well-engineered telephone communications facilities for administration, operation, and maintenance. Even more important is the communication need during emergency operations whether they be a minor local power failure or a major grid failure. Voice, data, command and control and telemetry communications are all part of the overall telephone system and are all equally essential to the proper operation of a power system. The telephone instrument and its associated Private Automatic Branch Exchange (PABX) or Computerized Branch Exchange (CBX) are among the primary interests of the power communications engineer when dealing with plant communications systems. In the context used herein, plant communications is taken to encompass both the generation and or associated headquarter facilities.

### B. Purpose

The purpose of this Bulletin is to serve as an applications and operations guide to telephone systems for electric system borrowers and their consulting engineers. The Bulletin presents guidelines and engineering and operating procedures to aid in the development of telephone communications systems and services for the electric system borrower.

### C. Scope

Bulletin 66-7 covers the technical aspects of telephone communications from the delineation of considerations through the design, selection, installation, and operation of the system. The Bulletin focuses on telephone systems and the use and application of PABXs and CBXs to provide the requisite power system communications needs.

Where subject matter has been treated in depth in other publications, only essentials are presented in this Bulletin with adequate reference made to those original publications in an extensive bibliography.

### D. Regulatory Constraints

Privately owned telephone systems may or may not be regulated by government depending on the configuration of the system. The Federal Communication Commission (FCC) has the authority to regulate all interstate communications. This generally applies to telephone systems that use radio as a means of transmission or systems that have interfaces with other systems that provide interstate services. If a telephone system is strictly intrastate, the local State Public

Utility Commission (PUC) has authority. Local PUC's usually do not effect control over privately owned systems except where there are intersystem interfaces.

Regulatory constraints often apply when privately owned communications facilities traverse public property. The use of city owned ducts, for example, may require payment of rental fees or use taxes as in New York City. Regulations also apply to cables run under or over streets.

E. Present Systems and Applications

The vital nature of communications in the power industry has caused considerable growth in the required telephone equipment and facilities in recent years. The complexity and diversity of the types of equipments used has also expanded. Most large power firms now employ extensive telephone systems for administrative as well as control purposes. The systems provide internal communications for the company as well as interfacing with outside systems.

F. Trends

Perhaps the most significant trend in telephony affecting the power industry is private ownership of equipment and facilities. This trend is a result of recent FCC regulations allowing for freer interconnection with existing telephone companies. The impact on the power industry is considerable. With the flexibility of being able to purchase and install one's own equipment, it is possible to expand operating features and reconfigure system structure with a minimum of delay. Accompanying this new trend, however, is a need for a greater range of technical skills within the power firms. This in turn tends to uprade the prominence of the communication functions within the power industry.

Advances in equipment design have been fostered by the recent rulings allowing interconnection. Numerous manufacturers are supplying the interconnect market with equipment containing features previously unavailable. The system designer now has a greater amount of flexibility in meeting user requirements; in the past, the needs were trimmed to meet available communications services.

The development of computers and the movement of telephone companies towards pulse code modulation (PCM) transmission techniques for long distance circuits means that CBXs using PCM switching techniques will be able to accommodate innovations in these fields. As digital transmission by utilities becomes more common, users should be able to lease relatively low-cost digital private lines and possibly Central Office trunk groups. PCM machines will be able to directly terminate these circuits, yielding operating economies.

Remote terminal, word processing and electronic mail use has been accelerating. These services, and some of the faster facsimile devices, use digital transmission. Presently, connections are provided either over dedicated digital circuits or through voice-type lines using modems to transform the digital signal into a form which can be transmitted over those circuits. It is possible to find situations where a digital signal from a terminal passes through a modem and is converted to analog form. This voice-type signal is then switched by a CBX, which redigitizes the signal for switching and then transmits an analog output onto an exchange trunk. The trunk may carry the signal to a long distance switching office, which again converts the data stream to a digital format for transmission to a distant city, where the process is reversed. As digital transmission becomes more common, fewer of these expensive and information flow-limiting conversions will be needed. Future developments may enable CBXs to act as controlling centers for these devices, streamlining electronic mail and computer time-sharing services.

Although it is still impossible to predict the final form of these activities, they are almost certain to rely on digital transmission with PCM techniques. Users contemplating further activity in these areas should consider the role a CBX could or should play in them and include this in their choice of a machine. It may also turn out that it is more efficient to use separate processors to control these other services, and the CBX design and configuration would then be irrelevant to their development.

## G. Summary

While it is the intent of this bulletin to convey sufficient technical information to the borrower to make an independent evaluation and selection of the plant communications system, it is recommended that prior to the commission of any substantial funds or resources the borrower contact the local telephone company serving his area. Many of the REA-financed telephone companies can provide the services, facilities, and equipments listed herein at a reasonable cost commensurate with the cooperative's needs and simultaneously alleviate the cooperative from the burdensome operations and maintenance responsibilities. It would seem prudent that any cooperative communications study should establish the cost to own via a comparison of either a leasing arrangement or a direct capital expenditure by the cooperative.

# II. PLANT COMMUNICATIONS SYSTEMS

## A. General

This section of the Bulletin deals with the functions and operations of telephone systems and equipments for plant communications systems. To properly plan, design, procure, install and operate these systems the engineer must be familiar with telephone facilities and terminology.

Plant communications used within the context and framework of this bulletin are taken as those facilities used at the borrower's operating locations (power plants and headquarters buildings) to effect communications. The transmission systems such as microwave line-of-sight radio, mobile radio and power line carrier are covered in companion bulletins forming a part of the REA 66 series bulletins dealing with communication systems.

## B. Telephone Transmission Facilities

### 1. Introduction

The fundamental function of a telephone system is to transmit voice or data. To accomplish this the system must have end instruments and a transmission path such as wires or radio. As a practical matter, telephone systems also use control, dialing, supervisory, signaling ,and ringing signals to operate the system.

Telephone terminology is replete with names and acronyms peculiar to telephone equipment, services, and circuits with which the systems engineer should be familiar. A glossary is included in Section V of this Bulletin to aid in deciphering telephone terminology.

Telephony systems are made up of numerous electromechanical devices converting mechanical motion into changing electrical currents and vice versa. The telephone instrument or subscriber's set is the first of these devices we will examine and is undoubtedly the most recognized telephone apparatus.

### 2. Telephone Transmitter

A telephone transmitter converts mechanical sound vibrations in the air to electrical "sound" vibrations in an electrical circuit. This is accomplsihed by varying the resistance in a portion of the transmitter in step with the incoming sound. The varying resistance causes a direct current to increase or decrease.

The transmitter (Figure II-1) consists essentially of two components: (1) a diaphragm and (2) a capsule filled with carbon granules. The diaphragm is generally made of stiff metallic material and is solidly held by a retaining ring. A rod makes a connection with the capsule. The capsule itself has four components. Two metal-backed carbon discs are held together by an insulating cup with paper bellows. The space between the discs is filled with carbon granules.

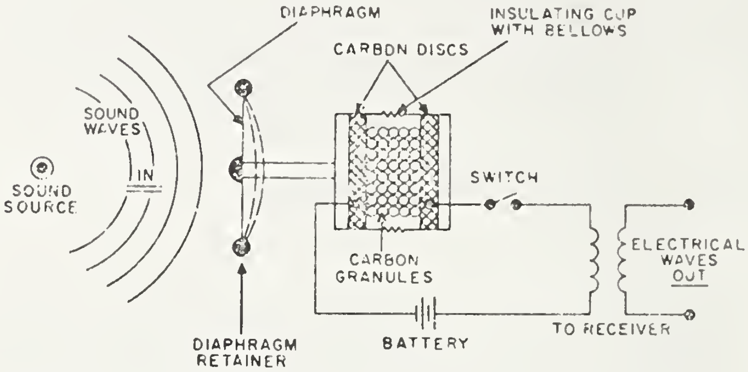



Figure II-1. Elementary Transmitter

Because of the bellows, one disc is free with the diaphragm. The other disc is rigidly held. The whole capsule is part of a circuit with DC current flowing in it.

The above components change sound signals to electrical signals in the following manner:

Sound waves meeting the diaphragm cause it to move back and forth. These movements are transmitted piston-like to the movable carbon disc. The carbon granules between the two discs are then alternately compressed or decompressed in step with the incoming sound. The compressions and decompressions vary the resistance of the granules causing the DC current in the circuit to increase or decrease.

The mechanics of the resistance changes are illustrated in Figures II-2 and II-3. Although the carbon granules are quite irregular in shape, for the sake of simplicity they can be thought of as round spheres.

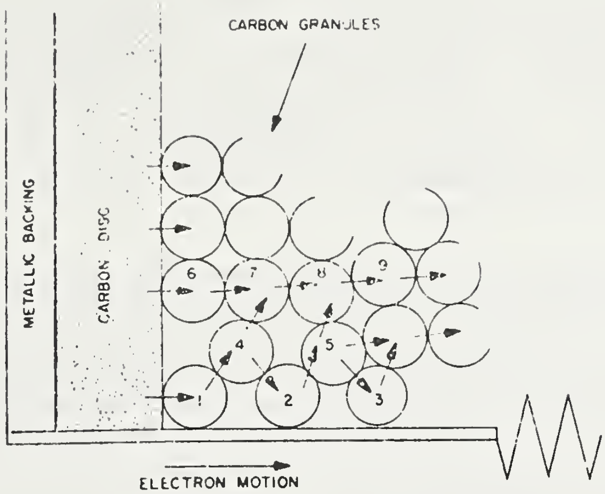



Figure II-2. Carbon Granule Action - Normal or Decompressed

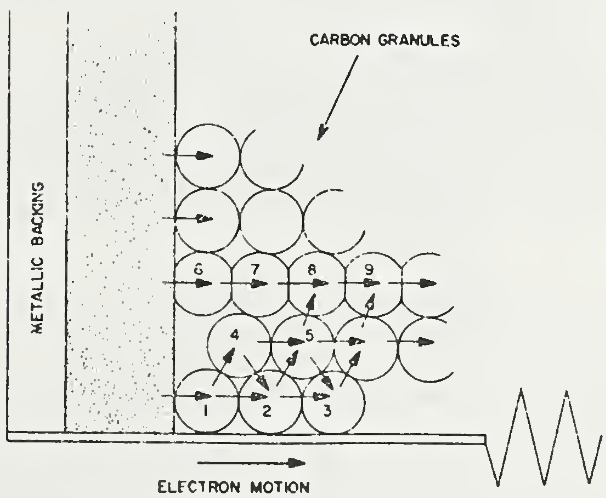



Figure II-3. Carbon Granule Action - Compressed

Assume Figure II-2 to represent steady-state conditions with no sound meeting the diaphragm and a steady current in the circuit. In this case, the current has several paths. It could go from the carbon disc to granule (1), (4), (2), (5), (3), etc. Also there is a path through (6), (7), (8), (9), and so on. Figure II-3 shows an instant when the granules are compressed by a wave. Here, granules (1), (2), and (3) have come in contact, thus providing an additional path for the current. Furthermore, granules (6), (7), (8), and (9) have been compressed so that instead of point contacts there are circular area contacts between them. This increase in contact area decreases the overall resistance and thus increases the current.

High resistance is caused by a decompression wave. The carbon disc moves to the left and allows the granules to separate; in some cases contacts are broken and in other cases only point contacts are established. The undulating voice currents are then carried by the line to the far end, where they are coupled to a receiver circuit and changed back into sound.

3. Telephone Receiver

A telephone receiver changes electric voice signals to audible sound. This is done magnetically vibrating a diaphragm in step with the incoming electric-voice signals. The operation is quite straightforward. Voice signals enter the receiver circuit over a coupling coil. The signals continue to the receiver capsule, where they pass through coil windings and generate a fluctuating magnetic field. This field vibrates a rigid diaphragm and thus produces an audible sound.

There are two types of receivers: a direct action receiver and an indirect action receiver. In the first type a magnetic diaphragm is directly vibrated by the fluctuating field. In the second type the field vibrates a magnetic armature which then transmits the vibrations through a linkage to a nonmagnetic diaphragm.

The direct action receiver in Figure II-4 has been a standard unit for many years. Its diaphragm is the link between the electric circuit and the air. Here, voice signals are changed into magnetic field fluctuations by two coils. These fluctuations then vibrate the magnetic diaphragm. The principal parts of this receiver are two inductive windings, the diaphragm, and a permanent magnet. The permanent magnet has the function of preventing double-frequency distortion.

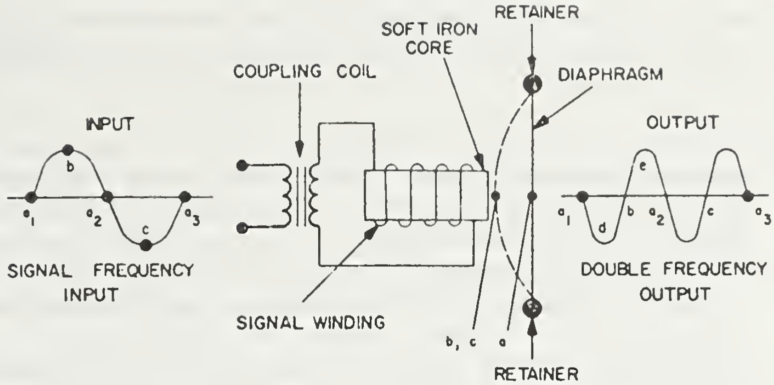



Figure II-4. Receiver Without Permanent Magnet

Assuming the receiver in Figure II-5 has no permanent magnet, the signal winding is wound around a soft iron core which becomes magnetized only while there is a current in the winding. When a signal is introduced, the core will be magnetized during each half-cycle. The diaphragm will be attracted as the signal grows from a to b; then, as the signal decreases from b to $a_2$, the diaphragm will be released. When the diaphragm is attracted, the air experiences a decompression; when it is released the air is compressed.

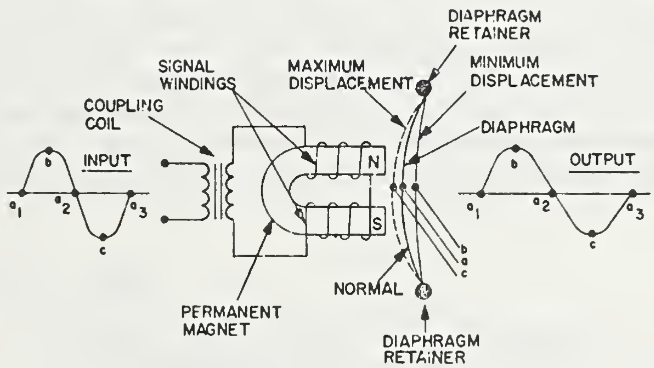



Figure II-5. Biased or Direct Action Receiver

Thus, while the input signal goes through a half-cycle - from zero at $a_1$, to maximum positive at b, and back to zero at $a_2$ - the output goes through a complete cycle: from zero at $a_1$, to maximum negative (decompression) at d, zero at b, maximum positive (compression) at e, and back to zero at $a_2$. The above action is repeated on the negative half-cycle of the input. Each input cycle, therefore, produces two cycles in the output.

The receiver shown in Figure II-5 was designed to prevent double-frequency distortion. The permanent magnet biases the diaphragm in an operating region where double-frequency distortion is at a minimum. The signal windings are wound on the permanent magnet poles in such a way that a positive going pulse will weaken the poles and a negative going pulse will strengthen the poles. When the input rises from a, to a maximum positive at b, and back to $a_2$, the diaphragm is released and returned, producing a compression. On the negative swing of the input signal - from $a_2$ to maximum negative at c, and back to $a_3$ - the diaphragm is attracted and returned to normal, producing a decompression. This action generates an output resembling the input. The same results may be obtained by introducing a direct current into the receiver of Figure II-4.

However, there is a certain amount of amplitude distortion. On the negative half-cycles of the input the diaphragm offers greater elastic resistance than on the positive half-cycles. This causes the decompressions to be weaker in amplitude than the compressions. These and other disadvantages of the direct action receiver have been considerably reduced by the design of the indirect action or polar receiver.

A more recent development in receivers is illustrated in Figure II-6. This receiver is more sensitive and introduces considerably less distortion than the direct-action receiver. In effect, the indirect-action polar receiver is capable of discriminating the polarity of the incoming signals. The principal parts of this receiver are: two signal windings, a permanent magnet, a movable armature, and the diaphragm.

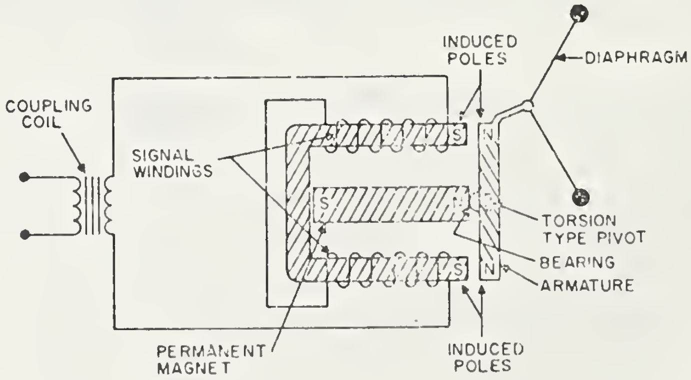



Figure II-6. Polar or Indirect Action Receiver

The permanent magnet polarizes the movable armature and the signal winding cores. The armature is held in normal position by a torsion bar and the equal attraction of the winding cores. The windings are wound so that current in one direction produces a magnetic field that aids the induced pole in one core and opposes the induced pole of the other. When the current reverses, the above effect also reverses. These unequal forces cause the armature to see-saw about its pivot, and in this way the diaphragm, which is attached to one end of the armature, moves back and forth.

Some of the advantages inherent in this receiver are: The diaphragm is designed specifically for producing sound and does not have to serve the dual purpose of being a good magnetic conductor and a good acoustical generator. Less electrical energy is required because the magnetic circuit is more compact and efficient.

4. Ringing and Dialing Equipment

The rotary dial of a telephone instrument is another of the electromechanical devices used in telephony. The dial rotates opening and closing contacts across the telephone line as it turns. This generates a series of DC pulses corresponding to the number of the selected digit. The pulses are then used to position switches in the automatic dial central offices. The pulses are generated at a 10 pulse-per-second (PPS) rate, regardless of the digit being generated. (Switchboard dials may operate at a 20 PPS rate, thus reducing operating time.)

Ringing a standard telephone involves another electromechanical device. The ringer converts a low frequency, usually 20 Hz, ringing current into mechanical motion of a bell clapper or buzzer armature to signal the called party.

C. Telephone Circuits

An essential function of a simple telephone circuit is the conversion of sound to electrical energy and back again to sound; this is accomplished separately by a transmitter and receiver. In addition, the circuit must include an arrangement to inform the distant station of the desire to converse. This is done by ringing a bell. Presented in this section are some basic telephone circuit configurations that include the transmitting, the receiving, and the ringing circuits.

Telephone systems may be divided into two classes according to the source of transmitter current. One, in which the transmitter current for each subscriber is supplied from batteries at the subscriber's station, is called the local-battery system. The other, in which the transmitter current for all subscribers is supplied from one battery source, is known as the common-battery system.

1. Local-Battery System

The simplest transmitter-receiver circuit is illustrated in Figure II-7. This circuit is actually two circuits. Since a carbon transmitter needs DC for proper operation and a receiver does not, we isolate the battery-powered transmitter from the receiver with a transformer. The isolation affects only the DC. As we know from previous discussions, a transformer passes from one winding to the other all current-changes and variations. Thus, speech currents from the transmitter circuit will pass readily into the receiver circuit.

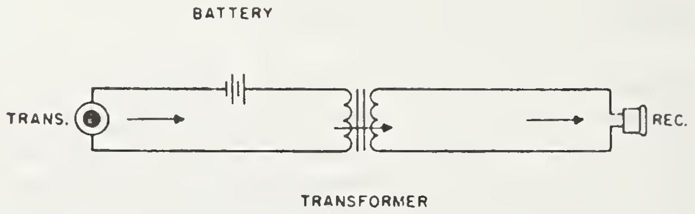



Figure II-7. Simple Transmitter-Receiver Circuit

By moving the transformer as close to the transmitter as possible, we are able to shorten the DC circuit, with a consequent reduction of power loss ($I^2R$) due to wire resistance. In addition, we make two-way communication possible by providing circuit II-8.

From an economic viewpoint, the four-wire arrangement of Figure II-7 is unacceptable for ordinary telephone circuits. By sacrificing some quality we can have a two-wire connection between the two telephones. This is illustrated in Figure II-9. The only undesirable feature of this circuit is that the speaker will hear his own voice in his receiver (side tone). By tracing the circuit from either transmitter in Figure II-9, note that the voice currents go through both receivers. This is not too serious, considering that some 50% is saved on outside connecting lines. Besides, sophisticated circuits can reduce side-tone below an objectionable level without resorting to four-wire connections.

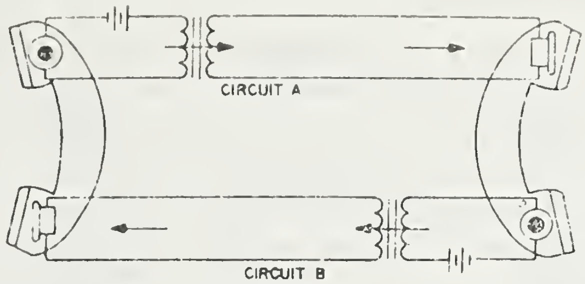



Figure II-8. Two-Way Transmitter-Receiver Circuit

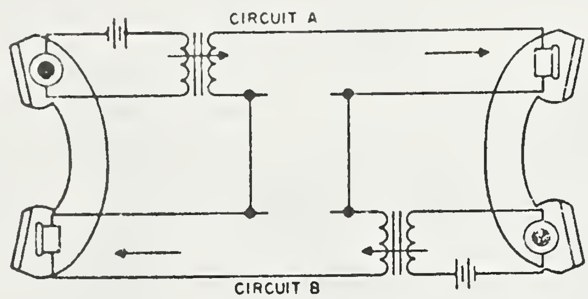



Figure II-9. Two-Wire Two-Way Telephone Circuit

Figure II-10 represents a clearer picture of the local-battery telephone circuit. There are additional savings by having only three wires running to the handset. As shown, the middle wire is used in common by both the transmitter and receiver circuits.

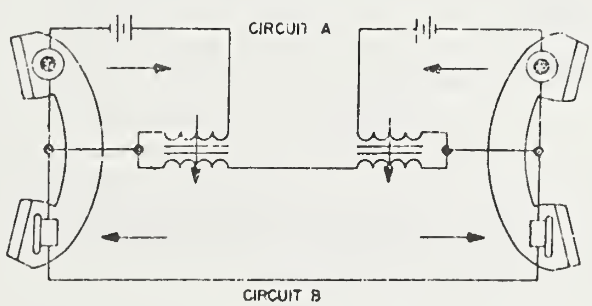



Figure II-10. Local-Battery Telephone Circuit

2. Common-Battery Systems

The next development in telephone circuits is the common-battery circuit shown in Figure II-11. The similarity between Figure II-10 and Figure II-11 is quite apparent. The difference is that in the latter there is a common power source. It is also a four-wire arrangement. However, Figure II-12 shows a simple two-wire connection. In Figure II-13 there is a clearer arrangement of the series common-battery telephone circuit. Figure II-14 is a parallel common-battery circuit. A telephone system and its various components depend on the stability of established voltage levels (48 or 24 volts) for proper operation. The parallel arrangement of Figure II-14 provides much of this stability.

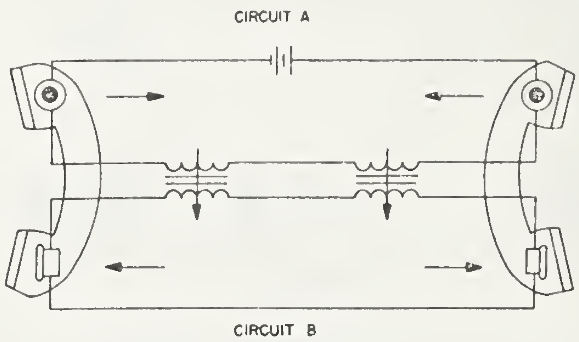



Figure II-11. Common-Battery Telephone Circuit

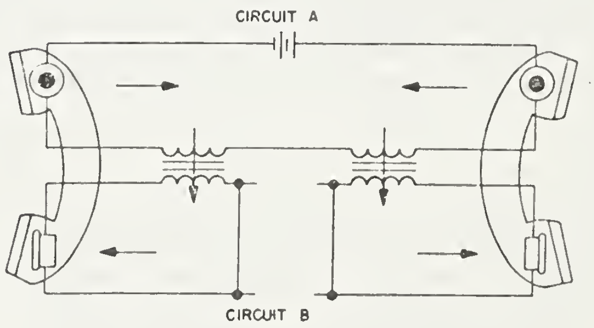



Figure II-12. Two-Wire Common-Battery Circuit

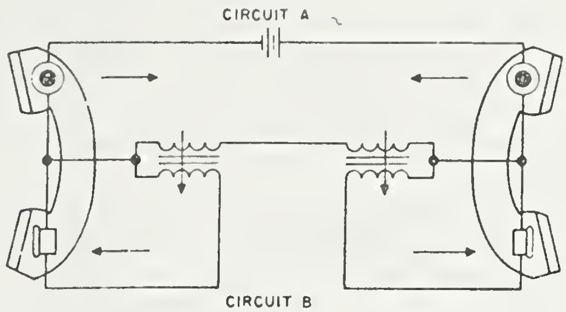



Figure II-13. Series Common-Battery Circuit

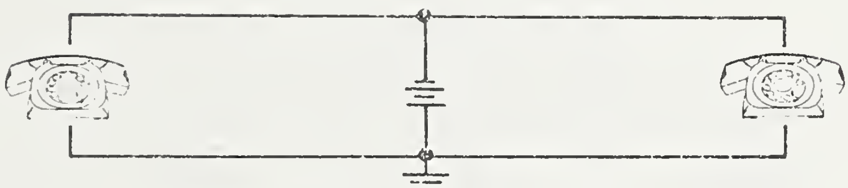


Figure II-14. Parallel Common-Battery Circuit

3. Capacitor - Inductor Common-Battery System

In a common-battery system one DC source serves all telephones in that system. This is illustrated in Figure II-15. If left as shown, a conversation between one set of telephones will be heard by all other telephones, since the voice currents will pass unhindered through the common element, the battery.

To correct this fault the capacitor-inductor common-battery system was designed, Figure II-16. Here, the inductors afford a high impedance to all current variations, by effectively blocking voice currents from the battery. Since the inductors alone would also prevent speech from reaching the distant station, we include by-pass capacitors when establishing a connection. The capacitors offer very little opposition to current variations.

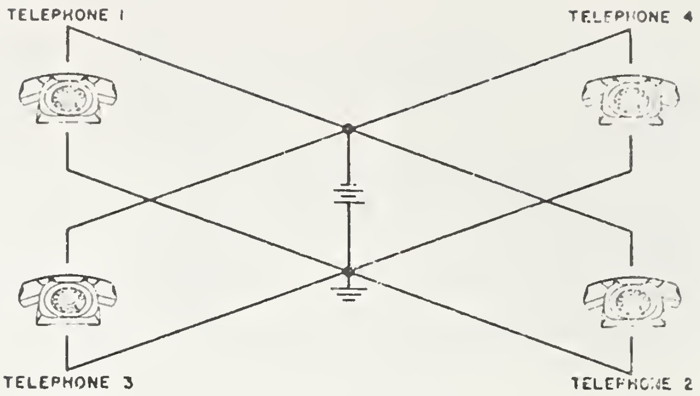



Figure II-15. Common-Battery System

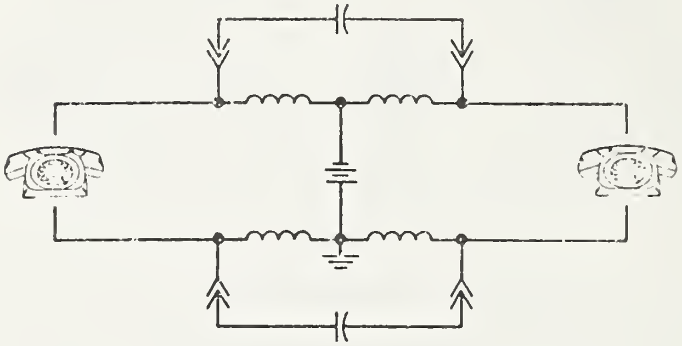


Figure II-16. Capacitor-Inductor Common-Battery System

Thus, in effect, the voice current travels through a circuit consisting of the two telephones, the lines, and the capacitors. (Very little voice current leaks through the central-office battery-feed inductors because of their high impedance to voice frequency currents.) In practice, the inductors usually are the coils of relays. The relays not only serve as battery-feed coils but also respond to the subscriber's hookswitch signals and dial pulses.

D. <u>Supervision</u>

Many forms of signals are used in telephony for indicating status of circuits, trunks, and equipment. They are lumped together under the heading or title of "supervision".

The basic supervisory signals are "ON-HOOK" and "OFF-HOOK". These terms are derived from the position of the handset on a standard telephone instrument. ON-HOOK, or with the handset on the cradle, can indicate one of two conditions, the first being that the subscriber (telephone user) loop is idle and ready to receive incoming calls. The second condition occurs at the completion of a call when the handset is placed on the cradle to indicate the end of a call and serves to disconnect the user.

OFF-HOOK supervision has several uses; the most common of these is to indicate that a particular subscriber loop is busy. Additionally, it can indicate to the subscriber (user) line equipment in the transmission facility that the subscriber desires to place a call, and that the call has been answered, or to indicate trouble on the line if it occurs when the telephone is actually in an ON-HOOK condition.

Dial tone is another supervisory signal indicating to the subscriber that dialing may begin; audible ringing, or ringback tone indicates the called line has been reached and is ringing. If a called line has been addressed but is busy a Line Busy (BY) tone is sent back to the calling party. When all local switching paths are busy, an All Trunks Busy (ATB) tone is heard; this is also called "reorder" or "overflow" tone. A No Circuit (NC) tone is sent when no inter-toll trunks are available. When an office code or exchange is dialed that does not exist, a Vacant Code tone is heard.

Many supervisory signals are DC and are not audible to the subscriber. One of these is reverse battery; on intra or inter-office trunks reverse battery is used to indicate that a particular trunk is busy. This is a function of the circuit seized (CS) relay.

E. Signaling

Signaling is a general heading covering a variety of control and supervisory functions for both intra and inter-office use in the telephone service. Several forms of signaling will be discussed in this section as applied to the power communications system.

Subscriber signaling generally falls under two headings namely rotary dialing and touch dialing. Rotary dialing, the most common signaling method for many years, has been discussed in the foregoing section on Switching Systems. Touch dialing, or dialing with the use of buttons, was one of the original dialing systems; however, it did not lend itself readily to the generation of the DC pulses required by the telephone SxS offices. It was not until the crossbar switching systems were developed that touch dialing came into wide use.

Touch dialing actually comes in two forms. The most common of these is the Touch Tone* or pushbutton dial used on subscriber telephones today. Figure II-17 shows the faceplate of the pushbutton telephone and Figure II-18 shows the tone matrix associated with the pushbuttons. Pushing a button on the instrument causes two rods to rotate, one associated with a row of pushbuttons and the other associated with a column of pushbuttons. The rotation of this rod activates switches which cause two tones to be generated, a high tone and a low tone. As may be seen in the figures each pushbutton has a distinct combination of tones associated with it. The tones are arranged with four rows of low frequency tones and four columns of high frequency tones; however, the fourth column tone is not used at the present time. The 4x3 matrix furnishes tones enough for the ten normal dialing digits plus two extra tone combinations for special use in Electronic Switching Systems (ESS).

ESS's accept the pushbutton tones directly into the switching system; this was part of the design objective of ESS. Tone receivers are part of the subscriber line equipment and convert received tones into DC pulses to operate the correct switching sequence. In electromechanical common control, such as the crossbar office, the tone signal detector translates the tones into a form which can be used by the common control equipment. Pushbutton line equipment will also accept rotary dial pulses. The pushbutton tone generator in the telephone instrument is a transistorized or integrated circuit device and is powered from the central office battery on the subscriber line.

The second type of tone dialing has been in use for many years; however, it is not as well known outside the telephone industry. This type of dialing is known as key pulsing and uses multifrequency tones. It has not been adapted to direct use by consumers because of the exacting filtering requirements to avoid interference from voice frequencies but is widely used in large telephone systems. MF pulsing is composed of six frequencies spaced 200 Hz apart in the range of 700 to 1700 Hz. Two frequencies are sent simultaneously for each digit or supplementary signal. Fifteen combinations are possible; however, only ten are used. Figure II-19 lists the frequencies and their use.

Figure II-20 depicts a typical application of MF pulsing from a toll switchboard to a crossbar central office.

