CHAPTER 1

BRIEF HISTORY OF COMMUNICATIONS

1.1 INVENTION OF THE TELEPHONE

As is commonly known, the telephone business was founded on inventions of Alexander Graham Bell, which grew out of experiments in telegraphy begun in Boston in 1873. Perhaps less well known is that Bell was not an "electrical man," but that instead, his training was predominantly in music, speech, elocution, and anatomy of the vocal and auditory organs. Bell first became interested in telegraphy in 1867, and this led him also to investigate electricity, mostly on a home-study basis.

In 1870, Graham Bell, as he preferred to be known, migrated with his father from England, to Brantford, Ontario. In April, 1871, Graham visited Boston, substituting for his father who had been requested by the Board of Education to experiment with his Visible Speech method of teaching the deaf to speak. After similar work in other New England towns, Graham Bell was appointed Professor of Vocal Physiology at Boston University, in 1873. His preoccupation with professional duties made it necessary to conduct most of his electrical experiments after university hours.

Bell's first interest in electrical communication was to develop a harmonic telegraph which, he hoped, would transmit several Morse messages over the same circuit simultaneously. After abandoning the use of paired tuning forks late in 1873, Bell considered the use of paired tuned-reed instruments. Early models made by himself proved unsatisfactory; this led him to place an order for instruments with Charles Williams, Jr., whose shop facilities and services attracted inventors.

Some of the delivered instruments had not been made in accordance with Bell's intentions, and one day, early in 1874, he strode through the office of Williams' shop and went to the work bench of the young mechanic, Thomas A. Watson, who had worked on the instruments. Although this was a rather unconventional procedure, Bell wanted to talk the job over directly with Watson, whom he had not met previously. Charles Williams continued to assign Watson to Bell's work; Watson also assisted Bell in his experiments after work hours.

Financial assistance soon was needed by Bell, who found the cost of his experiments to be quite burdensome. Fortunately, Gardiner G. Hubbard, who was interested in the problems of the deaf, and Thomas Sanders, whose deaf son had benefited from instruction by Bell, came forward, in the fall of 1874, with an offer to supply the needed money. These informal arrangements were embodied in a written agreement on February 27, 1875. Accordingly, Hubbard and Sanders, each, were to furnish one-half the money needed by Bell, and all three were to share equally in any patents which might be obtained.

While concurrently studying two very early types of acoustically actuated mechanical oscillographs...

These were the "Manometric Capsule" of Koenig, and the Phonautograph of Leon Scott, with improvements by Morey. Bell also obtained a human ear specimen and modified it to work about the same as the much larger phonautograph. Oscillograms recorded by Bell on smoked glass plates with this modified specimen in 1874 are in the Bell Telephone Laboratories' historical collection...

...as a possible means of improving his Visible Speech technique, and experimenting with his tuned-reed harmonic telegraph instruments, Bell conceived the basic principle of the telephone. He outlined it to Watson, for the first time, early in 1875 as follows:

> "If I can get a mechanism which will make a current of electricity vary in its intensity as the air varies in density when a sound is passing through it, I can telegraph any sound, even the sound of speech."

Bell's tuned-reed harmonic telegraph instruments were constructed and intended to function, according to Watson, as follows:

"1. The transmitter has an electromagnet with a reed made of steel clockspring mounted over it and an adjustable contact screw like that of an ordinary electric bell. The receiver had a similar magnet and spring reed but needed no contact screw."

"2. The operation also was very simple. The reed of the transmitter, kept in vibration by a battery connected through the contact screw, interrupted the battery current the number of times per second that corresponded to the pitch of the reed. This intermittent current, passing through the telegraph wire to the distant receiver, set the reed of that receiver into vibration sympathetically if it was of the same pitch as the transmitter reed. If the two reeds were not of like pitch, the receiver would not respond to the current."

"3. If six transmitters with their reeds tuned to six different pitches were all sending at once, their intermittent currents through the magnets of six distant receivers with reeds tuned to the same pitches, each receiver would, theoretically, select from the mix-up its own set of vibrations, and ignore all the rest."

A. EARLY EXPERIMENTS

Bell and Watson continued to experiment with models of instruments made by Watson as described above. In one room they set up:

1. Three circuit breaking transmitters, tuned to different pitches, each provided with a telegraph key to connect it with a battery and the line wire as desired, and
2. A set of three tuned-reed receivers having the same pitches as the transmitting instruments.

In the other room, designated as the receiving station, another set of three tuned-reed receivers, identical with the three receivers in the sending room, were connected to the far end of the line. Working with this experimental arrangement on June 2, 1875, Bell, at the receiving station at the far end of the line, made the critically controlling discovery, reported by Watson as follows:

"I had charge of the transmitters as usual, setting them squealing one after the other, while Bell was retuning the receiver springs one by one, pressing them against his ear.... One of the transmitter springs I was attending to stopped vibrating and I plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding: 'What did you do then? Don't change anything! Let me see?' I showed him. It was very simple."

