Introduction to Basic Data Communications

GENERAL ELECTRIC

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TO
BASIC DATA COMMUNICATIONS

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CONTENTS

EXECUTIVE SUMMARY

The purpose of this publication is to introduce the subject of data communications. It contains basic descriptive information on data communications equipment, the procedures involved in its use, and a presentation of some of the actual and potential values to the user. A glossary of data communications terminology is included as an Appendix for easy reference.

Modern business methods have created needs for faster and more efficient methods of information processing to control such things as inventory and production. Management has turned to electronic data processing and data communications techniques for satisfying these needs. The application of these data processing and data communications techniques to most types of business is a significant step towards effective planning, and control.

The design, engineering, and operation of a data processing system presents a myriad of problems. Selecting the design of a network operation, the communications facilities to be used, and the necessary hardware should be left to the communications specialist and the data processing specialist.

This manual is not designed to assist you in solving problems in data communications. It is designed to bring you sufficient information on data communications to orient you sufficiently to approach the subject with some degree of insight.

INTRODUCTION

The development, improvement, and refinement of electronics equipment has made possible the conversion of information to the machine language of electronics for data processing at a rate close to the phenomenally high rate of speed of electricity passing through a wire.

The computer, as we know it today, is a significant aid in attaining timely and efficient business action and decision. The primary value of a computer lies in its ability to digest large volumes of information, perform logical operations on the data, and make decisions based upon established criteria.

This ability, plus the pressure of competition in the area of customer service, has stimulated a desire on management's part to expand operations further by real-time processing of data from many remote facilities such as factories, warehouses, sales offices, and distribution centers. This desire has been fulfilled with the advent of economical data communications systems.

Data communications enables data processing centers to receive and transmit data and information. This makes possible central files, controls, et cetera, with resulting economies.

HISTORICAL DEVELOPMENT

In its general application, the term "communications" means a conveying of information from place to place or from person to person by speech, letters, telephone, telegraph, radio, television, or other medium.

The history of communications can be divided into three phases: (1) the period of origin and growth, up to the invention of the telegraph; (2) the period of early development of the telegraph, telephone, and radio, circa 1914 through 1940; and finally (3) the period of rapid expansion immediately following World War II to the present.

PRE-TELEGRAPH

During the late 1700's Claude Chappe devised a system of visual telegraphy employing semaphore platforms. This system was successfully used by European armies in military communications. Comparable developments were going on at sea while elementary methods of communication were being devised on land. Signaling between vessels through the use of flags, lights, or the movement of a sail were developed as codes. These codes were based upon the position and number of lights, flags, sails, and cannon firings.

Sir William Penn and Admiral Richard Kempenfelt are both credited with developing a regular code and plan of signal flags similar to that still in use today by naval forces.

TELEGRAPH, TELEPHONE, AND RADIO

In 1558 della Porta's suggestion of a "sympathetic telegraph" awaited only the discovery in 1745 of the Leyden jar by Pieter van Musschenbroek. It was demonstrated that the charge from a Leyden jar could be transmitted over a wire conductor. Also at this time Benjamin Franklin disclosed the results of his investigation of electricity.

The real development of communications began with the invention of the telegraph by Samuel F. B. Morse.

Morse completed drafts of his invention in 1832 but it was not until 1836 that he completed one that would work and one that the modern telegraph is substantially modeled upon. The famous message "What hath God wrought!" was transmitted on May 24, 1844, over a telegraph line strung from Annapolis Junction, Maryland, to Washington, D.C. The first telegram, however, had been sent three weeks earlier to Morse by Alfred Vail, flashing the news of the nomination of Henry Clay for President.

The Morse code of dots and dashes was soon adopted to augment the various means of signaling. Telegraph circuits in various parts of the world today still use the basic principle of the original Morse system. Assigning a short code to frequently used letters such as "E" and a long code to infrequently used letters such as "V," signals are transmitted as long and short pulses of current, separated by intervals of no current. The short and long pulses are called dots and dashes. The dot is a very short signal with a duration on a telegraph key of about 1/24th of a second. The dashes are about 1/8th of a second long.

In 1667 the term telephone was used to describe a device invented by Robert Hooke. This device transmitted soundwaves produced in a diaphragm along a string to a similar diaphragm which reproduced the sound. The term was also used to describe other apparatus for conveying sound to a distant point and was applied in 1796 to a megaphone.

Alexander Graham Bell, who patented, on March 7, 1876, the first telephone of practical use, is among the pioneer contributors to the field of communications.

Devices employing electric currents to reproduce the pitch of musical sound over a distance were called telephones; nowadays the name is assigned to apparatus reproducing speech through the medium of electric waves. The entire art and practice of electrical speech transmission including the many systems, accessories, and operating methods used for this purpose is termed "telephony."

The first telephones were extremely crude devices. The problems of transmitting speech over substantial distances were not completely understood. Only far-reaching developments on many fronts have brought telephony to its present state of perfection. Progressive improvement of telephone instruments as to quality and loudness of speech was one phase. Telephone lines and repeater circuits that could transmit speech currents over long distances without impairment or interference were other necessary developments.

Telephone circuits are furnished principally by wire lines. These lines comprise a network of wires interconnecting individual telephone stations, central offices, and communities. Wire lines are either cable or open-wire. The usual type of cable consists of insulated copper wires, twisted together, and covered with a protecting sheath. Open-wire lines consist of bare wires, generally made of copper, fastened to insulators and supported on poles. The first open-wire telephone line was used in 1885 between Boston, Massachusetts, and New York City.

Another development essential was switching mechanisms, whereby any two telephone instruments in a system could be connected together. It was the switchboard which made telephones commercially feasible.

Near the close of the 1800's progress in wireless communication led to the development of radio. In 1887 Heinrich Hertz of Germany demonstrated the production and reception of radio waves. His receiver consisted of a open wire loop with spheres attached to the ends to form a gap. The presence of waves was detected by observing a spark set up in the gap between the spheres. Hertz was interested only in studying the properties of the waves and it remained for Oliver Lodge of England to develop a system of wireless communication in 1894.

The inventor of a system for communicating intelligence without the use of connecting wires between sending and receiving points was Guglielmo Marconi. His famous Patent No. 7777 for "Improvements In Apparatus For Wireless Telegraphy" enabled several stations to operate on different wave lengths. In 1901 Marconi succeeded in receiving signals transmitted from England to Newfoundland. This achievement was the starting point in the development of radio communications, broadcasting, and navigation services.

The first known radio program in the United States was broadcast from Brant Rock, Massachusetts, on December 24, 1906. Other early experiments in broadcasting include those of Lee DeForest, who conducted a successful demonstration from the Eiffel Tower in 1908 and the General Electric station in Schenectady, New York - one of the first commercial stations.

From 1919 on, amateur telegraph experimentors began using radio more and more in preference to metallic wire telegraphy until finally radio broadcasting, intended for general public reception, came into being on November 2, 1920 when Station KDKA in Pittsburgh broadcast the returns of the Harding-Cox presidential elections.

Soon after broadcasting became established it was discovered that short wave lengths (radio energy with a short wave length) could be received over longer distances than that with a long wavelength. Short-wave radio communication was developed not only for program broadcasting but also for intercontinental radio, telegraph, and telephone services linkage.

Of outstanding importance in the field of communications is the simultaneous or network broadcast. This involves a system of interconnected telephone lines or radio links by which a studio or other place of performance is linked to a wide geographic listening area.

The first use of wire telephone lines for interconnecting stations took place in 1922 for a simultaneous broadcast of a football game. Interconnected stations in New York City and in Chicago set the pattern which, some 25 years later, was also used to interconnect networks for television reception.

The growth of radio broadcasting following World War I brought into existence a greatly increased interest in communications engineering and the expansion of communications industry manufacturing facilities.

WORLD WAR II TO THE PRESENT

Signal communications is the outstanding development of World War II. This embodies improvements in photography, television, radar, and relay sets.

High-powered mobile radio sets were designed, enabling communications to be conducted at distances of more than 100 miles even with vehicles in motion.

A system of relaying telegraph information reproduced on perforated tape was devised in addition to a system of message relay centers, so that remote stations could forward messages through the major centers. In this way, retransmission could be effected in a minimum of time by transferring the perforated tape message from the receiving to the transmitting stations.

Successful radar systems were developed, though pioneering dates back to 1887 and Hertz's work on electromagnetic waves. Radar (RAdio Detection And Ranging) is an electronic device which can detect and measure the distance to objects of a certain sort. Radio waves sent out from the transmitter are reflected by objects within range. A fraction of the outgoing energy returns as an echo to the radar receiver and forms a vivid representation of the object which caused the echo. At the same time, an extremely precise range measurement is made for each of the objects it detects.

Around 1950 the number of facets of communications increased. Two major additions were television and electronic equipment such as computers.

The word "television" has come to mean the instantaneous transmission of moving scenes and pictures. It is distinguished from the telescope in which a scene is viewed from a distance and from facsimile, which is the electrical transmission and reproduction of still pictures.

Data communications is the transmission of information between specific business machines. For example, data processing equipment takes information and performs a set routine of processing, presenting the information in measurable form. Present-day communications equipment has been designed with an eye toward interrelating data communications and data processing devices. The integration of data processing machines with modern communications provides flexibility, accuracy, and high speed of transmission as well as a central location for the accumulation of data.