* Registered Trade Mark AT&T

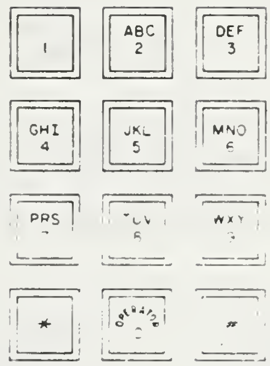



Figure II -17. Pushbutton Telephone Faceplate

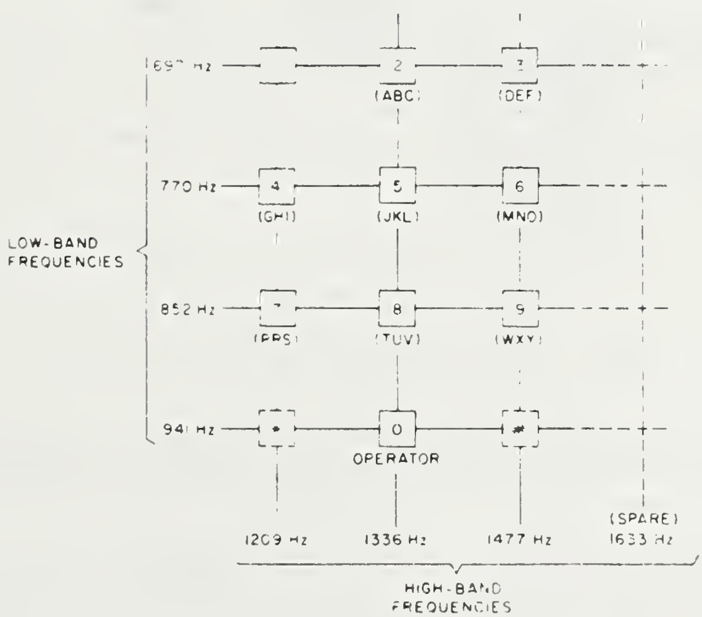



Figure II-18. Pushbutton Dialing Frequencies

| Digit | Frequencies (Hz) | Digit | Frequencies (Hz) |
|---|---|---|---|
| 1 | 700 + 900 | 7 | 700 + 1500 |
| 2 | 700 + 1100 | 8 | 900 + 1500 |
| 3 | 900 + 1100 | 9 | 1100 + 1500 |
| 4 | 700 + 1300 | 0 | 1300 + 1500 |
| 5 | 900 + 1300 | KP | 1100 + 1700 |
| 6 | 1100 + 1300 | ST | 1500 + 1700 |

KP = Signal to start MF pulsing
ST = Signal to indicate end of MF pulsing

Figure II-19. Multifrequency (MF) Signaling Code

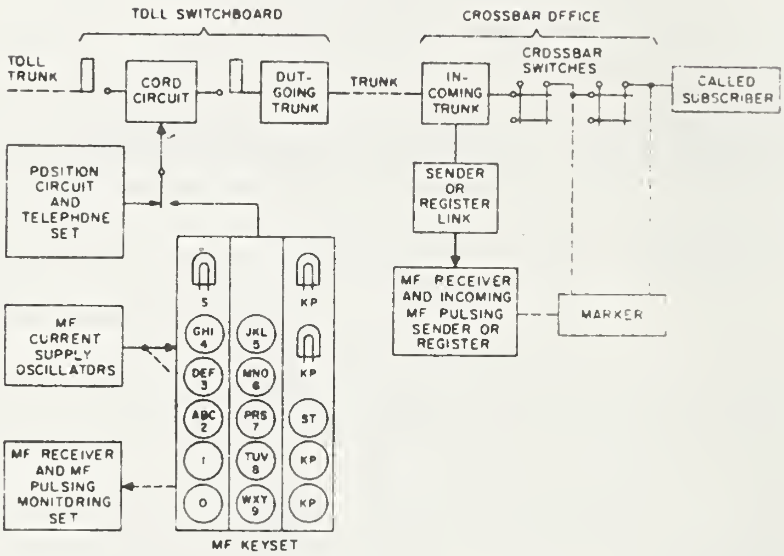



Figure II-20. M-F Pulsing to Crossbar (Toll)

Within and between telephone offices, two types of DC signaling are used and known as loop signaling and E and M or derived signaling. Loop signaling is most commonly used on interoffice trunks and is of the reverse-battery and battery-ground DC loop method. By operating on the reverse current flow principle, this signaling provides answering supervision, indicating when the called party has answered. On an idle trunk, a polarity exists on its conductors with battery on the R and ground on the T, and this is maintained by trunk supervisory relays during the progress of a call being placed. As soon as the called party answers, the OFF HOOK signal causes the terminating office equipment to reverse battery on the trunk toward the originating office indicating that the called party has answered and the switching equipment can complete the talking path.

In certain switching systems the subscriber dial pulses control the switching directly. In some cases it is possible that when going through several offices the loop resistance of the various trunk conductors may become too high for reliable loop pulsing. The battery-ground system furnishes battery and ground from the originating office in series with the battery and ground provided over the trunk thus nearly doubling the current flow over the trunk, ensuring reliable pulsing of the loop. Once the pulsing is complete and the connections made, the battery from the originating office is removed and only the trunk battery remains for the talking path and supervisory use.

The most widely used signaling system for long interoffice and short haul trunks is the E and M system. This is called a derived signaling method and where it received its designation has two schools of thought. One school claims that the E comes from the "ear" or receiving lead and the M comes from the "mouth" or transmitting lead. The other school says that the E comes from the middle "e" in receive and the M comes from the "m" in transmit. The E and M leads are the terms applied to conductors connecting the separate signaling device and these E and M leads can be used for either DC or AC signaling.

No matter whether the signaling is DC or AC, the functions and signals on the E and M leads are the same. Very simply stated, the E lead at the near-end reflects the condition of the M lead at the far-end and the M lead at the near-end reflects the condition of the E lead at the far-end. Figure II-21 shows the E and M conditions for trunk signaling and supervision.

The DC category of E and M signaling includes simplex (SX), duplex (DX) and composite (CX) signaling systems which provide dial pulsing and signaling over much greater distances than is possible with loop signaling. These DC signaling systems are treated in detail in the references in the Bibliography. Suffice to say that they function by either reducing the conductor resistance by paralleling the conductors for DC or they actually regenerate the DC signaling pulses and supervisory signals to increase the usable distance for DC signaling.

There are two basic types of AC signaling, in-band and out-of-band. These systems operate right on the transmission circuit; they generate signaling frequencies either in the 200-3000 Hz range (in-band) or in the 3400-3700 Hz range (out-of-band). They are also controlled by trunk E and M leads and reflect their conditions using audio frequencies.

| Calling Subscriber or Trunk State | Originating Office E Lead | Originating Office M Lead | Direction of Transmitted Signal | Terminating Office E Lead | Terminating Office M Lead | Called Subscriber State |
|---|---|---|---|---|---|---|
| Trunk Idle | Open | Ground | (none) | Open | Ground | On-Hook |
| Trunk Seized | Open | Battery | ⟶ | Ground | Ground | On-Hook |
| Off-Hook (Conversation Period) | Ground | Battery | ⟵ | Ground | Battery | Off-Hook |
| On-Hook (Calling Subscriber Disconnects) | Ground | Ground | ⟶ | Open | Battery | Off-Hook |
| Trunk Disconnected | Open | Ground | (none) | Open | Ground | On-Hook |

Figure II-21. E and M Lead Conditions for Trunk Signaling

The most common in-band signaling system is the SF or single frequency type. This type uses a standard frequency of 2600 Hz in one direction and 2400 Hz in the other direction on a 2-wire circuit. DC signals received from the trunk equipment are converted to SF tones for transmission over the voice channel and at the far end are converted back to DC signals. Voice and signaling tones are not normally on the voice channel at the same time. During the idle state of the trunk, the SF tone is being transmitted over the channel, at this point being used to indicate an IDLE or ON-HOOK condition. When the trunk is seized the M lead is changed from ground to battery state and removes the SF tone from the circuit. The called office SF unit detects this removal and changes its E lead condition from open to ground causing the switching equipment to function. As dial pulses are generated, the M lead now applies and removes the SF tone in unison with the dialing pulses. This is reflected in the E lead at the far end which pulses the switch to establish the connection.

Out-of-band signaling, commonly used for signaling, supervision and control on voice MUX systems, is placed above the voice band between 3400 Hz and 4000 Hz. It functions in the same manner as the in-band SF tone with the frequencies of 3700 Hz and 3825 Hz used for the tones.

F. Trunking

Trunks are named for their particular use such as inter-office trunks, tandem trunks, terminal trunks, etc.; there are more than 25 different trunk types and they are, in turn, broken down to indicate the type of circuit they serve such as data, voice, facsimile, telegraph, etc. In order to define the term trunk, we must first define another term, "circuit".

A circuit in communications transmission describes the total transmission path from one user to another. A circuit in the case of a telephone service is made up of the user transmission equipment, telephone switching equipment, repeaters, multiplex equipment, microwave links, etc. One or more portions of the circuit will probably include trunks.

The trunk can be defined as a common user channel between switching centers. They are classified as common user because only a limited number of trunks are installed in any one service to serve many users. As an example, interoffice trunks between two telephone exchanges serving the same community are generally installed on the basis of 1 trunk for each 10-25 subscribers served. The preliminary design of this trunking would be based on predicted traffic loads. After they are installed and operating, actual traffic counts are used to determine whether the number of trunks should be increased or can be decreased.

Trunks may be 2-wire or 4-wire depending on the distance to be covered. Two-wire trunks may require amplification in the form of repeaters; 4-wire trunks generally do require repeaters and quite often utilize multiplex facilities due to the length of the path. A list of the more common trunks and their uses is contained in the Glossary.

Again, it should be kept in mind that a trunk is a common user facility serving many users; the number of trunks installed is determined by very accurate traffic counts.

In power communications, the engineer will be concerned with only a very few different types of trunks. These will most likely be the Dial Repeating Tie Trunk and Automatic Tie Trunk used between the local telephone company and the borrower's transmission and switching facilities.

## G. Termination Equipment

The topic "Termination Equipment" includes a vast number of different pieces of telephone equipment. Webster defines "terminate" as "...bring to an end; finish; conclude; form the end, boundary, or limit of." All termination equipment in telephone usage performs to this definition in some fashion.

All telephone circuits, whether they are metallic (wire pairs) or carrier derived, have a characteristic impedance or a resistance in which they must be terminated. This is generally true whether the circuit is in use or, like a trunk, may be idle and waiting to be put into use. The various types of termination equipment used in the telephone industry either terminate the circuits in their characteristic impedance (in the case of voice or other AC circuits) or in a resistance (DC circuits). The proper termination of the circuit is necessary to allow the maximum transfer of energy in an operating circuit. In a non-operating circuit, such as an idle trunk, the proper termination is necessary to prevent the circuit from breaking into self-oscillation or "singing", and causing interference to other circuits. This is a very brief and basic explanation of what termination equipment does, but more detailed explanations of impedance and transmission characteristics are contained in other portions of this Bulletin.

Many pieces of equipment fall under the heading of termination devices. The telephone is probably the most common to the user. Within the telephone plant there are other devices used for termination such as hybrids, repeat coils, 2-wire to 4-wire term sets, resistors, etc. The detailed discussion of the theory of operation of each of these devices is beyond the scope of this Bulletin and the reader is directed to references in the Bibliography for more detailed discussions. Suffice to say, these devices perform a very necessary function in telephony and are of great importance to the operation of the system.

## H. Plant Communications PABX/CBX Systems

### 1. Background

The major function of a telephone system is establishing a communication path between any two telephones in that system. This is a basic function and originates from the fact that neither the telephone system nor the subscriber knows who is going to call whom and from where. The safest assumption is that sooner or later everyone will call everyone else.

A straightforward solution to this would be a system of directly interconnected telephones. However, coupled with the facts that the possibility of everyone calling everyone else is quite remote and that telephone conversations are not continuous, we can eliminate direct interconnection as very impractical and highly uneconomical. We are thus led to a system design that provides us with a connection on demand. This is the centralized switching system.

The idea behind centralized switching is simply this: each telephone is connected by a single pair of wires to a central location(sometimes called a central office-CO), where the desired connections are established on demand. Figures II-22 and II-23 are a comparison between a directly interconnected system and a centralized switching system.

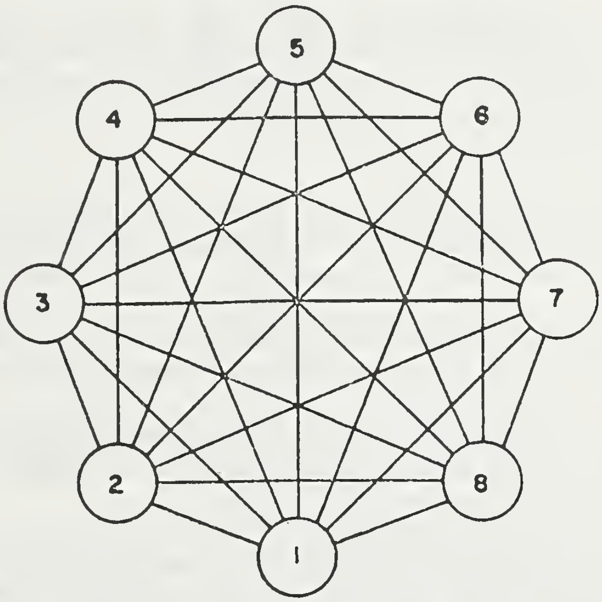



Figure II-22. Directly Interconnected Telephone System

Before discussing electronic switching systems, it is desirable to understand the concepts involved in the development of automatic telephone switching, and the operations of major electromechanical switching systems. Automatic switching equipment initially was designed to aid and later to replace a telephone operator and a manual switchboard. The evolvement of electromechanical systems has simulated to a large degree the switching functions of the cords, plugs, and jacks on manual switchboards. These functions performed by the operator in processing a local call on a manual switchboard are as follows:

a. The operator scans the switchboard panels for lights indicating an originating call.

b. When a lamp lights, the operator immediately notes its location, the identity of the calling line's jack, and records this information.

c. The operator inserts the plug of an answering cord into the jack of the calling line and announces, "Operator".

d. The called line number is received from the calling party and recorded by the operator.

e. The jack of the called party on the switchboard is located.

f. The operator determines the state of the called line by testing the sleeve of its jack with the tip of her calling cord's plug.

g. If the called line tests idle (click is not heard by the operator), the calling cord's plug is inserted into the called line's jack to complete the connection. Ringing is started automatically by the relay equipment in the cord circuit.

h. If the called line tests busy (click is heard by the operator) the plug of the calling cord is inserted into a busy-tone jack which transmits a busy tone to the calling party.

i. When the connection is completed, per steps g or h above, the operator is available to handle another call.

j. The progress of the call is indicated by lamps on the keyshelf of the switchboard which are associated with each answering and calling cord.

k. The operator releases the connection by removing the answering and calling cords when both lamps light to indicate that the calling and called parties have disconnected. The operator can perform this function while processing other calls.

Automatic or electromechanical switching equipments do not exactly duplicate the direct interconnections completed by the operator using the cords, jacks, keys, and other switchboard equipment. Relays, vertical and rotary motions of stepping switches, brush-type selectors, and crosspoint contacts of crossbar switches are utilized for interconnecting telephone lines in electromechanical central offices. Note that central offices, whether manual, electromechanical, or electronic switching types, are not designed for the simultaneous connections of all or even a majority of their customers. For instance, to permit all customers to talk to each other at the same time, the number of required interconnections in the central office would amount to one-half the number of customers. As a rule, only a small portion of customers, normally 10 percent to 14 percent, simultaneously originates calls within a given time of busy-hour periods. Consequently, the central

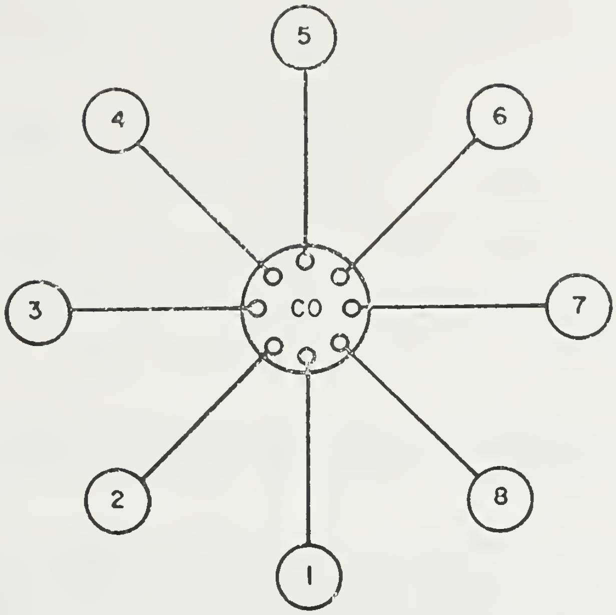



Figure II-23. Centralized Switching

office equipment needs the capacity to serve only that percent of the total lines. In a central office serving 6,000 lines, for example, approximately 700 calls would usually be connected or in progress of completion at any one instant in busy-hour periods. Thus, only the amount of equipment capable of handling that number of simultaneous connections need be provided. This principle is also followed in the design of electronic switching central offices.

The address information, registered by the dial pulses or push-button tones of a telephone, establishes the basis for the subsequent operations of the switching equipment throughout the complex system of central offices, tandem and toll centers, primary, sectional and regional centers.

Switching information represents a variety of categories: the last four digits of a line number, digits of a long distance call, information on a switch location of a central office trunk, or signals requesting a check on a line to test if it is idle or not. In most cases, this information can be reduced to two-state signals; a yes or no condition, an on-off current flow, or an open or closed relay contact.

The origin and destination of two-state signals, sent or received, may be between a subscriber station and a central office or completely within or between central offices. In responding to transmitted information, the switching equipment in common-control systems first translates or reevaluates it and then routes it along a complex series of electromechanical interactions. Upon completion of a connection, the control equipment continues to collect additional information from its interconnecting units, establishing further connections or starting a new train of switching operations.

In addition to the signals required for switching equipment, there are two other general signal classifications: signals normally transmitted and received over subscriber loops via the central office and signals between central office switching centers.

The signals transmitted over subscriber loops can be subdivided into three groups: information, supervisory and control signals.

a. Information signals - Information signals are audible tones in the voice frequency range. They convey information to the customer or operator on the progress of a call. The ringing of a subset bell indicates that the line is being called or a busy tone indicates that the called line is busy.

b. Supervisory signals - Supervisory signals are requests for service. Lifting the handset will send an off-hook signal, indicating origination of a call. Replacing the handset will send the on-hook signal indicating disconnection. The flow of direct current from the central office over the subscriber loop provides the power for this type of signaling.

c. Control signals - Control signals are required for completing connections. The subscriber's dial originates signals by interrupting the flow of direct current and the pushbutton set generates tone signals.

The most applicable of the telephone switching systems to power systems communications use is the Private Branch Exchange (PBX), or Private Automatic Branch Exchange (PABX)/ Computerized Branch Exchange (CBX). PBX, PABX and CBX are used synonymously today to describe a user-operated and, quite often, user-owned telephone system used for intracompany communications. Originally PBX indicated that the system was of the manual switchboard type requiring operator or attendant assistance to place all calls; PABX indicated that the system was dial automatic only utilizing the operator for certain functions. Today, manual switchboards are almost a thing of the past. In fact they often require special ordering to be produced. Also, the electromechanical PABX is fast becoming a thing of the past, being replaced with the newer CBX type of equipment. The CBX with its wide variety of options is the most practical system for power communications facilities.

Although a switching system for a power communications control center will probably not serve more than from 50 to 300 users, it will operate similarly to a telephone switch serving a major metropolitan area of several million users. It undoubtedly will have interfaces with local telephone systems at various locations and therefore must be compatible with them.

Figure II-24 depicts the typical hierarchy of a large telephone system. The solid lines indicate the primary routing of toll calls while the broken lines indicate alternate routings. Typically, a power communications telephone system will interface with a Class 5 or End Office (EO) with several direct trunks. This interface will allow direct dial access to users served by that EO and to the Nationwide Direct Distance Dialing (DDD) Network. The user of an EO who has essentially a small telephone central office (TCO) of his own is normally referred to as a Private Branch Exchange (PBX) or, more commonly used today, Private Automatic Branch Exchange (PABX)/Computerized Branch Exchange (CBX).

The PABX or CBX operates in the same fashion as a TCO except the number of digits dialed to complete a call within the PABX or CBX may only be three or four while the TCO requires seven to complete a call.

The following sections deal with the workings or functions of a PABX (CBX) and some factors to be considered in the selection of a PABX (CBX).

Appendix A is a compendium of the features available on today's modern CBXs.

2. Introduction

From the end of World War II to the beginning of the 1970s, the most significant advances in PBX technology consisted primarily of the introduction of transistorized circuits and more reliable contact switches. These developments influenced the speed and dependability of PBX systems, but had little impact upon the nature of the service which such equipment was able to provide. In the past few years, suppliers have introduced computer-controlled PBX switches, generically designated by the acronym "CBX". These machines are totally

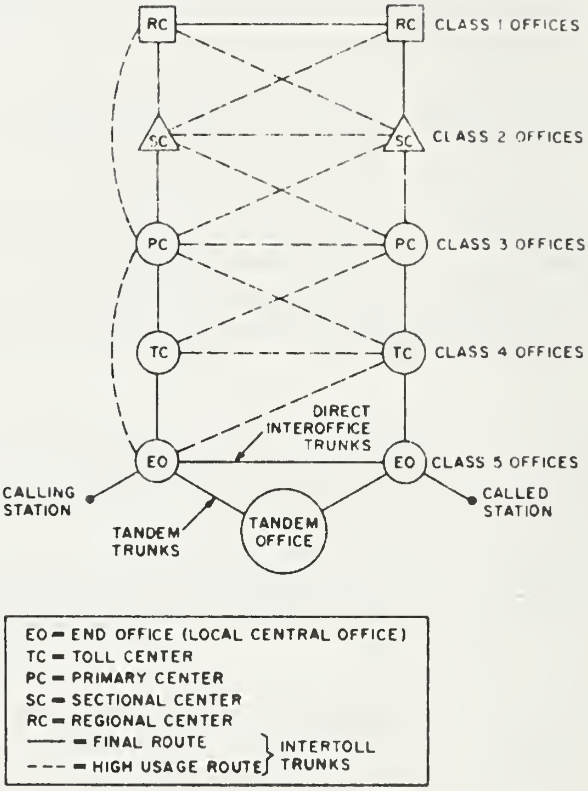



Figure II-24. Typical Telephone Switching Hierarchy different from the previous generations of equipment, in the same way that the automobile was a significant evolution in transportation from its functional predecessor, the horse.

It is impossible to say that this new generation of telephone equipment will have such a strong influence on communications, but it must be regarded as a significant factor which calls for a new, more imaginative approach to the subject. The most successful users of this equipment will not be those who simply regard it as an improved version of familiar PBXs, but those who can find new ways to use its potential to enhance communications capabilities while better controlling communications costs.

In addition to improving man's mobility, the automobile forced people to develop a new set of skills to control the machinery and its power. Similarly, CBXs have stimulated the development of a new area of man-machine communications. Instead of a limited repertory consisting of dial tone, ringing tone, busy signals, dialing and hookswitch flashing, callers must recognize stutter tone, camp-on tones, restriction tones and distinctive ringing and must also learn the procedures needed to activate the many new features. Although the consequences of reckless or incompetent use of a CBX may not be as catastrophic as with automobiles, communications managers are realizing that user education is becoming an important element of CBX installation.

The CBXs open new possibilities for financial savings, achieved largely by taking advantage of the switch's "intelligence" to replace such external equipment as key systems and other ancillary devices, ease the operator's workload by allowing callers to provide more functions for themselves and optimize toll call routing and restriction. As experience with the machines grows, new capabilities will be discovered and implemented. The most revolutionary aspect of the new machines, their programming facility is the one which will allow these new features to be easily implemented and help protect users from equipment obsolescence.

3. Functions and Characteristics of a Computerized Branch Exchange (CBX)

Intelligent specification and use of a CBX requires an understanding of the machine's operation. Computer technology brings two new aspects to telephone switching: the control system and the switching network. These elements must be considered from the point of view of their own operation and their interaction with the other elements of the CBX. While the control system is the source of many of the new capabilities, the switching network can set limits to the machine's operation.

This section describes the different elements of a CBX: the computer, the memory, the interface equipment which connects the lines and trunks, the switching network and their influence on system performance. These include the level of service a CBX can provide and its compatibility with future developments.

a. Computer-Central Processing Unit

As Figure II-25 shows, the computer, or central processing unit (CPU), is at the heart of the CBX. Operating from instructions stored in the memory and mass storage device, the CPU controls the switching network which connects CBX stations and trunks. Controllers and adapters attached to the line terminations of the trunks and stations inform the CPU of their status and allow the CPU to initiate such actions as ringing telephones.

The mini- or microcomputer which provides the CBX control is similar to the larger computers which have become familiar in many applications. In fact, some manufacturers have simply designed their systems to use generally available computers equipped with special interfaces to the switching network and stations.

The actual computer design and operation primarily affect the system's call handling capacity. In order to complete a call, the CPU must follow a set of program instructions. Since the CPU needs a fixed amount of time (which is influenced by the system's design) to read and execute each of its instructions, there will be a limit to the number of instructions which can be executed each second. That limit will, in turn, determine the maximum number of calls and other service requests the unit can deal with in a fixed period of time.

The minicomputer is able to follow binary coded instructions, read and store data and produce output, usually in the form of binary words which are fed into a command channel. The instructions and data can be stored in several different media, offering trade-offs among speed, economy and resistance to power failure, or volatility.

b. Memory Options

The fastest access memory, called the core, holds frequently used instructions, such as the basic program which allows the machine to recognize an off-hook station and send a dial tone. Designers have several options in providing the core memory, including its volatility.

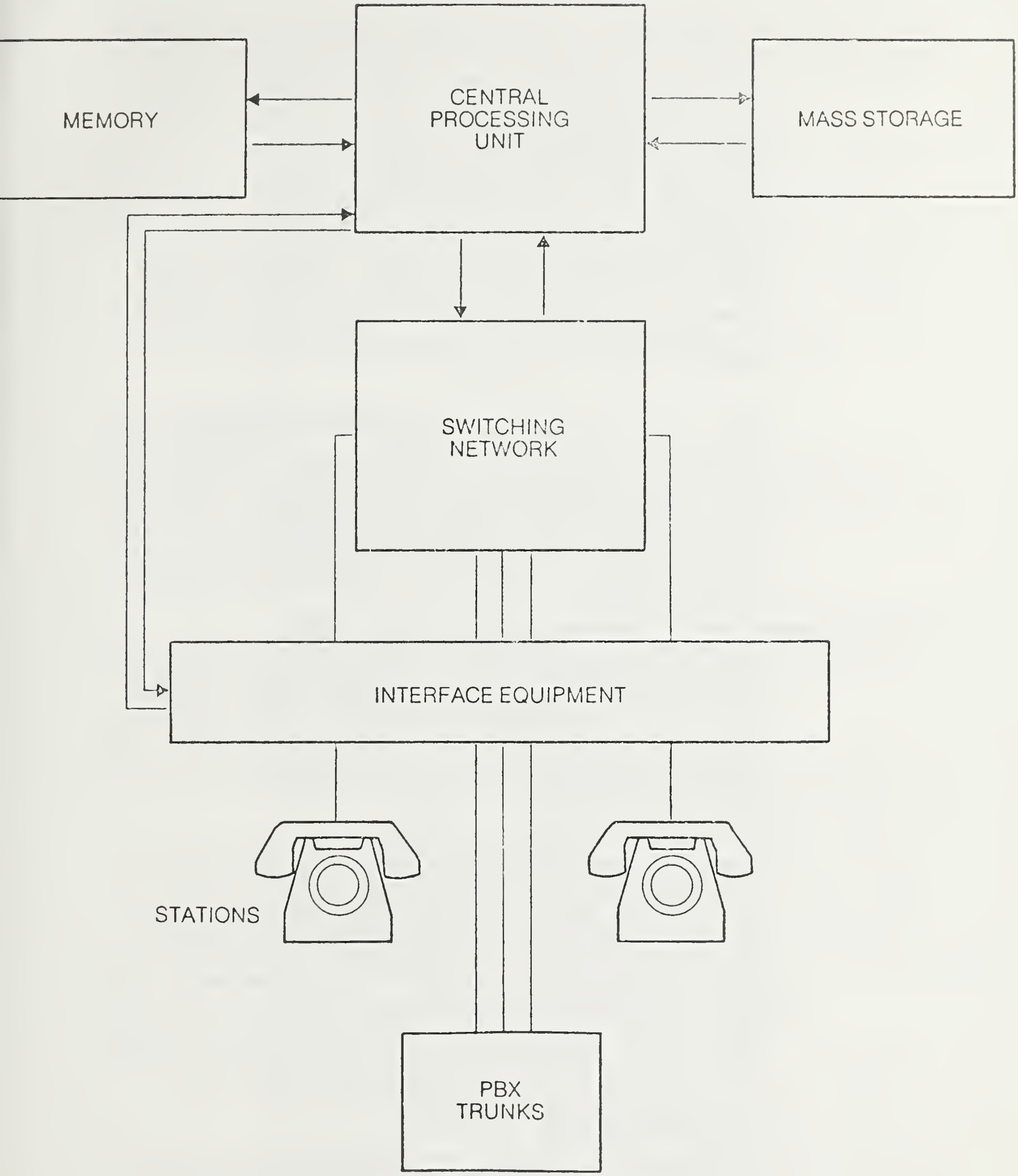



Figure II-25. Computer-Controlled PABX

The term "volatility" refers to the reaction of a memory to a power loss. A non-volatile memory is unaffected by a power failure, and if a computer is turned off, either intentionally or by accident, and then turned back on, it can begin operation immediately without losing any of the information it was working on at the time of power failure. A volatile memory, on the other hand, loses the data it was holding if power is interrupted. This means that a CBX with a volatile memory would have to go through a restart procedure, reading its instructions from a mass storage device, before it could provide service after a power interruption. This, in turn, would delay system availability for about 30 seconds. The CBX would permanently lose information on any calls it was handling at the time power was lost, so all users would have to re-establish their connections.

ROMs, read-only-memories, are permanent, inexpensive and fast, but as the name implies, cannot be modified to hold new data once they have been manufactured. ROMs are frequently used to hold basic routines, such as those necessary to restart programs after a power failure. Because control programs which provide machine features are still evolving rapidly, designers are reluctant to store them on ROMs, which are expensive to replace when a program is to be changed.

Semiconductor memories, like those used in pocket calculators, are manufactured on integrated circuit chips and are inexpensive and fast but volatile. Thus, all the information is destroyed if the system loses electrical power. Since most CBXs on the market rely primarily upon these semiconductor memories, mass storage must also be included as a back-up.

A more expensive and faster option would be forms of non-volatile magnetic core memory similar to those used on many large computers. Mass storage devices include magnetic tape and discs. They are portable, have a large capacity and are relatively inexpensive but offer slow access. The entire operating program is originally stored by the manufacturer on a tape or disc and reloaded by the system, following ROM instructions, into the volatile core after a power failure. Some switches also use these systems to store information on calls in progress, providing the foundation for various call accounting systems.

c. Interface Equipment

The interface and auxiliary equipment provides several functions. These include the translation of the CPU's instructions to the switching equipment, provision of system tones (dial tone, ringing and other signaling tones), relaying line and trunk status to the CPU, storing dialed numbers to be read by the CPU and controlling the attendant's console. There is a great deal of latitude in the way these functions are handled. If the CPU will be lightly utilized, it can be programmed to fulfill most of them. However, as the CBX size and call processing load increase, the designer usually frees the CPU to provide vital functions by assigning more of these tasks to other circuits, which then provide only the final result to the CPU or initiate their actions with very few CPU instructions. Since the demand for these functions is largely dependent on system size and traffic, users may be able to tailor systems to their needs more economically with CBXs which use discrete circuits to do this work.

d. Switching Network

As future applications develop, the most important element of a CBX will be the switching network. The network is important not only for its effect on system performance but also in the ways that it can be connected to different transmission systems.

There is a great deal of diversity in the switching circuits used on these new machines. They range from familiar discrete path techniques (space division switching) to novel binary encoding and data switching methods (time division switching).

Some discrete systems use matrices of relays, switching transistors or diodes, under the control of the CPU, to provide connections. Varying amounts of concentration are used, with some equipment featuring a switching matrix which includes all lines and trunks, removing traffic limitations and allowing all stations and trunks to be engaged in simultaneous conversations. Most others use some degree of concentration to minimize the number of relatively expensive switching points needed, thereby limiting the potential number of simultaneous conversations.

e. Concentration, Blocking and Levels of Service

Concentration in a switching network lowers the cost of the network while also reducing its ability to fully serve the stations and trunks connected to it. For a hypothetical CBX with 100 lines and 20 trunks, a non-blocking network (one with no concentration) would have 120 input points and 120 output points. (Almost any network will have as many outputs as lines and trunks served so that any call allowed to enter it may be completed.) A conversation between Station A and Station B requires two connections: one from A to B and one from B to A. This network would be able to make any one of 14,400 (120 x 120) connections at any time, regardless of the number of lines and trunks already being served by the network and occupying the input ports.

The same 120-input switching network could be installed in another system with 200 lines and 40 trunks. In this case the CBX would have a 2:1 concentration ratio, since only 120 stations and lines could be in use at any one time. If a call from a station were to be connected with another station, it would have to first go to one of the network input ports. If 120 stations and lines were already engaged in connections, all of the inputs would be filled, and the new call would be blocked. If there were fewer than 120 stations and trunks in use, the station would be connected to an input point and then its call would be switched through the network to its destination.

Blocking occurs when all available links are occupied, and it is thus impossible to meet additional demands for service or connections. Using Poisson statistical assumptions about the frequency of service demands, designers are able to specify the percentage of calls which will not be served during heavy demand periods, given typical peak loads. Most CBXs are engineered to a P.01 level, which means that, based on the Poisson assumptions about random service demands, 1% of the busy hour calls (measured on utility-provided equipment) will not be serviced because of insufficient equipment. Some systems provide a slightly lower grade of service, P.05, with 5% of service demands unsatisfied for intercommunication or station-to-station calls.

f. Overall Grade of Service

The grade of service of the PBX is not necessarily the grade of service which will be experienced by the system's callers. If there are not enough telephone company central office trunks, for example, people can use the system to dial 9 but then may get a busy signal since there isn't a trunk free between the CBX and the central office to serve them. In this case the switch may be providing P.01 service, but users may enjoy only P.10 or lower service since there is too much demand for the available trunks. On the other hand, it is also possible that, although there may be enough trunks available to serve the system, traffic has grown so much that there are not enough links in the CBX, and users either get no dial tone at all or receive a system busy signal after dialing for an outside line.

In conclusion, the apparent grade of service of a system is a function of the traffic demands placed on the system, the switching capacity and the number of trunks. Any CBX selected to be part of the system should have enough processor capacity, switching links and available trunk connections to serve the demand expected not only at installation but also during the expected facility lifetime. In this way, the switching machine will not limit system performance. Some machines using physical matrices may be expanded after installation by the addition of switching elements until the design capacity is reached. CBXs using modulation techniques generally have a fixed link capacity, determined by the number of slots on the main "highway" described next.

g. Modulation and Switching

Many machines use coding schemes (time division switching) instead of physical matrices to make connections. They code, or modulate, the signals from different sources in a variety of ways and then combine the signal streams on one cable, or "highway". Connections are established by ordering a receiver to decode a specific signal from the highway.

This technique is based on work in information theory and electronics which pointed out that any signal can be recreated from a series of samples, as long as the samples are taken at a rate which is at least twice as fast as the highest frequency of the signal. As an example, consider a single telephone line carrying a conversation. The highest frequency component of the conversation which is needed to preserve intelligibility is about 3,000 Hz. If we sample the signal at the rate of 8,000 times per second ( a common sampling rate for voice signals), we can transmit these samples and then easily use them to rebuild the original signal at a distant point.

Since the height of the pulse, not its width, is the important factor, we can make each of the samples half as wide and still accurately reproduce the signal at the distant point. If we have two sets of these "half width" pulses, we can interleave or shuffle them, transmitting first a sample of signal A, then a sample of signal B and then an A sample again. Equipment at the distant end can separate the two sets of pulses and return the A and B signals to their original form. At this point we have gained the capability of sending two signals at once over the same line.

As we make each sample pulse thinner and thinner, we can combine more signal streams on the same line, increasing the economy of the system. The only limits to the process are the sampling equipment and the pulse transmission line. The transmission line must be able to accurately carry the pulses, preserving the variations in amplitude of the different samples. As more signals are carried by the highway, the transmission line must make more amplitude variations in the same period of time. This ability to follow amplitude changes quickly is termed frequency response, and it becomes increasingly expensive to extend the frequency response of the "highway", thus limiting the number of signals which can be carried by a single line.

Figure II-26 is a block diagram of a time division switching PABX system. It shows the straightforward design which time division switching makes possible. The actual switching network is simply an information memory which can shift pulses from one time slot to another. These pulse streams are then transmitted to converters which transform them to voice-type signals for connection to the stations or trunks. The digital trunk circuit in the upper right-hand corner demonstrates the way these circuits can be connected directly to the system, going through a simple adapter and bypassing the converters. A single digital trunk circuit can handle a larger number of individual PBX trunk lines, reducing the operating company's use of wire pairs to link the customer location and central office.