The contact point of the transmitter which Watson was trying to start evidently was screwed too hard against the spring, so that when he snapped the spring the circuit had remained unbroken. Continuing with Watson's report:

> "...that strip of magnetized steel, by its vibration over the pole of its magnet, was generating that marvelous conception of Bell's -- a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room were the result of that recognition. The speaking telephone was born at that moment."

After trying many variations of their first successful transmission, with and without a battery in the circuit, Bell instructed Watson late on June 2, 1875, to build a new instrument, the one which has since come to be known as Bell's first telephone. A stretched parchment diaphragm. which had been contemplated by Bell while working with the human ear specimen in the summer of 1874, was now added to the previous type of coil and reed receiver assembly, with certain modifications. This first telephone, a "Gallows Frame" Magneto (Figure 1-1) was tried out, as a transmitter on the night of June 3, 1875, the receiver being one of the tuned-reed harmonic telegraph instruments used previously. Later on, two of the new telephones were used as transmitter and receiver. Whereas the harmonic telegraph tuned-reed instruments, when used in pairs, were found capable of transmitting and receiving the fundamental and harmonics of a vibrating spring, the new telephone was capable of transmitting and receiving speech sounds which were more complex, but it still was not good enough to transmit intelligible speech.

B. PATENT APPLICATIONS

During the latter part of 1875, and early in 1876, Bell prepared his specification for a patent application, including both the harmonic telegraph tuned-reed device and a stretched-diaphragm-type instrument. In these instruments the "undulating current" was generated by magnetic induction. "Almost at the last moment" Bell included in his specification a claim which also provided for the variable-resistance method of producing electrical undulations in current supplied by a battery. This application, completed on January 20, 1876, was filed in the Patent Office February 14, 1876. Patent #174,465 registered as an Improvement in Telegraphy, was issued to Bell on March 7, 1876 which happened to be his birthday. He was then 29 years old; Watson was not yet 22.

Although three additional patents were obtained by Bell during his association with Messrs. Hubbard and Sanders, Patent #174,465 has been considered to be the cornerstone of the Bell System of intercommunication. This original group of four patents was assigned in later years to "parent companies" which followed the original three-man association.

In the spring of 1876, Bell pursued further the variable resistance method of producing the desired undulating current. After abandoning other methods, he decided to employ a variation of a method used by him in his previous development of a spark arrestor. A crude device of this type, used in the early days of March, 1876, brought the two experimenters close to their objective. At Bell's request, Watson then built an improved liquid transmitter, consisting essentially of a diaphragm capable of vibrating at voice frequency, and having attached to it a small wire which moved up and down in a liquid conductor (acidulated water), thus varying the resistance in the closed circuit including a battery, at voice frequency.

On the night of March 10, 1876, with Watson stationed at the far end of the line to which one of the harmonic telegraph tuned-reed receivers (Figure 1-2) had been connected, Bell was completing the last wire connection to the new liquid transmitter (Figure 1-3) when he spilled battery acid on his clothes, and he summoned Watson with the now famous call for help, "Mr. Watson, come here, I want you!" Watson excitedly reported that he heard every word -- distinctly, and in this way the feasibility of transmitting and receiving intelligible speech was fully established.