To utilize high speed processing devices effectively, current information must be gathered and forwarded rapidly and accurately to the processing center. The rapid and orderly accumulation and transmission of information requires the design and establishment of responsive and compatible communications systems. These systems will provide for the establishment of information channels permitting centralized processing. By integrating data processing machines with effective communication facilities, information from widespread geographic areas can be recognized, separated, analyzed, and acted upon utilizing a central facility.

The integration of a computer with communication facilities demands transmission accuracy. In a data communications system the communications line is the prime source of error. The mind can reconstruct a mutilated word or character, but a mechanical processing unit cannot; in using a computer, data to be transmitted should be carefully prepared. It should be noted, however, that this careful preparation of data is even more important for a computer than for a Teletype machine.

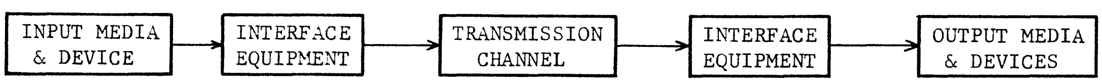
Several types of data communication systems are currently available, making possible speedy, accurate transmission of information received from one location and duplicated at another. Although the various systems configurations are basically similar, the size, scope, and versatility of any one system will naturally dependon the requirements and desires of the user. Systems have been developed for operation within the walls of a building, within a city, or over nationwide networks. Most organizations with business facilities in more than one geographic location can benefit from a data communication system.

PRESENT-DAY EQUIPMENT

The purpose of a communication system is to transfer information from one location to another. Various means of communicating from one point to another exist today as part of our nation's common and private carrier wire lines, cables, cable carriers, radio, and microwave facilities that carry the bulk of the nation's communications. Basically a communication system consists of two ends or terminals linked together on the same transmission channel. In such a system the transmission channel might be a pair of wires and the terminals a pair of Teletype terminals.

Today, almost all of the data transmission devices create, or can be adapted to, a medium which can be used as direct input to a computer. One such device transmits information from punched cards and recreates the card at the receiving end. Another machine permits perforated tape-to-perforated tape transmission, while yet another utilizes magnetic tape at both ends of the circuit.

The basic flow of data in most transmission systems may be illustrated as follows:



INPUT/OUTPUT MEDIA AND DEVICES

The input medium for a data communication system is information which has been converted to machine-usable form. Conversely, the output medium may be described as information converted to human- or machine-readable form. The cornerstone of integrated information flow has been the acceptance and success of the common media concept, i.e., paper tape, punch cards, etc.

Input/Output media in use today include:

Input	Output
Punched cards	Punched cards
Perforated tape	Perforated tape
Magnetic tape	Magnetic tape
Keystrokes	Printed Documents ("hard copy")
Computer controller	Computer controller
Combinations of the media above	Combinations of the media above

Media may be transmitted either in serial form or in parallel form. These two different modes place different requirements on transmission media. Speeds of data transmission devices are limited first by the internal design of the device and then by the type of circuit over which they are designed to operate.

Input/output devices are machines which are located at the ends of communication facilities and either generate information for transmission to other machines or receive information from other machines. These devices are designed to handle specific types of media. Depending on the number and types of circuits (telephone, teletype, etc.) employed, speeds of from 6 to 90,000 characters per second or greater are possible. General Electric's DATANET-60, for example, operates at $\leq$ 165,000 characters per second.

Speed of operation is an important consideration in the selection of a communication system, since it dictates the capability of the communication channel required. Data transmission systems can be divided into three groups by transmission speed and are further defined within each group by types of input/output media:

1. Low speed (5 to 20 characters per second)

    a. Punched card to punched card
    b. Perforated tape to perforated tape
    c. Keystrokes to printed characters
    d. Punched card, perforated tape, and keystrokes to computer
    e. Computer to punched card, perforated tape, and printed characters

2. Medium speed (20 to 300 characters per second)

    a. Punched card to punched card
    b. Computer to computer
    c. Magnetic tape to magnetic tape
    d. Perforated tape to perforated tape
    e. Punched cards, perforated tape, and magnetic tape to computer
    f. Computer to punched cards, perforated tape, magnetic tape, and printed copy

3. High speed (300 characters per second and higher)

   a. Computer to computer
   b. Magnetic tape to magnetic tape

It can be said that data communications is the function of machine talking to machine in machine language. In order to allow this, equipment such as computer controllers, providing a specific input/output mode of operation to permit a particular computer to communicate with various terminals or network configurations, is necessary. Controllers usually provide a means of communicating with such units as Teletype units, printers, input/output typewriters, card terminals, perforated tape terminals, magnetic tape terminals, sensing devices, and other peripherals.

A computer controller unit usually operates in an unattended mode to allow either random or pre-programmed two-way communication with the network or channel to which it is connected. Operating as a scanner it sequentially polls circuits for incoming traffic and distributes outgoing traffic.

TRANSMISSION CHANNELS

The transmission channel* plays a dominant part in the design of any data communication system. Although there are many types available, for any specific case there is usually one which can be used most economically.

For the reliable reception or intelligible transmittal of a voice conversation, it is necessary to reproduce a minimum frequency range of between 300 and 3300 cycles per second. The "standard voice channel" is a 3-kilocycle (3000-cycle-per-second) wide circuit for carrying the human voice. A "wide band" or "broad band" channel is one with a bandwidth greater than that of the standard voice channel.

In data transmission, the rate of transmission, stated in bits per second, is related to the bandwidth of the circuit. As a rule of thumb, the maximum bit rate is usually half the bandwidth, expressed in cycles per second. The number of bits per cycle is determined by the efficiency of the digital subset** and quality of the line. For most dialed channels in the public voice networks, 1200 bits per second for a 3-kilocycle channel are available; with private lines and more efficient subsets, 2400 bits per second are available.

Standard telegraph circuits use a transmission rate of 60, 75, or 110 bits per second. When higher rates are needed, special wide band channels or voice quality lines are available.

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*The terms "channel" and "circuit" are used interchangeably and are synonomous in this text.
**See Glossary for definition.

Originally, all transmission used metallic wire, one channel requiring two wires, or a cable pair. Local telephone and telegraph circuits continue to use this form of circuit, since it is the least expensive for heavy traffic over short distances. In long distance transmission, microwave radio is widely replacing the cable. By frequency multiplexing - that is, stacking several channels on a single cable or band - one microwave beam can carry several thousand telephone and/or telegraph circuits merely by assigning the individual circuit its separate frequency slot within a radio band.

Microwave radio operates at very high radio frequencies. It may be focused and beamed and will travel in a straight line of sight.

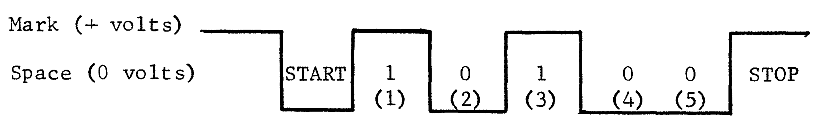
The following table summarizes the comparative transmission rates of the communication circuits to be discussed on the following pages:

Circuit Type	Bandwidth	Bits Per Second	Equivalent Number of Voice Channels
Telegraph	150cps	≤ 75	1/12
Telephone(voice)	3 to 4 kc	≤ 75 - 1200 - 2400	1
Wide band	48 to 1024 kc	≤ 2400 - 40,000 - 90,000	12 to 240

Telegraph Transmission

The fundamental requirement for telegraph transmission is a source of direct current controlled in such a way as to produce the code to be transmitted. This d-c power source sends sufficient voltage through a circuit to operate a device at the other end. When using telegraph transmission, the message to be sent is broken down into a series of codes. There are many different coding systems in use today; the one most widely used is the 5-level code - that is the code combination for each character is made up of five bits. These bits are either marking bits or spacing bits. A marking bit is the presence of d-c voltage for a length of time. A spacing bit is the absence of the d-c voltage for the same amount of time.

As an example, the code combination for the letter "S" is 10100. When transmitted, the character would look like this:



When no characters are being transmitted, the line is marking - that is, there is a positive d-c voltage potential between the two wires of the telegraph line. As a character is generated by a business machine and transmitted on this line, the bits of the character are placed on the line one bit at a time. Each bit of the character exists on the line for the same amount of time. This interval is known as "bit time" and is determined by the speed of the transmitting terminal.

The foregoing example shows a serially transmitted (one bit at a time) character five bits long. These five bits are preceded by a 'start bit' one bit long. This 'start bit' was generated by the business machine that produced the character. Its function is to alert the receiving terminal that a character is following it on the line. This alert allows the receiving terminal to prepare for the data bits to follow. Because of the start bit being a space, the receiving terminal can detect the presence of a character by the change in voltage from a positive potential to zero voltage.

The information bits of the character being transmitted follow the start bit. In Teletype transmission, there may be 5, 6, 7 or 8 bits per character, depending on the code and type of remote terminal device used. The 1-bits of the code are represented by a mark, the 0-bits by a space.

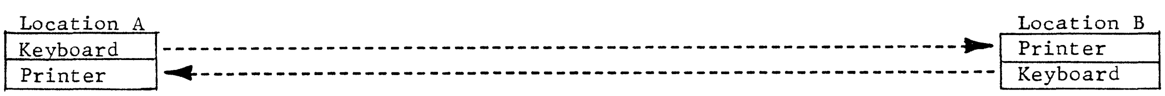
These data bits are accumulated by the receiving terminal until the entire character has been received.