The highway might be divided into 32 time slots. The CPU could then complete a call between Station A and Station B by ordering Station A to modulate its output into slot 3 and demodulate the signal from slot 4. Similarly, Station B would insert its output into slot 4 while receiving information from slot 3. At the same time, other time slots on the cable would be carrying other conversations among stations and trunks. When the connection between Stations A and B is terminated, the time slots would be available to make connections between other terminals. Since a single slot can carry conversation in only one direction, two spaces on the highway are needed to connect two lines.

Except in extremely small systems, it is impractical to design a highway with enough time slots to allow all stations and trunks to have connections at the same time. This means that there is a certain degree of concentration, as with most physical systems, and similarly a potential for blocking with heavy traffic. Large CBXs using this form of switching may be equipped with several highways in order to increase their capacity.

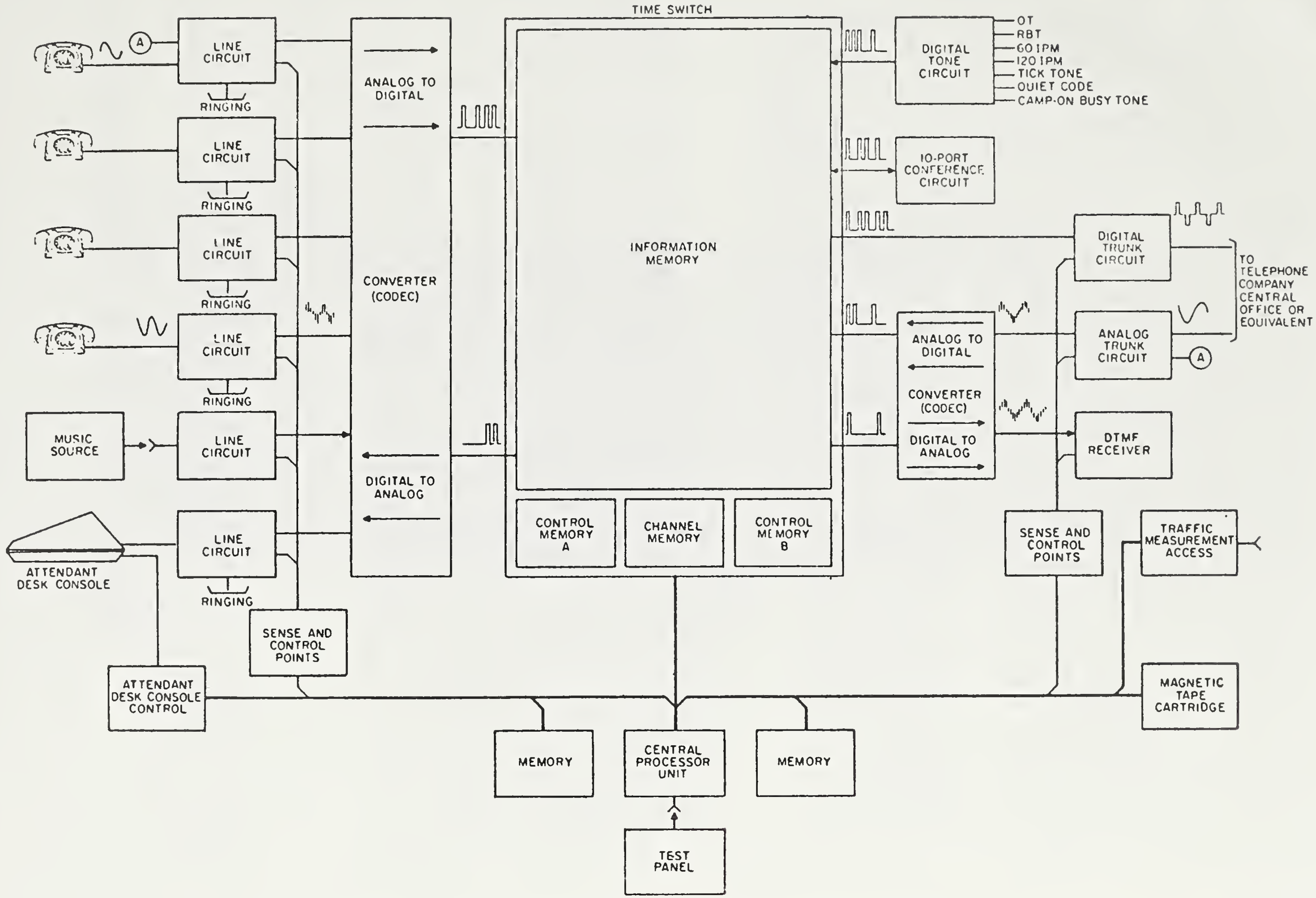



Figure II-26. Time Division Switching PABX System

1. Pulse Amplitude Modulation (PAM)

Modulation schemes were originally developed to allow more conversations to be carried on a single pair of wires or microwave link to reduce the costs of long distance transmission. In PAM, Pulse Amplitude Modulation, inputs are sampled at a high frequency. The samples are put, one after another on the common output line. At the destination, the samples are picked off the transmission line and directed to the proper output. Circuitry in the receiver for each line then recreates the whole signal from the transmitted samples. Since the modulation techniques for the CBX and some carriers are the same, a compatible high-capacity PAM channel may be terminated directly on the switch, eliminating the need for the usual modulation and demodulation circuits used to derive single voice channels. However, only a limited number of channels may be carried over PAM lines before it becomes impossible to cleanly separate the samples at the receiving end and cross-talk between voice channels becomes a problem.

2. Pulse Code Modulation

Certain CBXs, on the other hand, directly translate station and trunk information into PCM form. The signals are sampled, as with PAM, but instead of putting the sample directly onto the channel, the circuitry first measures the voltage of the sample and then inserts the numerical value (in binary form) of the measurement onto the bus at the proper time period. The receiver at the other end picks out the value for each line and uses it to recreate the signal. Although this would appear to be more difficult than PAM techniques, PCM offers several advantages. The signals on the output bus are in binary form (electrical 0's and 1's, just two voltage levels) so the line is much less sensitive to noise. Receivers need only decide whether or not a pulse is present in a time slot, not measure its exact value as with PAM. The highway simply becomes a data link, and as electronic computers have undergone rapid development, advanced circuits and techniques to deal with digital signal streams are readily available.

Since the signal highway in a PCM CBX is simply a data link, it is relatively easy for the CBX to handle computer data in addition to voice signals. The data is transmitted to the system in digital form and a straightforward interface device inserts the data onto the highway where the voice signal sample values (binary data) would have been inserted. A second interface at the output point reads off the data from the appropriate time slot and, instead of converting it into a voice signal, transfers it to a data output line from the CBX. Connections established in this way can carry data at rates as high as 64,000 bits per second on a voice-grade line within the CBX, as opposed to 9,600 bits per second, the usual limit for data speed on a voice line.

Delta modulation, another form of PCM, encodes the change in signal level since the previous sampling instead of the absolute level itself. The output of the process, however, is still a stream of binary signals. Delta modulation is easy to implement electronically but requires a higher data rate to maintain good signal quality.

h. Importance of Modulation Technique

Most CBXs perform signal modulation and demodulation in the main equipment cabinet, with two-wire lines connecting station equipment. This allows users to easily connect conventional, readily available station apparatus, including key systems and ancillary devices such as recorders, dialers and speakerphones. Several devices use special station instruments which insert and pick off the voice signal from the "highway", which is run throughout the facility. This minimizes the installation cabling, letting it resemble AC power distribution, with only one or two cables connected to the switch and subsidiary feeders tapping into these main lines. The user, however, is generally restricted to telephone instruments supplied by the CBX manufacturer which can understand the language of the feeder cable.

4. Selecting a PABX/CBX

From the user's point of view, the most significant aspect of the new generation of PBX equipment is the wide range of features that are now available. This increase in features is not an evolutionary change, but a radical jump in both the number and kind of features available and, almost as important, in the way they are provided.

Older PBX equipment generally offered users defined sets of features. In many jurisdictions, the equipment was tariffed with a "Series" structure, offering several levels of sophistication for varying prices. Capabilities such as Station Call Transfer were implemented through wiring changes in the switching equipment and frequently were limited to certain classes of calls or stations. Since these features depended on physical wiring arrangements, changes were slow, expensive and troublesome. Introducing a completely new set of features to a system could be nearly as expensive as installing an entire PBX. Finally, the equipment and tariffs were structured so that it was virtually impossible to give an advanced capability to just a few stations in a system. Instead, all stations associated with the PBX would have access to all features and would pay a higher monthly rate, whether they used the features or not.

The newer computer-controlled PBX systems (i.e. CBX) provide almost all features through modifications to the software of the computer that is part of the CBX. Once a manufacturer has developed the proper set of instructions for a particular feature, the cost of including these instructions in any user's system is very low since it is easy to write and modify the instructions in the system memory. This also means that almost all systems are protected from obsolescence. If, after the system has been installed, a customer wants another function included in his CBX, it can be introduced as long as there is enough computer memory space available and the manufacturer has produced the program to implement it. Finally, unlike wired PBX modifications, program instructions for a CBX can accept new capabilities and combine them with existing capabilities in order to provide new features for users.

Both interconnect and telephone company rate structures reflect the low marginal cost of adding more features to a basic CBX system. Rates are generally set on a "hardware" basis, with monthly payments reflecting the amount of equipment actually used to provide the service. Since most functions require only a small amount of additional memory to store the instructions, systems are available with a wide range of capabilities at little or no additional cost.

The choice of a CBX resembles the choice of a car; different models offer different feature groups at different prices and may provide diverse ways to achieve additional savings. The decision involves a three-step process of stating the installation's needs in terms of stations, traffic and features, finding a system or systems which can meet those needs and then selecting the proper payment plan for the optimum system. An overview of the procedure is necessary to provide a framework for the detailed explanations given in the other sections of this report.

a. Defining the System Requirements

Some aspects of the definition of the system requirements are straightforward: the number of stations, trunks and attendant positions the CBX is to serve, and the amount of traffic they will generate. These figures, with an allowance for growth, provide the minimum criteria for any system to be considered. The subsequent stages of the selection process are less clearly defined.

Since a major advantage of CBXs is the large number of features they offer, imagination and creativity are needed to identify rewarding applications for these new capabilities. The problem is compounded since different machines offer different sets of features and some operations call for outside equipment which is provided at an additional charge. This means that the final feature list must necessarily be a result of numerous trade-offs among factors of availability, cost and potential benefit.

Some feature uses are unquestioned - more effective toll restriction and Automatic Route Selection will reduce monthly calling charges - while others are more novel - the ability to install a remote cabinet instead of an entire satellite system at a second location in the same city may reduce tie line charges while also allowing the implementation of Centralized Attendant Service. Many system capabilities, provided simply through modifications of the CBX's program, are provided as part of the standard service or at no additional cost. The only point to be settled in this case is whether or not they are going to be necessary or useful to the system's users.

If there is an additional charge associated with a feature, the question is whether the potential benefits, both in terms of cost reductions and system streamlining, outweigh the costs. These considerations will yield two lists for the installation - one with features which are essential and another including those which could be useful but are not needed as badly. In both cases the cost-benefit trade-off may be involved.

Rapid technological obsolescence is an issue which telecommunications users have not previously faced. The choice of a CBX can limit the range of other equipment used with the system and thus constrain future activities. Digital transmission of information is becoming increasingly prevalent, and many utilities already digitize voice signals for long distance transmission, allowing more efficient use of cable and microwave facilities. Some users may foresee a time in the near future when it will be important to have a CBX which can deal with these digital signal streams, either with a direct interface to digital transmission facilities or to more efficiently support digital equipment such as computer terminals. These potential needs should be borne in mind when selecting the proper system.

b. Finding the Proper CBX

Many systems can be immediately dismissed from consideration for several reasons: they are inadequate to support present or projected capacity needs, they are uneconomical in the size range under consideration or there is no reliable local supplier. A CBX should not be immediately disqualified from consideration merely because it may not be compatible with future communications developments, however, since the savings to be realized from present use may still be more than adequate to justify its acquisition.

When investigating CBX interconnect suppliers, consider what other users say about the machine under consideration. Is the supplier known for good service and rapid response? Who would assume maintenance responsibilities for the interconnect system if the original vendor goes out of business? What degree of training for users is available and at what cost? The answers to these questions may eliminate interconnect suppliers from consideration in favor of leased facilities.

Each CBX has a unique set of features. All systems under consideration should be able to provide the features listed on the first, "must have", set of features considered essential to the system's capabilities. The potential savings and convenience provided by the features in the second, optional set for each system can be weighed against that system's cost. This procedure will winnow the field of possibilities down to a smaller group of systems with similar capabilities and prices, allowing for a final financial decision.

c. <u>Selecting a Payment Plan</u>

The cost of a CBX includes more than the payments for the equipment itself. The purchaser should also consider such factors as the rates for auxiliary systems such as multi-button telephones, requirements for protective connecting arrangements, insurance payments, federal excise tax on telephone company-provided equipment, other tax options such as investment credits and accelerated depreciation and the value of the floor space occupied by different CBXs.

Most telephone equipment is available under several payment plans: conventional monthly rates or rental or two-tier, lease-purchase structures. These different choices should be evaluated on the basis of their net present values (NPV) or a similar standard by the financial division of a company. Once the best rate plan, usually the one with the lowest NPV, has been found for a system, the potential savings produced by that CBX should be included in the total NPV, and this final figure will serve as a basis for comparison with the other systems under consideration.

This comparison will yield a ranking of systems, with the one with the lowest NPV being the most economic choice. Nonfinancial factors must also be considered with the understanding that the difference between the NPV figures shows the additional cost of choosing a system which may offer other desirable characteristics. The question finally becomes a matter of choice between financial savings and optimum system characteristics.

I. DC Power Plants

A central feature of a plant communications system is the DC power plant. Storage batteries and large heavy amperage rectifiers are the main ingredients of the telephone power subsystem. Storage batteries are utilized to provide an efficient, reliable source of direct current that is instantly available. The battery system is operated in a "floating" mode, where the storage batteries are always connected across the output of a rectifier or motor generator plant. The generating equipment actually powers the telephone exchange, carrying the load while it keeps the battery at full charge.

The batteries serve three main purposes:

1. Instantly take over the supply of power to the PABX in the event of a failure of primary AC power.

2. Provide extra current capability to the exchange in the event an overload may exceed the capabilities of the rectifiers or generators.

3. Act as a filter across the rectifier or generator output which is inherently noisy.

The normal communications office battery will be made up of 23 cells, each with a terminal voltage at full charge of 2.15 volts (2.15 x 23 = 49.45 volts). The nominal voltage used is 48 volts which allows for some losses from the battery plant. Other voltages used are ±130 volts for some carrier and microwave equipment and -24 volts for other applications and they are normally supplied by separate battery plants, the number of cells of which are derived in the same method.

The physical size of the cells of a battery plant is determined by the current rating of the plant given in ampere-hours (AH). The AH rating of any telephone battery plant is derived from the total current required to power the telephone facility for a period of 8 hours without primary AC power. Technically this 8 hour figure is the point at which the battery has discharged to a voltage of 1.75 volts per cell or a total of 40.25 volts for a 48 volt battery plant. This voltage is the point at which it has been determined a plant communications system will begin to experience numerous faults.

As an example, a communications system may draw a steady load current of 206 amperes under normal load conditions. This would amount to a load of approximately 1650 ampere-hours load in 8 hours. In sizing the battery for this facility it would be found that 1650 AH rated cells are a standard size. The average 1650 AH cell is approximately 10½ inches long, 14½ inches wide and 22½ inches high and weighs 310 lbs. filled with electrolyte. As a result of the size of these cells and the weight, special care is taken in the installation and maintenance of them. Special racks are used to hold the cells in the telephone office and special well-ventilated rooms are usually designed into the telephone building to house the battery plant.

Each cell case is usually constructed of a high impact thermoplastic; however, some cells are still available with rubber cases and glass cases. The cell covers are also thermoplastic with some older ones being made of rubber. During discharging of the cells, gases are given off by the cells due to the chemical action taking place within the cell. The gases usually contain hydrogen which is highly explosive and should not be subjected to open flames, cigarettes or sparks.

As stated, when the communications facility is operating normally, the battery is kept in a continuously charged condition. When failure of the primary outside power requires the battery to carry the load for an appreciable time, however, the battery will become more or less discharged and will therefore require special recharging action. In order to provide charging current in such a case, it is necessary to increase the output voltage of the charging unit above its normal value. Since the charging unit (rectifier or motor generator) is connected directly to the load, an increase in its output voltage would also increase the load voltage, possibly causing damage to the very equipment it is powering. To avoid this, the charging circuit includes a "counter-EMF (CEMF) cell" which is automatically switched in series with the load circuit when the output voltage of the charging unit is increased above its normal value.

The CEMF cell has the property, when current flows through it, of setting up a voltage opposing the voltage which is driving the current. The counter voltage is approximately 2 volts per cell and is substantially constant under wide variations in current. Electrically the CEMF cell is a battery with its polarity in the opposite direction of the rest of the cells.

In the modern communications facilities, the solid state rectifier is the most commonly found piece of equipment used for providing the DC to operate the plant and to charge the batteries. For many years the motor generator set was the common DC power plant for the telephone system, but they are being replaced in older plants, and newer plants are installing the solid state rectifier initially. The theory of operation of a rectifier will not be discussed in this bulletin as the engineer should be familiar with this subject. The special applications of rectifiers to the telephone power plant and some of their peculiarities will be discussed.

The rectifier performs two primary functions. The first is the powering of the communications system directly and float charging of the battery when normal AC power is available. They also power the system and recharge the battery after a failure and restoration of the primary AC power. Under these conditions, the rectifier must be especially designed to maintain a constant voltage output under widely varying loads. The widely varying loads range from the very large current demands of powering a fully loaded communications plant in combination with recharging a discharged battery after an extensive failure to the very low current demands of maintaining a fully charged battery on float and powering a PABX during the normal non-busy hours of 12 midnight to 5 AM when usage is down from the peaks of the heavy traffic hours.

All rectifiers should be equipped with alarm features to indicate that AC power has failed, a rectifier primary power fuse has blown, float voltage has increased above a set limit or decreased below a set limit, that an abnormally high current is being supplied by the rectifier, or that the rectifier has failed completely.

Rectifiers may be connected in parallel to share the load with special load-sharing options. Rectifiers connected in this fashion, however, should individually be capable of handling the full load of the telephone system should one or the other of the rectifiers so connected fail. Load sharing will materially prolong the life expectancy of the rectifiers when properly sized and can be a great asset when unexpected overloads occur. Improperly sized rectifiers can be disasterous should one fail during a recharge period following an extended power outage.

The need for emergency power in the form of battery power for communications in the power communications sytem cannot be stressed too much. Battery power adequate to supply the PABX, microwave equipment, data transmission equipment, and other associated communications equipment is an absolute necessity in the event of a massive power failure. The communications system engineer should give study to powering all communications equipment including two-way radio system base and repeater stations from telephone battery plants.

During emergencies, load control techniques can be used effectively in communications facilities to prolong the useful power supplying time of a battery plant. Judicious allocation of the battery power to the most critical communications subsystems, even though the properly sized battery can power the entire system, will add measurably to the number of hours support obtained from the battery plant.

# III. SYSTEMS ENGINEERING

## A. System Considerations

The close study of the telephone system in the planning stage is an absolute necessity. A poorly planned system can be a major deficit to the overall operations. Several factors must be considered in planning the plant communications portion of the total communications package. This planning can be broken down into three steps. These are:

- Definition of requirements in terms of stations needed, traffic load to be handled and special features desired

- Locating the system or systems which most nearly satisfy the defined requirements

- Deciding on a payment plan which most suits the borrower's communications budget

### 1. Defining Requirements

The most difficult part of the planning is the definition of requirements. There is no single source from which the systems engineer can gleen the total requirements for his system. A lot of digging is involved in this process and it is time consuming.

If all stations to be served are located within the same general complex of power company buildings, the gathering of requirements is not too difficult; however, should some of the stations be located at remote points such as substations, the engineer should be aware of any impact upon the microwave system. Some stations may, of necessity, have to be served through leased facilities of local telephone companies. These cases are very important to the overall requirements and must not be overlooked.

Construction of outside plant facilities to support the telephone system is a costly item and should be studied with great care while developing requirements.

The object of the installation of the telephone system is to furnish communications; a system which cannot handle the traffic load presented to it is useless. The actual traffic and projected traffic of each department and operation within the electric system must be analyzed to ensure adequate sizing of the telephone system for present and future needs.

Special features being offered on the newer electronic computer controlled PABX's are increasing in number almost daily.

The systems engineer should be thoroughly familiar with them and the application of them to the proposed system.

The compilation of the total requirements will then yield the information necessary for the systems engineer to determine the type of system required. It also tells him what is necessary in the telephone cable area, how many and what types of end instruments are needed, what type of back-up power is needed, how many trunks to the local telephone company will be needed and numerous other technical factors affecting system design and installation.

2. Selecting the System

Once the requirements have been clearly defined, selecting equipment to satisfy them becomes a relatively easy task. With the multitude of equipment on the market, comparison of capabilities with the requirements is the next step. Technical data available from a number of manufacturers should be obtained; these can then be set up in a simple matrix and compared to the requirements.

Although it is possible to obtain from a single manufacturer a matrix comparing their equipment features with other manufacturers', a single manufacturer's comparison will inherently gloss over or omit some features that their equipment may not have that the others do. It is, therefore, best to develop your own matrices on equipment vs. requirements.

In addition to an analysis of requirements satisfaction, these questions should be considered and have ready answers:

a. Is the supplier reliable?

b. Does he deliver on time?

c. What is the warranty on the equipment?

d. Is maintenance available locally or is comprehensive training for company personnel available?

Elimination of some equipment suppliers may result from the answers to these questions.

3. Cost of the Telephone System

The overall cost of the telephone system can be developed in several ways. System costs should be developed in such a fashion that costs for separate portions of the system can be isolated and analyzed.

Systems should be segmented in the following manner:

a. Switching System - includes PABX, end instruments, building space costs (new construction or modification) and installation and training.

b. Carrier Systems - includes equipment, building space and installation and training.

c. Outside Plant - includes cable, construction and installation.

After the cost evaluation has been made, this must be compared to the technical capabilities evaluation.

At this point, there may have to be trade-offs made; there must be a joint decision between the systems engineer and the financial department. The question finally becomes a choice between financial savings and optimum system characteristics and performance.

B. Design Considerations

In the design of plant communications systems, the single most important consideration is meeting the operating requirements. When the service requirements have been clearly defined, the detailed design of the system can proceed.

The system design is the point where all of the nuts and bolts are accounted for. Detailed floor plans are developed showing the location of each individual telephone instrument, teleprinter, data set, data terminal etc. The location of every piece of support equipment must be defined. This includes telephone operator consoles, multiplex terminals, microwave equipment, two-way radio equipment and communications cables distribution frames.

The location of cable ways in the form of floor ducts, floor trenches and overhead cable trays must be planned. AC power receptacles must be located to insure that equipment requiring power can be positioned where the user wants it.

Cable plans must be made and laid out on floor plans. This is the point at which numbers of cable pairs are defined for ordering purposes. This is also the point at which sizes of individual cables come to light. In this phase of developing the system, the system engineer has to be thoroughly familiar with the detailed technical characteristics of the equipment he has chosen. As an example, the engineer must be aware that certain telephone instruments may require AC power be available to light buttons on the instrument or that a speaker-phone (hands free telephone) has its own power supply which requires AC power. If the outside plant system is using pressurized cables, provision must be made to furnish power to the air dryer-compressor and telephone cable pairs must be available to tie alarms from the dryer-compressor back through the telephone system to the proper alarm indicators.

Detail is the key to ordering the right kinds and quantities of equipment and materials. Detail insures that a hole in a particular wall appears on the civil engineering drawings and is, in fact, there in the wall when the installer appears to place the cable duct in the hole. Detail also insures that the installers have adequate information concerning the system to properly install it without the need for constant consultation with the systems engineer.

## C. Systems Engineering Procedures

### 1. Planning

The determination of requirements is the first step in planning the system design and, in fact, is the most difficult task. Most communication systems designs involve a great many factors including technical evaluations and cost comparisons. Because of this, the definition of user requirements is most important. This section deals with the methods used in the overall system planning. The following are the fundamental steps of system planning and are listed in their order of execution:

- Definition of objectives - This requires the determination of who the users are, what types of information are to be conveyed, and the locations of the information sources and information users.

- Traffic analysis - Traffic flow and volume are analyzed to determine circuit loading. Preliminary routing and trunking are established to accommodate the projected loading requirement.

- Design criteria - This establishes the acceptability standards of comparison based upon the grade of service performance required by the user.

- Operating requirements - Traffic priorities, maintenance criteria, operating procedures and service schedules (in the order, critical, essential, necessary and routine) are determined.

- Facilities survey - Data concerning available services, building status, and transmission network availability and condition is gathered.

- Vendor analysis - Available communications equipment and techniques are investigated and analyzed to determine applicability to the requirements.

- Requirements satisfaction vs. cost - At this point a preliminary analysis is made of the user requirements applied to available equipment and the costs involved in satisfying the requirements.

- Maintainability and personnel skill level vs. cost - This factor will compare the skill level of maintenance personnel available to or necessary to be hired by the power company to the costs involved. Contract maintenance may be considered at this point.

- Growth - The system design and equipment to be purchased must be analyzed together with future traffic requirements to insure adequate provision for growth of the system. Cost of this growth must also be considered to determine whether or not it is more economical to procure the necessary equipment for the future growth during the initial design or make provision for it to be added at a later date.

2. <u>Developing Engineering Requirements</u>

In the preceeding sections of this Bulletin, "System Considerations" and "Design Considerations", it was stressed that, "The most difficult part of the planning (for the communications system) is the definition of requirements." This is the point at which the problems are defined. The systems engineer requires a clear understanding of the form of the information to be moved through the system, i.e. voice, facsimile, data, etc. He also requires a clear understanding of the characteristics of the source or sources of this information and what use the user intends to make of this information.

Some requirements may not be adequately defined at this point and the engineer may have to assign a range of values to these requirements to allow them to be carried through the evaluation with the well defined requirements. Although the solutions arrived at may be inconclusive, the range of the solutions may assist the user in more clearly defining his final communications requirements.

"How much communications?" is the question that can now be approached with some assurance that the answer will bring the total plant communications system into focus. The known requirements should now be placed in a particular time period for implementation and support so that predictions for future expansion can be extrapolated from past growth or, in the case of an entirely new system, growth factors can be developed.

With the requirements defined and the amount of communications determined a detailed examination of the quality of service can be made. This involves comparison of the requirements in terms of the expected or required technical performance characteristics. The operating requirements for the system and the service scheduling can be established at this point. If facilities, equipment or cable plans are inadequate, some compromises must be decided upon at this time. All compromises must be weighed against the user required technical performance to ensure that this is met.

Technical specifications can now be prepared. These should be generally in the form of performance specifications avoiding detailed equipment design specifications. Detailed equipment design specifications can prove costly if these specifications are different from those of an equipment manufacturer. Design specifications which deviate from a manufacturer's production equipment will require changes by the manufacturer with the cost to be borne by the purchaser. Even paint color changes can be expensive on production equipment.

In technical specification preparation,special attention to operating details should be given. For example, a major supplier of computer controlled PABX's makes no provision for the customer to reprogram the computer-controller and makes a substantial charge to furnish the new program information while most other manufacturers furnish all standard operating features to all stations at no additional charge and provide for customer reprogramming of the control.

The technical specification should also make provision for the training of electric borrower personnel in the operation of the communications system as well as maintenance of the system if the power company is providing its own maintenance.

If the user requirements have been thoroughly evaluated, the engineering requirements correctly developed and the technical specification properly prepared, the system objectives will be met.

## D. Transmission Operating Parameters

### 1. Introduction

Transmission operating parameters are the technical parameters that define the basic operational principles of transmission in a plant communications system.

2. Modulation

Generally, information signals(voice, data, etc.) cannot be transmitted long distances in their original form. The human voice for example will not carry very far through the air as an acoustical signal. To achieve long distance transmission, a carrier is used to "transport" the information signal. The carrier is any form of energy that can be modulated and will travel the long distance. The carrier may be electromagnetic energy anywhere from a few Hertz wave frequencies to light. The modulated carrier is transmitted from one point (s) using an appropriate transmission facility to another. Modulation is the varying of one of a carrier's parameters. Amplitude modulation (AM) is the oldest form of modulation commonly used in communications. The simplest form of AM uses DC as the carrier and a telegraph key to turn the DC source on and off. This system modulates the DC level between zero and some fixed nonzero level. Voice can also modulate DC using a microphone as the modulator. The amount of change in the level of the DC signal going through the microphone depends on the instantaneous energy level of the voice.

A more complex form of AM is the modulation of a frequency carrier. A modulating frequency, i.e. 1000 Hz is used to modulate the amplitude of another frequency carrier. See Figure III-1.

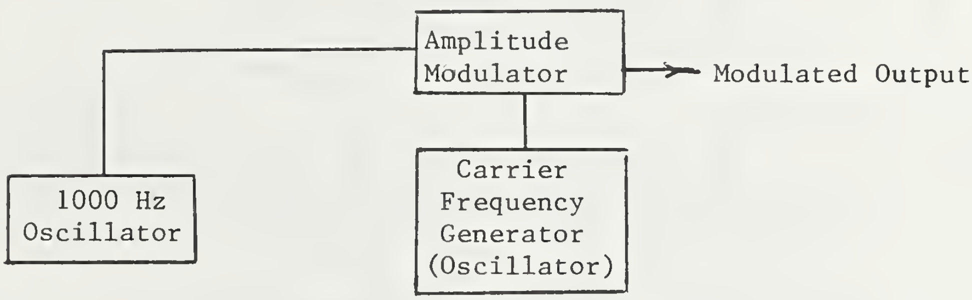



Figure III-1. Amplitude Modulation

The modulator is a non-linear device that mixes the input signals. The modulator's output includes the following frequencies:

- Modulating signal $F_1$
- Modulated signal $F_2$ (carrier)
- Mixer Products at frequencies $F_1 + F_2$ and $F_1 - F_2$

There are other possible products coming out of a mixer such as $2F_1 + F_2$ and $3F_1 + 2F_2$, but these are normally lower in power and not of concern presently.

The desired output is usually $F_1 + F_2$ and/or $F_1 - F_2$. Frequency filters are used to separate the desired signal(s) from the undesired.

It is significant that the modulator does not "add" the two frequencies; it mixes them. See Figure III-2 for the difference.

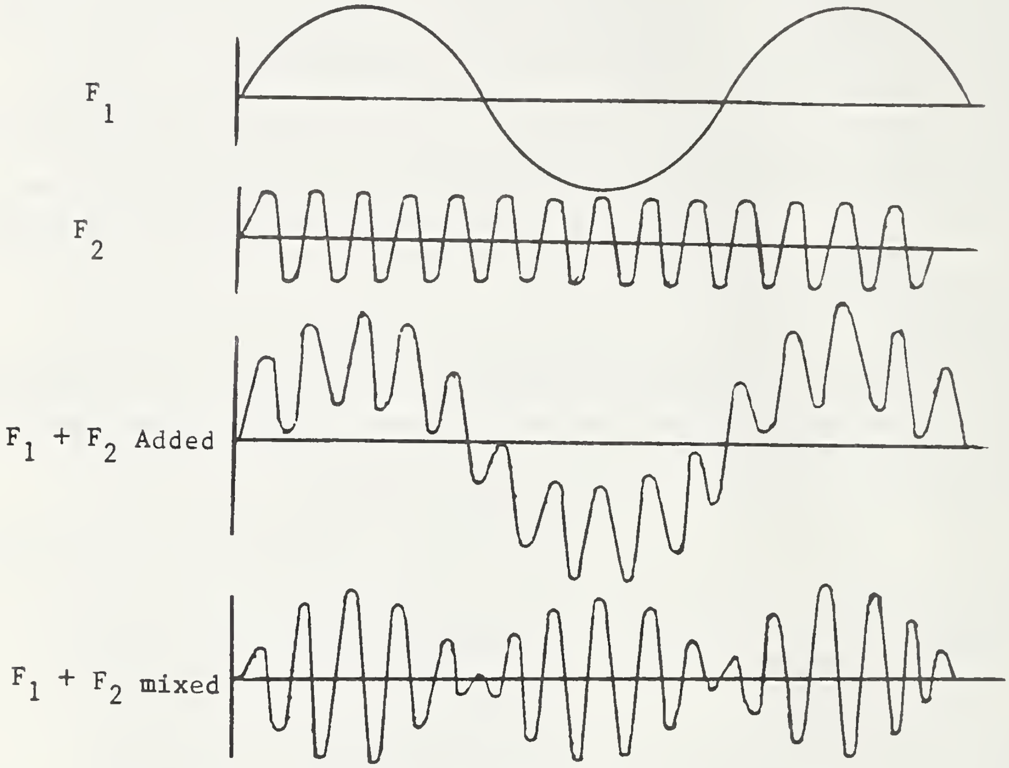



Figure III-2. Addition vs. Mixing of Frequencies

The modulator's non-linearity causes the mixing action. The carrier and/or modulating frequencies are distorted in such a manner as to produce the frequency products desired.

AM is used in numerous applications of communications technology. For example:

- Telephones
- AM broadcast

- Microwave radio RF mixers

- Frequency division multiplexers

- Data modems

The mixer input and output frequencies need not be related in frequency. For example, two high input frequencies can be used to generate a low frequency output or a high and a low input can produce a high frequency output. The principle that continues to apply is that the outputs are $F_1$, $F_2$, $F_1 + F_2$ and $F_1 - F_2$ whatever they may be.

In an AM communications system the transmitting end of a circuit uses a modulator. The receive end uses a demodulator to extract the desired information signal from the modulated carrier. Both the modulator and the demodulator use the same mixer principle. See Figure III-3 for an example of the circuit.