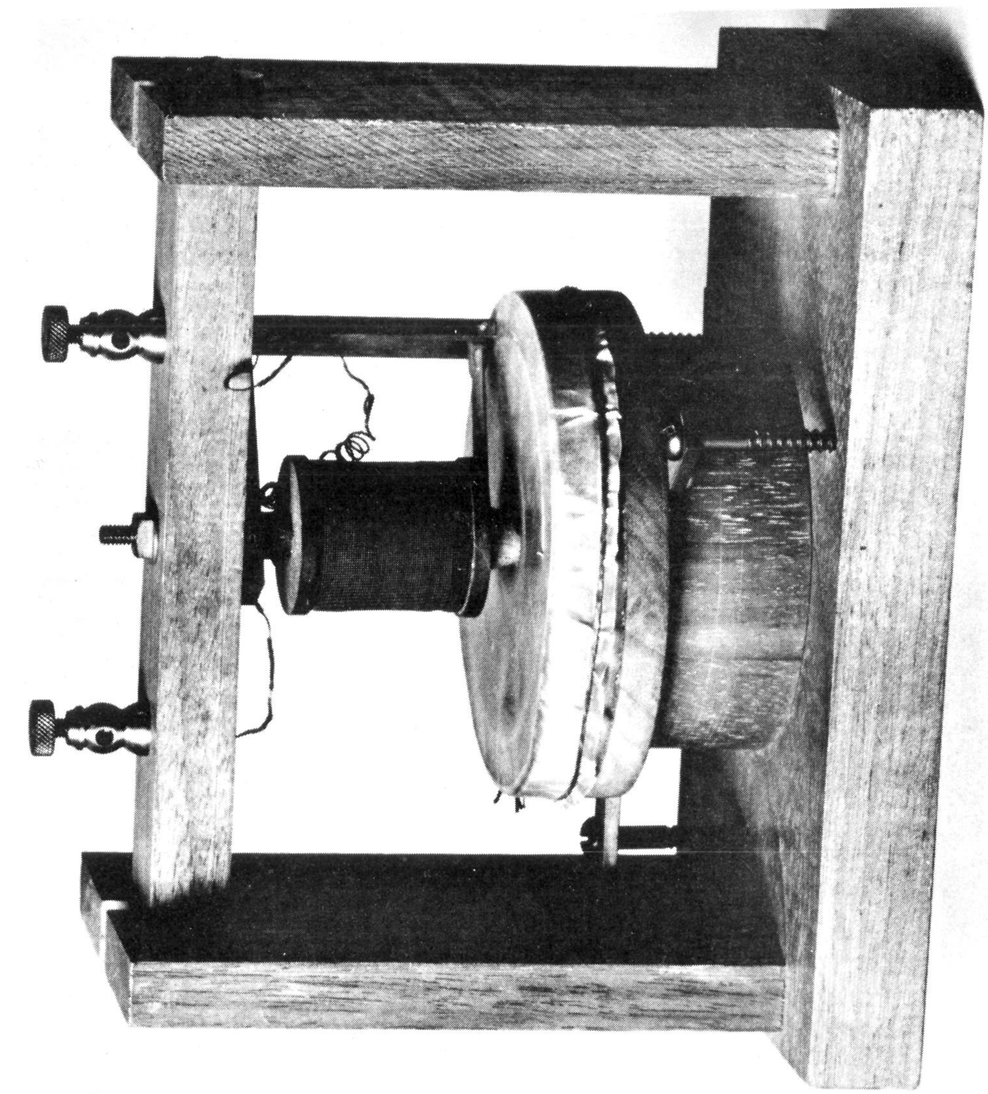

Figure 1-1 Gallows Frame Magneto Phone

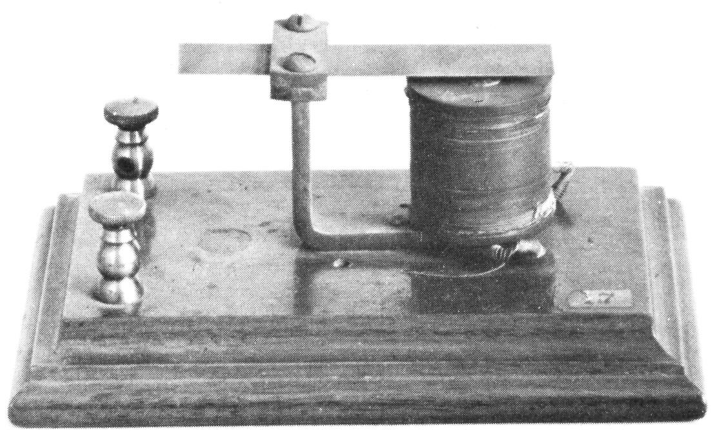

Figure 1-2 Vibrating Reed Receiver

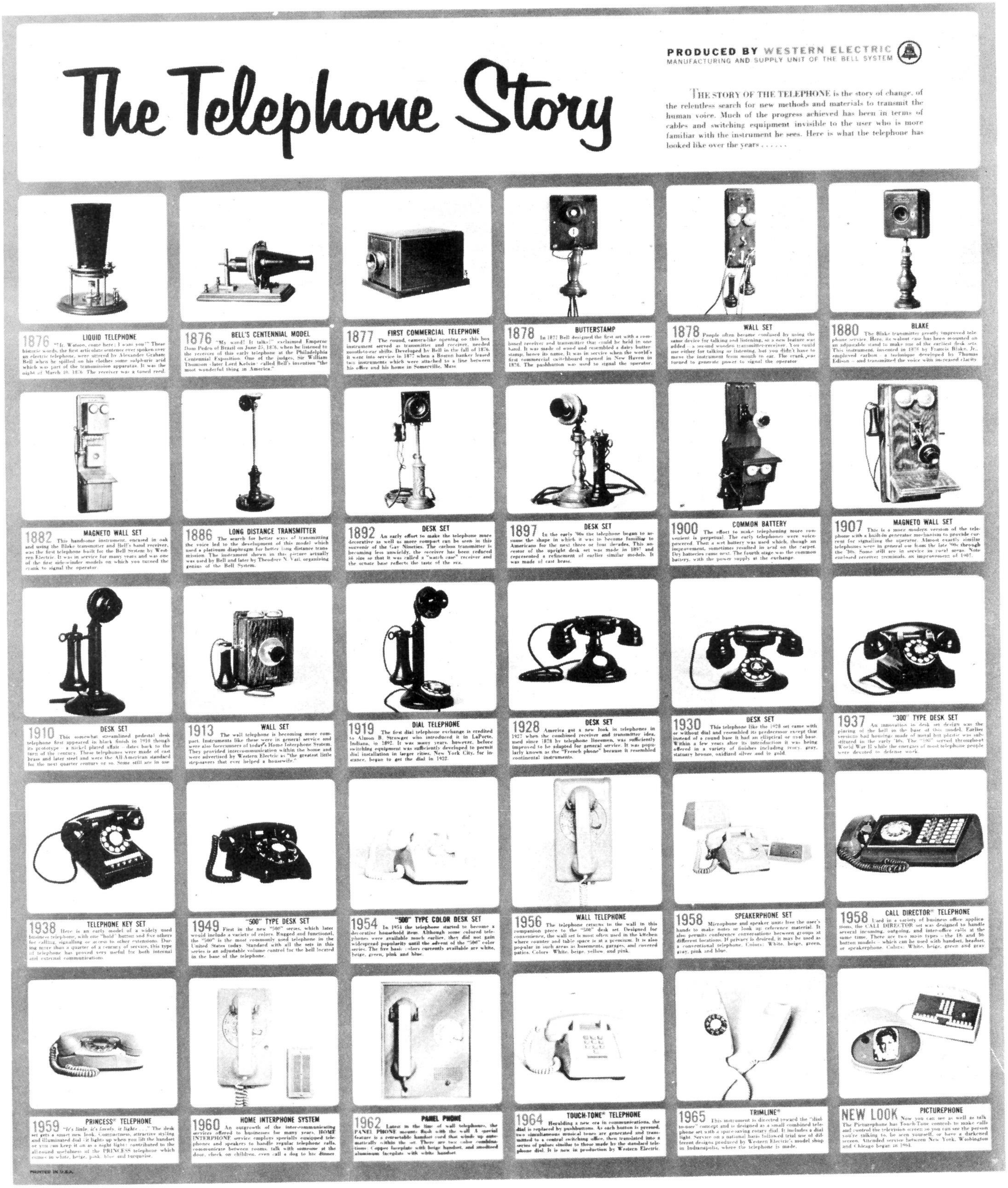
The Telephone Story
PRODUCED BY WESTERN ELECTRIC
MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM
THE STORY OF THE TELEPHONE is the story of change, of the relentless search for new methods and materials to transmit the human voice. Much of the progress achieved has been in terms of cables and switching equipment invisible to the user who is more familiar with the instrument he sees. Here is what the telephone has looked like over the years . . . . . .
1876 LIQUID TELEPHONE
1876 BELL'S CENTENNIAL MODEL
1877 FIRST COMMERCIAL TELEPHONE
1878 BUTTERSTAMP
1878 WALL SET
1880 BLAKE
1882 MAGNETO WALL SET
1886 LONG DISTANCE TRANSMITTER
1892 DESK SET
1897 DESK SET
1900 COMMON BATTERY
1907 MAGNETO WALL SET
1910 DESK SET
1913 WALL SET
1919 DIAL TELEPHONE
1928 DESK SET
1930 DESK SET
1937 "300" TYPE DESK SET
1938 TELEPHONE KEY SET
1949 "500" TYPE DESK SET
1954 "500" TYPE COLOR DESK SET
1956 WALL TELEPHONE
1958 SPEAKERPHONE SET
1958 CALL DIRECTOR® TELEPHONE
1959 PRINCESS® TELEPHONE
1960 HOME INTERPHONE SYSTEM
1962 PANEL PHONE
1964 TOUCH-TONE® TELEPHONE
1965 TRIMLINE®
NEW LOOK PICTUREPHONE

Figure 1-3

The first commercial telephone (Figure 1-3) of 1877 was enclosed in a box with a round camera-like opening serving as transmitter and receiver and needing mouth-to-ear shifts.

Telephones were sold in pairs (one for you and one for the person you wished to talk with).