The receiving terminal is then free, depending on its characteristics, to punch the character into paper tape, print it on paper, send it to a computer, etc.

After the last data bit has been transmitted, the transmitting terminal returns the line to the marking state for at least 1 1/2 bit times before the next character is transmitted. This is the stop bit, which gives the receiving terminal time to utilize the character just received and to reset its mechanism prior to receiving the next character. Note that the 1 1/2 bit time for the stop bit is a minimum figure. The stop bit may be any length in distance between characters but never less than 1 1/2 bit times.

In telegraph transmission, synchronization between the transmitter and receiver must be maintained. Synchronization is the means for indicating the beginning and the end of a character; the start and stop bits are used for this purpose.

The use of the start and stop bits to maintain synchronization is best explained by considering the operation of a Teletype keyboard-printer:



In the example above, one operator at Location A is manually typing a message which is printed at Location B. Each time the operator depresses a key on the keyboard, a character is generated and transmitted to Location B, and printed. The operator will be typing at a discontinuous rate; that is, there will be a variable distance between characters. If the operator types at the maximum rate allowed by the Teletype keyboard-printer, the stop bit will be the minimum of 1 1/2 bit times. The longer the distance between keystrokes, the longer the corresponding stop bit. Regardless of the length of the stop bit, each character is preceded by a start bit which signals the presence of a new character.

This mode of transmission using start and stop bits is called "serial asynchronous" transmission and is most commonly used by keyboard-printer and perforated tape reader-punch remote terminals.

The speed of transmission in characters per second is determined by the mechanical limitations of the remote terminals. An example of this is a perforated tape reader-punch, which, at full speed, is capable of transmitting 10 characters per second. At this speed, each character will have the minimum stop bit of 1.5 bit times. Each character will have one start bit, 5, 6, 7, or 8 information or control bits, and 1.5 or 2 stop bits. (Most 5-level codes use 1.5 stop bits, 8-level codes 2 stop bits.) For a 5-level code, each character will have 7.5 bits; for an 8-level code, each character will have 11 bits. Six- and 7-level codes will have an intermediate number of bits per character.

If the minimum number of bits per character is multiplied by the maximum speed in characters per second, the result is the transmission speed for that terminal in bits per second, as shown in the following example:

	5-Level Code	8-Level Code
Start Bits	1	1
Data Bits	5	8
Stop Bits	1.5	2
	7.5	11
Character/Sec	x 10	10
Bits/Sec	75	110

In telegraph transmission, the speed of transmission is determined primarily by the remote terminal; however, the Teletype circuit must obviously have sufficient bandwidth to handle the transmitted character. Most Teletype circuits in use today have sufficient bandwidth to handle transmissions at 75 bits per second, the limitation being in the electromechanical line-switching circuits presently in use. A recent offering by the common carriers provides private line services capable of transmitting 110 bits per second.

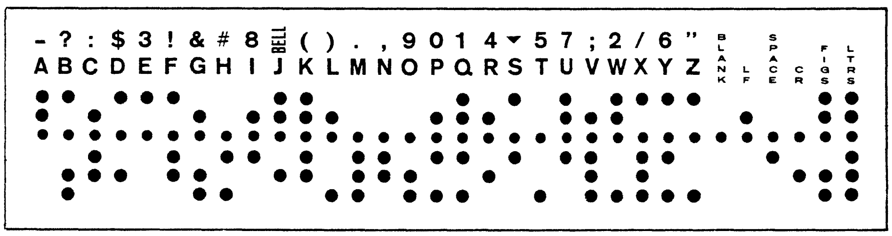
Another common measure of transmission speed is "words per minute." In Teletype communications a "word" is defined as 5 characters plus a space and is derived from the fact that the average word length in a telegram is 6 characters. If the transmission speed in characters per second is multiplied by 60 seconds a minute and divided by 6 characters per word, the result is in words per minute. As a rule of thumb, multiply characters per second by 10 to obtain words per minute.

Teletype speeds in common use today are 60, 75, and 100 words per minute - 6, 7.5, or 10 characters per second.

An alternate term for "words per minute" is "speed." Thus "60 speed" means 60 words per minute, "100 speed" is 100 words per minute, etc.

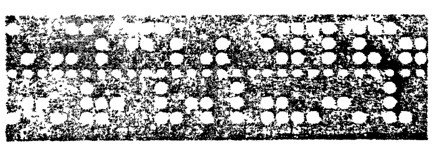
Basic Teletype transmission employs 5-level (5 bits per character) perforated tape, though it can use any number of bits. Historically the 5-level Baudot Code was used almost exclusively up to 1962.

The 5-level code allows a total of 32 code combinations as shown below. Twenty-six codes are used for the alphabet and 6 codes for machine functions. Of the six, 2 are Letters and Figures shift codes and are similar to the upper and lower case shift on a typewriter. All alphabetic data is preceded by a Letters shift code, while numbers and special characters are preceded by a Figures shift code. Once a Letters or Figures code has been transmitted, all succeeding characters are interpreted in that mode until the opposite code has been received.

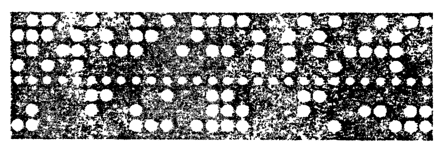


In addition to the 5-level (or channel) tape, perforated tape is also available in 6, 7, or 8-level codes (see the following figures). Tapes may vary in width, from 11/16 inch for 5-level and up to 1 inch wide for 8-level.

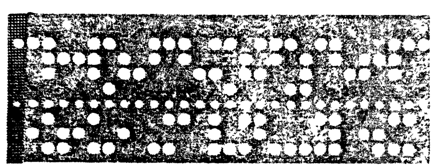
The 5-level tape differs from 6-, 7-, and 8-level tape in that certain letters and figures have the same code. This necessitates the introduction of the two functional codes, Letters and Figures, to make the needed distinction.



6-level tape

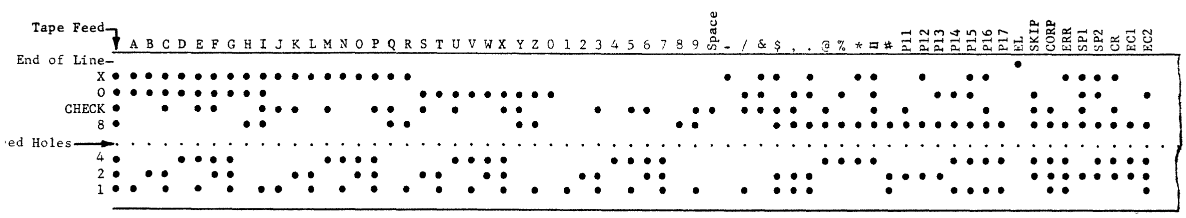


7-level tape



8-level tape

The 5-level code has limitations, especially in the area of error checking. Because of this the other codes, particularly the 8-level code, are gaining in prominence for use in data transmission. The main advantage of using the 8-level code (shown below) is the control of errors that may arise in transmission. Another is that upper and lower case characters need not be designated.



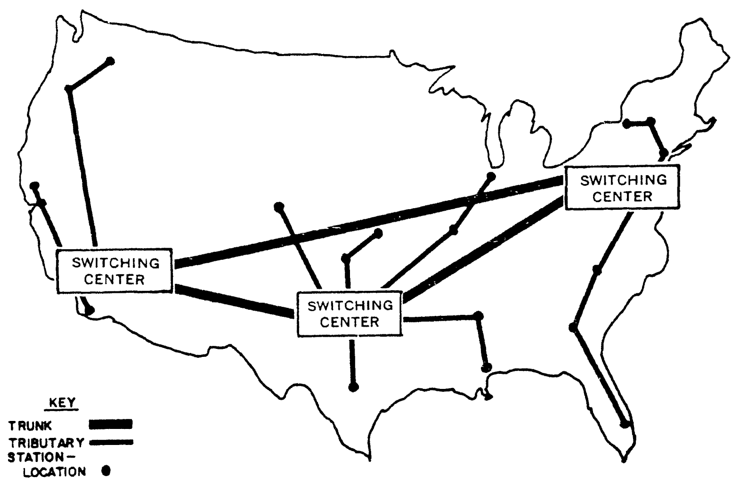
8-level code

In each column of the tape, it is possible to record either by punching a hole or leaving the column blank. In the figure above, a hole punched only in the 1 position of a vertical row on the tape represents the character 1, a hole punched only in the 2 position a 2, et cetera. Thus, combinations of punches equal varying numbers and alphabetics.

In common carrier transmission services, terminal ends are called subscriber stations. These are made up of Teletypewriters (keyboard printers) whose transmitters are capable of sending codes. The transmitter is operated by a keyboard which resembles that of an ordinary typewriter. The receiver is composed of a selector magnet and a number of levers and cams which transfer the incoming pulses to a printer mechanism. In essence the system represents a motor-powered typewriter that is controlled either remotely or by its own keyboard.