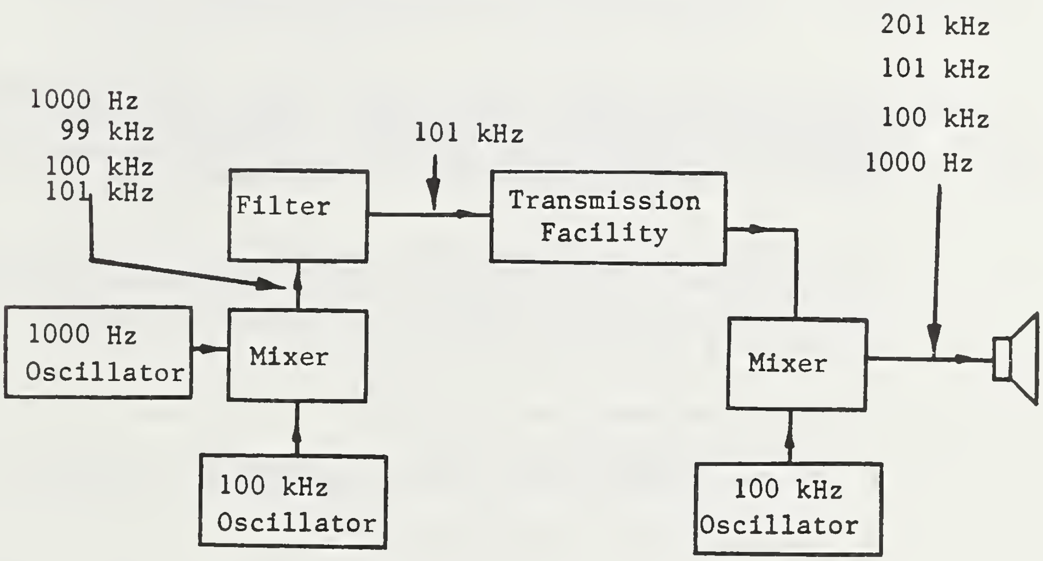



Figure III-3. Typical Circuit Using Amplitude Modulation

One of the parameters in AM is "percent modulation". It is a measure of how strongly the carrier's level is modulated by the modulating signal. See Figure III-4.

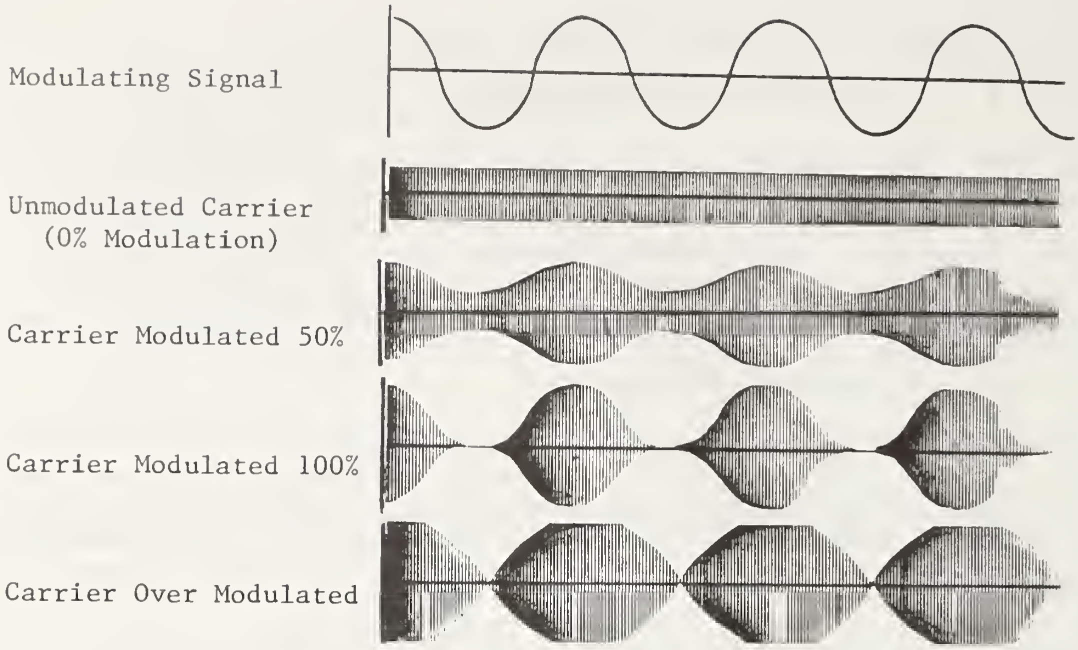



Figure III-4. Percent Modulation

Notice that the peaks and valleys of the modulated signal follow the modulating signal peaks. When the carrier is 100% modulated its peak is twice the average without modulation. This is shown on Figure III-4.

Over modulation occurs when the modulating signal input level is raised beyond the point where 100% modulation occurs. When this happens, numerous types of distortion may occur. The principle distortion products are:

- Noise and spurious response
- Harmonic distortion within a modulating voice channel
- Generation of carrier harmonics

Most systems are designed to operate at or below the 100% modulation point.

3. Units of Level and Noise Measurement

There are many different logarithmic ratio units to meet specific needs, such as measuring noise, crosstalk, signal power, etc. With so many different units it is not surprising that their use is often accompanied by doubt and confusion. In an attempt to remove some of the doubt and confusion, this section is included in this Bulletin.

It is divided into two parts, the first provides a basic introduction to the decibel and what it is. The second part discusses some of the special logarithmic units together with their uses and provides slightly more advanced reading.

Rather than use large numbers in correspondence and conversation, man has always invented new names or units for large numbers of the same items so that he can talk and write in smaller numbers. For instance, rather than say---

5,280 feet - he says one (1) mile
1,000,000 tons - he says megaton
12 - he says one (1) dozen

In electronics, particularly when dealing with signal-to-noise ratios, the ratio of one number to another is referred to in decibels (dB). For instance, instead of saying the signal is a million times more powerful than the noise, we say the signal is 60 dB above the noise, or the signal-to-noise ratio is 60 dB. It is important to note that dB is a measure of how much better or worse one thing is than another, i.e. a RATIO. (It is meaningless to say the signal is 60 dB. It is like saying the signal is 1,000,000. One million what?)

To convert from a power ratio to dB's we proceed as follows. If the ratio is a million, we determine how many times 10 has to be multiplied by itself to get 1,000,000. This is of course six times.

$$10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1{,}000{,}000$$

Or this is usually written

$$10^6 = 1{,}000{,}000$$

We then multiply this number by 10 and get $6 \times 10 = 60$ dB for a ratio of 1,000,000. For a ratio 1,000:

$$10 \times 10 \times 10 = 1{,}000$$

$10^3 = 1{,}000$ - so 1000 is 30 dB.

This leads to the following table:

| Ratio | dB |
|---|---|
| 1 | 0 |
| 10 | 10 |
| 100 | 20 |
| 1,000 | 30 |
| 10,000 | 40 |
| 100,000 | 50 |
| 1,000,000 | 60 |

One other simple rule to remember is that when you double the power ratio you add 3 dB. For instance, if we go from 10,000 which is 40 dB to 20,000, we get 43 dB, to 40,000,we get 46 dB, to 80,000, we get 49 dB, to 160,000, 52 dB.

All of the above is based on the definition of a logarithm which says the logarithm of a number is the power (number of times the number is multipled by itself) to which 10 must be raised to get the number. Since 3 is the power to which 10 must be raised to get 1,000, the logarithm of 1000 is 3. To get dB's we multiply 3 x 10 = 30.

Or mathematically - $dB = 10 \times \log_{10}(P_1/P_2)$

Where $P_1/P_2$ is the ratio of one power level to the other.

$$dB = 10 \times \log_{10} (1000)$$

$$dB = 10 \times 3 = 30 \text{ dB}$$

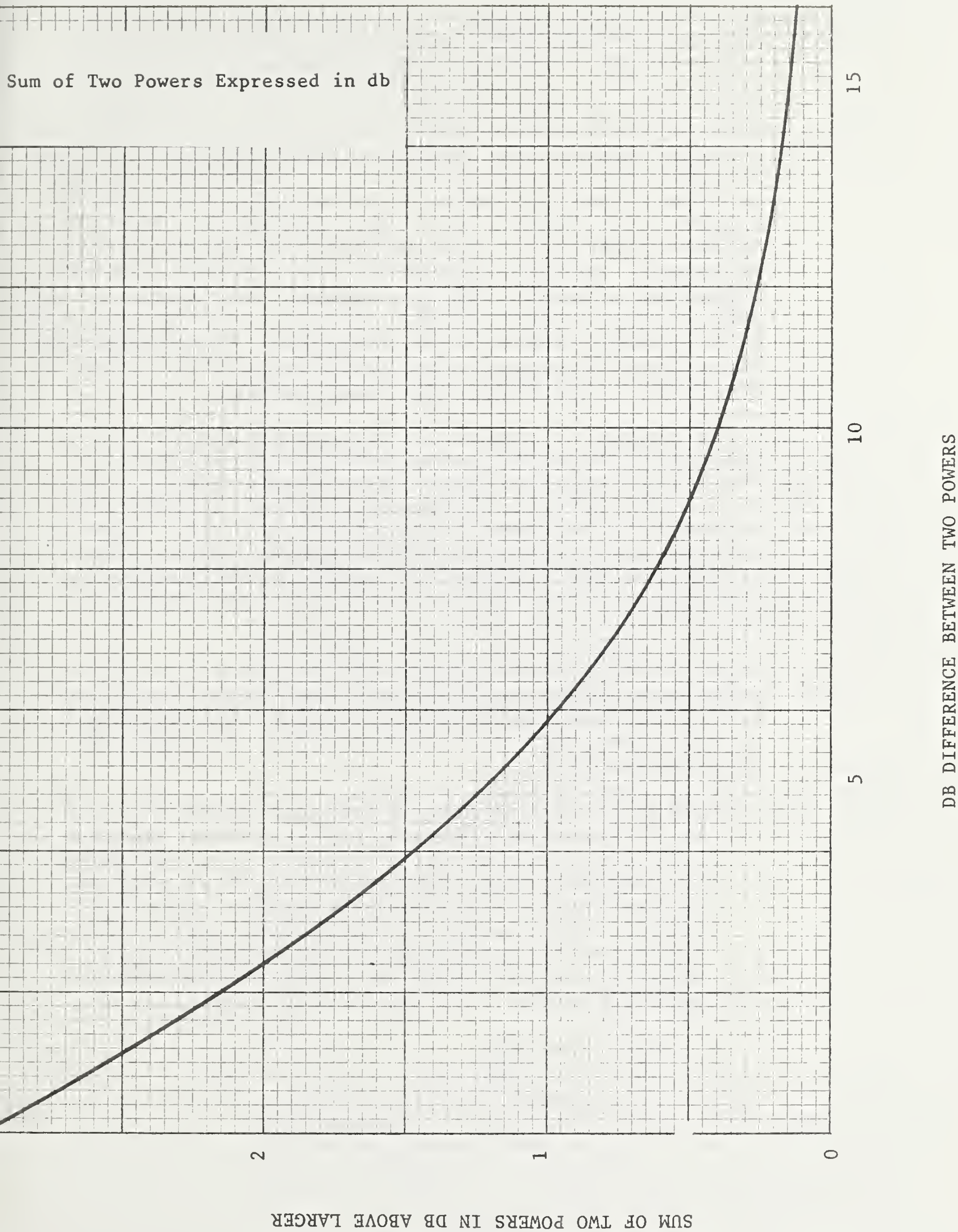
Therefore, to convert any power ratio to dB's, we merely find the logarithm of the number and multiply it by 10.

Since dB is a logarithmic value, two power levels (such as signal-to-noise ratios) expressed in dB cannot be simply added to obtain the total power. Instead, each dB value must be converted to watts, added, and the total reconverted to dB.

For example:

> To add 10 dB and 10 dB find the difference between the two values (0); enter the horizontal scale of the graph at 0 dB and read the value on the vertical scale where the curve intersects the 0 value; take this 3 dB and add to the larger of the original values (10) and the answer is 13 dB. Note that this is the same as doubling the power.

If two values such as 10 dB and 6 dB were to be added, the 4 dB difference would be used to enter the graph and the number to be added (1.45 dB) to the larger value (10 dB) would result in a total value of 11.45 dB.



Sum of Two Powers Expressed in db

Before proceeding further it will be useful to understand the difference between "power" and "level", as misunderstanding of this is often a barrier to understanding the difference between, and uses of, many of these units. Since all the dB "type" units are a way of expressing a ratio, it is important that one of the compared quantities be stated or implied. This is to say, without some accepted reference the "dB" is meaningless as a means of expressing power. It may, however, be used to express a level if the power at some point in a circuit is compared to the power at some other point in the circuit, without any reference to an absolute power, but just as a ratio. For example, consider an attenuator with a loss of 30 dB. This is accepted as meaning that when a signal is introduced at the input of the attenuator, it will appear at the output as 1/1000 of the original signal (30 dB-$10 Log_{10} 1000$). Here the reference is a point in the circuit, namely the input, and no mention is made of the actual power at the input or output.

If now a signal is applied to the input with a power of 1 milliwatt ( 0 dBm), the output power would be 1/1000 milliwatt or -30 dBm. This time the reference is a power, 1 milliwatt, so the output is expressed as a power, although in this case the level and power are numerically the same. If the input power is now halved to 0.5 milliwatt, the output power will now be 1/2000 milliwatt or -33 dBm but the level at the output will still be down 30 dB (-30 dB) referred to the input.

Below is a list of the more commonly used logarithmic and related units, together with a description of their derivation where appropriate, and their uses. Some of them may be encountered frequently in communications and others considerably less frequently.

<u>dB</u> - The dB is a logarithmic expression of the ratio between two powers and is frequently used to describe the power gain or loss in a component or system. This presents a big advantage, since the gains and losses of individual components may be added and subtracted to obtain the overall gain or loss of a system, rather than the more involved multiplication and division that would be required if the power gains and losses were expressed as numerical ratios.

$$dB = 10 \, Log_{10} \frac{P_1}{P_2}$$

The dB may also be extended to express a voltage or current ratio, gain or loss provided that the resistive component of the impedance, at the two points of measurement, is the same.

$$dB = 10 \text{ Log}_{10} \frac{P_1}{P_2} = 10 \text{ Log}_{10} \frac{I_1^2 \; R_1}{I_2^2 \; R_2} = 10 \text{ Log}_{10} \frac{V_1^2 \; R_2}{V_2^2 \; R_1}$$

or if $R_1 = R_2$

$$dB = 20 \text{ Log}_{10} \frac{I_1}{I_2} \quad \text{or } dB = 20 \text{ Log}_{10} \frac{V_1}{V_2}$$

If the resistive components of the impedances are not equal, then only the power ratio should be used.

dBm- The dBm is the most commonly used (and misused) logarithmic unit for stating powers in communication systems. The reference power is 1 milliwatt. If the power at some point in a system is expressed as 0 dBm, it means that under the specified conditions 1 milliwatt of power will be measured at that point. It is often found that voltmeters have a dBm scale. However, it has been stated that the dBm is a unit of power; this means that the dBm scale of the voltmeter must be calibrated by measuring the voltage across some specified resistance. The meter calibration will only be correct when measuring the voltage of a circuit terminated in the specified impedance (usually 600 ohms, but not always).

If the impedance terminating the circuit is not the same as that used to calibrate the meter, a correction must added to or subtracted from the meter reading as follows, correction = 10 $\text{Log}_{10} \frac{R_x}{R_m}$, where $R_x$ is the resistance of the circuit being measured, and $R_m$ is the resistance across which the meter was calibrated.

dBw- Similar to dBm, except that the reference power is 1 Watt.

dBk- Similar to dBm, except that the reference power is 1 kilo Watt.

dBv- The dBv is a logarithmic unit for the ratio of voltage irrespective of the impedance of the circuit being measured. The reference is 1 Volt and the unit is sometimes used for stating the voltage sensitivity of a device. This unit is also occasionally used for stating the voltage gain or loss of an amplifier or other electron tube device, irrespective of impedance in the input and output circuits.

dBRn- The dBRn is a logarithmic unit for the measurement of the interfering effect of noise frequencies when referred to a "reference noise power". The selected reference is 1000 Hz tone with a power of -90 dBm ($10^{-12}$ Watt). The interfering effect of noise is not the same at all frequencies, due to the response of the human ear and of the telephone apparatus. Subjective tests were carried out some time ago, using the then common 144 handset, to relate the interfering effect of noise frequencies to reference noise. The result of these tests is incorporated in the 144 weighting network. Measurements made using this network and an instrument calibrated to read -90 dBm at 1000 Hz as zero will be in DBRn.

dBRnC- C-message weighted circuit noise power in dBRn, measured on a line by a noise measuring set with C-message weighting. With C-message weighting, a 1 mw 1 KHz tone will read +90 dBRn, but the same power with white noise randomly distributed over a 3 KHz band (300-3400 Hz) will read +88 dBRn.

dBa- dBa really stands for dBRn adjusted and is now one of the most commonly used units for expressing the interfering effect of noise on a telephone circuit. When the 144 handset was replaced by the F1A handset, it was found that the previously used weighting was no longer correct, so further tests were carried out to relate the interfering effect on a telephone circuit to the 1000 Hz reference noise. These tests resulted in the F1A weighting network. The F1A handset is about 5 dB more sensitive than the previous 144 handset, so the reference noise was adjusted by 5 dB to -85 dBm of 1000 Hz tone - hence the term dBa or dBRn adjusted.

DBa may be used to express the interfering effect of noise using either the F1A or 144 weighting networks. Since the reference noise is not the same, it is necessary to state the weighting used. If no weighting network is specified it is assumed that F1A is used. The interfering effect of any single noise frequency can readily be converted to the actual noise power in dBm by using weighting curves. When multiple noise frequencies are present that are not uniformly distributed, as is often the case in transmission systems, it becomes quite complicated to convert the interfering effect in dBRn to the actual noise power in dBRn. If the noise is uniformly distributed across a 3 KHz voice frequency band it is fairly simple to make the conversion. 0 dBRn of uniformly distributed noise will have an interfering effect of +82 dBa. This is true with either F1A or 144 weighting. To sum up:

| Noise | dBm | dBRn | dBa (144) | dBa(F1A) | dBRnc |
|---|---|---|---|---|---|
| 1000 Hz tone | -90 | 0 | 0 | -5 | 0 |
| 1000 Hz tone | -85 | +5 | +5 | 0 | +5 |
| Evenly distributed 3KHz band | -82 | 0 | 0 | 0 | +6 |
| 300 Hz tone | -50 | +40-25* =15 | 140-22* =18 | +35-13* =22 | +40-16* =24 |

* From weighting curves for this frequency

In Europe noise is usually expressed as a voltage or EMF and the interfering effect as Psophometric voltage or EMF. The term psophometric is derived from the Psophometer, which is the instrument used to measure the interfering effect of noise. The weighting of this instrument is the same as the F1A network, except that the reference frequency is 800 Hz instead of 1000 Hz. Figure 2 shows the most commonly encountered weighting characteristics.

**Pico-watt** This is not a logarithmic unit and strictly speaking has no business here, but as it is often used for measuring noise power it is included. The picowatt is $10^{-12}$ Watt or -90 dBm. This form is often an advantage when calculating the total noise of a system, since individual noise components may be added rather than combined on a logarithmic power ratio basis, as is necessary with "dB type" units. If weighting is used it should be specified, i.e. pwp = picowatts psophometrically weighted.

**dBx-** The dBx is a logarithmic unit for expressing the interfering effect of crosstalk on telephone circuits. It may be defined as decibels above reference (crosstalk) coupling. Reference coupling is that coupling which would exist between two circuits such that when a test tone of +90 dBa is applied to the disturbing circuit, a 2B noise meter connected to the disturbed circuit will read 0 dBa, the same weighting being used on both circuits.

**Cross-talk Units** Cross talk unit is another term sometimes used for expressing the crosstalk coupling between two circuits. The number of crosstalk units (C.U.) is defined as $10^6$ times the ratio of current or voltage at the point of measurement on the disturbed circuit to the current or voltage at the source of the disturbing signal, providing that impedances are the same at both points. If the impedances are not the same, the C.U. will be $10^6$ times the square root of the power ratio. 0 dBx is approximately equal to 32 C.U.

Cross-talk Coupling Loss - The crosstalk coupling loss is expressed in dB and is the loss between the source of interference on the disturbing circuit to the point of measurement on the disturbed circuit. Sometimes this is expressed as the Equal level crosstalk coupling loss, which simply means that the losses of the two circuits have been taken into account.

Cross-talk Index - The crosstalk index is a unit devised to express the grade of crosstalk performance of a circuit. It takes into account the number of disturbing circuits and various statistically obtained qualities, such as talker volume.

dBm0- The dBm0 is a logarithmic unit used to express the level of a tone below that of the test tone at the same point. For example, if a tone of -35 dBm is present at a +7 dBm relative level point (e.g. output of multiplex channel) this tone may be said to have a level of 7-35 or -28 dBm0. Although the actual power of this tone may vary throughout the system, it will always have a level of -28 dBm0 and conversely the test tone will always be at 0 dBm0. For simplicity the term dBm0 has been explained using a single tone, but it can be used to express the combined level of several tones.

dBr- The dBr is a logarithmic term commonly used in Europe to express the level at any point in a circuit when 0 dBm is applied at a zero relative level point. For example, the input and output levels of multiplex channel modems, usually described as -16 dBm and +7 dBr points respectively.

V.U.- Volume units are logarithmic units for expressing the average power of a varying singal, such as voice or program material. The reference power is 1 milliwatt. To give meaning to this unit, the time constant and frequency characteristic of the meter, as well as the method of reading the meter must be specified or accepted as standard. The reading of a volume indicator in V.U. will only be the same as the numerical power in dBm, for a steady tone.

dBmA1- Is a very specialized unit for measuring the effect of impulse type noise on Lincoln Laboratories A1 data equipment.

dBRap- It is a logarithmic unit for measuring acoustical power. The reference acoustical power (Rap) is $10^{-16}$ Watts.

neper-The Neper, although rarely used as a practical unit except in Europe, is the forerunner of all the dB units. The Neper differs from the dB in two major respects. The logarithmic ratio is to the natural or naperian base "e", instead of the base 10 as is the dB. It is also an expression of current ratio, whereas the dB is an expression for power ratio. The Neper can be extended to express a power ratio if the resistive component of the impedance at the point of the two compared powers is the same, or to express a voltage ratio if the impedance at the point of the two compared voltages is the same.

$$\text{Neper} = \text{Log}_e \frac{I_1}{I_2}$$

and if the resistive component of the impedance is the same,

$$\text{Neper} = \text{Log}_e \frac{P_1}{P_2} \quad \text{or if the impedance is the same} \quad \text{Log}_e \frac{V_1}{V_2}$$

Also provided that the two resistances are the same, the attenuation in dB = 8.686 x the attenuation in Nepers, or the attenuation in Nepers = 0.1151 x the attenuation in dB.

Note: A suffix "0" is often applied to units to indicate that the dB value is referred to or measured at a point of zero relative level: - i.e. dBa0, dBRnc0, dBm0 (refer to dBm0 for a more complete explanation).

## 4. Channel Characteristics

### a. Net Loss

Net loss is the difference in level between two points in a circuit. The net loss, for example, on a typical telephone circuit is between 3 dB and 10 dB. The measurement is usually made at a standard reference frequency in the channel. 1000 Hz is commonly used for voice channels. Levels throughout a communications system have standards or objectives. Too high a level can cause annoyance to an end user and also overload the transmission facilities. Too low a level can cause unacceptable signal to noise ratios and data errors.

b. Frequency Response

Frequency response is a measure of the net gain at different frequencies within the passband of a channel. Normally the frequency response is fixed and rolls off at the edges of the passband. The frequency response is also known as the gain response, linearity or amplitude response.

c. Absolute Delay

Absolute delay is the total time it takes for a signal to be transmitted through a system. For example, the absolute delay of a circuit going through a geostationary satellite is about 1/4 second per hop.

d. Relative or Envelope Delay

Relative delay is a measure of the delay time through a system for different frequencies within the channel. In a voice channel the human ear can start to detect relative delay distortion when the relative delay between 1000 Hz and 2600 Hz exceeds 30 milliseconds. High speed data, however, may be sensitive to delay variations of no more than ¼ of a millisecond over the same frequency range. The significant point here is that data is usually more sensitive to delay distortion than voice.

e. Noise

Voltages within the voice-frequency range, induced in a telephone circuit from some exterior source are manifested to the listener as noise. In many cases, crosstalk may appear merely as noise. This is particularly true in the case of cable circuits where any crosstalk heard is likely to come simultaneously from a considerable number of other circuits.

The disturbing effect of noise to a listener depends first, of course, on the volume of the noise. It also depends on the frequency of the noise currents. Tests have been made on the effects of noise vs. frequency, and it has been found that noise at frequencies around 1100 Hz is particularly annoying to the average telephone listener and can considerably reduce the intelligibility of conversation. Intelligent noise, that noise which is recognizable as voice, is the most objectionable noise in a voice circuit.

Impulse noise is spasmodic in nature with high peak values. This type of noise may not cause intelligibility problems in voice circuits, however it can definitely cause problems to data services. The impulses may appear to the data terminal as data bits and cause errors in the data stream. Impulse noise can be caused by a variety of occurrences, such as:

- Lightning strikes
- Adjacent cable pairs carrying high energy DC pulses
- Switching transients from relays and switches
- Induction from starting motors
- Poor grounding systems
- Overstressed system components
- Loose or intermittent connections

f. "C" Notch Distortion

Multiplex, termination equipment and other analog voice components are not perfect devices. In the presence of modulating energy, they generate additional noise across the voice channel. This is called modulation noise. It is measured by inserting a tone in the voice channel at one end. At the other end the tone is notched out using a very sharp bandstop filter. The noise in the rest of the channel is then measured. The sources of this modulation noise are phase and frequency jitter, shot noise in the equipment, noise accompanying the signal itself and noise generated by the termination and mux equipments which are electrically stressed more under the presence of a modulating tone. Typical levels of modulation noise are minus 30-40 dBm0. The term "C" notch comes from the fact that the measurement device normally uses a C-message weighting filter. Modulation noise is not as annoying as steady noise at the same level because it does not exist in between syllables since there is no modulation between syllables.

g. Harmonic Distortion

Harmonic distortion can be considered part of modulation noise since the harmonics exist only in the presence of modulation. To determine harmonic distortion levels, a 1000 Hz tone is sent through the channel and a narrow frequency selective voltmeter is used at the other end to measure the levels of the 2 kHz and 3 kHz harmonics in the channel. The 2 kHz harmonic is normally 40-50 dBm0 and the 3rd harmonic another 5-10 dB further down. Harmonic distortion for other frequency tones may vary, especially at the bottom end of the channel. Harmonic distortion of tones above 1700 Hz are of no significance since they fall outside the passband of the channel (300-3400 Hz). For this reason, many data modems operate with carrier frequencies of 1800 Hz and above.

h. Echoes

Echoes in communications are portions of a signal delayed (or advanced) in time traveling along the same transmission path. They cause annoyance in voice circuits and data errors in data transmission. If echoes are high enough in level, they can cause a circuit to burst into self oscillation. This is called "singing". Impedance mismatches are the most common cause of echoes.

i. Drop Outs

"Drop out" is another term for loss of signal. A drop out may occur as a severe attenuation of, or complete loss of, signal and may be of a temporary of permanent nature. Temporary drop outs are quite often caused by microwave fades. Both temporary and permanent drop outs may be caused by loose connections, dirty switch or relay contacts, poor solder joints, etc.

j. Frequency Translation

Frequency translation is the frequency displacement of a signal in a channel. It is a constant displacement whereas frequency jitter is not constant. In frequency translation a 1000 Hz tone inserted in one end of a circuit may appear as 1002 Hz or 997 Hz at the distant end. Frequency translation can be caused by misadjusted equipment or multiplex equipment that has gone out of sync. Most applications of voice and data can tolerate many Hertz of translation. The standard limit, however, is $\pm$ 2 Hz. This stringent requirement is designed to avoid the buildup of translation when many systems are connected in tandem.

k. Phase and Frequency Jitter

Phase jitter is the random movement of the phase position of a signal, a jittering of the time displacement of the signal. It normally appears as noise on a signal. Data modems using phase modulation are sensitive to phase jitter and sometimes require the peak jitter to be within $\pm 3^{\circ}$. Frequency jitter is the first derivative of phase jitter, and also appears as noise on the signal.

Jitter is normally produced in mixers where the local oscillator is unstable due to noise from its power supply or elsewhere.

5. Crosstalk

Crosstalk is the cross coupling of one channel to another. It can occur in any part of the telephone system. Intelligible crosstalk is crosstalk which appears as intelligent information such as a weak voice heard in the background. Unintelligible crosstalk is crosstalk that is distorted beyond recognition or frequency inverted, as can happen in multiplex. Subjectively, the human ear is more disturbed by intelligible crosstalk than unintelligible crosstalk. Crosstalk specifications are, therefore, more stringent for intelligible crosstalk. Specifications for unintelligible crosstalk are similar to noise level requirement.

6. Impedance

a. Concept of Impedances

Impedance is the opposition (resistance and reactance) of a device to the flow of alternating current electrical energy. In microwave systems, we are concerned with characteristic impedances of devices and input/output impedances. The concern is to insure that two devices connected in parallel have matching impedances to ensure maximum transfer of energy. Figure III-5 exemplifies the principle of matching impedances.

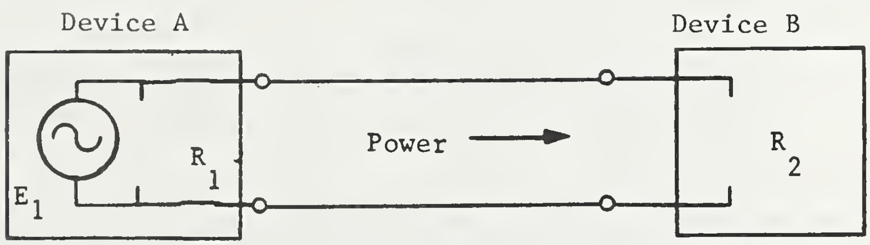



Figure III-5. Power Transfer

From elementary electronics, the power transfered to Device B is maximum for a given $E_1$ if $R_2 = R_1$. If we look into the input of Device B we measure an input impedance of $R_2$. Likewise, $R_1$ is the output impedance of Device A. In voice circuits, the reactive component of impedances is usually close to zero and is normally ignored.

Transmission lines (coaxial cable, waveguide, twisted pairs) have characteristic impedances. If a cable is infinitely long, its input impedance is the same as its characteristic impedance. If a cable is finite in length, then the input impedance will depend on the termination at the other end of the cable. For example, if a short section of 50 ohm cable is terminated with 100 ohms, the cable's input impedance will vary from 3 to 100 ohms depending on the frequency and the cable's length. The same type of impedance variation occurs if the source impedance of the device generating the frequency does not have the same impedance as the cable or its termination. In the ideal situation the impedances of the source, line and termination are identical. Consider Figure III-6.

The maximum amount of energy will be transfered from Device A to Device B if $R_1 = R_2 = R_3$. The importance of the transmission line's impedance is also a function of its electrical length and line loss.

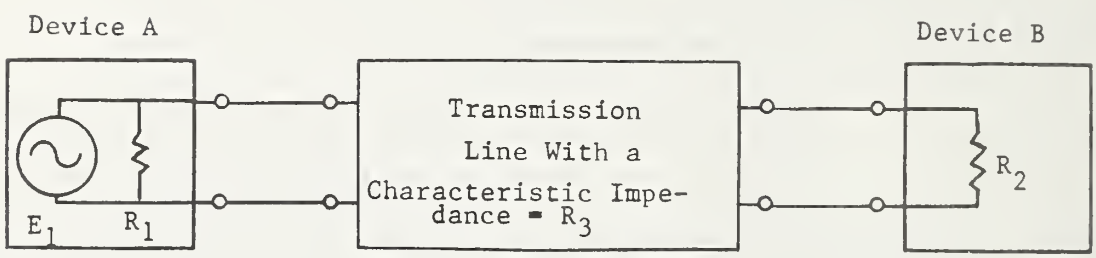



Figure III-6. Mismatched Impedance Case 1

If the line is a twisted pair of wires transmitting audio frequencies, its characteristic impedance is not important if the line is short. See Figure III-7.

With such a short (10 cm) line the characteristic impedance is not significant since the line loss is insignificant and the line length is very short compared to $\lambda$ of the voice frequencies. If the line were many kilometers long with 20 dB of loss, then Device A would be "looking" into 600 ohms as it attempts to insert power into the transmission line. A mismatch occurs, and little of the power enters the cable. At the other end of the line, the 600 ohm transmission line attempts to feed power into Device B which has an input impedance of 100 ohms. Another mismatch occurs.

When a mismatch is discovered to exist between two devices, an impedance matching device is often used. Figure III-8. shows two such devices.

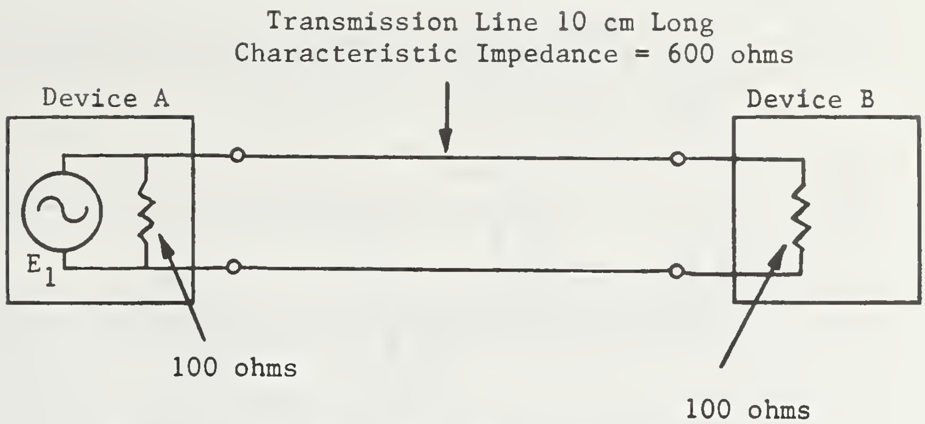



Figure III-7. Mismatched Impedance Case 2

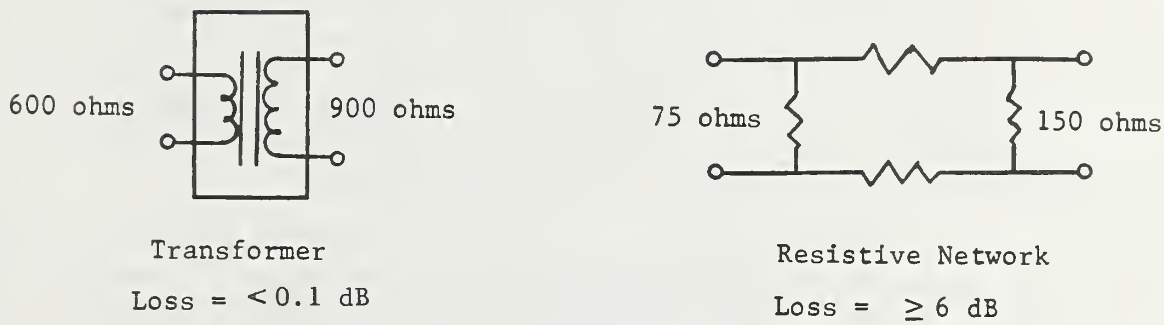



Figure III-8. Impedance Matching Devices

A second method of impedance matching is an indirect method which controls the signal levels desired rather than directly match impedances. The method is used at lower wire line frequencies for resolving the impedance mismatching when multiple connections are to be made to the same point. A single source with an output impedance of $R_1$ can only be matched to one $R_1$ load. If a source of $R_1$ is to feed multiple loads of $R_1$ impedance, isolating bridges and amplifiers can provide the matches without causing reflections. See Figure III-9.