To use those early phones was simplicity itself. First you placed one telephone in your own home or business, and the other in the home or business of whomever you wished to talk with. Next, you somehow had to connect the two phones. The first telephone advertisement announced, quite helpfully, that you had two choices as to method. One possibility was to purchase the necessary wire and telephone poles yourself and to hire a "mechanic" to install the poles, string the wires, and connect them to the telephones. If this was to be your decision, that first ad gave you the necessary specifications,

> "...No. 9 wire costs 8-1/2 cents a pound, 320 pounds to the mile; 34 insulators at 25 cents each...."

and even calmed you as to any doubts you may have had with the cheery encouragement that

> "...any good mechanic can construct a line...."

or, if you weren't very good at construction projects, the Bell people offered to do the construction for you and give you a "firm" quotation such as the following, which is also taken from the first telephone advertisement:

> "...The price (of poles and setting) will vary (in every locality)...from \$100 to \$150 a mile...."

(Small wonder that the telephone was at first considered a rich man's toy!)

Once your two phones were connected, you were ready to use them. Now there was a problem at this point - how to signal the person in whose home or office the other phone was installed that you wished to speak with him. (There was no signal bell attached to those early phones.) Here again, the Bell Company was thoughtful enough to provide you with two choices. If you had strong lungs, you could simply shout into your phone to draw the other party's attention. In fact, in that historic first telephone ad, the Bell people assured you that

> "...Any person within ordinary hearing distance can hear (your) voice calling through the phone...."