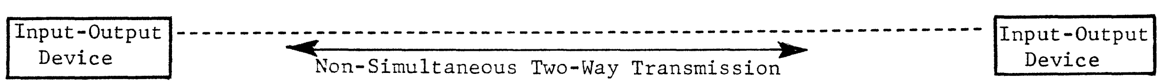
Both Western Union and the telephone companies offer private use of Teletypewriter lines and terminal devices. Circuits utilized for the transmission of data rate their capacity in bits per second (bauds). Available speeds of 60, 75, and 100 words per minute are, respectively, 45, 56, and 75 bits per second. The average number of characters per word (including a space) is 6. This is the equivalent of 360, 450, and 600 characters per minute for the three types of circuits, or 6, 7 1/2, and 10 characters per second. These lines may be leased for either 24 hours per day, 7 days a week, or for only a certain number of hours per day, subject to Federal regulations.

Telegraph network users can send a message to one another without having a direct connection. The sending station sends a message to a switching center where it is recorded on some form of temporary storage medium. The initial portion of the stored message contains the call signal (or code number) of the called station. This call signal is used in the switching center for setting selectors to the outlet on which the line of the called user terminates. As soon as the line becomes available, the waiting message is transmitted from storage to the station for which it is intended. The map below illustrates the switching center concept. Switching centers have a prominent place in networks and are discussed in detail later.

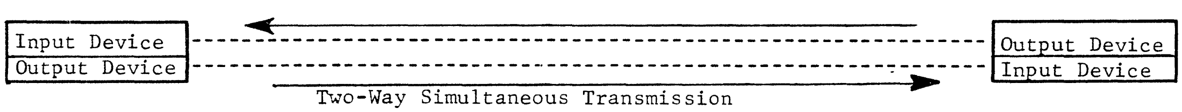


Circuits are the connecting links between users; a trunk circuit is the connection between switching centers; a tributary circuit connects the individual station to a switching center. When more than two stations share a circuit on a party-line basis, the circuit is known as a way-operated circuit or a multipoint line. The volume of traffic each station contributes governs the number of stations on a way circuit. For example, the maximum theoretical capacity of a single 75-word-per-minute circuit for an 8-hour day is 36,000 words, or 216,000 characters. The sum of the traffic from all the stations on the circuit cannot exceed this limit.

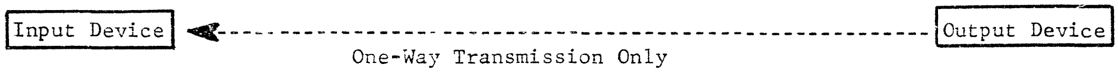
A single circuit (see below) permits two-way operation but in only one direction at a time. A single circuit is also commonly referred to as a "half-duplex circuit."



A duplex circuit as shown below, permits simultaneous transmission and reception in both directions and is also referred to as a "full-duplex circuit."



A simplex circuit allows information to flow in one direction only and would be used with a receive-only printer, no keyboard-type of device.



The equipment used in Teletype remote terminals can differ in both constructional features and circuitry. A remote terminal is usually made up of a keyboard-printer and a remote control unit, supplemented when needed by a perforated tape reader and perforated tape punch. The keyboard-printer serves for transmitting and receiving intelligence, while the remote control unit accomplishes the functions inherent in the setting-up and breaking-down of connections.

One keyboard-printer may be connected to another via a direct-connected half-duplex line. The two interconnected stations transmit in alternate succession with either keyboard-printer producing a record of the data transmitted.

This connection allows the terminals to be located up to ten miles apart. Telegraph transmission for distances greater than 10 miles depends on a long distance telegraph circuit in which digital subsets are used for connection with the line-terminating circuit.

Telephone Transmission

The term "carrier system" is usually associated with the communications industry and is described as a communication system which makes use of "carrier signal," a wave with amplitude (size or magnitude or voltage) or frequency (rate at which current alternates) modulation to carry an information-bearing signal. The term applies to systems which transmit a carrier signal over open-wire, cable pairs, coaxial cable, and radio systems.

The common carrier networks in the United States are maintained by the American Telephone & Telegraph Company, the Bell System operating companies, Western Union, and General Telephone. There are about 3100 other telephone companies in the country, ranging in size from 11 subscribers to 280,000 subscribers to add up to over 63 million telephones in use.

The telephone companies are traditionally recognized as "voice," while "written messages" are furnished by the telegraph companies. However, recent innovations of the digital subset have adapted this vast network for the transmission of data at speeds higher than 10 characters per second.

The simplest transmission medium employed is a channel which will transmit normal voice communication with a bandwidth of 3 or 4 kilocycles per second. This can be subdivided into several 150-cycle Teletype channels, making it possible to transmit several teletype signals simultaneously over one voice line.

The transmission of data takes place either in serial form or parallel. Considering transmission mediums as roads, serial transmission requires a single-lane road, while parallel transmission requires a multilane road. Serial transmission is the most commonly used technique. The wider the "road" (bandwidth) of a circuit, the faster information can be transmitted.

The common carrier may use higher level (microwave) carrier equipment to get data from one place to another; but normally, as far as the user is concerned, all that is seen is a pair of wires tied into a digital subset.

If one uses a Teletype line or a dial-up Teletype connection, the common carrier may decide to multiplex the channel into a voice line or higher speed line. Another possibility is a user who has a high volume of traffic between two locations. By leasing a private voice line the user can transmit one message at 2400 bits per second or, through the use of multiplex equipment supplied by the common carrier, transmit 12 Teletype messages simultaneously at 75 bits per second.

The telephone companies have developed voice services which make possible speeds up to 2400 bits per second or about 200 characters per second with 8-level code. Data is sent over regular telephone lines with connections made by simply dialing the distant point manually or automatically.

When using voice lines information may be transmitted in a bit-serial, asynchronous mode (with start and stop bits), as previously described. When using voice lines in synchronous transmission, a new mode becomes feasible. This technique transmits bits at a constant rate (no start and stop bits), as opposed to asynchronous transmission. With any given bandwidth, transmission is faster in the synchronous technique than in the asynchronous.

The bit rate transmitted in a synchronous mode is controlled by the digital subset (See "Interface Equipment"). Synchronous subsets are available with bit rates of 2000 or 2400 bits per second. These devices continually transmit a bit stream at this fixed rate. Characters transmitted via this bit stream are bit serial, with the last data bit of one character immediately followed by the first bit of the next succeeding character. The receiving terminal has the necessary logic required to count up the bits in a character and separate individual characters from the incoming bit stream.

It is characteristic of most remote terminals that they cannot supply characters at exactly the constant bit rate required by a digital subset. To compensate this speed differential, a transmitting terminal will automatically generate one or more extra "status" bits for each character and transmit these along with the 5, 6, 7, or 8 data bits. The transmitting terminal will fill in the spaces between data characters with fill or status characters, and represent these by the coding of the extra status bits that are added. The receiving terminal examines the status bits in each character received and determines if the character is a data character which must be utilized or a fill or status character. If it is a data character, the receiving terminal will strip off the status bits before utilizing the character (writing on magnetic tape, sending to the computer, etc.).

Broadband Transmission

Broadband transmission facilities are capable of transmitting data at speeds faster than those for a voice circuit. Where voice circuits are limited in speed to about 300 characters per second, broadband facilities can transmit at over 90,000 characters per second. Thus, broadband is required by higher speed communications terminals, such as magnetic tape, high speed printers, and some computer communications controllers.

Broadband facilities can be provided by microwave equipment or coaxial cable. In general, microwave is used for long distance transmission, while coaxial cable is supplied for short distances and to carry a signal from a microwave tower to a user's terminal equipment.

Broadband is supplied on a lease basis by the common carriers and by private manufacturers of radio equipment such as General Electric. The broadband offering of the common carriers is explained in more detail later.

It should be noted that the common carriers use broadband facilities extensively within their own facilities as part of the nationwide "common user" telephone network. These broadband channels are used for high-volume trunk lines between major cities across the country.

Broadband is a group of voice channels combined, or multiplexed, within a wider bandwidth. These voice channels can be used separately and individually to transmit simultaneous voice conversations or simultaneous data messages at voice channel speeds. For data transmissions, however, it is more economical to use the entire bandwidth as one broadband to transmit one message at higher speed. As noted previously, the speed of transmission is directly related to the bandwidth.

As an example, a broadband channel which has twelve 4 kilocycle voice channels could transmit 12 separate data messages at 300 characters per second for a total of 3600 characters per second. If channels are combined, however, a bandwidth of 48 kilocycles, capable of transmitting serial, synchronous data at about 5000 characters per second, is availbale.

In addition, 5 channel banks of 48 kilocycles each can be combined into a basic supergroup of 240 kilocycles. Four supergroups form a microwave baseband of about 1 megacycle. This is equivalent to about 240 voice circuits. Thus a microwave baseband can be divided into 240 individual voice channels or any desired combination of channel banks or supergroups. A 240 kilocycle supergroup is required for transmitting magnetic tape at 15,000 or 41,700 characters per second. For faster speeds from 62,500 up to 165,000 characters per second, a baseband will be required.

SWITCHING CENTERS

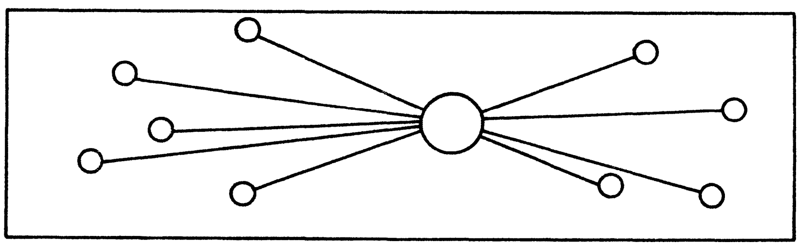
Early telegraph networks established the network as a number of individual (point-to-point) circuits terminated at either end by a transmitter and a receiver. These circuits were later changed to converge into switching centers where transmitters and receivers associated with several lines were accumulated. Telegrams to be conveyed to places which were not interconnected by a direct line required intra-office relaying before they could be sent to the destination.