$R_3$ provides a proper termination for the source impedance of Device A. $A_1$ has an output impedance of $R_1$ to match the Device B (likewise for Devices C and D).

$R_2$ is such a high resistance as to effectively isolate $A_1$'s from Device A. The gain of $A_1$ is set to overcome the loss through $R_2$'s.

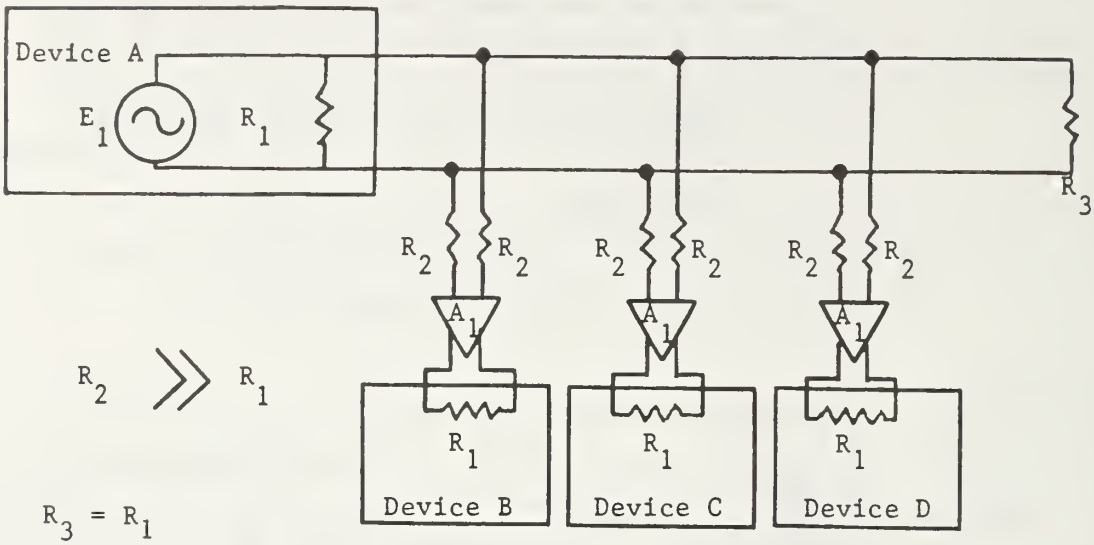



Figure III-9. Bridging Network

Besides matching of impedance in system design, it is important to understand testing procedures in measuring circuit levels. Measurement devices are designed to make measurements either in the bridging mode or terminating mode. Terminated measurements are used to measure the output of a device which is out-of-service. Bridging measurements can be made on "in service" circuits that are already properly terminated. See Figure III-10.

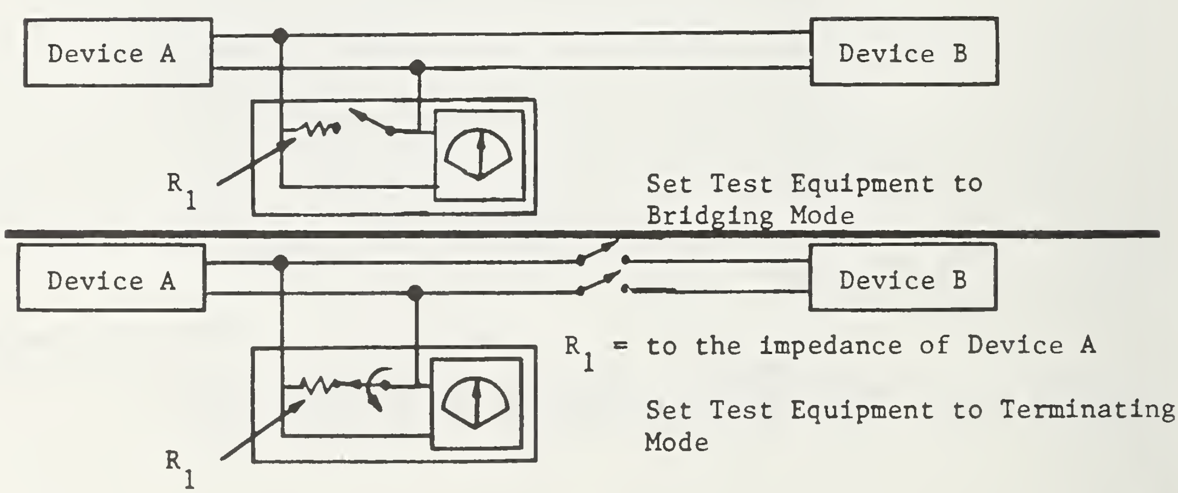



Figure III-10. Measurement Techniques

In the first test arrangement in Figure III-10, the input impedance of the test equipment is very high compared to Device A's output impedance. In the second arrangement, the test equipment's input impedance is set to match Device A's output impedance. This properly terminates Device A for the measurement.

So far, the reactive component of impedance has been ignored. In many circuits it is the cause of minor reflections. At VHF frequencies and above, the impedance mismatch is caused by slight imperfections in connectors, cables and components. Counteracting capacitance or inductance is often provided for tuning out reactive impedance imperfections. The compensating components are commonly placed in output/input circuitry. Generally speaking, the ideal impedance is purely resistive. In reality, they are almost purely resistive with frequency dependent variations in both the resistive and reactive aspects of the impedance. In the final adjustments of impedances, the system parameters that are monitored during the fine tuning are signal distorting parameters like frequency and delay response rather than impedances directly. Naturally, it is more important to have an undistorted signal than an essentially perfect impedance.

When measuring signal power in a bridging mode across a given impedance many meters measure the voltage only. The meter face is equipped with a voltage scale as well as a power scale in watts, milliwatts, dBm or some other power scale. The bottom of the meter face will have a notation saying "600 ohm meter" or other ohmic designation. This means that the "power" scale(s) on the meter is only valid if the voltage reading is taken across a 600 ohm impedance. The voltage scale is valid for all impedances, of course.

If a 600 ohm meter is used to measure the power across a 75 ohm impedance, the voltage reading is used to calculate the power at 75 ohms.

$$P = \frac{E^2}{R(75\text{ ohm})}$$

The power scale is not valid for 75 ohms since it represents power across 600 ohms only. The scale can be used, however, with the use of a correction factor:

$$\text{Correction Factor} = 10 \text{ Log} \left( \frac{\text{Meter Impedance}}{\text{Actual Impedance}} \right) \text{dB}$$

$$= 10 \text{ Log } \frac{600}{75}$$

$$= 9 \text{ dB}$$

If the meter reads + 10 dBm and 2.45 volts across 75 ohms, the actual power is:

power reading + correction factor

$$= 10 \text{ dBm} + 9 \text{ dB}$$

$$= 19 \text{ dBm}$$

7. Voltage Standing Wave Radio

Improper impedance matching whether in system design or testing causes reflections and distortions of signals and can directly affect the operation of various circuit elements causing abnormal changes in signal characteristics. System equipment usually is specified with specific input and output impedances with a tolerance range. The most common tolerance value is known as Voltage Standing Wave Ratio (VSWR). VSWR is an indirect measurement of an impedance's imperfections. It is a measure of the reflected wave that occurs when a source of calibrated output impedance is used to feed a device with an imperfect impedance.

To understand the mechanism of standing waves, assume a source as in Figure III-11.

The source feeds energy into the transmission line whose characteristic impedance is the same as $R_1$. The energy reaches the short, is reversed $180^o$ and returns back down the transmission line. (When it reaches $R_1$, it is fully absorbed since the transmission line matches $R_1$.) At the point of reflection, the incident and reflected waves cancel each other because they are $180^o$ apart. The voltage at the short is therefore always zero. As we move away from the short, however, the phase relationship between the two waves begins to shift until they are $360^o$ apart at A. At this point they are in phase and add. The sum of the two waves is not constant, however, since the amplitude of the two waves at A is changing sinusoidally. The voltage at A is 2E at one moment, zero half a cycle later, then -2E, back to zero, up to 2E, and so forth. In other words, the voltage at A varies between -2E and +2E, sinusoidally at the frequency of $E_1$.

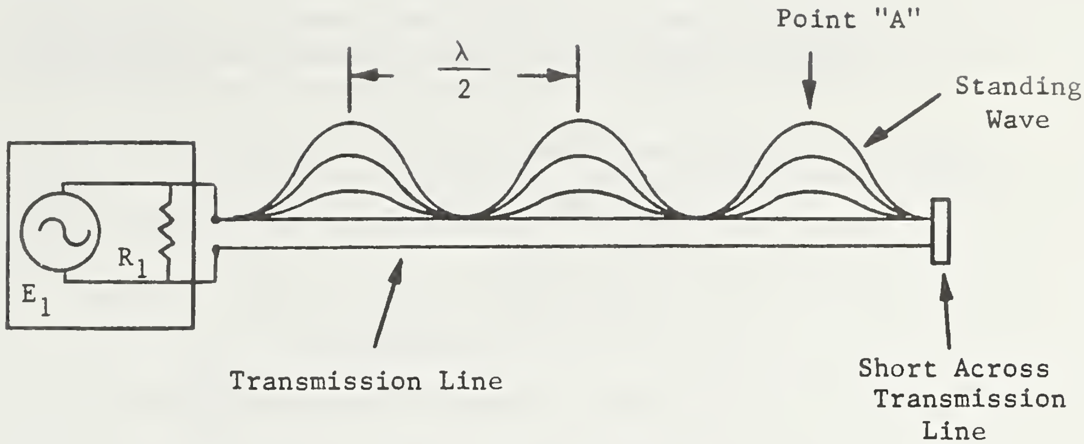



Figure III-11. Standing Wave Formation

When the reflection is due to only a partial short (impedance mismatch) the standing wave at the partial short is not zero but some finite level. The peaks likewise do not reach $\pm 2E$ but something less. See Figure III-12.

The voltage ratio of the peaks (A) and valleys (B) in Figure III-12 is called the VSWR. The larger the reflection, the higher the value of VSWR.

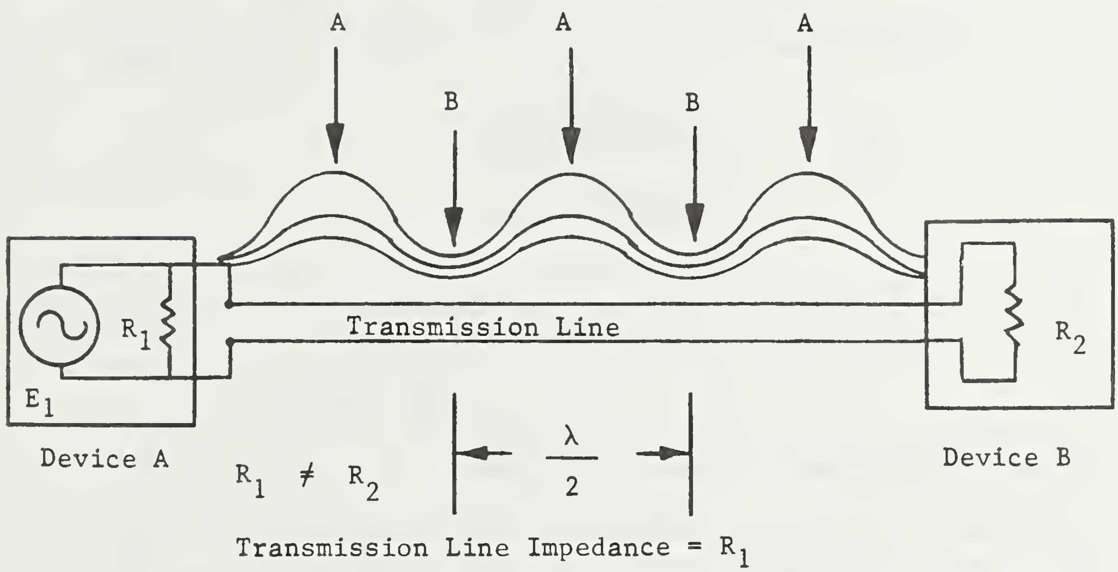



Figure III-12. Standing Wave Due to Partial Reflection

It should be noted in the condition of a partial short the standing wave at the peaks, A, never quite reached $\pm 2E$ and the maximum level at B is always greater than zero.

Let us assume:

$E_1$ = 10 volt RMS

$R_1$ = 50 ohms

$R_2$ = 52 ohms (mismatch)

The power entering the transmission line is:

$$P_1 = \frac{E_1^2}{R_1} = \frac{100}{50} = 2 \text{ watts}$$

The power absorbed by $R_2$ is:

$$P_2 = \frac{E_1^2}{R_2} = \frac{100}{52} = 1.923 \text{ watts}$$

The difference is the reflected power

$2 - 1.923 = .0769$ watts.

The voltage along the line due to the reflected power is:

$$E_R = \sqrt{(.0769)\quad(50 \text{ ohms})}$$

$$= 1.961 \text{ volts}$$

The maximum of the peaks in the standing wave pattern is the sum of the E incident and E reflected.

$= 10.0 + 1.961 = 11.961$ volts

The ratio of the two = VSWR

$$\frac{11.961}{8.039}$$

$= 1.488$ OR

VSWR = 1.488:1

There are other measurement terms for specifying mismatch. One is "return loss". It is a ratio of the incident power to reflected power. A typical value is 26 dB.

To calculate the return loss in the example given for Figure II-    , we determine $E_R$ which is half the difference between the peaks and valleys of the standing wave.

$$E_R = \frac{11.961 - 8.039}{2} = 1.961 \text{ volts}$$

$$P = \frac{E_R^{\ 2}}{50} = .0769 \text{ watts}$$

The incident power is 2 watts. The return loss is

$$\text{return loss} = 10 \text{ Log} \left( \frac{P_{incident}}{P_{reflected}} \right) \text{ dB}$$

$$= 10 \text{ Log} \left( \frac{2}{.0769} \right)$$

$$= 14.15 \text{ dB}$$

A more direct conversion from VSWR to return power exists which says

$$\text{return loss} = 20 \text{ Log} \left( \frac{VSWR+1}{VSWR-1} \right)$$

$$= 20 \text{ Log} \left( \frac{1.488+1}{1.488-1} \right)$$

$$= 14.15 \text{ dB}$$

8. Echo Return Loss/Singing Point

As discussed above in Section II.D, the echo return loss is a measure of the net circuit loss from the origin of the energy to the reflection point and back again. Care must be taken in telephone circuits that the return loss does not become too low. If the reflected energy reaches a high enough level, the circuit can burst into oscillation.

This can occur in a circuit with reflections at both ends of the circuit. The echo continually bounces at both ends building up the energy level to the point of sustained oscillation.

9. Balance

The word balance has several uses when applied to cables. An unbalanced line such as coaxial cable usually implies that one side of the line is connected to ground. Likewise, a balanced line uses two wires that are both isolated from ground. The resistance of the two wires to ground should be high as well as identical for the two wires. If the wire resistance or the resistance to ground is not identical for both wires, the line is said to be unbalanced.

If a twisted pair of wires becomes unbalanced, it becomes more susceptible to external interference. To understand the mechanism of interference, imagine a balanced line with both wires experiencing inducement by an interfering source. Both wires receive an equal inducement. The resultant currents cancel each other at the receive end. If one wire has a greater loss, however, the two currents will not be equal at the receive end, and therefore cannot cancel each other.

## E. System Design

### 1. System Plan

A system plan for a telephone system requires a vast amount of coordination and scheduling to accomplish a cohesive program of construction and implementation. The chart in Figure III-13 graphically shows the steps to be followed in the System Plan. It is important, in following this approach, that maximum use be made of available support functions in both technical and administrative aspects of the plan. The system engineer performs the functions of overall project management and coordinates the activities of the various company departments support for the project. The steps shown in Figure III-13 constitute a logical, proven procedure for this type of project.

### 2. Transmission Plan

Speech transmission capability is one of the principal concerns in telephone system design. After a circuit has been established between two subscribers, adequate speech transmission is essential regardless of their respective locations.

The primary transmission objective is to provide quiet, low loss, good quality circuits between subscribers. All trunks must be designed to operate at the lowest loss practicable in a manner that will permit minimum transmission impairment when any combination of trunks is used to form the connection.

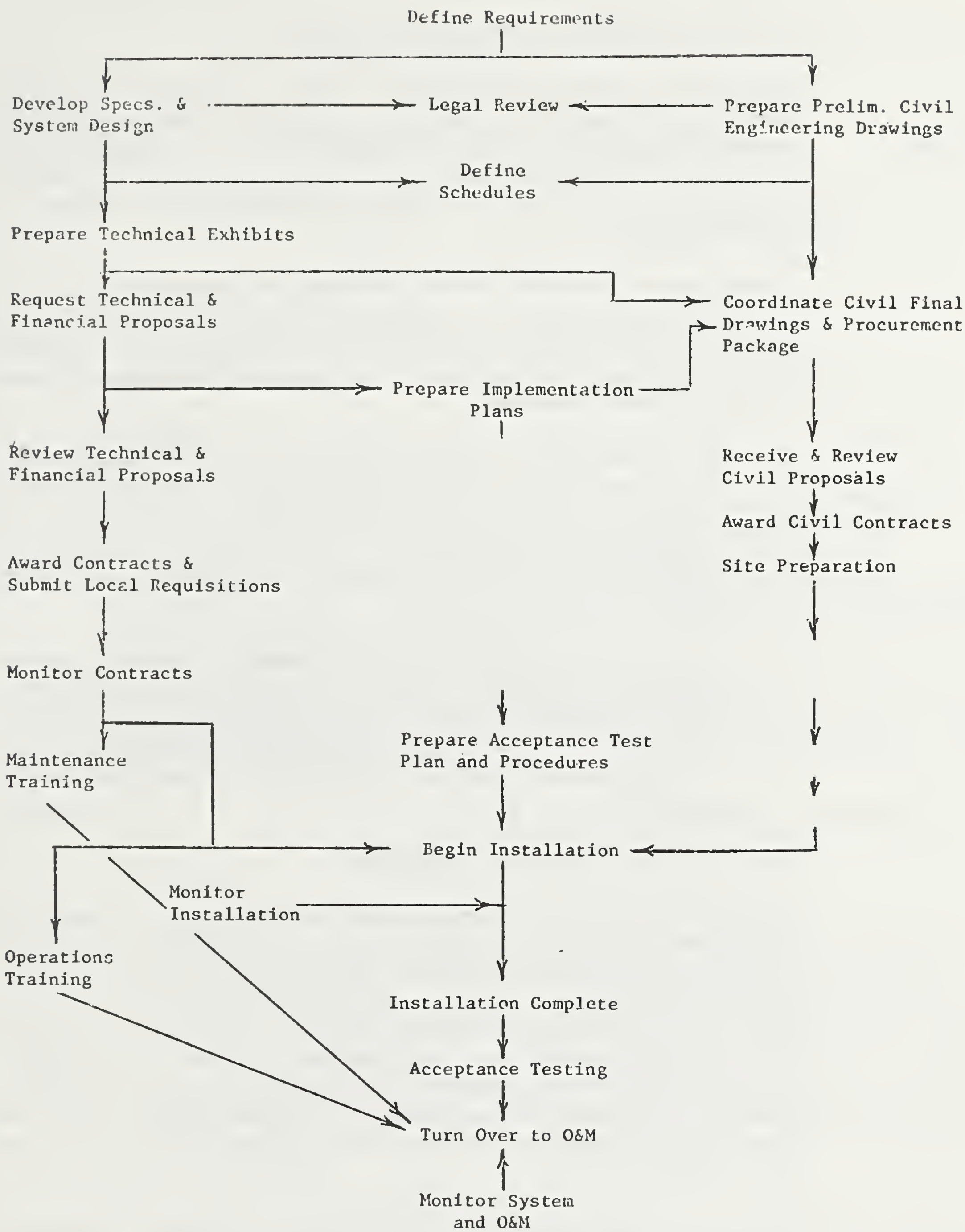



Figure III-13. System Planning

The transmission plan is used to ensure that all trunks, subscriber loops, and switching equipment provide the transmission objective when tied together to serve subscribers.

a. Subscriber Lines and PBX/PABX Trunks

Subscriber lines and PBX/PABX trunks normally contribute most of the total circuit loss in a switched connection even though they are relatively short in length. This condition makes them the controlling links and therefore equal in importance to trunks in transmission design considerations.

Subscribers located at the greatest distance from a central office generally receive the poorest service because of poor transmission. This problem becomes more apparent when there are many subscribers located in an area that falls in this category.

- The transmission objectives are 8 dB for subscriber lines and 5 dB for PBX/PABX trunks.
- Transmission improvement in the order of 6.5 dB can be realized on certain lines using common mode operation.
- Station carrier can readily provide excellent transmission to the most distant subscribers. Subscriber radio-link can fulfill the requirements of the most inaccessible subscribers which otherwise could not be served due to terrain characteristics and geographic isolation.

b. Net Loss and Frequency Response

Circuit net loss is perhaps the most important transmission characteristic to the subscriber. This net loss, measured at 1000 Hz, must be as low as possible in order for the listener to enjoy the benefit of good transmission; however, too little loss can result in a totally unacceptable condition to the talker and listener if echo or singing occur. Modern telephony must provide the listener with good volume and also recognition of the talker. The latter is a function of the circuit's frequency response (attenuation distortion).

Details of the design of the two-wire physical subscriber loop are covered in Part 4 of this section.

Carrier derived trunks can be set to the prescribed net loss by a simple adjustment or by the use of fixed pads.

Carrier derived subscriber circuits are generally factory adjusted to a fixed loss within limits specified by the user.

The 1000 Hz net loss and frequency response objectives are shown in Figure III-14.

| Type of Circuit | 1000 Hz Net Loss* | Frequency Response Ref. to 1000 Hz | Comment |
|---|---|---|---|
| Toll Connect. Trunks | 3 dB Obj.<br>4 dB Max. | +1, -3 dB, 300 to 3400 Hz<br>+1, -1 dB, 600 to 2400 Hz | Note 1 |
| Non-Toll Trunks | 3 dB Obj.<br>4 dB Max. | " | Note 1 |
| Subscriber Lines | 8 dB | +1, -3 dB, 300 to 3200 Hz | Note 2 |
| PBX and PABX Trunks | 5 dB | " | Note 2 |

*Toll and non-toll trunk losses include central office loss. Subscriber line and PBX/PABX trunk losses do not include central office loss.

NOTES:

1. Should be no less than 3 dB down at 300 and 3400 Hz from 1000 Hz reference level. A roll-off at these frequencies is generally desirable though not required.

2. High frequency roll-off on physical circuits may occur at less than 3200 Hz depending on the facility, i.e. nonloaded, loaded, type of end section, etc.

Figure III-14. Circuit Net Loss and Frequency Response Objectives

c. Noise

With lower net loss and improved frequency response the unwanted signals (noise) become increasingly important. User dialing deprives the subscriber of operator assistance in avoiding unsatisfactory circuits which means that a higher percentage of usable circuits must be in optimum condition at all times. Certain objectives which in the past were often difficult to meet are now requirements of connecting companies for allowing circuits to be turned-up for service.

Noise is generally categorized as (1) steady state, and (2) impulse. Steady state noise is the most objectionable in message circuits and is usually characterized as hum or hiss, whereas impulse noise is more detrimental to data transmission because it consists of pops and clicks that look like data to the data communications equipment.

3. Grade of Service

Grade of Service is a probability factor associated with telephone switching systems. It indicates the probability that at a specific point in time a line will be "blocked" or unable to complete a call. Grade of Service and CCS-per-line combine to indicate the traffic handling capability of a telephone switching system.

CCS is defined as "hundred call seconds"; one CCS is equal to one call in progress for 100 seconds. (A "call in progress" starts from the initial OFF-HOOK and continues through the final ON-HOOK disconnect.) One call for one hour (3600 seconds) equals 36 CCS. An individual CCS figure is usually given for originating and terminating calls, however an average of these two figures is useful for system analysis purposes.

For each CCS figure, there exists a probability factor, Grade of Service. A Grade of Service factor of P .02 would indicate that one can expect 2% of all calls attempted through the system to not be completed. A CCS/line of 8.0 or over indicates heavy traffic, medium traffic a CCS/line of 5.0 and 3.5 and below indicates low traffic.

In most switching systems, the only economical way to improve Grade of Service is to increase the numbers of cross office links or junctors and the number of outward and inward trunks.

It is important that the system engineer have an analysis of the switching system performed after installation is complete and the system is in full operation. This is the only way that the preliminary figures for these factors, used during the design phase, can be checked for a new system. The trunk and junctor numbers can then be adjusted to yield the Grade of Service desired. At this point it is well to utilize the services of a traffic consultant to perform the analysis. The consultant should be independent of the supplying company but should be thoroughly familiar with the type of switching equipment. The use of a consultant is an investment well made.

4. Loop Design

This part of the "Systems Design" section gives an overview of the design considerations used in the design of subscriber loops and PABX trunks.

Certain factors should be considered in the design of the subscriber loop and PABX trunks. These include:

- Use of 24 and 22 gauge cable for the main cable distribution plant with an average of 0.083 mfd/mile capacitance.

- Limited use of 26 gauge cable in high density areas.

- De-emphasis of the use of 19 gauge multi-pair cable.

- Maximum loading of loops.

- Utilization of loop extenders or long line adapters (LLA) with additional 48-volt booster power supply for outside plant loop resistances exceeding 1700 ohms.

- Elimination of transmission computations in most instances.

Application of all these design considerations will result in satisfactory transmission to all subscribers.

The design-by-loss method of calculation is used to compute the 1000 Hz loss to the subscriber or trunk. This method is based on the actual transmission loss in the loop or trunk. In the case of a subscriber, the actual loss, after installation, can be measured by the installer from the subscriber premises. The installer equipped with a portable loop checker (measuring set) connected to the subscriber station can verify the design-by-loss by dialing up a quiet termination.

5. Distribution Frames

Distribution frames come in two basic styles; the in-aisle, double sided floor style has one side for vertical mounting of blocks and one side for mounting blocks horizontally. The second style of frame is the single sided wall frame with only vertically mounted blocks.

The floor style frame is the most commonly seen frame in telephone central offices. This frame is bolted to the floor and stabilized by supports run to walls along the sides and to overhead cable tray. The vertical side is considered the front of the frame. Each individual block location on the frame is identified in a standard fashion; looking at the vertical (front) side, the verticals are numbered from left to right (1,2,3,etc.) and the horizontal levels lettered from the bottom to the top, i.e. A,B,C, etc. The horizontal (back) side of the frame is a mirror image of the front side for location identification purposes. The horizontal levels maintain the bottom to top lettering scheme while the vertical columns are numbered from right to left.

With the identification scheme standardized in this fashion, it is a relatively easy task to locate a particular block on the frame. There are just two rules to remember. If the block identification begins with a number it is a block on the vertical side of the frame; if the identification begins with a letter, it is on the horizontal side of the frame. Therefore, Block 26-K is a block on the vertical side of the frame, located in vertical "26" at level "K". Conversely, Block K-26 is on the horizontal side of the frame on shelf "K" at column "26", or is the complement of Block 26-K. (These two blocks may not have anything in common other than their complementary numbers for location.)

The wall style frame is of particular use where space is at a premium and the number of terminal blocks needed is small. This frame is mounted on the floor against a wall and is secured to both the floor and the wall. A wall frame normally has only vertically mounted blocks. Its numbering scheme is the same as the front side of a floor frame, i.e. numbered from left to right, lettered from bottom to top.

The length of a frame, whether it is a floor or wall frame, is determined by the number of verticals required. Vertical spacings are available with 10.04 cm (7.5 in.), 20.32 cm (8 in.) and 22.86 cm (9 in.) centers. (Most line terminal blocks are available with adjustable mounting brackets to allow for the vertical spacing.) The height of the frame will depend on the clear ceiling height and is determined by the number of horizontal levels required. (Horizontal levels have a standard spacing of 20.32 cm (8 in.), with the distance above the floor for the first level being a variable.) Overall frame heights are standardized at 2.438 meters (8 ft.), 2.743 meters (9 ft.) and 3.505 meters (11 ft.6 in.). Most manufacturers will tailor the height of a frame to the user's needs if standard heights cannot be used due to space limitations, but this is usually an extra cost.

On a floor MDF, all outside plant cables are terminated on the vertical side and tie cables or house cables are terminated on the horizontal side. The outside plant cables may or may not be terminated on protectors. On a wall MDF, of necessity, all cables are terminated on the vertical.

On a floor IDF, all tie cables to the MDF are terminated on the vertical side and all equipment cables terminated on the horizontal side. Again, the wall frame is an exception.

The CDF is the frame which will most likely be used in the power communications system. On a floor CDF, the vertical side will contain a combination of outside plant cables (usually on protectors), tie cables and house cables. The types of cables are usually grouped together with several consecutively numbered verticals assigned for outside plant cables, several assigned for tie cables and several assigned for house cables. Equipment cables will be terminated on the horizontal side of the frame with like equipments grouped in the manner used for like cables on the vertical side. The wall CDF is, again, peculiar in that all cables, outside plant, tie, house and equipment, are terminated vertically. These too, however, are grouped.

It is important to remember when grouping cables, as well as planning the size of the frame, to allow for expansion.

6. Line Terminal Blocks

Cables terminated on terminal blocks follow set patterns whether they are terminating cables pairs or equipment functions. Cables are always terminated on the left hand side of a vertical block with the terminals used from front to rear, top to bottom. The right hand side of the block is reserved for cross-connects. On horizontal blocks, cables are terminated on the bottom of the block with terminals used from front to rear, left to right. The top of the block is reserved for cross-connects.

The terminals, often called "punchings" or "clips", on a line terminal block are exposed on both sides of the block and are encased in wood, hard rubber or high grade bakelite. Terminals are available to accept wire-wrap, solder or a combination of both connections. Today, with wire-wrap techniques most desirable for cable termination (cable pairs or equipment termination), the combination block is widely used in new installations; the solder terminal being the most desirable for the cross-connect side of the block.

Terminal blocks are available in standard sizes (numbers of terminals). The blocks are made in from 2 to 12 terminals deep with either 20 or 26 rows of terminals. As stated before, most blocks are available with adjustable mounting brackets to allow for mounting on various size frames.

7. Cable Tray (Cable Ladder)

Most telephone equipment does not lend itself to cabling from beneath, so in general all cabling will be installed from above. To support the masses of cables necessary, cables trays or cables ladders are used. The trays used are three-sided with holes or slots for cables to drop through to the equipment or frames. The tray is supported usually from above by hanging it from anchors attached to ceiling support structures or imbedded in the ceiling itself. Ladder is supported in the same fashion, but it is made of welded iron bars, angles and flat stock and very much resembles a ladder when assembled.

Many types of accessories are made for both tray and ladder to allow for bends, level changes, changes from horizontal to vertical runs, etc. In planning the layout of the cable support it is wise to refer to manufacturers catalogs to obtain helpful guidance and installation details. Both tray and ladder are available in various widths from 10.16 cm (4 in.) to 91.44 cm (3 ft.) and numerous section lengths.

8. Cable Installation

The orderly installation of cables to and from equipment and frames will not only add aesthetically to the installation, but will make the future addition and deletion of equipment easier. The cable installation should be planned in advance. Points to plan, as where a cable enters the cable support system and where it will exit the support to enter a rack of equipment, are very important. Cables should be laid into cable supporting structures in neat, square bundles and follow the general rule that the first cable to be leaving the structure should be at the bottom of the bundle and as near the relative exit position (horizontally) as possible. Cables should always be kept near the edges of the structure to allow for installation of later cables as the system grows. Vertical exiting cables should never exit directly up or down from the cable support, but should be routed to the edge, then up or down, to allow for addition of cables later. Cables should be lashed to the cable support either with plastic cable ties or lacing cord following telephone practices.

A cable running list is an absolute necessity in planning the installation of any communications system. It is also an invaluable tool in its use as a check list to ensure that all cables are accounted for and to ensure that all cables are run at installation time.

9. Connectorized Cables and Terminal Blocks

Connectorized cables, terminal blocks and equipment racks are gaining wide acceptance and use in the telephone industry today. Installation time has been reduced tremendously through the use of these items. Cables of pre-cut lengths are available with standard 50 pin connectors (25 pairs). The cables come in lengths of 1.52 m (5 ft.), 3.04 m (10 ft.), 7.6 m (25 ft.), 15.2 m (50 ft.), 30.4 m (100 ft.), 45.6 m (150 ft.) and 60.8 m (200 ft.) making the combination of different lengths possible to solve almost any installation problem. Line terminal blocks, jack fields, TCO equipment and subscriber instruments are all available with connectors to mate to these cables. Connectorizing the installation as much as possible not only reduces the initial installation time, but also makes the removal and re-installation procedure easier and less costly.

### 10. Jack Fields

An extremely important tool in the operation and maintenance of any communications system is the jack field. The properly planned and installed jack field can be used to by-pass faulty equipment, re-route circuits, provide monitoring of circuits or equipment in use without disrupting service and allow easy access for testing of equipment and circuits. In many large communications facilities, all cable pairs from the outside plant distribution system are routed through jacks on a "primary board" before being routed to equipment. This arrangement allows immediate access to cable pairs for testing and temporary rearrangement due to cable pair failure.

The jacks used in a primary board and most commonly throughout a communication facility are of the "normal-through" type. This jack is actually two jacks mechanically connected so that the circuit passes through the jack normally when no patch cord is inserted. A patch cord may be inserted in one hole of this jack to allow "looking" toward the cable pair or drop, or in the other hole to allow access toward the equipment. The normal-through or "double-normal" jack is used on the inputs and outputs of equipment such as repeaters, hybrids, bridges, MUX, etc.

Again, the properly installed and used jack field can be an excellent maintenance tool. It not only allows access to circuits and equipment for testing purposes and emergency or temporary service changes, but can be a visual indicator of service problems which must be corrected. When the communications facility follows the rule that a patch cord is placed in a jack field only for testing purposes or for emergency or <u>temporary</u> service changes, a maintenance technician merely has to look at the jack field to know that there may be a problem that requires attention.

Many times jack fields are left out of the communications system due to cost. Experience has shown that this initial cost is far outweighed by the flexibility the jack field lends to the system.

## F. System Performance Analysis

### 1. Introduction

The analysis of the plant communications system performance is an important function to insure that the primary transmission objective of good quality circuits between subscribers is met. Equally important is the assurance that the design Grade of Service is being met. For those system parameters for which standards have been set and testing procedures developed, reference is made to applicable publications. If testing and analysis procedures are not readily available in other publications, procedures will be outlined in this Bulletin.

2. Channel Transmission Parameters

Channel transmission parameters can be simply stated as loss objectives. Each type of telephone circuit, whether it is a complete circuit from one subscriber to another or a trunk used in some portion of a circuit, has as its design basis a loss objective. The loss objective in most cases will not be zero loss, even though that would appear to be the ideal case. From the discussions in other portions of this Bulletin, it has been pointed out that loss is very important to a circuit to avoid echo and singing. Loss also is important to the listening comfort of the subscriber.

The loss objectives listed in Figure III-15 are all based on the loss at 1000 Hz. The average loss can also be looked upon as the minimum loss for good transmission characteristics.