As an alternative to this method, if you were willing to pay an extra $5 installation charge, the Bell Company offered to attach a "thumper" just below the mouthpiece of your phone. When operated, this device activated a hammer within a chassis of the phone, making a loud thumping noise that was transmitted to the other phone.

The following year, Alexander Graham Bell designed the "Butterstamp" (Figure 1-3) the first set with a combined receiver and transmitter that could be held in the hand. Made of wood, it resembled a dairy butterstamp and hence its name.

The platinum-carbon contact transmitter (Figure 1-3), the receiver induction coil, the receiver and transmitter in a common handle, the receiver-operated switchhook, and Watson's polarized two-gong ringer actuated by a hand cranked magneto were thought of, or patented, or actually in use by 1878.

About this time, a young Bostonian named Francis Blake invented the variable contact transmitter (Figure 1-3). Capable of transmitting voice with extreme clarity, this instrument, every bit as good as those of Western Union, was offered with patent rights to the Bell Company in return for some of the Bell stock. His offer was quickly accepted. The Blake transmitter placed the Bell Company on even footing with Western Union and became a standard for years to come.

In 1897, one of the most important patent cases in the United States was decided by the Supreme Court. In its decree, it established Emile Berliner, whose formal schooling ended at age 14, as the inventor of the microphone transmitter. This transmitter gave the Bell System, holders of the patent, an advantage over the highly-competitive telephone systems of the day.

By 1900, telephone customers were benefiting from a common battery at the central office for talking and signaling, a bi-polar hand receiver, and some even had Almon Strowger's rotary dial.

New materials have come into play in the evolution of telephone sets. These range from magnetic materials, used in the receivers, to plastics that have made possible the long-life, nonfading, almost-everything-resistant, colored telephones.

Between 1878 and 1919 the telephone saw many changes both as a wall set and as a desk set. Then the deskstand-with-dial of 1919 became a "settled" design. It was followed in 1927 by the "French phone" comprising the receiver and transmitter in one "handle." In 1937, the Bell System began to produce the "300" type desk set wherein the bell was taken off the wall and put in the base of the telephone.

In 1950, the first of the present-day "500" series came into use and soon thereafter began to appear in a variety of colors. With color came an avalanche of new designs and new accouterments to the basic telephone.

Later additions to the Bell Telephone family are shown in Figure 1-3.

Of recent vintage are the Touch-Tone[R] Trimline[R] set (Figure 1-4) and the Picturephone[R] (Figure 1-5). The former combines in one attractive hand-held instrument the receiver, transmitter and push buttons which enable customers to tap out phone numbers quickly. The latter, on the other hand, makes possible not only the transmission of the human voice but also charts, drawings, products, processes and, if need be, the image of those conversing. Indications are that this service may have industry-wide usefulness in the carrying on of day-to-day business.

C. THE FIRST SWITCHBOARD

While the first switchboard used manually operated rotary switches to connect subscriber lines, many of the early switchboards contained jacks connected to each subscriber's line. The operator had a supply of flexible wires with plugs on both ends. To connect two parties, the operator plugged the ends of a cord into the two jacks associated with the lines; auxiliary devices produced the signaling service for ringing and disconnect. The manual switchboard positions were arranged so that additional positions could be placed side by side to obtain larger capacities. One operator could reach over three positions which could serve 150 subscribers. As the number of

Figure 1-4

Figure 1-5

The Bell System's new Model II PICTUREPHONE set can be used to transmit drawings or charts by setting the camera focus at one foot. In the photograph, the "self-view" option is being used to position the graph while it is being transmitted.

subscribers increased, a multiple of three switchboard positions was added. Trunking (permanent connections between nonadjacent positions) added a new dimension to telephone switching networks.

Much of the progress in the design of the early telephone switchboards can be attributed to the efforts of one of the most prolific inventors in telephony, Western Electric's Charles E. Scribner. Responsible for the "Jack-Knife" switch and holder of 441 patents, he made his greatest contribution in developing multiple switchboards.

1.2 THE ORIGINS OF A NATIONWIDE COMMUNICATIONS NETWORK

In August 1876, Bell set up a successful one-way telephone circuit from Brantford to Paris, Ontario. Though the distance was but 8 miles, and the signal none too strong, the event was proclaimed the world over.

A. THE FIRST TELEPHONE EXCHANGE

In the office of E. T. Holmes, in Boston, a simple plug and block apparatus was used in May, 1877, to connect four banks and a manufacturing concern, using in the daytime, wires provided previously for a burglar alarm system in effect at night. The first strictly commercial telephone exchange was established in New Haven, Connecticut, in January, 1878, interconnecting 8 lines and 21 subscribers. It is interesting to note too, that during this period the first classified directory was issued.

At the time of Bell, it must be remembered the communications technology was very much in its infancy. It was the gas light era, commutation was slow: trolleys, trains and ships; and, electric power distribution was primitive.