A telegram in a relay office was passed on to another operator who would then transmit it to the desired terminal.

The principle underlying a modern switching center employing automatic techniques is in essence the same as that on which the old-fashioned telegraph office was established. The difference is that most of the manual intervention has been replaced with automatic operations.

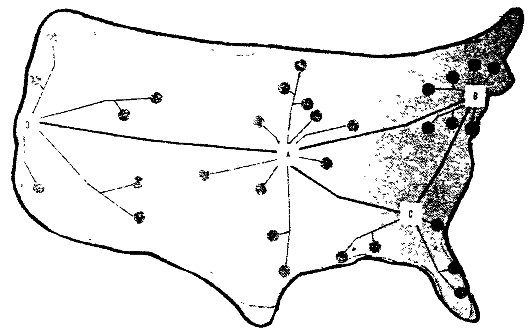
Within communications system, an interconnection of terminals is needed. The number of circuits required and the complexity of the equipment at each terminal must be reduced, or the interconnecting links could be numbered in billions. Terminals in a network can number from a minimum of 2 to several million, as evidenced by the 63 million terminals of the telephone system.

An interconnection can be single switching or multiple switching. Single switching means that all stations are linked as shown below on a direct line to a center point.



When a large number of terminals are dispersed over a large area the most efficient approach is to establish two or more switching centers, connect each terminal to the nearest center, and provide high speed trunk facilities between them which can be used to interconnect users served by different switching centers. This is called a multiple switching center network. Such a network is shown graphically on the accompanying map.

In any data communication network, rearranging of traffic and rerouting of messages are handled by switching centers. Of various sizes and complexity, the switching centers perform many functions.



An example of a stored program computer switching center is the DATANET-30, manufactured by the General Electric Computer Department. The DATANET-30 can automatically service many incoming and outgoing lines simultaneously, the number of lines depending on the traffic load and the processing requirements.

Message priority and routing are examined by the program, and then messages are retransmitted to the proper terminal without the delays of manual handling. Business data or administrative messages are handled equally well, and message delay time is significantly reduced.

Message traffic is not limited to directly connected lines. Common carrier dial-up equipment can be used to handle data to or from any location in the country.

The DATANET-30, under real-time program control, performs such functions as priority and queueing, intercept storage, automatic feed-back analysis of message traffic, and supervisory systems control.

Message concentration is accomplished by accumulating several messages from incoming low speed lines and switching these to a high speed outgoing line. In the process, the messages are stored for short periods of time and counted and checked out when forwarded. This provides for accumulation of statistical information that serves to assist in planning new centers and modifying existing centers. Multiple address messages - messages with more than one destination - are recognized and the information they contain dispatched to the several destinations.

INTERFACE EQUIPMENT

Interface equipment is required in data communications as a link between the communication circuit and the terminal input/output equipment.

The common user telephone network and private, leased voice lines are designed by the common carriers for the transmission of human speech. "Voice" is a range of frequencies varying from about 300 to 3300 cycles per second, hence the 3 or 4 kilocycle bandwidth of a voice channel.

The problem is that no data communication terminal generates these frequencies as a direct output. As noted previously, these devices generate d-c pulses, or bits. Thus, a "bit-to-tone translator" is required at the transmitting terminal and a corresponding "tone-to-bit translator" at the receiving terminal of a voice channel, as shown below.

These devices have the generic name of "digital subsets" (sometimes called "modems", an abbreviation of "modulator-demodulator"). They are supplied by both the telephone companies and Western Union. These digital subsets usually come supplied with a regular telephone handset, so that they can be used for normal voice conversations when not being used to transmit data.

A connection between two terminals is effected by an operator at one location dialing the telephone number of a digital subset at some distant location. After this connection has been verified, the business machines are directly connected through the digital subsets and can transmit their data. After the transmission has been completed, the connection is broken by the simple process of hanging up the handset.

Some of the digital subsets now available are equipped for unattended operations. An operator at a central location can dial an unattended terminal which automatically answers the call and switches on the attached business machine. When the transmission is completed, the connection is broken by hanging up; and the unattended digital subset turns off the business machine.

Interface equipment is also required on d-c Teletype facilities. Here the main function of the interface is simply to change the d-c current and voltage levels of the line to levels acceptable to the remote terminal; the signal is not altered or modulated. The equipment usually used for this purpose is a relay line, which can be obtained from the common carrier or from private manufacturers.

ERROR CHECKING

The need for error checking in data transmission is heavily dependent on whether the transmissions are administrative messages (telegrams) to be read by humans or data to be used as input to a computer. The mind can often reconstruct the meaning of a message if a character is altered because of transmission error. The computer, lacking the logic of the human mind, depends heavily on the accuracy of its input.

We have seen previously that the prime source of error in a communication system is the transmission facility rather than the terminal device. Transmission facilities of various types have a wide range of reliability and, correspondingly, the need for error detection varies.

In general, private or leased facilities are more reliable than dialed facilities. This is because the quality of a leased line can be controlled, due to its known location. In contrast, connections dialed through the public networks may take a different route each time a number is dialed.

The second consideration in transmission reliability is speed. Generally, the error rate increases in direct proportion to the speed of transmission. This is due to a factor known as the "signal-to-noise ratio." Noise or static, is the main reason for error, and can be caused by a multitude of sources, such as lightning, heavy machinery, nearness to other lines, etc. Noise is usually of short duration; thus the shorter the bit time (faster speed), the more closely noise resembles the signal.

In error checking the most commonly used methods are:

1. Check totals - This is the method in which an additional figure, equal to the sum of all the figures contained in the transmission, is transmitted along with the message.

2. Redundant transmission - This is the method of sending each character of the message twice and comparing the two at the receiving terminal, and is usually considered the most accurate type of error check, although for 100 percent redundant transmission the effective character rate of transmission will be cut in half.

3. Word check - An accuracy check can be made on each word or group of characters between Space codes in 5-level perforated tape transmission. The total number of bits in each word or group is counted and, depending on whether this number is odd or even, a Space code or Alternate code is transmitted at the end.

4. Parity check - This is the counting of bits within a character or within a block to determine whether the bits add up to a predetermined odd or even number. This is perhaps the most commonly used method, since it is accurate and does not greatly reduce transmission speeds.

Data transmission terminals presently available differ in the manner in which they utilize the detection of an error. Some, upon detecting an error, simply inhibit further transmission and signal the operator, who manually takes corrective action. Other, more sophisticated terminals will automatically retransmit until the data is successfully transmitted.

BUFFERING

Buffering is used to accumulate a group of characters, words or messages sent at slower speeds at a terminal station and then to transmit them at full speed. For example, the output of a Teletypewriter can be accumulated on perforated tape at an average typing speed of from 30 to 60 words per minute and then transmitted by a tape reader at 750 words per minute.

Circuits may be multipoint private lines with several input/output devices attached to the same line and with these stations time-sharing the line capacity. If six stations were sharing such a line, each station might be assigned two five-minute periods each hour or five two-minute periods. The scanning circuitry in such a case would be set up to skip over a station if it had nothing in its buffer and to cut short its cycle if the buffer were emptied before the full cycle time had elapsed.

Another form of buffering is to collect all of a location's low priority message on perforated tape and then transmit these messages at high speed at night or during idle line periods.

Buffering is used in many forms to aid in optimum transmission medium utilization. It is also used to accumulate data during periods that the transmission facility is out of order or the computer is not in service.

ECONOMIC FACTORS

Initially the use of telegraph circuits has provided a very nominal means of data transmission from one point to another. However, many times the cost associated with the low capacity for data transmission provided a very unattractive economic structure. Recently, however, new equipment has been designed to connect the equipment for transmitting digital data directly over voice circuits using regular telephone lines and digital subsets. This affords approximately a 15 to 1 increase in data rate compared with that obtainable with a standard 60 word per minute telegraph grade circuit at about a 3 to 1 increase in cost. The user is charged toll rates only for the time that the circuit is used. New facilities can transmit as much data in one 20 minute toll call between New York and Los Angeles costing less than $15, as can be carried in 8 hours on a 60 word per minute Teleprinter circuit costing more than $75.

At present, Teletypewriter lines can be leased for either 24 hours a day, 7 days a week, or for a certain number of hours per day. The following is a summary of approximate private line Teletypewriter rates:

	Days Per Week		
Service Hours	5	6	7
8 AM to 4 PM	$ .6545/mi/mo	$ .7315/mi/mo	$ .77/mi/mo
8 AM to 5 PM	.7438	.8313	.875
8 AM to 8 PM	.9095	1.0165	1.07
9 AM to 5 PM	.714	.798	.84
9 AM to 6 PM	.833	.8978	.945
24 Hour Basis	1.2325	1.3775	1.45

Approximate private telephone line costs are as follows:

Distance (mi)	Cost (mi/mo)
First 100	$ 3.00
Next 200	1.95
Next 400	1.65
Next 800	1.35
Each Additional	1.05

Approximate broadband costs are as follows:

Bandwidth	Equivalent Number of Voice Circuits	Cost Per Mile Per Month
48 KC	12	$ 15
96 KC	24	$ 20
230 KC	60	$ 25
Approx. 1 MC	240	$ 40

In data transmission the most important factor to determine is the volume of information to be transferred. The traffic pattern, length and time distribution of messages, and the points of interconnection should be known. The economic success of a communication system depends on a knowledge of these factors.