There are, of course, many more types of circuits with set loss objectives. Those listed in Figure III-15 are some of the more common which may be associated with a telephone system used in a power communications system.

| From | To | Loss Objective |
|---|---|---|
| TCO | Any PABX station | 5 dB AVE, 7 dB MAX |
| TCO | PABX switchboard | 2 dB AVE, 3 dB MAX |
| PABX | Any station | 3 dB AVE, 4 dB MAX |
| PABX | PABX | 2 dB AVE, 3 dB MAX |
| TCO | Foreign exchange line PABX | 2 dB AVE, 3 dB MAX |
| TCO | FX PABX station | 5 dB AVE, 7 dB MAX |
| TCO | Off premise extension (OPX) | 5 dB AVE, 8 dB MAX |
| TCO | PABX OPX station | 2 dB AVE, 3 dB MAX |

Figure 111-15. Loss Objectives

3. Signaling and Supervision

Signaling and supervision are discussed in Section II. Many of the parameters are discussed there also. It would be well for the reader to refer back to that section discussion for a review of signaling and supervision.

The functions of E and M signaling are the most applicable to the power communications system. This signaling scheme will, undoubtedly, be the one used for both trunk signaling between the PABX and the local telephone, and signaling over any microwave and voice MUX circuits.

4. Subscriber Loops

There are several parameters tied to the subscriber loop which are used in the analysis of performance of the loop. The two most important are the loop loss at 1000 Hz and the DC loop resistance. These parameters are established at the time the subscriber loop is designed and should be available in the records of the particular subscriber.

In measuring the loop loss and the loop resistance, the subscriber service will generally have to be interrupted for a short period of time. Although the subscriber should be notified when these tests are being performed, they can be performed without the subscriber's knowledge should the subscriber not be available for notification. Loop resistance can be measured in accordance with REA TOM (Telephone Operations Manual) Section 1356.6. This Section is titled "Buried Plant Maintenance" and includes complete testing information for cables pairs and an Appendix detailing the use of the Wheatstone Bridge.

REA TOM Section 1358.1 describes the testing of the subscriber loop loss. These tests are performed from the subscriber location and require only one man to perform them.

It must be kept in mind that the results of any testing must be referred back to the original records for that subscriber to make any data meaningful.

5. Traffic Analysis

In Section II, the primary traffic parameters of CCS-per-line and Grade of Service and their importance as traffic analysis tools were discussed. As previously stated, telephone switching systems are engineered and designed based on estimated traffic. The only true way of analyzing the system is after it has been operating in the environment upon which the estimate was made. Estimates of telephone traffic can be very accurate; however, these should be checked under actual operating conditions after an initial period of time to allow personnel to become familiar with the capabilities of the system.

It is recommended that whenever a telephone traffic study is to be performed, a qualified traffic consultant be utilized. Although most telephone systems engineers are somewhat familiar with traffic studies, the detailed performance and analysis of a traffic study is better left to a consultant. The implementation of changes to the system should be a joint venture with the systems engineer, the consultant, and the equipment supplier conferring.

A compilation of trouble reports on the system is an important adjunct to the traffic study. This information should be supplied to the traffic consultant by the systems engineer. An analysis of troubles reported can reveal problems which may be solved by regrading of the switching equipment rather than adding new equipment. (Accurate trouble reports should be kept on a routine basis by the system operating function.)

# IV. OPERATIONS AND MAINTENANCE

## A. Introduction

The operations and maintenance of a plant communications system takes on a leading role in the overall operation of the power system and can be considered the backbone of the power generating and distribution operation. A major breakdown in the generation or distribution of power can paralyze a wide area; a breakdown in communications can paralyze the restoration efforts of the power company.

The operations and maintenance structure, as well as the systems engineering structure of communications system, will vary with the size and complexity of the communications system. An overview of this structure and areas of responsibility is discussed in this section of the Bulletin. Some examples are shown based on various sizes of systems; these, of course, are only examples and actual structure and manning will vary with the power company personnel structure.

## B. System Structure and Operation

When planning the O&M function, it is necessary to take into consideration the total communications system. The entire communications system, engineering, operation, and maintenance, should be placed under one management function. A fragmented management structure can cause endless problems in the operation of any communications system.

Figure IV-1 shows the areas of responsibility in the organization of the communication operation. These responsibilities are arranged under the four main headings of Operations, Engineering, Telephone Maintenance, and Radio Maintenance. Support from other functions within the power company is required and is shown for information purposes.

In a large communications system, it may be desired to form a Communications Department with a Manager, and Managers and staff for Operations, Telephone Maintenance, Engineering, and Radio Maintenance. In a small system, the personnel might well be limited to a Communications Manager with a Systems Engineer, a Secretary to handle records, several telephone operators, two or three telephone maintenance technicians, and two or three radio maintenance technicians reporting directly to him.

It is difficult to determine the number of personnel required to support a system. This is an area in which a communications consultant can be of great assistance to the electric system borrower. The consultant's expertise can be brought into play in many areas, once the size and complexity of the system has been established.

COMMUNICATIONS

OPERATIONS

- Telephone Operators
- Records
- Assignments
- Work Orders
- Equipment Inventory
- Supply
- Commercial Service Orders

ENGINEERING

- Planning
- Systems Engineering
- Maintenance Engineering
- Technical Procurement Management
- Technical Coordination with Manufacturers and Suppliers
- Traffic Engineering
- TelCo Coordination and Liaison

TELEPHONE MAINTENANCE

- PABX
- Station Instruments
- Station Installation
- Battery Plants
- Emergency Generating Plants
- Cable Plant
- Pole Lines

RADIO MAINTENANCE

- Two-Way Installations
- Two-Way Maintenance
- Microwave Systems
- Multiplex Systems
- Towers
- CCTV
- Interference Location

Support from other Power Company Depts.

- Personnel
- Accounting
- Purchasing
- Legal

Figure IV-1. Organizational Responsibilities

C. Project Management

The management of a communications system requires a thorough familiarity with engineering, operation, and maintenance of communications facilities. Only in this way can the problems which develop in any one of the areas be dealt with properly and the effect of the solution on other areas properly appraised.

The size of the system will determine whether 24-hour coverage is required or call-in coverage will suffice. No matter what the size of the system, some provision for emergency restoral must be made. It is extremely important that personnel be aware of their call-in status during evening and weekend hours. This holds true for both operating and maintenance personnel, and a firm schedule should be published and disseminated regularly. This form of scheduling will not only assure that call-in personnel are available, but will also allow personnel to plan their personel activities well in advance.

The communications system will undoubtedly be operating on a budget. Regular planning meetings should be held with operations, engineering, and maintenance supervision. These meetings should include discussions of problems affecting each area which may require budget action to solve. In addition, operations and maintenance should be made aware of engineering planning and actions which may have an effect on their areas of responsibility.

The operations section of the communications organization will, historically, have the closest contact with other functions within the power company structure. It is important that operations be staffed with personnel who are aware of their responsibility to the rest of the electric system. The complaints will come to operations. These should be acted upon with all speed. All areas of the communications organization, and especially operations, must maintain close contact with other sections of the power company, looking for potential problem areas. Often, a slight difficulty with communications will not be reported because the person experiencing the difficulty is too busy at the time to stop and notify the communications organization. Personal contact can, more often than not, head off a major failure of the system.

D. Manpower Requirements

It has been stated that the actual manning numbers for the communications system cannot be defined without knowing the size and complexity of the system. There is also no "rule of thumb" for determining that if System "A" requires "X" number of telephone maintenance technicians, then System"B" will require "Y" number of telephone technicians. We can, however, define the technical requirements or backgrounds for personnel.

1. Engineering

The Systems Engineer(s) employed require a good knowledge of:

- Telephone Inside Plant
- Telephone Outside Plant
- Multiplex Systems
- Microwave Systems
- Maintenance Engineering
- Telephone Company Leased Facilities
- Two-Way Radio Systems
- Transmission
- FCC Rules and Regulations
- Public Service Commission Regulations
- Tariffs

Often, for small systems, it is possible to employ a Systems Engineer who is familiar with aspects of several of the above areas. This type of person is not unusual in the communications field and can be a genuine asset to the power company communications organization. For large systems, it is wise to employ engineers with a specialty in one or more of the areas and, in addition, employ one or more engineers in the "generalist" category as recommended for a small system. The generalist is most useful in "pulling together" the planning and designs of the specialists.

2. Telephone Maintenance Technicians

The Telephone Technicians employed require a thorough maintenance and installation background in:

- PABX's
- Switching
- Subscriber Instruments
- Station Installation
- Cabling

- Frame Wiring

- Cable Plant

- Circuit and Cable Pair Testing

As with Systems Engineers, it is often possible to employ Telephone Technicians with a variety of experience in many areas. In larger systems, it may be necessary to staff Cable Splicers, Cable Testers, Linemen, Switchmen, etc. as separate functions in the telephone maintenance area.

3. Radio Technician

The Radio Technicians must be familiar with the following:

- Two-Way Radio Installation

- Two-Way Radio Maintenance

- Microwave Maintenance

- Multiplex Maintenance

- CCTV Maintenance

- Interference Location

** In addition, this Technician must hold an FCC 2nd Class Radiotelephone License as a minimum.

Two-Way Radio Technicians generally have had microwave and multiplex experience. It is not unusual to be able to employ a technician with broad experience. Again, the size of the system will dictate whether a technician with broad or specialized experience can be employed.

It should be noted that there is a requirement for a radio technician with interference location experience. The majority of power companies employ one or more specialists in the location of noisy connections, transformers, insulators, etc. that may be causing interference to radio services, TV broadcast reception, etc. The Radio Maintenance function is the ideal assignment for these specialists, as they are usually licensed radio technicians.

4. Telephone Operators

The Telephone Operator can be looked upon as the "door" to the power company. The Operator is, more often than not, the first person the power customer meets and, many times, the one who sets the tone for the company-customer relationship. Courtesy and quick reaction to the customer's needs is the prime requisite for a good Operator. Most Operators can be trained "on-the-job"; however, the system must employ at least one experienced Operator who should carry the title of Chief Operator.

The Chief Operator should be completely familiar with the following:

- Company emergency plans
- Night service
- Proper use of trunks
- Training needs
- Operation of special equipment
- Special service needs
- Supervision and scheduling

The experience levels of other Operators will be dependent upon the hours of operation of the company PABX or switchboard. At least one Operator with a good experience background must be available to supervise arising emergencies after normal business hours, if the switchboard is manned.

5. Clerical

Under the general heading "Clerical" are included several positions which must be filled to handle peculiar communications tasks, very important to the proper operation of the system. Again, the staffing of each position will be dependent on the size of the system. The position responsibilities are described for information purposes. It may be found that more than one area of responsibility can be assigned to a single individual.

a. Assignments - Prepares the assignment of equipment and support facilities based upon user needs; maintains up-to-date records of assigned numbers, equipment, etc.; maintains directory information.

b. Records - Maintains cable records for both Inside and Outside Plant; assigns cable pairs; maintains cable pair assignment records; keeps up-to-date cable fill data available to the Systems Engineer; assist in planning circuit routings for cable facilities.

c. Work Orders - Work load control for new service and support work order requirements.

d. Equipment Inventory - Control of capital equipment records.

e. Supply - Maintains and distributes all parts and materials for the communications system. This function should be a separate operation from the power company supply system because of the multitude of peculiar communications material handled.

f. Commercial Service Orders - Places orders for commercial services from local telephone companies; maintains records for these services; coordinates installation of these commercial services.

The foregoing are outlines of the basic responsibilities of various positions required to support the communications system. They are meant as a guide to staffing the communications organization. The actual numbers of personnel required to fill these positions will depend upon the size of the communications system and the geographical area to be covered by these facilities.

## E. Training

The training of operations and maintenance personnel is an extremely important aspect of the successful operation of a communications system. It is vitally important that both operations and maintenance personnel be thoroughly trained in their areas of responsibilities. Here again, the overall service to the power company and the service necessary during emergency operations of the company are prime factors.

In most instances, suppliers have standard training programs which can be offered to users of their equipment. In the operations area, this is usually provided as on-the-job training. This training can be begun prior to the completion of installation of equipment and continued for a period of time after the system becomes operational. Provision for this training should be included and funds provided for in the initial procurement documentation and negotiations.

Maintenance personnel and engineering personnel should be provided factory training prior to installation of equipment with a program continuing during installation and check out phases on the actual installed equipment.

An On-the-Job training program should be instituted within the communications organization to provide training for new personnel and continuing training of older personnel.

The properly organized and functioning training program can be a great asset in the evaluation of both operating and maintenance personnel capabilities.

It is stressed again that much of the training required can be obtained from suppliers of the various portions of the communications system. Provision for this training must be made in the procurement of the systems.

F. <u>Support Requirements</u>

The electric system borrower will have expertise in various other departments which can be an asset to the communications system. In an effort to minimize costs, the talents within these departments should be utilized whenever possible by the communications organization.

Many electric system borrowers maintain Right-of-Way Departments. This department can be utilized to obtain sites for microwave repeaters, pole lines, and communications buildings, as an example. They are familiar with the problems in this area and duplication of this effort would be costly.

A building and construction department can assist in the planning and siting of communications facilities. They can also oversee the actual construction of these facilities. The Purchasing Department of the electric system borrower can act as the procurement arm of the communications organization. Again, there is no need for duplication of this effort.

Even in the maintenance areas, there is support available to communications. As an example, power companies maintain crews to provide maintenance of large transmission towers; the maintenance is not unlike the maintenance required of microwave towers and antennas.

Careful screening of the responsibilities of other areas and departments of the company will reveal many more support functions which can be economically used by the communications organization.

## G. Preventative Maintenance

Although failure of equipment and components can occur and will occur at the most inopportune moments, a large percentage of failures can be prevented with a well organized and planned Preventative Maintenance Program. Preventative maintenance is, just as the name implies, the performance of certain maintenance procedures as a deterrent to failures.

The majority of preventative maintenance procedures will be performed on a periodic schedule, with set periods of time between inspections. Depending upon the equipment or facility, these procedures will be scheduled for periods varying from daily to annually. As an example, battery plant inspections of plant voltage, cell specific gravity, and rectifier operation are normally scheduled on a monthly basis. Multiplex channel levels are generally tested on a six months basis, along with other multiplex equipment operating parameters.

Equipment manufacturers can supply data concerning preventative maintenance schedules for their particular equipment. These schedules are based on their experience level with the equipment in various types of environment and, normally, can be relied upon to keep the equipment in optimum operating condition.

No matter what the equipment or system, a definite schedule should be documented and adhered to. A suspense file must be set up through which the preventative maintenance schedules for each piece of equipment or system rotates. Documentation of the checks and tests performed must be maintained. This documentation will include not only a record of the tests performed, but a record of deviations from the norm and corrective actions taken. The notation of corrective action should indicate whether the action was taken immediately or referred to another group or department for action.

Trouble reports from the telephone operators and radio dispatchers should be reviewed daily. These reports can give an indication of system deterioration and flag potential failures that may not otherwise show up until the system has actually failed or a scheduled preventative maintenance procedure is performed. Although the analysis of trouble reports is a time consuming task, and quite often the reports are the result of human error, they are an essential part of the overall communications preventative maintenance program.

Although it has been stated that preventative maintenance is generally performed on a scheduled basis, some preventative maintenance is performed on what may seem to be a haphazard basis; it is, however, a very effective program. For instance, in a communications system which has a large outside plant installation, it is very difficult to schedule regular inspections of each and every pole, manhole, etc. The entire field staff of the power company can assist in preventative maintenance here. All departments should be encouraged to notify communications of any potential problems spotted by their personnel in the field such as new construction on roads, digging near communications cables, etc. Even a survey crew, not associated with the power company, working in an area can indicate to the communications department that some new construction affecting their system is about to commence. Many reports may be false alarms, but all reports should be treated initially as potential trouble spots. Some will be.

## H. Test and Evaluation

Test and evaluation of all portions of the communications system is an important part of the Operations and Maintenance responsibilities. This pertains not only to the system after it is fully operational, but to the system during acceptance testing.

### 1. In-Service/Out-of-Service Tests

The testing of communications equipment and circuits falls into two categories, In-Service Tests and Out-of-Service Tests.

In-service tests are tests that can be performed on circuits or equipment without actually interrupting to a user or group of users. Out-of-service tests are, conversely, those tests which require an interruption of service to be performed. There are also tests on communications services that normally would be considered in-service tests, but because of loading of facilities, require an interruption of service to perform.

In-service tests can be performed on a subscriber loop. These tests, such as dial speed, loop loss, supervision, ringing, etc. can all be performed without loss of service. In the computer controlled PABX many of these tests are performed automatically without removing the subscriber from service. Many other tests on systems can be performed without a loss of service such as transmitter power output power on microwave equipment, voltage measurements on various pieces of equipment, battery plant tests and rectifier tests, emergency power generating equipment tests, etc.

Some testing will require the removal from service of pieces of equipment or entire communications circuits. These out-of-service tests might include carrier channel line-up, replacement of a faulty microwave receiver or transmitter where no hot-standby is available, or replacement of a faulty cable serving a subscriber or group of subscribers, etc. Out-of-service tests should be avoided whenever possible.

There are certain times when testing can be performed that may appear as out-of-service testing when, in fact, service is not interrupted. The testing of carrier channels is quite often done without interrupting service overall. Most carrier systems are not completely loaded, therefore spare channels may be available to substitute for operating circuits or trunks. Here the channel is actually removed from service, but an equivalent channel is substituted leaving the trunk or circuit intact and continuing to provide service while the testing is in progress. Many other instances of this occur such as testing of cable pairs and testing of hot-standby microwave systems.

2. <u>Acceptance Testing and Final Inspection</u>

All newly installed systems will require a program of acceptance testing and final inspection before being placed into operation in the overall communications system. During the preparation of procurement specifications, the supplier should be charged with the responsibility of preparing and submitting acceptance testing procedures and schedules. These submittals must be presented to the systems engineering group in sufficient time to allow review and comments. Acceptance procedures must be detailed enough to exercise each new system to the fullest extent of the specifications and must prove that the supplier has met or exceeded all requirements of the specifications to the satisfaction of the systems engineer.

If the new system is to interface with existing or other new systems, the acceptance testing must include tests which prove that the systems can interface properly, without degradation to either system or the overall communications system. This is an important point in acceptance testing; experience has shown that even though equipment and systems may meet the criteria set forth in the acceptance testing procedures for that particular piece of equipment or system, interfacing with other equipment or systems may pose a problem. The ability to interface with other portions of the communications system must be demonstrated by the supplier of the new system.

The importance of acceptance testing cannot be stressed too much; it is a key factor in the procurement and implementation of new portions of the communications system.

3. <u>Test Schedule</u>

It has been pointed out previously that the test schedule should be a part of the acceptance test procedures. The systems engineer should review the test schedule and make the necessary provisions for personnel to be available to observe the testing and the final results.

As the systems engineer cannot possibly be at all locations where testing is in progress, it is important that other communications personnel charged with witnessing the tests certify the results to the system engineer.

## V. GLOSSARY OF TERMS

Absolute Delay - The total time (usually measured in microseconds) required for a signal to be transmitted from one end of a circuit to the other.

AC-DC Ringing - A type of telephone ringing which makes use of both AC and DC components - alternating current to operate a ringer and direct current to aid the relay action which stops the ringing when the called telephone is answered.

Address - (Sometimes referred to as "called number".) That group of digits which makes up a telephone number. For example, an address may consist of area code, central office and line number.

AMA - (Automatic Message Accounting.) An automatic recording system which documents all the necessary billing data of subscriber-dialed long distance calls.

ANI - (Automatic Number Identification.) Automatic equipment located at a local or toll dial central office used to identify the calling number in customer dialed toll calls. The identity of the calling number is transmitted to CAMA by means of multifrequency pulses that are sent over the same trunk after dial pulsing has taken place.

Answer Signal - A supervisory signal (usually in the form of a closed loop) from the called telephone to the central office, and back to the calling telephone (usually in the form of reverse battery) when the called number answers.

Appearance - Location on switch frames, switchboards, and/or patch panels of wires and equipment.

Area Code - The national three-digit prefix assigned to a telephone number for direct distance dialing purposes. The first digit may be 2 thru 9, the second digit is either 1 or 0.

Attenuation - The decrease in signal amplitude when transmitting from one point to another, usually expressed as a ratio in dB.

Audible Ringing Tone - That tone received by the calling telephone indicating that the called telephone is being rung (formerly called ringback tone).

Automatic Toll Ticketing - System whereby toll calls are automatically recorded, timed, and toll tickets printed under the control of the calling party's dial pulses without the intervention of an operator.

Back Up Power - See UPS.

Battery - Usually refers to the DC power source located in the central office. Nominally -24 or -48 volts.

Battery and Ground Signaling - A type of loop signaling designed to double the available signaling current by using battery and ground at both ends of the loop, but with opposite polarities at each end. This technique doubles the signaling range, but also doubles the impulse noise.

Baud - Term used to define the operating speed of a printing telegraph or data circuit. Baud is equal to the length of the shortest element transmitted in seconds, divided into one second.

$$\frac{\text{1 second}}{\text{shortest element (seconds)}}$$

Bifurcated Contact - A single contact in a switch, relay or jack whose end is divided into two parts for better contact make ensurance.

Block (Terminal Block) - Set of terminals fixed in wood, hard rubber or plastic and mounted on a distributing frame. One side of the terminals is usually wired permanently to telephone equipment or cables and the other side is used for cross-connecting to other cables or equipment.

Bridged Ringing - Any system where all ringers on a line are connected across that line. To avoid shunting of the DC component, a capacitor is placed in series with each ringer.

Bridged Tap - Those pairs in a lateral cable which are spliced in parallel with pairs in the main feeder cable (see Multiple).

Buried Cable - Cable placed directly in the ground without benefit of a protective duct. Such cable will have a specially constructed sheath for waterproofing and special armor (steel tape, etc.) to protect from physical damage.

Busy Signal - (1) Audible and/or flashing signal, usually 60 impulses per minute (IPM), which indicates that the called number is unavailable, (2) a signal transmitted at 120 IPM which indicates that all voice paths are temporarily unavailable.

Cable Rack, Tray or Ladder - The frame used to support and route cables to and from equipment and distribution frames within a telephone office or communication facility.

Cable Vault - Usually a room under a telephone office where outside plant cables enter and are spliced to more flexible "tip" cables.

CAMA (Centralized Automatic Message Accounting) - An automatic message accounting system which is located at a central office, but which serves various adjacent central ofiices. Calls not processed by ANI (automatic number identification) must be routed through an operator who dials the calling number into the equipment.

Carrier Derived Circuit - A telephony circuit utilizing MUX for some portion of its path.

Carrier Signaling - Any of the signaling techniques used in multi-channel carrier transmission. The most commonly used techniques are in-band signaling, out-of-band signaling, and separate channel signaling.

Carrier Transmission or System (MUX) - A system for transmitting many voice, data, or teletype channels over a common telephone circuit.

CBX - Computer controlled automatic exchange (see PBX/PABX).

CCIS (Common Channel Interoffice Signaling) - A type of signaling system in which all of the signaling information, including supervision and address signals, for a number of interoffice trunks is encoded and transmitted over a separate signaling link by means of time division multiplexing.

CCS - Telephone traffic unit meaning hundred-second calls or the total traffic in seconds divided by 100.

CCSS (Common Channel Signaling System) - A two-way signaling system which, in telephone usage, carries 2-state signaling, such as E and M or dial pulsing, for 24 voice channels over a separate signaling link. CCSS should not be confused with CCIS, which utilizes data processors, TACs (Terminal Access Circuits) and other control circuitry not found in CCSS. The CCSS can also be used for low-rate (15 pps and lower) data transmission such as burglar alarms and supervisory and control systems.

CDF (Combined Distributing Frame) - A distribution point in a communications facility or TCO where outside plant cables, house cables and equipment cables are terminated and cross-connected to each other (see IDF and Main Frame).

Class of Office - The ranking of a telephone office assigned to a switching point in the DDD network determined by its switching function. Classes of offices are: Class 1 - Regional Center, Class 2 - Sectional Center, Class 3 - Primary Center, Class 4 - Toll Center and Class 5 - End Office.

Class of Service - The categorization of telephone subscribers according to specific type of telephone usage. Telephone service distinctions include, for example, rate differences between individual and party lines, flat rate and message rate, and restricted and extended area service.

Clear Count - The pairs in consecutive count of a telephone cable which are cleared of all services and bridged taps from the central office to some termination point. Often used to allow serving a building with a consecutive pair count in a cable.

Code Ringing - The selective alerting of telephone subscribers on multiparty lines by combinations of short and long rings.

Common Battery - A DC power source in the central office that supplies power to all subscriber stations and central office switching equipment.

Common-Battery Signaling - The method by which supervisory and telephone address information is sent to a central office by opening and closing the circuit at the telephone, i.e. depressing and releasing the switch on the cradle of the handset.

Common Control Office - Any of three types of central office - electronic, common control step-by-step, or crossbar. Any common control office receives dial pulses or dual tone multifrequency (DTMF) signals from calling subscribers, or dial pulses, revertive pulses, or multifrequency signals from other offices.

Compandor - Electronic circuit used in carrier systems to improve signal to noise ratio. The name is derived from the words compressor and expandor.

Composite signaling (CX) - A DC signaling system which requires a single line conductor for each signaling channel, and which provides full duplex operation. In this system, voice frequencies above 100 Hz are separated from the signaling currents by a filter network known as a composite set. Two composite signaling channels are derived from one pair of wires, and four from a phantom group. Composite signaling channels may also be used for DC telegraph or teletypewriter circuits.

Concentrator - A device used to time share a limited number of telephone pairs between two points among a larger number of subscribers or services. A typical use would be between a telephone answering service and a telephone central office.

CO Relay - In a subscriber's line circuit, the relay which operates on an incoming call to disconnect the equipment for making outgoing calls.

Counter EMF Cell (CEMF) - A cell or series of cells connected in series with a central office battery to reduce to voltage of the office battery (see End Cell).

Coupling Factor - The relationship between power line current flow and the induced voltage in a telephone line.

Cord Circuit - The term applied to a circuit that operates by means of a manual switchboard to make connections to subscriber lines and trunks. A three-conductor cord is used with designations of tip, ring, and sleeve used for the conductors.

Cross - Accidental contact between wires of different pairs as opposed to a short which is the accidental contact between wires of the same pair.

Crossbar Switching System - A method of switching which, when directed by a common control unit, will select and close a path through a matrix arrangement of switches.

Crosspoint - The operated contacts on a crossbar switch.

Crosstalk - Unwanted noise in a voice, data, or teletype circuit caused by cross-coupling from another circuit.

Cross-Connect - The wire or wires used to interconnect equipment and cables on a telephone distributing frame or in a telephone distribution box or terminal.

Cut Sheet - The wiring information furnished to an installer showing the block and terminal assignments for cross-connects or equipment terminations.

DATS - Dial automatic telephone system.

Decimonic Ringing - A type of party line selective ringing which uses ringing frequencies of 20 Hz, 30 Hz, 40 Hz, 50 Hz and 60 Hz.

Delay-Pulsing Signal (Delay Dial, Stop Dial) - An off-hook signal from the called end of a trunk, which is sent to the calling end of a trunk, to indicate that it is not ready to be pulsed.

DDD - Abbreviation for direct distance dialing. Subscriber dialing over the nationwide intertoll telephone network.

Delay Distortion - The distortion caused to a signal by delay as a function of frequency in transmission.

Delay Equalization - The correction of delay distortion by the addition of delay to certain frequencies or frequency bands in a transmitted signal. Usually added at the end of the transmission path. Can be detrimental to data circuits or television circuits, but not generally to voice circuits.

Dial-Normal Transmission Signal - A secondary dial tone which is returned to an operator to indicate that the rest of a number may be dialed.

Dial Off-Normal Tone (Dial Key Off Normal) - The tone that reminds an operator to restore the dial key after a call has been completed into a step-by-step office, and after the called party has answered.

Dial Pulsing - The transmission of telephone address information by the momentary opening and closing of a DC circuit a specified number of times, corresponding to the decimal digit which is dialed. This is usually accomplished - as with the ordinary telephone dial - by manual operation of a finger wheel.

Dial Speed - The measurement, in number of pulses, that a rotary dial can transfer in a given amount of time. The dial speed of a typical rotary dial is 10 pulses per second.

Dial Tone - A 90 Hz signal (the difference between 350 Hz and 440 Hz) sent to an operator or subscriber indicating that the receiving end is ready to receive dial pulses.

DID - Direct inward dialing with reference to a PABX. Refers to the capability to receive directly dialed calls from outside the PABX.

Digit - One of a successive series of pulses incoming from a dial to operate switching train.

Disconnect Signal - A signal (on-hook) from the calling and called subscribers, which notifies the operator or office switching equipment that the call is over and the connection should be released.

Divided Ringing - See ground return ringing.

Drop - Used commonly to denote the subscriber loop. Originates from an old manual switchboard term designating the method by which the operator was signaled by the subscriber.

Dry Circuit - A circuit over which voice signals are transmitted, and which carries no direct current.

DTMF (Dual Tone Multifrequency Signaling) - A method of signaling in which a combination of two frequencies out of a possible eight are used to transmit numerical address information. The eight possible frequencies are 697 Hz, 770 Hz, 852 Hz, 941 Hz, 1209 Hz, 1336 Hz, 1477 Hz, and 1633 Hz.

Duplex Signaling (DX) - A signaling system which occupies the same cable pair as the voice path, yet does not require filters. One duplex signaling section is confined to 5000 ohms of loop resistance, though several sections may be used in tandem.

Echo - The result of impedance mismatches and time delay in long telephone circuits.

Echo Return Loss - The difference, in dB, between the transmitted level of a signal and the level of the echo returned to the originating point.

E Lead - The receiving lead of a two-state signaling system commonly used in carrier systems (MUX) (see M Lead).

E and M Signaling - A signaling arrangement characterized by the use of separate paths for the signaling and the voice signals. The M lead (derived from "Mouth") transmits ground or battery to the distant end of the circuit, while incoming signals are received as either grounded or open condition on the E (derived from "Ear") lead.

End Cell - A cell or cells connected in series with a central office battery to boost the battery voltage when the regular battery voltage has fallen below a certain limit (see Counter EMF Cell).

End Office - The local central office at which subscriber lines and trunks are interconnected. It is designated a class 5 office in the DDD network.

ESS/ESO - Electronic switching system or switching office, referring to the generally all solid state telephone central offices.

E-Type Pulsing Signal - In PCI (panel call indicator) pulsing, the end of pulsing signal informs the distant end that all digits have been sent. This signal is required when (PCI) traffic is completed through a crossbar tandem.

Even Count Cable - A cable with a core made up of 25 pair units. It gains its name from the make-up of larger cables in even 50's and 100's pairs count (see Odd Count Cable).

Exchange Area - One or more central offices with associated plant and stations in a specified area, usually with a single rate charge.

FAX - Facsimile, a circuit or facility allowing the transmission of still pictures or printed matter over telephone circuits (not television). Usually transmitted at a slow scanning rate.

FDM - Frequency division multiplex - the transmission of two or more signals over a common path (cable, microwave, etc.) by using a different frequency band or carrier for each signal.

FDX - Full-duplex circuit allowing simultaneous transmission in two directions.

Float-Charging - The charging of a storage battery at about the same rate as it is being discharged.

Four-Wire Circuit - A telephone circuit in which two pairs are used, one for receive and one for transmit.

FSP (Frequency Shift Pulsing) - A signaling technique which uses a frequency shift between 1070 Hz and 1270 Hz. This type of signaling is used with narrow band systems, such as teletypewriter switching networks.

Full Duplex - Telegraph or signaling circuits arranged for transmission in both directions at the same time.

Full-Period Circuit - A telephone, teletype, data, etc. circuit dedicated to a user or users 24-hours a day. Usually installed between two or more fixed locations and not allowing access to other locations not included in the circuit.

FX - Foreign exchange circuit, a telephone number assigned in one exchange area, which when dialed by a subscriber in that exchange area, rings a switchboard or telephone in another exchange (and rate) area.

Go Signal (Start Dial) - A supervisory on-hook signal received by the calling end of a trunk after a stop signal has occurred. The go signal indicates that the called end is now ready to receive additional digits.

Ground-Return Ringing (Divided Ringing) - A party line system where ringers in a telephone circuit may be connected between one or both sides of the line and ground, with a capacitor placed in series with each ringer.

Group-Busy Tone (All Trunks Busy Tone) - A low audible tone on the sleeve of trunk jacks at cord switchboards indicating that all trunks are busy. An absence of this tone informs the operator that there is at least one idle trunk in a group.

Half-Duplex - A communications system in which information can be transmitted in either direction, but only in one direction at a time.

Harmonic Ringing - The technique of selectively signaling individual ringers on a party line using frequencies which are harmonics of fundamental frequencies. The fundamental frequencies used are 16-23 Hz and 25 Hz; the harmonics are 33-1/3 Hz, 50 Hz, and 66-2/3 Hz.

High-Low Signaling - Signaling in which a high resistance shunt indicates an on-hook condition, and a low resistance shunt an off-hook condition.

High Tone - A -17 dBm, 480 Hz information signal that may, for example, be used as a partial dial tone.

Homing - The operation of restoring telephone switch to normal position.

Hookswitch - Refers to the switch in the cradle of a telephone instrument.

House Cable - Cables normally serving small cable terminals in a building from a large distribution frame.

Howler - A device which may be manually or automatically connected to a subscriber line, emitting a high tone of varying loudness to gain the attention of the subscriber to the fact that his receiver is off-hook.

Hunting - The action of a selector moving from line terminal to line terminal until one is found to be idle.

Hybrid (Hybrid Coil) - A four winding repeating coil or transformer so wound that incoming and outgoing currents in a two wire path are separated and kept from interfering with each other.

IDF (Intermediate Distributing Frame) - A distribution point at which equipment cables and house cables from the main frame are terminated and cross-connected to each other (see CDF and Main Frame).

Idle Circuit Termination - An artificial load connected to a trunk or line in its idle condition to prevent singing.

In-Band Signaling - The transmission of signaling information via tones at some frequency or frequencies that lie within a carrier channel normally used for voice transmission.

Inside Plant - Generally refers to the portion of the telephone plant inside the telephone central office including switching equipment, distributing frames, line conditioning equipment, etc.

Intercept (also Intercepting) - The routing of a call placed to a disconnected, non-existent or unassigned number, to the operator.

Interoffice Trunk - The telephone channel between two central offices.

Intraoffice Trunk - The trunk connection within the same central office.

Jumper Wire - The wire used to cross-connect terminals on equipment, combined, intermediate or main frames.

Keypulsing Signal - The signal which indicates a circuit is ready for pulsing, in multifrequency and direct current keypulsing.

LAMA (Local Automatic Message Accounting) - A combination of automatic message accounting equipment and automatic number identification equipment in the same office. In such a system, a subscriber-dialed toll call can be automatically processed without operator assistance.

Leak and Loop Tests - Two tests designed to simulate the worst-case loop pulsing conditions in the exchange network. The tests are made at the central office switching equipment to assure that it will accurately respond to any pulsing signals generated by telephones connected to that exchange network.