In the 1880's, the rapid growth of the telephone posed two problems: one, how to interconnect the ever-increasing number of exchanges which tied together subscriber's lines and two, how to hold back the tide of wires blackening the sky; and, poles as high as 90 feet carrying 30 crossarms and 300 wires. The answer to the first problem came in a statement by Theodore N. Vail, the first President of the American Telephone and Telegraph Company, when he remarked, "This linking of city to city, state to state and nation to nation has greater possibilities than we know of yet." The idea of a nationwide network of communications was born.

On June 2, 1880, a telephone line from Boston to New York was authorized. This line was put into service on March 27, 1884. On May 9, 1883, lines were authorized from New York to Philadelphia and Washington, and from New York to Albany. These events marked the beginning of the Long Lines System.

B. PHANTOM CIRCUIT

The answer to the second problem came in the practical application in 1886 of John J. Carty's "Phantom Circiut," a method of transmitting three conversations simultaneously over two pairs of wires which, via careful balancing methods, reduced the number of wires needed. Mr. Carty was also responsible for the adoption of balanced pairs of telephone wires instead of single wires with return through the ground, thus eliminating much of the interference from other telephone wires and power lines. He also developed the first theory of transportation whereby it was possible to balance out the crosstalk that accumulated over long distance from one pair of wires into other pairs.

C. INDUCTIVE LOADING

In 1889, George A. Campbell discovered, simultaneously with Professor Michael I. Pupin, an electrophysicist of Columbia University, that the benefits of inductive loading the adding of inductance - could be realized by locating "loading" coils at specified intervals along Transmission lines. This discovery led to the doubling of the distance that could be reached over open wires on poles, and the tripling or quadrupling of the distance over pairs of wires in cables. It wasn't long before, Campbell extended his circuit theory to the invention of the wave filter which, in turn, led to multichannel telephony.

In 1911 the New York-Chicago line had been extended an additional thousand miles to Denver. The line was built with large copper wires (No. 8, - almost as thick as a lead pencil), and was inductively loaded. There were two pairs of wires, giving two two-way telephone channels (a two-way telephone channel is called a "circuit"), plus a third circuit obtained by phantoming. These heavy wires - more like rods, really - were strung on thousands of poles stretching across the plains and the desert - a big and venturesome project and, for its time, a triumph of engineering and construction unsurpassed.

But Denver was the end of the line - the point of exhaustion. There was nothing left. The engineers who planned that long and slender route hoped it would somehow extend ultimately to the Coast, but they knew that this would depend on developing some kind of amplifier that might respond to the voice currents before they became too feeble, and build them up to a level where they could be projected on to more distant points. Bell people had been working on this, and there were already amplifiers of several sorts - mechanical amplifiers, mercury arc amplifiers - that demonstrated this possibility, but they were either too crude and cumbersome, or too imperfect in response, to be really promising for practical use in a long system.

D. VACUUM TUBE

It was in 1906, when the need was critical, that the "audion" or primitive tube, was being perfected by Lee Deforest. Basically, this device magnified electrical signals which heretofore were too weak for transcontinental projection. Recognized by the Bell System scientists as a technological breakthrough of extreme importance, a concentrated research and development effort was initiated to adapt the vacuum tube to large scale telephone communications.

In 1913, construction began on the route from Denver to Salt Lake City. Vacuum tube repeaters were installed at Philadelphia, Pittsburgh, Chicago, Omaha, Denver, Salt Lake City and Winnemucca, Nevada. In mid-'14 the first trial conversations were held from coast to coast. And, in January of 1915, Alexander Graham Bell, from an office in New York, placed the first official transcontinental call to Thomas Watson in San Francisco - the Watson who had been his assistant in the attic laboratory in Boston where the first telephone was made nearly forty years before. In the same year, speech was transmitted for the first time by radio telephone from Arlington, Virginia, across the continent to San Francisco, to Hawaii, and across the Atlantic to Paris.

The telephone has come a long way since that historic call in 1915. From a single transcontinental line, furnishing three circuits, the capacity for simultaneous coast-to-coast conversations has grown to many thousands. The time for setting up a call has dropped from about a half an hour to a small fraction of a minute.

The quality of transmission too, has improved tremendously. All of this did not happen by chance. The needs of the fast growing communications industry had veritably marked major areas for technological and financial effort.

E. NEGATIVE FEEDBACK

In the 1920's, when multiplex was moving ahead fast, and transmission engineers were interested in long-haul systems with hundreds of channels, the problem of ridding amplifiers of distortion, which accumulates as the telephone lines lengthen, and more and more amplifiers are added, seemed incapable of being overcome. One day in 1927, Harold S. Black, a Bell Telephone Laboratory scientist on his way to work, who too had pondered long on this very same problem envisioned the answer. Using an accidental blank page, he recorded equations that led to a solution destined to completely revolutionize the art of signal amplification over long distances. Known as "Negative Feedback" principle, it was employed in amplifiers used commercially in 1936 between New York and Philadelphia and made possible the installation of a 12 channel carrier system - operating in nonloaded cable pairs - in 1938, between Toledo, Ohio and South Bend, Indiana.