COMMON CARRIER SERVICES

The following discussion covers some of the common carrier services which may be incorporated into a data communication system. These do not, however, include a complete description of all of the communication services that may be used. The best sources for this information are the local communications companies.

Common User Telegraph Service

The common user telegraph service utilizes the telegraph lines available to various common user telegraph networks, such as American Telephone and Telegraph's TWX or Western Union's TELEX. Users are connected to a central switching system serving a geographical area. These central stations are interconnected in an extensive network.

Common user telegraph services are capable of transmission speeds of 10 characters per second and are most useful in applications that have relatively low data message volumes with a large number of geographic points.

Common User Telephone Service

The common user telephone service employs the existing local and long distance telephone network, the same network that is used for making regular telephone calls. By using a digital subset which includes a regular telephone, a person completes the call as he would with a normal telephone - either by dialing or placing the call through an operator. When the connection is made, a signal is given and the data is transmitted. Charges are based on regular telephone toll schedules. Because the telephone lines are designated to transmit an intelligible human voice, the channel bandwidth characteristics are considerably broader than those of telegraph lines. Considerably faster transmission speeds of up to 2400 bits per second can be achieved.

Leased Telegraph Channels or Networks

Leased telegraph channels or networks are point-to-point channels without external switching or dialing provisions - for example, home office to a plant, a number of stations sharing a common line to a central point, or a switchboard within a company allowing for transmission to and from all stations.

Leased Telephone Channels or Networks

Similar to the telegraph services, leased telephone channels or networks provide services for exclusive use for a designated period of the day. Although channels are like those of the common network provided to all telephone users, there are two significant differences, which are important for data transmission: a particular line may be made available, reducing the time lost in making a connection, and higher data speeds of up to 2400 bits per second may be obtained. As with the common user services, digital subsets must be used for the transmission of data.

Examples of Telegraph/Telephone/Wideband Services

The following are examples of Teletypewriter services:

1. TELEX - Western Union has initiated a public dial-up user-to-user Teletypewriter service called TELEX. Operating much like a telephone, but unlike telephone voice communication, TELEX involves conversation between two Teletypewriters.

2. TWX - The Bell System's public user-to-user Teletypewriter service is termed TWX. TWX calls are charged to the user on a per-call basis; rates vary in relation to distance and duration of the call.

The distinctive feature of these services is the "automatic answer back"; after dialing the number of another user, the answering machine is automatically started, even if unattended.

The following telephone and telegraph services are also available:

1. WATS (Wide Area Telephone Service) - This service is offered to large-volume business users by the telephone companies and is a long distance toll telephone service. WATS access lines may be obtained to any one of six zones within the United States on a full-time or measured basis.

2. TELPAK - This service is an offering from both American Telephone and Telegraph and Western Union that has thoroughly changed the economics of telecommunications. TELPAK is a private line offering, designed to give large users of communications the benefits of various communication capacities. An important feature of TELPAK is that channels wider than those used for voice communication are available. TELPAK is available in four classes, A through D, ranging from 12 to 240 voice grade circuits:

TELPAK Class	Bandwidth	Equivalent Number of Voice Circuits
A	48 KC	12
B	96 KC	24
C	230 KC	60
D	1 MC (approx.)	240

This service offers substantially higher transmission rates than the others described previously. For instance, the TELPAK Class C, permits the transmission of magnetic tape at 15,000 characters per second.

The following chart summarizes the various services just discussed and their applications.

	Few Calls Few Places	Few Calls Many Places	Many Calls Few Places	Many Calls Many Places	Many, Many Calls Few Places
Voice	Commercial Toll	Commercial Toll	Private Leased Telephone line	WATS	TELPAK
Written	TWX or TELEX	TWX or TELEX	Private Leased Teletype-writer line		
Data	DATA-PHONE and Data Channels				

APPLICATIONS

A data communications system can consist of a variety of equipment. The choice of equipment depends mainly on the three basic purposes of a data communications system:

1. To transmit inquiries to a computer. The computer generates answers to the inquiries and transmits back to the originator. This type of application is usually used in connection with a large random access memory and/or a real time basis.

2. To transmit data to a computer to update the computer files. The computer generates status reports to return them to the remote locations. Used on a real-time basis, random access files are needed; if on batch transmission, the files can be on tape.

3. To transmit data to a computer to be processed. The computer processes and generates results to be returned to the remote locations.

In the following paragraphs are discussed some of the possible combinations designed to fill the communications requirements of business activities:

1. Message switching center - Messages and data are sent from one remote terminal to another.

2. Remote data processing - Data from remote stations is processed at a central computer.

3. Automatic data accumulation - Data is sent from a variety of points for batch processing by a computer and then redistributed.

TELEGRAPH MESSAGE SWITCHING

The fully automatic message switching center designed to provide store and forward message switching can be used to communicate with any of the following:

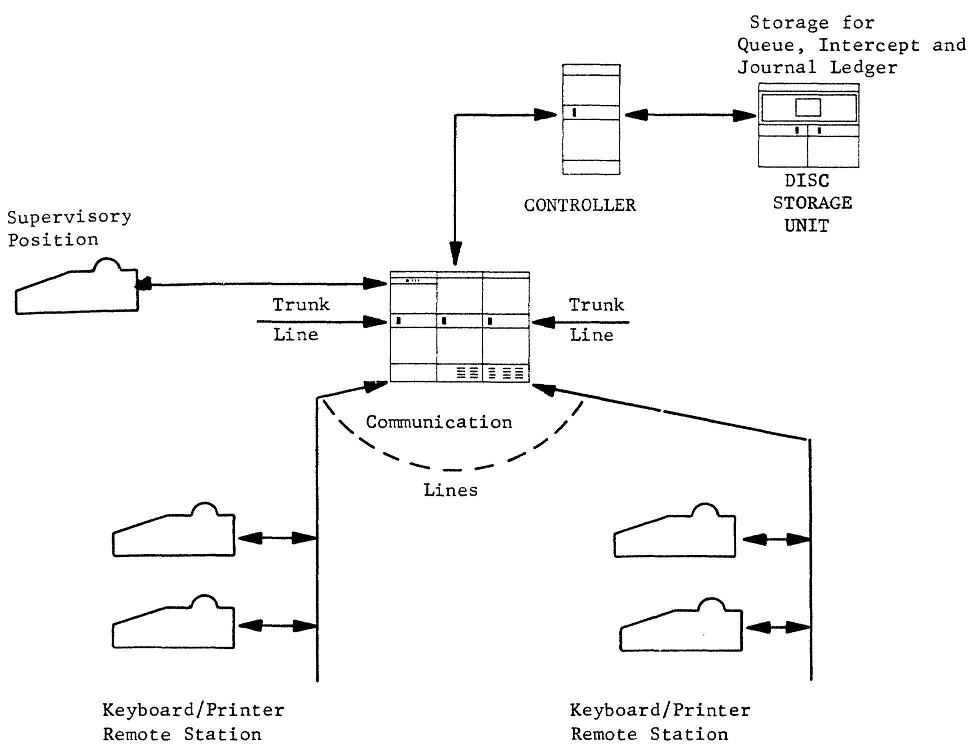
1. Directly connected communication stations
2. Multipoint private line stations
3. Dial-up stations on public message networks

4. Computer systems for direct input/output
5. Computer systems for indirect input/output
6. Other networks or portions of a network.

The operation of the fully automatic switching center can be under program control as well as serving to control the sequence of transmission of terminals on a multipoint private line. Each message contains a destination code - the name or the number of the remote station or stations where the message is going. After a message is received from a remote station, the program interrogates the destination code of the message, then transmits it to the proper remote terminals. Control is accomplished through the supervisory terminal to open or close stations by time of day and enter other control messages.

The supervisory terminal normally consists of a keyboard/printer Teletype unit. This terminal is used as a message intercept position for incorrectly routed or formatted messages. The supervisor looks at the messages and decides what action is necessary - such as correcting the heading and re-entering the message, asking for retransmission, etc. The terminal is also used for notifying the supervisor of line malfunctions and for printing out periodic status reports on the switching center operation.

The detailed operation of each system is developed according to individual system requirements: routing, service and control codes, format, number of line and remote terminals, and the many other overall system operational requirements. A sample switching center configuration is shown below:



REMOTE CONCENTRATORS

The remote concentrator acts as a relay station and a store-and-forward switching center between remote terminals and the switching center. All messages go one way to the switching center and then back to the concentrator for transmission to one of the remote stations. Remote concentrators take traffic from low volume areas with low speed terminal devices and perform the following functions:

1. Message accumulation and distribution
2. Code conversion
3. Speed conversion
4. Multipoint private line control
5. Error control
6. In-transit storage
7. Unattended operation.

Messages are accumulated from many remote terminals and held in the in-transit storage until they can be transmitted at higher speed over a trunk line to a switching center. When messages are received from the switching center by a remote concentrator, speed and code conversion are accomplished and the messages are transmitted out to the lower speed terminal devices.