Local Battery - A telephone circuit power source usually in the form of dry cells, and located at customer's end of the line.

Loop - The closed circuit that is formed by the subscriber's telephone and the cable pair and other conductors that make the connection to central office switching equipment.

Loop Pulsing - Signaling achieved by the repeated opening and closing of the loop at the originating end of the circuit. Rotary telephone dials are loop pulsing devices.

Loop Resistance - The ohmic resistance of conductors of a telephone pair measured by placing a short across one end of the pairs and measuring the total resistance between the conductors (see Loop Mile).

Loop Signaling Systems - Any of three types of signaling which transmit signaling information over the metallic loop formed by the trunk conductors and the terminating equipment bridges. Transmission of the loop signals may be accomplished by (1) opening and closing the DC path around the loop, (2) reversing the voltage polarity, or (3) varying the value of the equipment resistance.

Low-High Signaling - A variation of high-low signaling. The on-hook condition is indicated by a low resistance shunt and an off-hook condition shows high resistance.

Low-Tone - A 480 Hz plus 620 Hz tone at -24 dBm. The 140 Hz difference (620-480=140) frequency gives the tone its low-pitched sound. A low tone is used for line busy, reorder, and no-circuit tone signals that are reached by a subscriber.

Make Busy - The process of inhibiting calls to or from a station or subscriber line or a trunk usually for maintenance purposes.

Main Frame (MDF) - A distribution point for terminating outside plant cables and cross-connecting them to house cables for further distribution within a TCO or other communications facility (see CDF and IDF).

Metallic Circuit - A circuit which has DC continuity throughout.

M Lead - The sending or transmitting lead of a two-state signaling system commonly used in carrier systems (MUX) (see E Lead).

Multifrequency Pulsing - A method of transmitting address information (usually performed by an operator). The identity of each of the ten possible digits (0 to 9) plus the required supervisory functions is determined by a combination of two out of six possible frequencies.

Net Loss - The total loss of a circuit from end to end between two locations measured at 1000 Hz.

No Circuit (NC) Signal (Fast Busy Signal) - A low tone (140 Hz) which is interrupted at 120 impulses per minute (IPM), and which indicates that there is no circuit available.

Odd Count Cable - A cable with a core made up of "odd" numbers of pairs, such as 101, 202, 253, etc. (see Even Count Cable).

Off-Hook - Signaling and supervision term indicating, for example, that the handset on a telephone has been removed from the hookswitch. In toll trunk switching off-hook will indicate that the trunk is busy.

Office Code - The three digit prefix of a seven digit telephone number denoting the telephone central office location.

On-Hook - A signaling and supervision term denoting that the telephone handset is on the cradle or that a trunk is not busy.

Open-Circuit Signaling - Direct current signaling accomplished by opening and closing the telephone circuit. There is an absence of current flow when the circuit is in the idle condition.

OPX - Off-premises extension, referring to a station served by a PABX but not located within the building or area normally served by that PABX.

Out-of-Band Signaling - A method of signaling which uses a frequency that is within the passband of the transmission facility, but outside of a carrier channel normally used for voice transmission.

Outside Plant - Refers to the portion of the telephone system external from the telephone central office including cables, pole lines, duct systems, subscriber instruments, etc.

Panel Call Indicator (PCI) Pulsing - A DC pulsing system where information digits are each transmitted as a series of four marginal, polarized pulses, which are detected at the receiving end and registered on relays or switches at terminating offices. In manual offices, received digits, as registered on the relays at the terminating office, are displayed in front of the operator.

Partial Dial Tone - A high tone that notifies a calling party that he has not completed dialing within a specified period of time, or that not enough digits have been dialed.

PBX/PABX - Private branch exchange/private automatic branch exchange - small telephone exchange usually installed on a customer's premises and used for intracompany communications (see section on PBX/PABX's in this Bulletin, SYSTEMS ENGINEERING, Section A.2.k, for glossary of PABX features).

Percent Break - In dial pulse testing, it is the percentage of time the dial circuit stands open compared to the total time of the dialing signal.

Permanent - A subscriber line which is shorted or grounded (or has the receiver off-hook accidently) and thus shows a "permanent" signal at the switchboard or ties up the dial office equipment.

Physical Circuit - A two-wire or four-wire circuit utilizing only wire pairs, not utilizing MUX (see Metallic Circuit).

Polar Relay - A permanent-magnet core relay which is designed to operate only when current flows in a specified direction.

Polar Signal - A signal whose information is transmitted by means of directional currents.

Protector - Carbon block, heat coil, or gas module used to protect telephone equipment from high voltage or high current surges. Installed at the point a telephone cable enters a building or on a telephone central office main frame.

Pulsating Current - Current which varies in amplitude but does not change polarity.

Pulse Correction - The restoration in a dial pulse repeater of signaling pulses which have been distorted during transmission.

Pulse Link Repeaters - A telephone repeater which connects one E and M signaling circuit directly to another E and M signaling circuit.

Pulsing - The transmission of address information to a switching office by means of digital pulses. Pulsing methods include multifrequency, rotary dial, and revertive.

Pulsing Limits - The maximum amount of pulsing distortion that a central office can tolerate in the dial pulses generated by a customer's telephone, before the switching equipment begins to make errors.

R - Designates the ring side of the conductors of a telephone pair (see T).

Random Splice - A technique used in cable splicing whereby intermediate cables in a cable run are not spliced pair to pair in order, i.e. Pair 1 to Pair 1, Pair 2 to Pair 2, etc., but are spliced randomly. The cables at each end maintain the normal pair count, however.

Register - (1) A device capable of storing digital information. (2) The first unit in the assembly of common control equipment in an automatic central office. The register receives address information in the form of dial pulses or dual tone multifrequency (DTMF) signals, and stores it for possible conversion or translation. A register frequently operates in conjunction with a sender.

Repeat(ing) Coil - A transformer which may have numerous impedance ratios available to match a variety of telephone cable and equipment impedances.

Repeater - An amplifier; some repeaters may have separate amplifiers for each direction of transmission or a single amplifier which is switched from one direction to the other.

Reserve Power - See UPS.

Restriction of Message (Toll Diversion) - A telephone arrangement where outgoing calls from a private automatic branch exchange (PABX) must either be routed through an operator or are limited to specified trunk groups.

Retard Coil - Filter choke-audio, RF, or power.

Return Loss - The measure of the amount of transmitting current transferred to the receiver at the same location due to impedance mismatches.

Reverse-Battery Signaling - A type of loop signaling in which battery and ground are reversed on the tip and ring of the loop to give an "off-hook" signal when the called party answers.

Revertive Pulsing - Pulsing over a trunk in reverse direction. That is, from the terminating office instead of from the originating office. When the incoming office trunk is seized, it sends open or ground pulses to the office that originated the call. The originating office counts the pulses and opens the trunk when the correct number of pulses has been received.

Ring - The ring-shaped contact of a plug usually positioned between, but insulated from, the tip and sleeve. The audible alerting signal on a telephone line.

Ringback Tone - An interrupted low tone indicating that the called telephone is ringing. Now called audible ringing tone.

Ringdown - A type of signal that uses either a 135 Hz or 1000 Hz signal interrupted 20 times per second. The type of signaling employed in manual operation, as differentiated from DC signaling. Ringdown signaling utilizes continuous or pulsing AC signal transmitted over the line. The term ringdown originated in magneto telephone operation, where cranking the magneto of a subscriber set would ring its bell and cause a marker to fall "down" at the central switchboard. In ringdown signaling, a key is operated in a cord circuit to ring on a trunk. On intertoll trunks, ringers are used to transmit and receive the signals. While ringdown trunks are unsuitable for intertoll dialing, connection of dial trunks to ringdown trunk can be provided with operator intertoll dialing.

Ringer - The bell or other signaling device associated with or in a subscriber's telephone instrument.

Ringing Signal - Any AC or DC signal transmitted over a line or trunk for the purpose of alerting a party at the distant end of an incoming call. The signal may operate a visual or aural device.

Ring Trip - The circuitry required to disable the ringing signal when the called telephone is answered (placed in the off-hook condition).

Selective Ringing - A system designed with the capability of ringing only the desired subscriber's telephone on a multiparty line. Ringers tuned to one of five possible frequencies are used to achieve this effect.

Semi-Selective Ringing - A four-party line ringing arrangement in which each party hears his own ring plus one other (usually a one and two ring code). Two of the parties on the line are rung from the tip of the line to ground, and the remaining two are rung from the ring of the line to ground.

Sender - A unit which receives address information from a register or routing information from a translater, and then outpulses the proper routing digits to a trunk or to local equipment. Sender and register functions are often combined in a single unit.

Separate-Channel Signaling (a type of CCSS) - A carrier system signaling arrangement where the signaling for several channels is multiplexed on a single voice channel.

Shoe (Test Shoe) - A test connector used to replace the protector on a telephone main frame, allowing maintenance testing in both directions, either toward the cable pair or toward the equipment.

Signaling - The process by which a caller on the transmitting end of a line informs a particular party at the receiving end that a message is to be communicated. Signaling is also that supervisory information that lets the caller know that the called party is ready to talk, that his line is busy, or that he has hung up. Signaling also holds the voice path together while a conversation goes on.

Simplex Signaling (SX) - Signaling over a trunk circuit. Signaling information is sent over the circuit when a signal-transmitting relay at the calling end is energized. A signal-receiving relay at the called end provides the signaling information to the voice channel. Both relays are connected to the midpoints of repeating coils or retardation coils at each end of the circuit.

Single-Frequency Signaling - A method of signaling in which a single frequency tone, 2600 Hz for example, is placed on the voice path. The tone is on during the idle condition, pulsed during dialing, and off when the circuit is being used. (This condition is known as tone-on-when-idle.)

Sleeve (S) - (1) The third contacting part on a telephone plug - preceded in location by the tip and ring. (2) The sleeve wire is the third control wire of each telephone in an automatic switching office.

Speech-Simulated Signal - A signal made up of those components of a voice signal which will cause the false operation of tone-operated supervisory equipment.

SR Relay - Slow-release relay; a relay having a copper sleeve over one end of its core causing it to be slow in releasing.

Start-Dialing (Start Pulsing) Signal - The on-hook condition indicating that the receiving end is ready to receive pulsing information.

Station - Refers to the subscriber of a PABX.

Step-By-Step - (1) The process by which a call is progressively carried to the desired terminal under the direct control of subscriber-initiated pulses, or pulses from a sender. (2) Also refers to an electromechanical rotary switching system.

Subscriber Loop - Includes the entire subscriber service from equipment permanently assigned to the subscriber circuit in the TCO, i.e. line relay, etc., to the subscriber instrument including the cables pairs.

Subset - A subscriber's telephone apparatus.

Superimposed Ringing - A type of semi-selective ringing which uses a combination of AC and DC.

Supervisory Signal - A signal which indicates whether a circuit is in use. A signal which gives an indication of status or change of status in a telephone system. For example, a signal used to attract the attention of an operator.

Switching Office - A location where either toll or local telephone traffic is switched or connected from one line or circuit to another. Also called switching center.

Synchromonic Ringing - A type of party line selective ringing which uses ringing frequencies of 16 Hz, 30 Hz, 42 Hz, 54 Hz, and 66 Hz.

T - Designates the tip side of the conductors or a telephone pair (see R).

Talking Battery - The DC voltage supplied by the central office to the subscriber's loop to operate the carbon transmitter in the handset.

Talking Path - In a telephone circuit, the transmission path consisting of the tip and ring conductors.

TASI (Time Assignment Speech Interpolation) - Because audible speech on the average voice circuit is only present approximately 45% of the time, the efficiency of the expensive overseas channels can be improved if some of the remaining 55% of the time could be utilized. TASI switching equipment connects a party to an idle circuit while speech is taking place but disconnects the party when speech stops, so that a different party can use the same circuit. During periods of heavy traffic, TASI improves line efficiency from 45% to 75-80%.

TCO (CO) - Telephone central office.

TDM - Time division multiplex - the process of transmitting two or more signals over a common path by using different time intervals.

Telex - A nationwide and international teletypewriter service operated by various companies in the U.S. and other countries. In the U.S., quite often referred to also as TWX service although TWX is operated on a different basis.

THL - Trans-hybrid loss. The loss between the transmit and receive sides of a hybrid network.

Through Supervision - Total supervision of a toll call by the originating operator through any intermediate switching points to the called telephone.

Tie Cable - Designates a cable used to connect two distribution frames together within a communications facility or connecting two TCO's together. Tie cables do not normally have any multiples or bridge taps. They may carry various types of trunk circuits between switching centers.

Tie Line - A dedicated telephony circuit usually between two distantly separated offices of a company, often terminated on the company PABX to allow communication between individual stations at the two locations.

Time-Division Signaling - Signaling over a time division multiplex system in which all voice channels share a common signaling channel, with time division providing the separation between signaling channels.

Tip - The contacting part at the end of a telephone plug or the top spring of a jack. The conductors associated with these contacts.

Tip Cable - Flexible telephone cable spliced to outside plant cables in a splice pit or cable vault and used to extend the outside plant cables to the main or other distribution frame in the telephone central office.

Toll Trunk - A telephone trunk used normally for long distance circuits.

Tone Signaling - The transmission of supervisory, address, and alerting signals over a telephone circuit by means of voice frequency tones. Also used in "Touch Tone" dialing.

Trunk - (1) A communications channel connecting two switching centers or a switching center with an individual terminal. (2) A communications channel between two offices or between equipment within the same office. A trunk is used commonly for all calls of the same class that are generated between two terminals. (3) The different types of trunks, some of which can be classified as (a) direct trunk - interconnects two class five end offices, (b) toll-connecting trunk - connects a class five end office to any higher ranking toll office, (c) intertoll trunk - connects any class one through four toll switching office to any other class one through four office.

Trunk, Automatic - A trunk arranged to provide signaling automatically when connection is made to it.

Trunk, Cross-Office - A trunk used to tie different sections of an exchange together. More commonly called a "Cross-Office Link".

Trunk, Dial Repeating - A trunk arranged to repeat dial pulses generally by regeneration of the pulses.

Trunk, Exchange - A trunk used to connect two different exchanges; may be within the same TCO.

Trunk, Intercept - A trunk used to automatically route an incoming call to a disconnected, unassigned, or non-existent number to an operator or automatic announcement.

Trunk, Interoffice - A trunk connecting two End or Class 5 offices.

Trunk, Intertandem - A trunk connecting two tandem offices together.

Trunk, Intertoll - A trunk connecting two Toll Centers or a Toll Center with a higher class of office.

Trunk, Manual Tie - A tie trunk operated on a manual signaling basis either ringdown or automatic.

Trunk, Number Checking - A trunk arranged to allow an operator to verify the calling subscriber number.

Trunk, PBX Tie - A trunk used to connect two or more PBX/PABX's.

Trunk, Recording - A trunk from a local office to a toll office used only for communication between operators and not arranged for completion of toll connections.

Trunk, Tandem - A trunk used to connect an end office to a tandem office.

Trunk, Terminating - Any trunk which terminates within a TCO and is not used to perform additional switching functions to switch a circuit to another office.

Trunk, Test - A circuit which allows a testboard to connect to any line or trunk for maintenance purposes.

TTY - Common acronym for teletype or printing telegraph.

Turnover (Tip-Ring Reversal) - In cable splicing, the accidental splicing together of the tip to the ring and the ring to the tip of the same numbered pair when joining cables. The terminating of the tip and ring of a cable pair to the ring and tip (in that order) terminals on a piece of equipment or on a jack.

Two-State Signaling - Any signaling system which only transmits two states, such as "on hook" and "off hook", or "off" and "on". Such systems are often used for transmission of dial pulses or supervisory signals.

Underground Cable (also see Buried Cable) - Cables installed in ducts especially designed to hold telephone cables and not cables direct buried.

UPS - Uninterrupted power system - power system which takes overload with no interruption in service when the primary power system fails. Sometimes called No-Break Power which is a particular manufacturer's name for UPS they manufacture. UPS usually involves a large battery plant in telephone systems but can include electrically driven or internal combustion engine driven generator sets. Systems that allow a break in power, however slight, are not classified as UPS. Power may be supplied for only a short period of time or indefinitely until primary power is restored.

Varley Loop - Arrangement of the Wheatstone Bridge circuitry which gives, in one measurement, the difference in resistance between the two wires in a loop.

WATS - Wide area telephone service - allows customers to make an unlimited number of long distance calls within a certain region for a flat monthly rate or a measured monthly rate.

Wet Circuit - A circuit which carries direct current.

Wheatstone Bridge - A very accurate and very sensitive resistance measuring device used to make tests on telephone cables. The device is accurate and sensitive enough to make resistance measurements of a short on a telephone pair to allow locating the short to within fractions of a foot over distances of several thousand feet by comparing the measured resistance to tables indicating resistance per foot for the size conductors being measured.

Wink Operation - In wink operation, trunk equipment sends on-hook signals toward each end during the idle condition. When a connect signal is received, the called office requests a register or sender. However, the on-hook signal to the calling office remains until the register or sender is connected at the called office. At that time, the idle on-hook signal changes to off-hook. The register or sender retains the off-hook signal for not less than 140 milliseconds, then returns an on-hook signal to the calling end, indicating that it is ready to receive pulses from the calling office.

Wink Signal - A short interruption of current to a switchboard busy lamp to indicate that the circuit is busy. On key telephone sets, the wink signal indicates that a line is being held. It is also an indication of change of state between an on-hook and off-hook condition.

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# APPENDIX A

## ALPHABETICAL LISTING OF PABX/CBX FEATURES

Abbreviated Dialing - See Speed Calling.

Abbreviated Ringing - The station receives a shorter than normal ring signal.

Additional Directory Numbers - See Multiple Listed Directory Number Service.

Alarm Display - The attendant's console has indicators to show the status of the system. Usually two alarms are included, a minor alarm to alert the user of a malfunction in a part of the system and a major alarm to indicate the system will not work at all.

Alphanumeric Display for Attendant Console - A readout on the attendant's console gives the source of incoming calls. For example, an incoming WATS call could be labelled "WATS5" on the display, indicating that it is from the Band 5 WATS trunk group. This identification allows the attendant to easily handle calls for several listed number groups, with the response depending on the number called. This feature also allows Calling Number Display to Attendant and Class of Service Display to Attendant to be implemented.

Alternate Routing - See Route Advance.

Attendant Conference - The attendant can add inside and outside parties to a call until a limit, usually eight or ten parties, is reached. Any number of outside trunks can be included in the conference, as long as the limit to the total number of parties is not exceeded.

Attendant Console - Position(s) where incoming calls and inside requests for service are handled. The attendant may also complete outgoing calls for restricted stations. If the system is provided with Direct Inward Dialing, the volume of incoming calls to the attendant position may be so low that it is unnecessary, and calls to the main number can be handled by an ordinary set or group of sets equipped with call transfer.

Attendant Control of Trunk Group Access - Although stations in the system may ordinarily be able to gain access to a trunk group such as outgoing Band 5 WATS by dialing an access code, the attendant can instruct the system to direct calls for the trunk group to the console. This means that all outgoing calls on the trunk group must be completed by the attendant, giving greater control over the system. This feature is useful with measured WATS lines, which are uneconomical compared to Direct Dialing rates after 5 on a business day, since the operator can effectively shut the lines off at 5 PM. This feature is also useful if there are periods when a two-way trunk group should be reserved primarily for incoming traffic.

Attendant DSS with Busy Lamp Field - The attendant at a console can place or complete calls to stations within the PBX by depressing a nonlocking pushbutton associated with the desired station line. A light associated with the button shows whether the station is idle or busy. This allows the attendant to quickly inform a caller if the number wanted is busy, and the DSS may also allow faster call completion than dialing the inside number.

Attendant Recall - Calls which are held, camped-on or completed by the attendant are returned to the console if they are not answered within a preset period. The attendant can then reassure the caller that the call is not being ignored or can extend it to another number.

Attendant Transfer - All Calls - This is similar to the attendant transfer offered on older dial PBX systems. An inside party may get the attendant on the line to transfer a call by flashing the switchhook. Unlike the older systems, which would immediately ring the attendant, CBX's generally provide a second dial tone. At this point the inside party may transfer the call by dialing "0" to reach the attendant and instructing her or him to make the transfer. The caller could also dial the number of the station the call is to be transferred to when the second dial tone is given and effect the transfer without assistance. To the degree that users perform the transfer without help from the attendant, the operator load is reduced.

Audible Signal Control - The attendant and users can set the volume of signals such as tones and bells.

Automatic Call Distribution (ACD) - See Uniform Call Distribution.

Automatic Callback - Calling - A user calling a busy station line may arrange to have the system complete the call when the called line is idle. This is generally done by hanging up, entering a command code and then redialing the busy number. When the busy line becomes idle the system will first ring the originating station. When that station is picked up the previously busy station is rung.

Automatic Dialing - A custom key set button can be assigned to dial a user-set telephone number when pressed.

Automatic Identified Outward Dialing (AIOD) - This feature was first introduced with Centrex service, as was Direct Inward Dialing. AIOD automatically identifies which station placed each long distance (toll) call and reports the call detail monthly by station instead of having all long distance calls listed without station identification on the CBX's main bill, as is normally done with PBX service. This facilitates control and allocation of long distance calling expense by providing a detailed record for each station. The service has three main shortcomings: it only lists long distance calls placed over the exchange network, not over WATS, FX or other private lines; callers cannot enter a charge code to allow calls to be billed to different accounts; and there is an additional charge to get the information in machine readable form. Station Message Detail Recording (SMDR) service should be considered as a preferable alternate. There is a significant surcharge applied to trunks equipped for AIOD service, and a data line between the CBX and the Central Office must be installed for the transmission of the station identification information to the utility's billing equipment.

Automatic Preselection - See Line Preference.

Automatic Recall - See Attendant Recall.

Automatic Route Selection (ARS) - Provides access to automatic routing of outgoing calls over alternative facilities with optimization based on the DDD number dialed. The user dials an access code followed by the area code and number to be reached. The CBX routes the call over the first available special trunk facility (WATS, foreign exchange or CCSA), checking in a customer specified sequence. The CBX also does any translation necessary (dropping the area code if the call is to be routed over an FX line, for example). The system can also be arranged to route the call over the local PBX trunks if all the special lines are busy. If users are also restricted from making toll calls on the PBX trunks, ARS can be a powerful tool to maximize the savings from special service lines such as WATS without engaging in lengthy education sessions. ARS can also make rearrangements in special service lines transparent to users, increasing the responsiveness of the system to changes in demand patterns and rate structures. The Dimension ARS service has an optional update service, provided for a monthly rate, which updates the program to include new area codes and exchange codes introduced by the telephone operating companies. Some CBX ARS features may not accept the programming needed to route calls over private line facilities, including foreign exchange lines.

Bridged Call - Allows a station user to join a conversation by entering the proper command code, thus becoming an extension of another line.

Busy Lamp Field - As explained in the Attendant DSS feature, a lamp associated with each station shows the busy or idle status of the lines, without the attendant's having to dial them.

Busy Override or Intrude - See Busy Verification of Station Lines; Executive Override.

Busy Verification of Station Lines - Allows the attendant to confirm that a line is actually in use by establishing a "talking" connection to an apparently busy line. Prior to the attendant's connection the CBX applies a burst of tone to the line to alert the talking parties to the monitoring. The tone may be repeated periodically if the attendant remains in the connection. Idle lines are rung when the attendant attempts to verify them.

Call Distributor - See Uniform Call Distribution.

Call Forwarding - All Calls - The user may instruct the CBX to forward calls directed to his station to another number. The feature is usually activated by dialing an access code followed by the number to which calls are to be forwarded. For example, if station 125 is set up to have its calls forwarded to station 378, even though a caller dials 125 the CBX automatically completes the call to station 378. In Dimension systems, calls may only be directed to other stations in the system, although some other CBXs allow calls to be forwarded to points outside the system. The forwarding station may still be used for outgoing calls while the feature is activated. This feature has many uses. Someone who is frequently in another office may arrange to have calls to his office automatically forwarded to the office he is visiting, reducing the number of missed calls. In addition, telephones on the selling floor can be restricted from making outside calls to reduce unauthorized calling expense. A separate unrestricted number on the CBX can then be set to forward to a credit card verification service. Thus, when sales clerks need to verify a credit card, they simply dial the extension number of the unrestricted station, which automatically completes the call to the verification service. This arrangement provides the additional benefit of Speed Calling for the credit number. An organization with several locations can establish a form of foreign exchange service using call forwarding, where Division A is assigned an extension on Division B's CBX in a distant city. Calls to that extension on the Division B system are automatically forwarded over the most economical route to the Division A switchboard. Division A, without having to buy a dedicated foreign exchange line, is thus able to give its customers in the distant city a local number to call for service. This feature is even more useful when combined with Direct Department Calling, which allows a listed number trunk to automatically connect to the extension number on the B system. Since that number is set to forward, customers calling the listed number are automatically connected with the system A operator, bypassing the system B attendant and making the operation completely transparent.

Call Forwarding - Busy Line - Similar to the familiar Station Hunting or rotary service, calls directed to a busy line are routed to an alternative source. In this case, however, the station user can turn the feature on or off. Calls may be routed to the attendant.

Call Forwarding - Don't Answer - Unlike the busy line service described above, this option allows the system to direct calls to another destination if the original station is not answered within a set period of time. This can replace key systems in situations where a receptionist is provided with a key set to answer calls for a group of people when they are away from their desks. Call Pickup could also be used in such a situation.

Call Hold - A station user may "hold" any call in progress by flashing and then dialing a hold code. The line is then free for another call or can return to a previous call which was put on hold. Most CBX's allow only one call at a time to be held, with the user able to switch between calls. The held call usually cannot be combined with another call.

Many users have problems with this feature since most CBXs provide no visual indication of a held call, and it may thus become difficult to believe that the call was held and not lost. It is also possible to forget the held call and ignore it for a long period. Nonetheless, the feature clearly can replace key systems in locations with light to moderate traffic, particularly in combination with Call Waiting Service and Three-way Conference Transfer.

Call Park - A call may be transferred to a busy extension and camped-on or parked. The extension can then connect to the call when it is free.

Call Pickup - A station can answer any call directed to another station line within its preset pickup group by dialing a special code. This feature, or Call Forwarding - Don't Answer, can replace some key system functions by allowing a secretary with a single line set to answer calls for several people while they are away from their desks.

Call Status Indication - See Line Status Indication.

Call Transfer With Consultation Hold - See Three-way Conference Transfer.

Call Waiting Service - A call directed to a busy station line is "held" while a tone burst is directed to the busy station user. The station user may connect to this waiting call by hanging up and then being rung with the waiting call. Alternatively, the user may flash and put the first call on hold by dialing the hold code and then answer the waiting call. This feature also helps replace key systems by allowing a user with a single line set to handle more than one call at a time and not miss incoming calls because of a busy line.

Attendant Call Waiting - All calls extended by the attendant to a busy station are held waiting while a burst of tone is applied to the busy station when the attendant leaves the connection. If the waiting call is not answered and attendant returns to it to verify that the party still wants to wait, another burst of tone will be applied when the attendant again leaves the connection.

Originating - Provides the station user with the ability to direct a tone burst to a station which he is calling if he wishes to talk and the other station is busy.

Terminating - A user may have call waiting service for all calls directed to his station when the line is busy. Callers do not need to use the Call Waiting - Originating feature to activate the tone burst.

Calling Number Display to Attendant - Provides the attendant with the number of the inside station that has been connected either by dialing "0" or through interception. Some CBXs also display the restricted class of the station.

Calling Number Display to Station - Provides a called station with a display of the number of the calling station within the CBX. Although this feature generally requires additional equipment for implementation, it is useful in hotels and motels for room service answering positions or the front desk if the attendant's position is elsewhere.

Camp-on - Similar to Attendant Call Waiting. The operator may extend a call to a busy extension, putting the incoming call on hold while the busy extension receives a tone burst to indicate that a call is waiting. Most camp-on features provide for the automatic return of waiting calls to the attendant after a set period.

CBX Bypass Unit - See Power Failure Transfer.

CCSA Access - Provides inward and outward service between the CBX and the CCSA network, which is a company's network of private lines equipped with switching arrangements to allow more flexible service. Although the Dimension system will not allow CCSA trunks to tandem through the switch, or be completed without going through the attendant position, other CBXs do provide this capability. If a user has several locations with an extensive private line network connecting them, Automatic Route Selection and CBXs with the ability to tandem can provide economical long distance service without requiring an investment in additional switching equipment by allowing the CBXs to route long distance calls over their connecting private lines, passing through one or more machines before completion, if necessary.

Centralized Attendant Service (CAS) - A service introduced for retailers with several stores in a city and its suburbs. This feature allows a group of attendants at one location to answer and service calls for all the stores' telephone systems. This arrangement works on a switched loop principle, where the call, arriving on a trunk at location A, is extended through a tie line to the attendant at location B. The attendant responds to the call, and using a tie line acting as a data link between her console and the CBX at location B, instructs the machinery at that location to complete the call. When the attendant releases from the call, the tie line between A and B is freed to handle another call. This feature allows users to take advantage of the fact that one large facility can handle a given quantity of traffic better than several small ones. If the operators at the remote locations had not been fully loaded, the potential savings increase since it is easier to arrange efficient use of the attendants at the central location. Problems of training are also reduced with the arrangement. Users should consider the cost of the local, short-haul tie lines needed to provide the service, and their likely sharp increases, before making a decision in favor of CAS.

Circuit Group Busy Identification - See Trunk Group Busy Indication on Attendant Position.

Class of Service Display to Attendant - The attendant's position shows the class of service for operator calls from inside extensions. The class of service can show which trunks or lines the extension is restricted from accessing. This feature is useful in conjunction with Attendant Control of Trunk Group Access, since it quickly tells the attendant, when a trunk group has been restricted, which users should be allowed to complete their calls and which should be blocked when the calls to the restricted trunk group are directed to the console.

Code Calling Access - Station users dial an access number and then a code to have the CBX broadcast a series of chimes over the loudspeaker system. This reduces the operator workload by eliminating his or her intervention in the process and may replace additional wiring previously needed to provide the service, used primarily in retailing.

Code Restriction - Denies selected station lines completion of dialed outgoing exchange network calls to selected exchange and area codes, both local and distant. This feature can be used to provide a "partial restriction" where users are allowed to dial calls to exchanges where customers or suppliers are located while all other calls, which are probably not business related, are restricted and directed to either the attendant, a recording or an intercept tone. In a department store, for example, sets on the selling floor could be provided with Speed Calling to reach credit verification numbers, and Code Restriction could be used to cut off all other outside calls.

Com Line Service - An intercom-like service where a common-interest group of stations is defined. These stations can reach each other with single-digit speed dialing codes.

Common Audible Ringing - A station bell can ring to show incoming calls for two or more different lines.

Conference - See Attendant Conference; Loudspeaker Paging Access, Deluxe; Progressive Conference; Three-way Conference Transfer.

Controlled Restriction - This feature allows the attendant to control the restriction of stations or groups of stations. It is particularly useful in hotels and motels to shut off service to room phones during the time between the check out of one guest and the check in of the next.

Controlled Outward Restriction - The attendant can restrict stations from making dialed outgoing calls while inward calls are completed normally.

Controlled Station-to-Station Restriction - Although the restricted stations may receive incoming calls and complete outgoing network calls normally, originating station calls to other extensions in the system are blocked.

Controlled Termination Restriction - Restricted stations may complete outgoing calls normally, but incoming calls are directed to either the attendant or intercept tone.

Controlled Total Restriction - When activated, restricted lines are unable to make or receive any calls. If the system has Direct Inward Dialing, restricted calls may be routed to the attendant position and all others are connected to intercept tone.

Custom Intercom - A form of Speed Calling which permits a group of stations to have "intercom" service, with callers dialing two- or three-digit codes to ring other CBX extensions. This feature can replace the separate intercom line frequently provided with key systems. Most CBXs allow station users to set and reassign the codes.

Custom Key Set - A multi-button telephone designed expressly for a particular CBX. Unlike buttons on normal key telephones, which are pushed down to select a particular line, the buttons on a custom key set are used to communicate with the CBX. They are typically momentary contact, nonlocking buttons that do not stay down. Although the custom key set can be arranged to provide key telephone functions such as connecting the set with one of several lines and putting a line on hold, it has a greater potential because of its direct communication with the CBX's controller. Custom key set buttons can be arranged to activate CBX features such as Speed Dialing and Executive Override as well as to select lines. This ability makes it much easier for users to make the fullest possible use of the CBX since it eliminates the need for dial codes and hookswitch flashing.

Data Line Privacy - A user-controlled feature for critical lines which provides for the cancellation of many other features. Station lines used with such devices as facsimile machines and computer terminals are very sensitive to extraneous noise, and the CBX signals for Call Waiting, Executive Override and Busy Verification, for example, could cause severe data errors. Data Privacy cancels activities which would insert tones on the station line while it is in use. This feature allows data lines to be connected through the CBX without danger and reduces the number of WATS and other special service lines that must be dedicated to a separate data processing telephone network. The channeling of all voice and data communications traffic through one switch and network allows a more efficient and cost-effective system design.

Data Restriction - This is similar to Data Line Privacy except that the feature is permanently activated and not subject to the user's control.

Data Transmission - The CBX will accept PCM data streams as well as voice signals for switching and transmission. This increases the flexibility of the switch, allowing a user with a central computer and several remote terminals in the same building to provide dial-up service to connect the terminals with the computer without requiring the use of modems at both the computer and terminals. Most CBXs using time division switching will impose a limit on the rate at which data can be transmitted through their network by modems and facsimile machines.

Delayed Ringing - A second set on a line will not receive the ringing signal until the first set has not responded to a preset number of rings. This allows a semi-mechanical implementation of Call Forwarding - Don't Answer.

Dial Access to Attendant - Station users within the system or on dial type tie lines are allowed access to the operator. The digit 0 is customarily assigned for operator access.

Digital Clock - CBXs with Station Message Detail Recording include an internal clock to provide time-of-day information for that feature. Some systems also display the clock reading at the attendant's console.

Digitone - See Touch-Tone.

Dimension Custom Telephone Service (DCTS) - See Custom Key Set.

Direct Department Calling (DDC) - Inward calls on a certain trunk or group of trunks are routed to specific stations or groups of stations. For example, if the main number were 555-1000, a separate group of trunks starting with number 555-1500 could be assigned to the catalog order department. Calls received on the second trunk group would bypass the attendant and be directed to answering positions in the catalog department. If a few areas with large amounts of incoming traffic can be pinpointed, this feature offers a less expensive alternative to DID. Calls received over DDC lines still have access to the full range of CBX features and thus can be transferred to other stations or the attendant.

Direct Inward Dialing (DID) - Incoming calls from the exchange network (not foreign exchange or WATS lines) may be completed to specific station lines without attendant assistance. This service also involves special trunks provided by the telephone operating company which relay the called station number to the CBX. DID is an integral part of Centrex service and obviously offers a great potential for reducing the operator load in a system. Most DID trunk tariffs specify per-station elements applied in addition to normal trunk rates, so it may be most economical to provide DID only to stations with heavy incoming traffic. Another option is to provide some stations or areas with Direct Department Calling, which does not involve expensive special trunks.