Later, George C. Southworth, a Bell Telephone Laboratory research engineer, transmitted television, radar and other broad-band signals through hollow pipes and dielectric wires, a discovery that led to the development of the Microwave Radio Relay System.

1.3 SWITCHING SYSTEMS - LOCAL DIAL CENTRAL OFFICE EQUIPMENT

In switching, new concepts and applications have made their impact felt in step-by-step panel, crossbar with its centralized intelligence and the stored program of the Electronic Switching System (ESS). The following are brief descriptions of these systems prior to their presentation in the chapters that follow.

A. NO. 1 STEP-BY-STEP AND 350A, 355A, AND 356A COMMUNITY DIAL SYSTEMS

Once started, the telephone network grew rapidly. Engineers began to think in terms of completing calls without the aid of an operator by using switches in the connecting network and a dial for the subscriber. A

Kansas City undertaker, Almon B. Strowger, in 1889 invented a rotary stepping switch that formed the basis for much of the telephone switching equipment now in service. Automatic switching systems had been patented as early as 1879 but the Strowger System, developed by A. E. Keith and others of the Automatic Electric Company, was the first commercailly feasible system. Step-by-Step switches are electromechanical devices usually activated by dial pulses. These switches are mounted on shelves in such a manner that in the establishment of the talking path through the office, the contact brushes of each switch move over a series of terminals arranged in semicircular stacks - an array of 10 rows of 10 sets of contacts.

As the name Step-by-Step implies, the connection of a telephone call is established progressively through a series of such switches. Upon dialing the first digit or letter, a **selector** steps up to the level indicated by the dial pulses and at that level hunts for a vacant trunk to another selector. This process is repeated at each selector. The dialing of the final two digits operates one of the connectors serving the called line. The next to the last digit dialed steps the switch up to the level indicated and the last digit rotates the switch to the terminal associated with the called subscriber's line. The last switch, known as the connector switch, in addition to making a connection, rings the subscriber, sends a busy tone back if the line is busy and places a busy condition on the called line.

In 1892 the first Step-by-Step office (automatic telephone exchange) was unveiled in La Forte, Indiana by the Strowger Automatic Telephone Exchange. Today, approximately 44% of all lines are **still** being served by a step-by-step office. Depending upon the type of office, step-by-step systems may accommodate anywhere from 100 to 10,000 subscribers.

B. <u>PANEL DIAL SYSTEM</u>

The first panel dial office units were placed into service in 1914 at the Mulberry and Waverly offices in Newark, New Jersey.

The panel system was developed for use in large metropolitan multioffice areas where, in most cases, the fully mechanical step-by-step system could not be used advantageously. Although this equipment is still being used, it has been superseded by the more efficient crossbar and electronic systems.

In the panel system, the digits, which the subscriber dials, have no direct relation to the groups of trunks to which the various selectors move in completing the call, and the selectors do not move in unison with the dialing. Therefore, it is necessary to provide equipment which will receive the dialing from the subscriber, record it, hold it, change it as necessary, and transmit it to the various selectors to control their movements and direct them to the proper setting. This mechanical operator is called the sender and generally speaking, acts as the control in setting up a call through a Panel office.

Terminals, over which the selector switches move, are arranged in flat vertical rows in multiple banks. The selectors are moved by electric motors rather than electromagnets. As noted above, there is no direct control of selections by the subscriber's dial, but rather, the dialing is registered in a sender which controls and operates the selector circuit. This allows for greater flexibility, more efficient trunk groups and permits dialing over a more complex and extensive trunking arrangement than is possible with the use of the direct control.

C. NO. 1 CROSSBAR DIAL SYSTEM

No. 1 Crossbar, like Panel, was developed for use in large metropolitan areas. A common control system, using extensive logic circuits for the first time, it replaced panel dial for new installations.

In the No. 1 Crossbar system, mechanical motion, which is utilized in the Panel and Step-by-Step systems for hunting in the various switching functions, has been reduced. The Crossbar switch is the principal switching element and it is, briefly, a device employing horizontal and vertical members, each magnetically operated. The operation of a vertical member, in conjunction with a horizontal member, will cause a particular set of contact springs associated with the vertical member to close and to remain closed as long as the magnet of the vertical member remains in operation.

To set up a call in this system, an idle path going in the proper direction is found, seized and immediately used to progress to the next diverging point, where this operation is repeated. Calls are set up on a "marker" basis, under which each step is "marked" before any of the intervening paths are actually seized. When the connection is completed, the common equipment, consisting of senders, markers, connectors, etc., drop out of the call and proceed with another call. This reduces the amount of equipment tied up during the period of conversation and hastens the setting up of a call. The primary advantages that Crossbar has over Panel are the provision for alternate routing calls and less maintenance.

Some offices are equipped with the Automatic Message Accounting (AMA) System, for billing of 7-digit calls without the assistance of an operator. Others, not so equipped, obtain automatic billing through Crossbar Tandem with Centralized Automatic Message Accounting (CAMA).