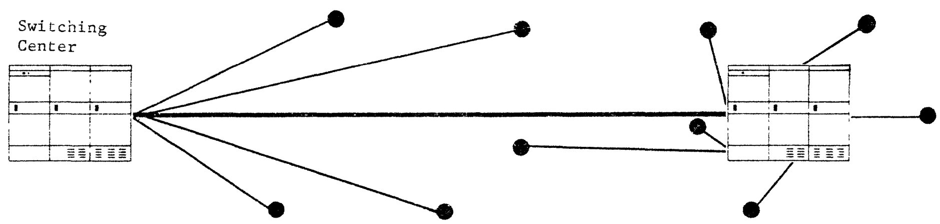
When many remote stations are located many miles from a switching center, it may be desirable to include one or more concentrators for the more distant terminals. This will reduce the number of long distance lines coming into the switching center.

The remote concentrator is connected to the switching center via a high speed voice-quality trunk line and provides two advantages in use:

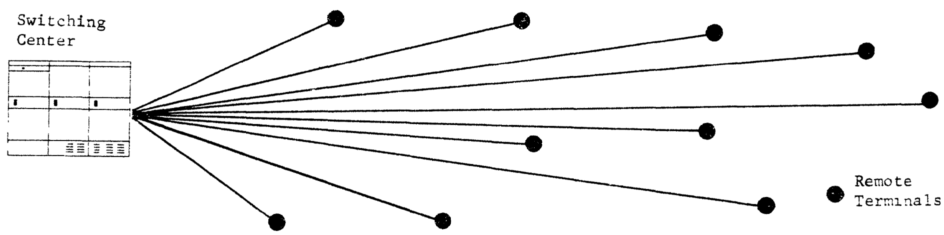
1. Where the switching center would be overloaded if all remote terminals were directly connected, the use of the remote concentrator will reduce the time delay in a message from its origin to its destination. This is especially so if the remote stations are connected by multipoint private lines, since it is then possible to connect them via single lines on the remote concentrator.

2. Transmission line costs will be reduced. If all remote stations were directly connected, there would be many parallel telegraph lines. With a remote concentrator, there is only one voice line.

Systems with and without a remote concentrator are illustrated on the following page.



Communication Lines with a Remote Concentrator



Communication Lines without a Remote Concentrator

DATA ACCUMULATION AND DISTRIBUTION

The primary purpose of data accumulation and distribution system is to accumulate digital data (in message format) on magnetic tape from remote terminals and distribute data to remote terminals such as perforated tape reader/punches or Teletype units.

With the use of appropriately equipped remote terminals, fully automatic data gathering can be achieved. The digital data on the magnetic tape may then be transferred to the computer system and processed. Data to be distributed - that is, sent to the remote terminals - will be recorded on the magnetic tape by the computer system and the data transmitted to the proper destination.

The data accumulation and distribution system will:

1. Collect data from remote terminals by dialing each site
2. Convert the relatively slow input of keyboard/printer or perforated tape to magnetic tape for computer entry

3. Convert codes

4. Change formats

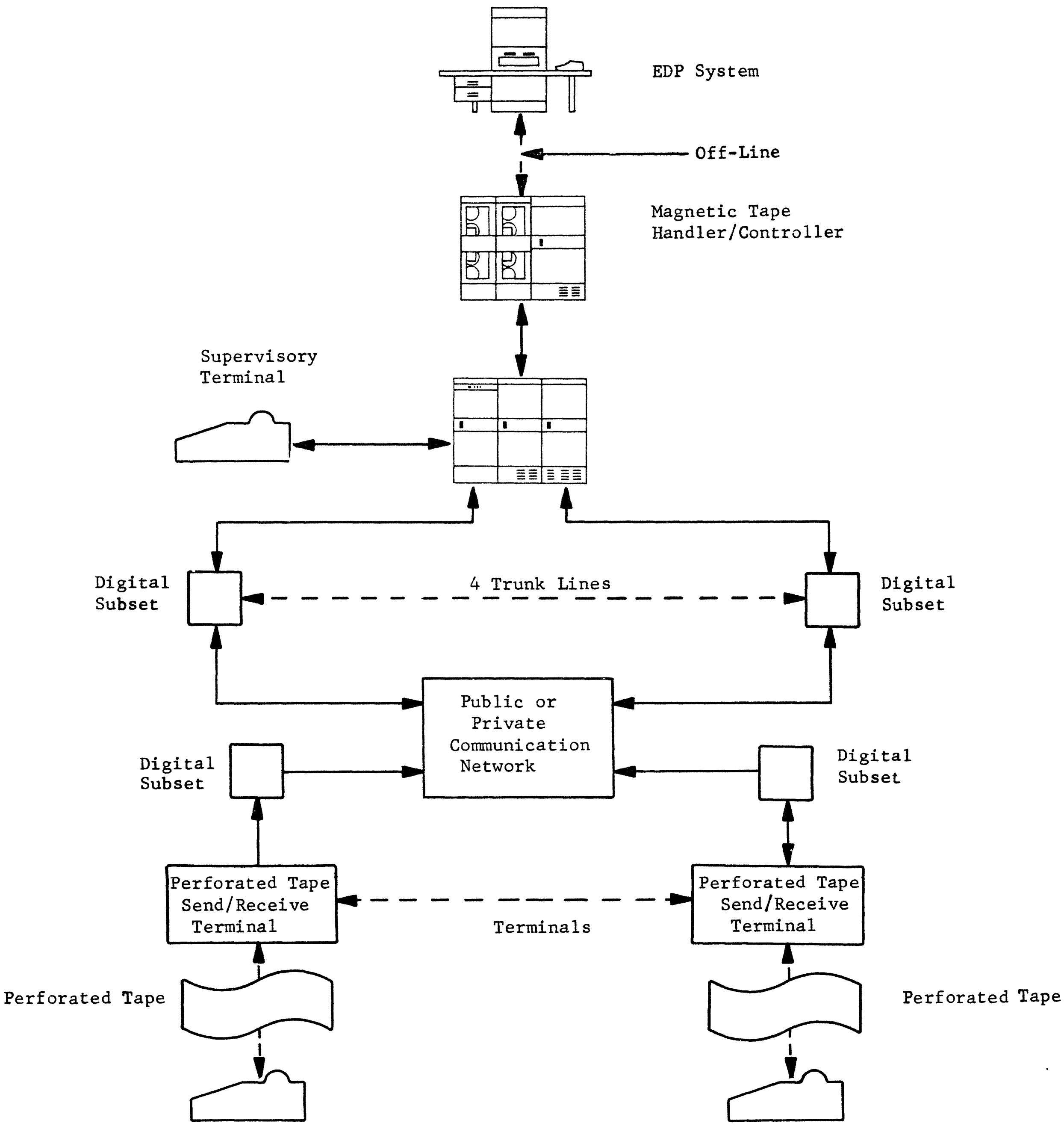
5. Repeat the entire operation in reverse to accomplish distribution of processed data

6. Permit unattended operation at an appropriately equipped terminal

7. Adapt readily to changes, in the number of remote terminals, in codes and formats, etc.

At the end of the business day at a remote terminal, the perforated tapes generated as a by-product of business activity are collected and combined into a single tape by the tape send/receive terminal. The single tape is placed in the sending unit, and the associated digital subset is set in the automatic mode.

When each remote station has been dialed, the correct connection has been made, and the remote terminal is ready to transmit, control is turned over to a program to receive the data and record it on magnetic tape. When an End-of-Message code is received, the next station in line is dialed. This process is reversed to distribute the data to the remote station. Each remote station is dialed in turn and the data transmitted and punched at the remote station. A typical data accumulation and distribution system is shown in the following illustration.


EDP System
Off-Line
Magnetic Tape
Handler/Controller
Supervisory
Terminal
Digital
Subset
4 Trunk Lines
Digital
Subset
Public or
Private
Communication
Network
Digital
Subset
Digital
Subset
Perforated Tape
Send/Receive
Terminal
Terminals
Perforated Tape
Send/Receive
Terminal
Perforated Tape
Perforated Tape

BENEFITS

Most segments of business, industry and Government can benefit in some way from digital data transmission. Some examples are discussed below.

MANUFACTURING

In the manufacturing industry, fast movement of data can serve as an operational tool for controlling such functions as production or transportation. Most industrial manufacturing concerns could benefit considerably by being able to communicate data swiftly and accurately between remote locations and the data processing center. Production control is a major factor in industry. Building a complicated piece of machinery involves a large number of steps and machining operations, some of which may be widely scattered geographically. With a data communication network, management is able to know, within short notice, how work is progressing at the varied locations, where shop orders are, what machines are working, and the status of parts and materials - and be able to do something about them if necessary.

BANKING

Centralization of detailed operational records, including demand deposit, savings loan, trust, and other banking operations is possible with data transmission devices and techniques. Many banks have a large number of local branches which are somewhat autonomous, but which must communicate business and administrative matters to each other and to a central bank. A properly designed data communication system allows them to bring all their accounting information and paperwork up to date each evening after closing. Deposits can be transferred to the proper branch quickly, or accounting can be centralized, thus improving the bank's service to its customers.

SCIENCE AND ENGINEERING

The solution of many of the more complicated scientific and engineering problems requires the availability of large-scale computer facilities. In most organizations, it is economically impossible to duplicate the large central computer facility at remote locations. With data communication networks, however, the problem program and input data can be transmitted from a remote location to the central computer at high speeds. The problem solution can then be transmitted back to the originating site.