Direct Outward Dialing - Allows a CBX station user to gain access to the exchange network without the assistance of the attendant by dialing an access code and receiving a second dial tone. Systems are typically arranged so that users can access exchange lines by dialing 9. It is easy to assign different access digits for different line groups, with WATS, for example having an access code of 6. Stations or groups of stations can also be restricted from dial access to all groups or any subset of groups to minimize unauthorized calling.

Direct Trunk Group Selection - The attendant can access an outgoing trunk from a particular group by pushing a single button associated with the group instead of dialing an access code.

Distinctive Dial Tones - Internal calls, external calls and internal calls placed with a caller on hold are provided with different dial tones.

Distinctive Ringing - Different ringing patterns distinguish calls from different sources. A call from the exchange network would have a different ringing pattern than an internal call would. This feature allows users to provide a better response to outside calls by distinguishing them.

Do Not Disturb - The user can instruct the system to cancel all ringing at the station.

Emergency Right of Way - See Executive Override.

Emergency Transfer - See Power Failure Transfer.

Executive Override - Allows a station user equipped with the feature to break into another station's connection. Before the break-in is established, a burst of tone advises the other parties that the conversation is going to be broken into.

Extendible Information Trunks - The attendant can connect callers who dial "0" to outside lines.

Flexible Numbering of Stations - Station numbers may be assigned to lines at the time of installation according to customer specifications and are easily changed thereafter. Some CBXs allow the user to perform the modifications while others require the attention of a service person. This feature takes advantage of the ease with which the CBX's program may be modified to associate different numbers with different telephone terminations, and it allows station numbers to correspond to room numbers or employees to keep a telephone number while being moved from one office to another.

Flexible Numbering of Stations - Mixed Numbering - In addition to the standard Flexible Numbering of Stations capability, provides for variance from one to four digits for extension numbers within the same installation.

Foreign Exchange Access (FX) - Provides access to foreign exchange line terminations in the same way trunk lines can be reached (see Direct Outward Dialing). Foreign exchange lines provide a customer with "local" service in a distant location. The user buys one or more exchange lines (trunks) in the distant exchange and the private line(s) to link the exchange lines with the system. Callers in the distant exchange may then dial the foreign exchange line number (a local call for them) and directly reach the user. Similarly, the user may place calls to points in the distant exchange over the foreign exchange (FX) line, and the calls are billed as originating in the foreign exchange. FX lines can provide significant savings if there is heavy traffic to some point which is not within the local, either flat rate or single message unit, calling area, largely replacing usage sensitive costs with flat monthly payments.

Four Wire Switching - Although normal telephone sets are connected with only two wires to carry the conversation in both directions, long distance transmission is generally done with four wires, one pair dedicated to each direction. Time division switching networks also work on a four-wire basis, although there are no physical wires dedicated to any particular connection. Since there is some degradation of signal quality when the four-wire transmission mode is converted to two wires, some CBXs allow the user to maintain almost all transmission and switching in the four-wire mode to provide higher quality connections.

Fully Restricted Station - Restricted stations may only make calls to other stations in the CBX. Attempts to reach outside trunks or other lines are routed to an intercept tone or recording or the attendant. This option can reduce billable calls made from a system by preventing stations with no need for discretionary calling from making cost-incurring calls. Restriction should be applied with judgment, since outward calls from a restricted station must be placed by the operator, and it is possible to overload the operator with legitimate outside call requests from restricted stations.

Handset/Headset Operation - Most consoles give the attendant the option of using a telephone type handset or a headset.

Handsfree Operation - A speakerphone is supplied as part of the station set.

Hold - Allows a station user to maintain a connection to a line while not offhook to the line. This is one of the basic features of key system service. CBXs have allowed the introduction of a new range of Hold features which are more easily implemented through their programmed intelligence than through mechanical arrangements.

Exclusive Hold - The key station which placed a call on Exclusive Hold receives a hold signal (winking light) while all other stations receive a line busy (steady light) indication for that line.

I-Hold - Provides a flutter signal indication for the line at the station which placed it on hold while all other stations receive a normal wink hold signal.

Priority Hold - Provides a priority signal at all appearances of a line placed on priority hold.

Hot-Line Service - Provides the capability for stations on the CBX system to automatically place a call to a preassigned number when the station user goes offhook. Hot-Line stations can receive calls in the normal manner. Hot-Line calls can be directed to stations, exchange trunks, CCSA trunks or internal miscellaneous trunks such as Loudspeaker Paging. This feature has many uses in situations where either a private line or an automatic dialer might have been used. Hot lines to a security position can be put in elevators or secured entrances, a set outside the loading dock can automatically dial the receiving office or sets can be arranged as "Courtesy Phones" in hotel lobbies. Since a Hot-Line phone does not need a dial, it can help prevent abuse of the CBX by outsiders.

Hunting - See Station Hunting.

Identified Outward Dialing - See Automatic Identified Outward Dialing.

Immediate Ring - A called line is rung immediately after it is found to be idle without waiting for the "active" portion of the regular ringing cycle. This feature, although provided as a normal part of CBX service, has little utility unless some machine placing calls within the system has an unusually short connection time and has its efficiency improved by spending less time waiting for called lines to ring and answer.

Incoming Call Identification (ICI) - Indicator Lamps - Allows an attendant at a switched loop console position to visually identify the type of service or trunk group associated with a call directed to that position. The visual indication can be provided via indicator lamps or the alphanumeric display feature. This option allows the attendant to tailor the response to the trunk group on which the call arrives. If two divisions of an organization have separate listed numbers but share a console(s), the attendant(s) can identify the objective of the call and respond accordingly.

Indicator Lamp - A light on each station is used to indicate ringing, call waiting, station busy and message waiting.

Intercept Treatment - Calls which cannot be completed, either due to system limitations or station restrictions, are routed either to the attendant, an audible signal or a recording. Different noncompletion conditions can be provided with different treatments.

Attendant Intercept - Calls which cannot be completed are routed to the attendant. Direct Inward Dialed calls which are intercepted in this way are charged as completed.

Intercept Recording - Calls to unassigned numbers can be routed to a recording indicating that there is no such number in the system.

Intercept Tone - A continuous tone indicates that either a restricted number of service or an unassigned number has been reached. Most CBXs use the Bell tone plan which specifies a tone alternating between 440 Hz and 620 Hz.

Intercom Line - Key systems are frequently provided with intercom lines that allow quick communication between stations on the key system. The CBX's capabilities can replace or enhance the familiar key system intercom functions on Custom Key Sets.

Automatic - When the station goes offhook on the intercom line, the CBX signals the predetermined station and establishes a connection when it also goes offhook. This is similar to Hot-Line Service.

Dialed - A CBX line is assigned as an "intercom" line and Speed Dialing is provided. When the user selects that line and dials one of the speed codes, another station on the intercom is signaled.

Manual - A predetermined telephone can be signaled by pressing an assigned button.

Interposition Calling - An attendant at one attendant position of a system with more than one console can call an attendant at another position for consultation.

Interposition Transfer - An attendant at one console can transfer a call to an attendant at another position. This is used where certain positions are assigned to handle certain classes of calls (such as conferences, WATS access or internal directory assistance). This feature also facilitates operator training by allowing the trainee to transfer difficult calls to more experienced attendants.

Inward Restriction - Prevents selected station lines from receiving incoming exchange network calls and CCSA calls, either DID or attendant completed. Calls can be given any intercept treatment.

Inward System Access - The attendant can connect incoming calls to special service trunks such as WATS lines as well as stations.

I-Use Indication - Provides a custom key set user with an indication of which line will be automatically connected with his set when it goes offhook without the user having to push a line selection button.

Last Extension Called - The CBX records the internal extension last called by a user and will redial it when signaled with a special code or button.

Least Cost Routing - See Automatic Route Selection.

Line Lockout - See Lockout.

Line Preference - On conventional key systems, the user selects the line to be used for receiving or placing calls by pressing the button associated with that line. The line buttons on a custom key set do not stay down and, instead of selecting a line, they signal the CBX, which actually connects the desired line. There are several ways to specify which line is to be connected when the user picks up the handset without requiring him to press a line selection button before going offhook. These features can prevent accidental disconnection of held lines and facilitate the user's work.

Idle Line Preference - Automatically connects the user to an idle line upon going offhook.

Incoming Call Preference - Automatically connects the station user to an incoming call. The incoming call need not ring at the station, although it must be defined as having an appearance at the station.

Last Line Preference - No line is automatically connected when the user goes offhook.

Prime Line Preference - Automatically reconnects the station user to the line designated as the prime line for that set when he goes offhook.

Ringing Line Preference - Automatically connects the user to a line which is ringing at the station. The first line to ring is given priority if two or more lines are ringing.

Line Ringing - Allows a multi-button telephone to receive ringing signals for incoming calls on specific lines.

Line Status Indication - Provides the user with a visual indication of line status--idle, busy, held or ringing.

Local Maintenance - A teletype or special console is used on the customer's premises to reprogram the CBX to change station features or numbers.

Lockout - The attendant and executive override capabilities are not allowed to operate on a station line, ensuring privacy.

Loudspeaker Paging Access - Allows attendant to have direct access and station users to have dial access to paging equipment. CBXs that use special sets with internal speakers may provide paging access to those speakers, eliminating the need for separate speaker systems in some cases.

Deluxe (Meet Me) - Allows the paged party to be connected to the paging party by dialing an answering code from any station with the CBX. When connected, the two parties are disconnected from the paging trunk, freeing it for reuse. Some systems also allow inside parties to connect with paged incoming calls this way. These features can reduce the attendant load by allowing station users to do their own paging. Restriction can be arranged to prevent abuse of the paging. The Deluxe, or Meet Me option, simplifies the paging process and increases the chances of success.

Manual Exclusion - A CBX station user, by entering a code, can prevent all other stations on that line from entering the call, assuring privacy on the line.

Manual Originating Line Service - Provides station lines that require the attendant to complete all outgoing calls. All nonattendant handled call attempts are given intercept treatment. This treatment can be used for lobby phones or some emergency telephones to minimize system abuse.

Manual Signaling - When a station user presses a button on his set, a tone is emitted at a predetermined station.

Manual Terminating Line Service - Provides station lines which require all terminating calls to be completed by the attendant. All nonattendant handled call attempts are given intercept treatment. This feature can be used on some patient phones in a hospital to prevent disturbance.

Meet Me Paging - See Loudspeaker Paging Access, Deluxe.

Miscellaneous Trunk Restriction - Selected station lines and dial tie lines may be denied access to trunk groups including WATS, CCSA, tie lines and auxiliary trunks. Restricted attempts are given intercept treatment.

Multiple Appearance Directory Number - A single telephone number can be assigned to several stations, in a similar manner to a main station and several extensions. The CBX allows several different implementations.

Multiple Call Arrangement - The telephones which share a listed number will all ring when the number is called, and any of them will be able to answer the call. If another call is directed to that number, any stations which are still onhook will again receive the ringing signal and will be able to answer. This will continue until all stations assigned to the number are offhook, at which time calls to that number will receive a busy signal. Similarly, any station can go offhook when there is no incoming call ringing and place an outgoing call regardless of whether the other stations on the line are onhook or offhook. This arrangement can be used to provide a simple form of automatic call distribution, with all order clerks assigned the same number and answering calls when they are able to.

Single Call Arrangement - This is similar to the familiar extension arrangement where only one set at a time can use the listed number. Any call directed to the number when the line is in use will receive a busy signal unless the line is equipped with Call Waiting.

Multiple Classes of Service - Features and restrictions are grouped into classes of service and stations are then assigned to a particular class which most closely meets the user's calling pattern and needs. For example, a clerk's telephone could be assigned to the class with outside restriction and access to very few features, while an executive telephone would be assigned to another class with unlimited calling privileges and a wide array of features. Most CBXs will support a large number of different classes, allowing them to be tailored to meet many different needs and circumstances.

Multiple Console Operation - The CBX will support more than one attendant's position to handle heavy traffic. Service demand is spread evenly among consoles in use.

Multiple Customer Group Operation - A CBX can be shared by several different companies, with separate consoles and trunks for each. Stations are assigned to one company or the other and are then able to reach only that company's trunks and attendants. This feature is of most value to telephone utilities, which can coordinate payments from separate customers sharing a switch more easily and thus take advantages of economies of scale. Centrex-type service for an airport, where different customers share a single building is one example of how the feature could be used.

Multiple Listed Directory Number Service - Provides for more than one listed directory number to be associated with a single CBX installation. Each listed number can be assigned a unique incoming call identification. (See Incoming Call Identification for uses).

Music on Hold Access - Provides access to music or other audible indication that the system is retaining the call to a held party.

Custom Station - The music on hold is activated only when a caller is put on hold by a Custom Key System station user.

System - Activation by Attendant Position Hold, Call Hold, Three-way Conference Transfer Hold or other feature's hold will access the feature.

Night Console Position - Provides an alternate attendant position which can be used at night in lieu of the regular attendant position to answer all calls directed to the attendant. This position provides all of the regular attendant functions.

Night Station Service - Fixed Service - Provides arrangements to route calls normally directed to the attendant to preselected station lines within the CBX system when regular attendant positions are not manned. In addition, calls to specific trunks can be arranged to terminate at specific station lines. The receiving station can then transfer the call if necessary.

Full Service - Provides arrangement to route calls normally directed to the attendant to preselected station lines within the CBX system when the regular attendant positions are set to night service. In addition calls to specific exchange trunks can be arranged to route to specific station lines. The routings can be assigned on a flexible basis by the attendant and remain in effect until changed. Trunk Answer From Any Station capability is provided for calls which are not handled by assigned night stations. All night stations have Three-way Conference Transfer capability for transferring calls to other stations and may also be equipped with Call Waiting Service for night calls.

Off-Premises Stations (OPX) - Using private lines, an extension station can be located away from the main CBX installation. A set of off-premises stations may serve a nearby branch operation, or one located in a distant office may provide better communication between the two sites. An OPX is economical if its installation will provide a reduction in long distance calling bills, local message unit usage, attendant workload or a great increase in convenience. Some users install an OPX at a customer's office to facilitate communication and possibly reduce calling expenses.

Onhook Dialing - A station user can dial a number and monitor the call's progress over the set's speaker, leaving the receiver onhook until the call goes through and conversation begins.

Originating Restriction - A station line with this restriction cannot be used to place calls at any time. Calls directed to the station will be completed normally.

Outgoing Trunk Queuing - Provides a means for stations to dial a busy outgoing trunk group, be automatically placed in a queue and then signaled when a trunk in the group is available. This feature allows more efficient use of expensive special lines such as WATS or FX facilities by giving users a way to cope with a low grade of service on these trunk groups. Instead of being forced to continually redial the trunk access code until a line is free, the caller may dial a special code to activate the feature and then the trunk access code, taking care of other affairs until a line is free. This feature can also reduce the operator workload in situations where operators currently handle special line requests and allocations.

Outward Restriction - Preselected station lines within the PBX are denied the ability to access the exchange network without the assistance of the attendant. Restricted calls are routed to intercept tone. This option can obviously reduce the usage expenses incurred from unauthorized calls by making it more difficult to place them.

Override - See Executive Override.

Paging - See Loudspeaker Paging Access.

Power Failure - There are several courses open to the CBX user attempting to cope with commercial power failures, ranging from setting up alternate power sources to arranging for the system to fail in a "graceful" manner. There is obviously no single correct choice and the higher cost of increased protection must be balanced against the expected frequency of failure, and its consequences.

Brownout Operation - Electrical utilities may lower their system voltage in response to heavy demand, leading to brownouts, where power is not lost but reduced. Although conventional PBX equipment is relatively immune to brownouts, the computer controlling the CBX is very sensitive to variations in its supply voltage, and the system is likely to fail under these conditions. Most CBXs are supplied with the capability to cope with these reductions, or a heavy-duty power supply can be furnished as an option. Unless an Uninterruptible Power Supply is to be installed, the CBX should be given the means to deal with brownouts.

Reserve Power - The CBX can be given a set of rechargeable batteries which will allow system operation for some length of time--15 minutes to 12 hours--after commercial power has failed. This term actually applies to two different provisions. In the basic case, the system has enough power to maintain the memory but is unable to supply talking voltage and ringing signals, leading to an interruption in service but allowing a fast recovery. A more adequate reserve power supply will enable the CBX to provide complete service during the failure or brownout.

Transfer - Once the CBX is unable to get enough power, this feature provides service to and/or from the exchange network for a limited number of prearranged stations at the customer location. This feature is not available with DID service. Users with interconnect CBXs should find out the characteristics of the utility-required and supplied trunk line connecting arrangements during power failure, since they may effectively cut off service if they also fail. If they do, which is usually the case, it is possible to have the utility install extension sets for some or all of the trunk lines at important locations. Similarly, the amplifiers and equalizers associated with private line and foreign exchange service will also stop working during a failure, cutting off those lines.

Uninterruptible Power Supply (UPS) - This is similar to the reserve power arrangement, featuring a bank of batteries which are continually charged from the electric utility power supply. As with Reserve Power, it also protects against brownouts. An inverter, drawing its power from the batteries, generates an extremely "well behaved" AC power signal for the equipment, which would include the CBX, private line terminating equipment and connecting arrangements, if required. The UPS cost is related to the amount of power it is to supply and the length of time it must operate during a failure. If a particularly heavy demand is anticipated, the system can be coupled with an auxiliary generator which is started when commercial power is interrupted.

Privacy and Lockout - Privacy automatically splits the connection whenever an attendant would otherwise be included on a call with more than one person. When privacy is provided, the attendant lockout feature is also supplied. This produces a tone warning when the attendant bridges into a conversation in progress.

Privacy and Privacy Release - All other extensions of a line are unable to enter a conversation in progress on that line unless the initiating station releases the feature. This reserves the confidentiality of conversations and reduces interruptions.

Private Call - See Data Privacy.

Private Central Office Line - See Direct Department Calling.

Private Line Service - An outside exchange line, independent of the CBX, can be set up to appear on one of the buttons of a key telephone. This feature offers the greatest amount of privacy available in a business telephone system and also provides the user with service in case the switching system fails. Since the line is not connected through the CBX, none of the system's features are available, although the key system will generally offer the hold capability.

Progressive Conference - As part of the Attendant Conference feature, parties can be added and sometimes dropped from the conference while it is in progress.

Recall Dial Tone - A stutter, interrupted, dial tone which indicates to a station user that he has successfully used the hookswitch flash to gain access to service features. Training should emphasize the difference between this dial tone and a normal dial tone to minimize user frustration.

Recorded Announcement Intercept - See Intercept Treatment.

Recorded Telephone Dictation - Permits station users to dial connections to telephone dictation equipment. The dictation equipment termination is usually treated as a trunk connection by the installation. This easy access to dictation facilities can improve the efficiency of office word processing centers and reduce the investment in dictation recording equipment distributed to individual offices. The effectiveness of the feature is enhanced if easy access is granted to office personnel calling from outside the system through Remote Access to CBX Service.

Release with Howler - If a station stays offhook without originating a call (or the receiver is accidentally knocked off) the system transmits a loud tone over the line and then "disconnects" it, ignoring it until it goes onhook again.

Remote Access to CBX Service - Allows a user outside the CBX to access the CBX services via an exchange network connection. The user dials a preestablished trunk number to connect to the CBX and then dials an authorized code. All signaling is done using touch-tone, and the attendant may change the authorization code. Since several connections are involved in providing this service, transmission quality may suffer, although additional amplifiers may be installed. This feature offers two advantages. When there is no attendant on duty, users outside the system may still place calls to extensions within the system or gain access to special trunks (WATS, FX or tie lines). Even when the attendant is present, calls placed over these trunks will reduce the attendant's workload while providing the caller with faster call completion. The easily changed password offers some measure of security, especially if it is changed on a regular basis, although the CBX user is still liable for all calls placed using the feature.

Remote Maintenance - A service person can dial the CBX and be connected, usually through the attendant, to the control computer to test or modify the program. There is an element of danger in this feature since unauthorized people could inactivate the system with this capability.

Remote Service Order Administration - See Remote Maintenance.

Remote Traffic Measurement - Traffic and feature usage data can be read from the system by a distant service person.

Reserve Power - See Power Failure.

Restriction - See Inward Restriction, Originating Restriction, Outward Restriction, Toll Restriction.

Ring Again - The CBX remembers the last number called by a station and will redial it when the feature is activated, saving the user's time.

Ringing Transfer - Only certain bells in a group of stations may be set to ring for incoming calls. Ringing transfer allows a second set of bells to be designated, with the user controlling which set is to ring. This allows more effective night service, since the daytime pattern can be limited to include only receptionists while the night set could be more extensive, reaching employees staying after hours.

Rotary Dial Calling - Most CBXs will still accept dialing from conventional rotary dial sets, although touch-tone sets offer faster calling and greater reliability.

Rotary Output to Central Office - Most CBXs are equipped to provide touch-tone service in all areas. In cases where the Central Office trunks are not designed to accept touch-tone signaling, the CBX will translate the number entered by a station in touch-tones into rotary dial pulses which can be handled by the exchange trunks. This feature can also be used to avoid the touch-tone service surcharges imposed on Central Office lines, but that is inefficient since a greater proportion of the trunk's time is then occupied in receiving the signaling and this may lead to increased trunking requirements.

Route Advance - A different version of Automatic Route Selection which allows the caller to select the first-choice trunk group. If that group is busy, the system will attempt to place the call over alternate trunk groups. Unlike ARS, translation is not provided. If a user selects a Band 2 WATS line to place a call, for example, the system may find all Band 2 lines busy and attempt completion over Band 5 and then DDD facilities. The equipment could not remove the area code from the dialed number in order to place the call over an FX line. If ARS is available, there is no reason to specify Route Advance.

Route Optimization - See Automatic Route Selection.

Secretarial Intercept - Call Forwarding - All Calls or Line Busy can be provided to executives' telephones with the calls forwarded to a secretary/receptionist who can take messages. If the secretarial set is equipped with Three-way Conference Transfer, it can also be used to screen incoming calls. This arrangement eliminates the need for a key system.

Self-Test and Fault Isolation - Most CBXs include a processor-check capability that allows the controlling computer to test itself and the rest of the CBX. If a fault is found, an alarm light is lit and a message is printed on the system teletype, if one is provided. This feature also expedites service since the computer can pinpoint faulty equipment saving diagnostic time.

Serial Call - Allows the attendant to set up a call so that it is returned to the attendant position after the extension it was connected to hangs up. This lets the attendant easily connect a caller with a series of inside extensions without the risk of losing the call. It is usually more efficient to have the extension users transfer the call using the Three-way Conference Transfer, reducing the attendant's workload.

Single Digit Dialing - Provides for single digit dialing to reach a preselected group of stations. An accelerated version of Speed Calling, it also helps reduce the need for key systems by replacing the intercom function. If some of the codes coincide with the first digit in the full station numbers, the system will not complete the call until a fixed period of time has elapsed, reducing the usefulness of the feature.

SL-1 Station Set - See Custom Key Set.

Special Dial Tone - See Distinctive Dial Tone.

Speed Calling - Station users can dial two or three-digit codes to reach frequently called PBX stations or outside telephone numbers (some CBXs limit the number of digits which can be stored with Speed Calling and cannot handle International Direct Dialed calls). Station lines have individual lists which they can change, and group and system lists may also be provided. This feature replaces ancillary equipment such as automatic dialers, and more important, facilitates system use by people such as sales clerks who must frequently dial credit verification services and other numbers, accelerating the process and reducing misdialing. Guest rooms can also have one- or two-digit codes to reach hotel or motel services.

Splitting - One-Way Auto-Manual - Allows an attendant to consult privately with one party on a call without the other party's hearing.

Standby Central Control - A second control computer, capable of directing CBX operations if the primary one fails, can be provided, increasing system reliability.

Station Busy Indication - One custom key system station can be provided with a visual indication of whether or not a second station is onhook. This helps an answering position know whether to forward a call to an idle set or take a message if the set is busy without dialing the number.

Station Direct Station Selection - A station user can dial other stations by pressing a button corresponding to them on the set. This button activates a speed calling routine on the CBX to establish the connection. This feature probably does not offer a significant improvement over one- or two-digit speed calling.

Station DTMF-to-Rotary Conversion - See Rotary Output to Central Office.

Station Hunting - Routes a call to an idle station line in a prearranged group when the called station line is busy. Although this feature obviously enhances the efficiency of high-traffic line groups by ensuring that all calls will be answered as long as there is an idle line, it should not be confused with Call Distributor services. Station hunting places the heaviest incoming call load on the first lines in a group while Call Distributor services spread the calls evenly over the serving lines.

Circular Hunting - The hunt starts with the called station line and proceeds in a prearranged order to test all lines in the group once, completing the call to the first idle line found.

Terminal - Similar to conventional line hunting services, the hunt always starts with the called station line and ends with the last station line in the prearranged group, with the call being completed to the first idle station line found. Unless the first station line in the group is called, only a portion of the group is tested.

Station Message Detail Recording (SMDR) - Provides a record of the CBX station (or attendant) number, starting time, duration and the trunk group used for outgoing and/or incoming calls. The system cannot tell when an outgoing call is answered, so call timing usually begins several seconds after dialing is completed. This means that the system may record busy signals and unanswered calls as billable completed calls. The CBX will record the number dialed as well, and most systems will also allow the caller to enter an account or billing code into the call record. This is one of the most powerful money-saving features of the CBX. If the data is output in a machine readable form (magnetic tape or punched paper tape), the user's data processing system can produce several reports which will give excellent control over cost-causing toll and message unit calling. The calling records of individual stations can be analyzed, long distance calling expenses can be billed back to individual departments without the expense and inconvenience of operator ticketing, system traffic can be analyzed to find the most efficient configuration of trunks and WATS lines and the operating company's bill can be verified. Users considering the installation of a CBX system primarily to take advantage of this feature should also consider add-on systems which offer similar features. Some organizations offer a service which provides both SMDR and ARS through peripheral equipment, allowing their customers to enjoy most of the money-saving features of a CBX without the large expense of a system installation.

Station Message Registers - Message unit information is centrally recorded on a per-station line basis for each completed outgoing local call made by the station user. This feature is aimed at the hotel/motel user, replacing the mechanical registers still used by many systems with either an electronic or printed output. Most systems provide for surcharges on station usage, and automatically reset the counter after readout.

Station Message Waiting - A "message waiting" light on a station can be activated by either a button on another station or by a dialed code to the CBX. This feature can alert hotel/motel guests to messages waiting at the front desk, or office workers to messages taken while they were out. Some systems provide for a repeating abbreviated ring as a signal of a waiting message instead of the more familiar light.

Station Ringer Cutoff - Allows the audible signaling device at a station to be cut off by a control on the station.

Station-to-Station Calling - The station user can directly dial other stations within the same system without the assistance of the attendant.

Straightforward Outward Completion - Allows the attendant to place an outgoing call for a station user, either by dialing "0" or by an intercept arrangement, without requiring the station user to hang up and redial the operator.

Stutter Dial Tone - See Recall Dial Tone.

System Access, Outgoing Calls - The CBX allows users access to such features as three-way conference and transfer on both incoming and outgoing calls, unlike many crossbar and step-by-step switches, which limit these features to incoming calls.

System Alarm Indication - See Alarm Display.

TADS - See Station Message Detail Recording.

Tandem Tie Trunk Switching - The CBX will allow the lines to "tandem" through the switch. This means that an incoming tie line call from a distant PBX receives a dial tone instead of automatically connecting with the operator. The caller can then dial a connection with either a station on the CBX or an outgoing line. The outgoing line can be a local trunk, in which case the distant PBX has access to a form of foreign exchange service, or another tie line which links a third system. This system of tie lines can form a corporate communications system, allowing economical connections between distant offices. In order to provide this tie line tandeming ability the CBX must be able to detect when either tie line goes onhook at the distant end so that it can break its tandem connection and allow the tie lines to be used for other calls.

Three-way Conference Transfer - By flashing while on any two-party call, a station user can effect a three-way conference or transfer. After flashing, the station user receives an interrupted dial tone and then dials the third party for private consultation while the second party is held in a waiting state. By flashing a second time, a three-way conference is established as the first party is taken off hold and joins the conversation. The user can then transfer the original call by hanging up on the call. Where both calls are on outside lines, and the system is unable to verify the outside party's disconnection, the conference and transfer are ended when the user goes onhook. Finally, the user can drop the second call from the conference by using a hookswitch flash. This feature, introduced in Centrex II, has an obvious potential for reducing the operator workload by allowing users to perform their own call transfers. Experience has shown that users are slower to grasp the advantages offered by three-way calls, which eliminate the need for call-backs in many instances. This feature is also helpful in reducing key system use as calls to a principal can be directed to a receptionist's set. When the call has been screened, the receptionist flashes and then dials the principal's number, possibly using a Speed Calling code of one or two digits. When the principal has answered, the receptionist announces the call, then flashes and hangs up to effect the transfer. This technique requires only one-line instruments for all parties.

Through Dialing - At the discretion of the attendant, station users can complete dialing after the attendant selects the trunk facility on attendant-handled outgoing calls. This is a two-edged feature. On one hand it can reduce the attendant's load by allowing restricted users to dial their own calls. On the other hand, especially without Station

Message Detail Recording, it releases control over calling use of the system's trunks. Any station which consistently uses the feature should have some of its restrictions lifted.

Tie Trunk Access - Allows the system to handle tie lines. Callers can access these lines either by dialing a trunk group access code or through the attendant. Tie lines can link a CBX with another CBX or a distant key system. The user pays a flat monthly fee for the lines, which can be a cheaper way of handling heavy traffic to a distant point than exchange network or WATS calling. If the distant point is arranged to allow the tie line to place network calls, the service can also provide many of the advantages of a foreign exchange line to the distant point.

Time Recall - The CBX can be instructed to place a call at a designated time. When the time comes, the CBX rings the station. When the station answers, the call is placed.

Timed Recall on Outgoing Calls - Allows outgoing trunk calls to be automatically transferred to the attendant after a timed interval. A warning note is sent to the calling party several seconds before the transfer takes place. This feature is mainly useful for limiting excessive use of expensive special service lines such as WATS or FX. Station Message Detail Recording reports outlining extraordinarily long calls may be a more effective deterrent.

Timed Reminders - See Attendant Recall.

Toll Restriction - A limited form of Code Restriction which permits station users to access the local Central Office and to dial local service area calls but prevents completion of toll calls to the toll operator without the assistance of the attendant. The feature can be implemented on a line-by-line basis in some CBXs, allowing some classes to have unlimited access while giving others the restricted service. There are two bases of operation:

Battery Reversal - In some Central Offices the switching equipment reverses the voltage on the trunk line to signal a toll call. When the CBX senses this reversal, it cuts off the call, routing it to the intercept service.

0/1 - Another form of restriction where the CBX checks the dialed digits looking for calls including the toll access code or "0" as the first number dialed on a trunk group. The CBX may be programmed to allow calls to some area codes while intercepting all other long distance calls placed by the restricted stations.

Toll Terminal Access - A hotel/motel feature which allows guest telephones to use a single digit code to access a trunk connecting the system to a toll operator.

Tone Ringing - Different tones replace bells and buzzers on incoming calls.

Touch-Tone Calling - Most CBXs are designed to accept touch-tone dialing using the Bell System standard frequencies. Many systems, including Dimension, require additional equipment to perform the touch-tone translation.

Touch-Tone-to-Dial Pulse Conversion - See Rotary Output to Central Office.

Traffic and Feature Usage Table - Some CBXs can record internal traffic and facilities usage data. This information is useful in checking on the level of service furnished by the system. A count of busy hour completions, for example, can show whether additional WATS lines or local trunks are needed if either record a large number of busy signals.

Traffic Measurement - See Traffic and Feature Usage Table.

Translation - As part of the Automatic Route Selection or with Trunk-to-Trunk Connections, the CBX can add or delete area codes and toll access digits from numbers so that the call will be handled properly by the switching network. For example, if a long distance call is diverted from a WATS line to a foreign exchange line, the CBX would drop the area code from the number before dialing it on the FX line.

Trunk Answer from Any Station - When the system is set for night service, incoming calls which would normally be handled by the attendant activate an alerting signal if the system is not set up to handle them on night stations. Any station user may then answer the calls by dialing a special access code.

Trunk Code Access - See Trunk Verification by Customer.

Trunk Group Busy Indication on Attendant Position - A light associated with a trunk group is activated when all lines in the group are busy. This allows the attendant to easily monitor the status of the system and its lines.

Trunk Group Warning Indication on Attendant Position - Provides the attendant with a visual indication when a certain number of trunks in a trunk group are busy.

Trunk Reservation - The attendant can hold a single trunk in a group and then extend it to a specific station. This means, for example, that a WATS line can be held for a heavy caller. This technique is generally less efficient than allowing contention for the WATS lines with high priority callers able to overflow to the exchange trunks.

Trunk-to-Trunk Connections - The system can extend an incoming or outgoing call from one trunk to another. Most CBXs provide this capability with Central Office, WATS, FX, CCSA and tie lines. If the system can detect a distant party disconnection and then break its connection, the attendant does not need to monitor the connection. Otherwise it must be checked periodically and released when no longer in use.

Trunk Verification by Customer - Provides the attendant or station user with access to individual lines in a trunk group to check their condition.

Uniform Call Distribution - Unlike Station Hunting services, which always start at a base number of a service group and thus give it the heaviest load of incoming calls, Uniform Call Distribution spreads the calls coming in on a group of lines to the assigned stations as smoothly as possible, so all stations handle relatively similar loads. Most call distribution systems also provide for a queuing of incoming calls with the incoming call with the longest holding time presented for service first. This feature is useful in areas with heavy incoming traffic such as ordering departments and reservations centers. The CBX is particularly valuable since its own program can provide the service, replacing the ancillary equipment which is frequently used.

Universal Forward and Do-not-Disturb Cancellation - The attendant can cancel on a system-wide basis Call Forwarding and other features activated by individual stations in order to reach specific stations.

Voice Calling - See Loudspeaker Paging Access.

Voice Paging - See Loudspeaker Paging Access.

WATS Access - The system can accept direct connection of WATS lines, which are treated as either incoming or outgoing trunks. Most systems allow station restrictions to be tailored to restrict dial access to these lines to only selected groups of users, forcing others to go through the attendant.



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# International System of Units

In December 1975, Congress passed the "Metric Conversion Act of 1975." This Act declares it to be the policy of the United States to plan and coordinate the use of the metric system.

The metric system, designated as the International System of Units (SI), is presently used by most countries of the world. The system is a modern version of the meter, kilogram, second, ampere (MKSA) system which has been in use for years in various parts of the world.

To promote greater familiarization of the metric system in anticipation of the U.S. converting to the system, REA is including metric units in its publications. This bulletin has, therefore, been prepared with the International System of Units (SI) obtained from ANSI Z 210-1976 - Metric Practice. Approximately equivalent Customary Units are also included to permit ease in reading and usage, and to provide a comparison between the two systems.