It is also possible to break down a large problem into subproblems which can be worked on independently by separate computer facilities. In this case various computers throughout a widespread corporation can be used for solving parts of the same problem with the aid of a data communication network. Problem solutions transmitted over the communication network can be tabulated and reported by the use of direct, on-line high-speed printing equipment.

RAILROADS

Computer-based data communication systems can be used to handle a tough job for railroads by controlling and keeping track of freight cards and by automating the handling of waybills and train lists. Centralized car reporting will facilitate routing and car tracing, reduce rolling stock and yard requirements, and lower car penalty payments. Such a system would mean big savings to shippers of perishable goods. For example, positive control of rolling stock locations can help expedite cars carrying perishables to take advantage of the best possible market prices.

PUBLIC UTILITIES

Data transmission can benefit public utilities providing electric, gas, and water services by expanding the application of their data processing systems and by simplifying customer data acquisition procedures. Data transmission equipment can also be used for utility customer billing. Meter readings transmitted to a central processing center from field locations will save one or two days in the billing cycle. In addition, cash balances at local banks may be kept at a minimum by transmission of balance figures at the end of each working day.

TERMINOLOGY

Band	(1) the gamut or range of frequencies; (2) the frequency spectrum between two defined limits; (3) the frequencies which are within two definite limits and are used for a different purpose; (4) a group of channels.
Bandwidth	(1) a group of consecutive frequencies constituting a band which exists between limits of stated frequency attenuation. A band is normally defined as more than 3.0 decibels greater than the mean attenuation across the band. (2) A group of consecutive frequencies constituting a band which exists between limits of stated frequency delay.
Baud	(1) a unit of signalling speed equal to the number of code elements per second; (2) the unit of signalling speed equal to twice the number of Morse code dots continuously sent per second. Clarified by (rate, bit) and (capacity, channel).
Baudot Code	Referred to as "5-bit code," "5-channel code," "5-unit code," and "teletype code," this is a system for encoding symbols in printing telegraphy.
Bit	(1) an abbreviation of binary digit. (2) A single character in a binary number. (3) A single pulse in a group of pulses. (4) A unit of information capacity of a storage device.

Cable	A cable is an assembly of one or more conductors usually within an enveloping protective sheath in such structural arrangement of the individual conductors as will permit of their use separately or in groups.
Channel	(1) A path along which information, particularly a series of digits or characters, may flow. (2) One or more parallel tracks treated as a unit. (3) A path for electrical communication. (4) A band of frequencies used for communication.
Circuit	A communications link between two or more points.
Circuit (Four-wire)	A two-way circuit using two paths so arranged that communication currents are transmitted in one direction only on one path, and in the opposite direction on the other path. The transmission path may or may not employ four wires.
Common carrier	A company recognized by the U.S. Federal Communications Commission or appropriate state agency as having a vested interest in furnishing a communications service to the public. Such services are recognized as "voice" or "written" messages.
Common language	A machine sensible information representation which is common to a related group of data processing machines.
Data communication	The transmission of information to and from data processing equipment. This includes assembly, sequencing, routing, and selection of such information as is generated at independent remote points of data origination, and the distribution of the processed information to remote output terminals or other data processing equipment.
Data transmission	This term has been all-inclusive to describe the transfer of business data, destined generally to machines. In a strict sense data transmission means the transmission of data-comprising digital information which is intelligible to both humans and machines.

Digital subset	A subscriber apparatus in a communications network.
Echo check	A check of accuracy of transmission in which the information which was transmitted to an output device is returned to the information source and compared with the original information to insure accuracy of output.
Facsimile	Transmission of pictures, maps, diagrams, etc. by communication circuits. The image is scanned at the transmitter and reconstructed at the receiving station.
Frequency	Rate at which a current alternates, usually measured in cycles per second.
Full-duplex operation	Full-duplex, or duplex, operation refers to communication between two points in both directions simultaneously.
Half-duplex operation	Half-duplex operation refers to communication on a circuit in only one direction at a time, with or without a break feature. The break feature enables the receiving station to interrupt the sending station.
Information channel	The transmission and intervening equipment involved in the transfer of information in a given direction between two terminals.
Input	(1) information or data (2) describing the routines which direct input as defined in (1).
Input/output	A general term for the equipment and the data involved in a communication system.
Interface	A common boundry between systems or parts of a single system.
Leased line	Generally refers to a private full-period line.

Local loop

Portion of a connection from a central office to a subscriber.

Message

A group of words, variable in length, transported as a unit. In telegraphic and data communications as message may be composed of three parts.

1. A heading containing a suitable indicator of the beginning of the specific message together with information on any or all of the following: the source and destination, date and time of filing, and routing or other transmission information.

2. A body containing the information or advice to be communicated.

3. An ending containing a suitable indicator of the conclusion of the specific message, either explicit or implicit.

Message routing

The function performed at a central message processor of selecting the route, or alternate route if required, by which a message will proceed to the next point in reaching its destination.

Modulation

Process by which certain characteristics of a wave are modified in accordance with a characteristic of another wave or a signal.

Off-line

Implies no direct connection between a communication line, and either terminal or central equipment.

On-line

Implies a direct connection between a terminal equipment function and a communication line between, or a centrally located exchange or other device and a line.

Parity check

A summation word in which the binary digits, in a character or word, are added and the sum checked against a single, previously computed parity digit, that is, a check which tests whether the number of binary 1's is odd or even.

Pulse	A signal characterized by the rise and decay in time of quantity whose value is normally constant.
Radio	Communication by electrical waves in space. It is distinguished from microwave in the greater distances that can be spanned, though providing fewer circuits.
Radiocommunication	Any telecommunication by means of radiowaves.
Receiver	A device which transforms a varying electromagnetic signal into sound waves or other usable form.
Redundant check	A check which uses extra bits or characters, including complete duplication, to help detect malfunctions or mistakes.
Reperforator	A device for receiving telegraphic signals and punching them into paper tape.
Sequential	In an equal length code system, if the signal elements are transmitted successively in time over a channel, the transmission is said to be sequential. If the signal elements are transmitted at the same time over a radio circuit, the transmission is said to be "coincident."
Serial transmission	A system of transmitting the bits of a character on the line in sequence, generally used in telegraphic operations.
Signal	Aggregate of waves propagated along a transmission channel and intended to act on a receiving unit.
Speed of transmission	The rate at which information is processed by a transmission facility expressed as the average rate over some significant time interval. The quantity is usually expressed as average characters per unit time or average bits per unit time.

Store-and-forward switching center
A message switching center in which the message is accepted from the sender whenever he offers it, held in a physical store, and forwarded to the receiver whenever he is able to accept it.

Subscriber
Customer of a telephone or telegraph company served under an agreement or contract.

Switching
Operations involved in interconnecting circuits in order to establish temporary communications between two or more stations.

Switching center
An installation in a communication system in which switching equipment is used to interconnect communication circuits.

Telegraph signal
The set of conventional elements established by the code to enable the transmission of a written character (letter, figure, punctuation sign, arithmetical sign, etc.) or the control of a particular function (spacing, shift, line-feed, carriage return, etc.) this set of elements being characterized by the variety, the duration and the relative position of the component elements.

Telephone
An instrument designed to reproduce sounds at a distance by means of electricity. A sounding body is always vibrating, and the more rapid the vibration the higher is the note produced.

Telephone line
Telephone line is a general term used in communication practice in several different senses, the more important of which are:

1. The conductor or conductors and supporting or containing structures extending between telephone stations and central offices or between central offices whether they be in the same or in different communities.

2. The conductors and circuit apparatus associated with a particular communication channel.

Telephone network	Describes a system of points interconnected by voice-grade telephone wire whereby direct point-to-point telephone communications are provided.
Teleprinter	Name used for printing telegraph equipment.
Teletype	System of transmission of messages employing keyboard sending and type-printed reception over a distance.
Teletype network	A system of points interconnected by telegraph channels, which provide hardcopy and/or telegraphic coded (5-channel) punched paper tape, as required, at both sending and receiving points. Typically, up to 20 way-stations share send-receive time on a single circuit and can exchange information without requiring action at a switching center. If two or more circuits are provided, a switching center is required to permit cross-circuit transmission.
Teletypewriter	Trade name used to refer to printing telegraph equipment.
Teletypewriter exchange (TWX)	Service whereby a customer rents one teletypewriter which is connected to a switching exchange permitting the customer to interconnect to other such stations.
Terminal	A general term referring to the equipment at the end of a telegraph circuit.
Transmission lines	Lines or conductors used to carry electric energy from one place to another, for example, telephone lines, telegraph lines, and lines connecting computer units to other units.
Transmission link	A section of a channel (or circuit) between: 1. A transmitting station and the following telegraph repeater. 2. Two successive telegraph repeaters. 3. A receiving station and the preceding telegraph repeater.

Transmitter

1. A device for converting sound waves to electrical waves or electromagnetic waves.
2. Electrical generating and sending device which originates radio waves.
3. Any of the class of equipment used to prepare electrical signals for transmission.

Trunk

A trunk is a line or channel between two central offices or switching devices.

Voice frequency

Any frequency within that part of the audio frequency range essential for the transmission of speech of commercial quality.

Way circuit

A circuit shared by three or more stations on a "party-line" basis. One of the stations may be a switching center.