The addition of auxiliary senders to the No. 1 Crossbar (non-AMA type) and Panel offices, permitted 10-digit direct distance dialing to other numbering plan areas through the Crossbar Tandem or No. 4 type toll Crossbar offices with 10-digit CAMA. No. 1 Crossbar offices with local AMA were similarly arranged.

Another feature, Automatic Number Identification (ANI) enabled local offices, using CAMA, to identify a calling number and pass this information along to the CAMA machine for billing. Before this, operators were required to manually record this information. ANI is designed to identify one and two party subscribers in No. 1 Crossbar, Panel and Step-by-Step local office areas. The first No. 1 Crossbar system, President 2 Office in Brooklyn, New York, was cut into service on February 13, 1938.

D. NO. 5 CROSSBAR SYSTEM

The No. 5 Crossbar Office is a common-control local and/or toll telephone switching system designed for use in areas having more than 2000 lines. It operates with all local, tandem and toll switching systems and can serve as a combination local and tandem or toll center switching office. No. 5 can be readily arranged for Direct Distance Dialing (DDD), by operators or customers, and for Automatic Message Accounting (AMA) or centralized Automatic Message Accounting (CAMA). It has been designed to operate with as few as 4 digits in a subscriber number or as many as 11. No. 5 provides the following features essential to the expansion of operator and customer toll dialing:

1. 10-11 digit capacity
2. Alternate routing
3. Code Conversion
4. Marker pulse conversion and
5. Six-digit translation

The first No. 5 Crossbar Office went into service on July 11, 1948 at Media, Pennsylvania.

1.4 SWITCHING SYSTEMS - TOLL DIAL CENTRAL OFFICE EQUIPMENT

A. TOLL APPLICATION

Crossbar equipment can be used for switching toll traffic as well as local traffic. In the toll switching application, toll lines or trunks are switched to other toll lines or trunks, whereas in local switching, subscribers' lines are switched to other subscribers' lines or trunks. Long distance operators and, in many areas subscribers, can complete calls directly to subscribers in other distant areas on a dialing basis. For example, an outward toll operator in New York can dial a subscriber's number in any other city which has appropriate switching arrangements. No intermediate or end operator is required. With Direct Distance Dialing (DDD), no operator is needed at the originating end on certain types of calls.

The general toll switching plan divides the United States and part of Canada into many numbering plan areas. Switching systems employing No. 4 Crossbar, Crossbar Tandem, No. 5 Crossbar and, in some cases, Step-by-Step Intertoll are provided at strategic points in each area.

B. NO. 4A/4M TOLL SWITCHING SYSTEM

This is a Crossbar Common Control Switching Point (CSP) system that provides 4-wire paths for establishing connections electromechanically on a nation-wide basis, between intertoll trunks, or between intertoll and toll connecting trunks. Operating on a destination route basis, it is capable of routing a call over a preferred route or any one of as many as six predetermined alternate routes automatically without operator assistance. The 4A System and its predecessor the 4M have the same features and operating capabilities. The No. 4 System uses multi-frequency (MF) pulsing, that considerably shortens the time required for transmitting pulses controlling the switching equipment. Features essential to the operation of the No. 4, and to Direct Distance Dialing (DDD) are:

1. Crossbar switches, arranged on incoming and outgoing link frames, together with the necessary trunks and toll terminal equipment, care for the switching path.

2. Common control equipment (consisting of senders, connectors, decoders, card translators and markers) determines routing, sets up switching paths, and receives and sends the pulsing and signaling information required for completion of the call.
3. Selection of routes in rapid succession accomplished by the electromagnetic card translator.
4. Predetermined and alternate routing is punch coded on metal cards.

Philadelphia, Pennsylvania was the recipient of the first Toll Switching installation in 1943.

C. CROSSBAR TANDEM SYSTEM

Crossbar Tandem is a two-wire switching system using Crossbar switches and other apparatus. Originally developed as an intermediate mechanical switching office for large metropolitan areas with Panel and No. 1 Crossbar local offices, it provides three functions for the local office:

1. Permits economical trunking by combining small volumes of traffic into larger volumes which are routed over common trunk groups.
2. Translates almost any type of inpulsing to any type of outpulsing, thereby connecting otherwise incompatible local offices.
3. Permits centralization of equipment and services.

With the advent of Extended Area Customer Dialing and Direct Distance Dialing (DDD), the following switching features have been developed for Crossbar Tandem to accommodate interzone trunking:

1. Intertoll traffic
2. Alternate Routing
3. Storing and Sending Forward Digits as Required
4. Code Conversion
5. 6 digit Translation

1.5 SWITCHING SYSTEMS - ELECTRONIC

In Crossbar Systems, electromechanical switching was developed to the fullest extent feasible. Major advances are now taking place in Electronic Switching.

The Bell System's Electronic Switching System (ESS) is a stored program system which utilizes the high speed of electronic devices to perform the basic functions of telephone switching.

High operating speed permits a very small number of control circuits to serve a very large number of lines and trunks. System control is accomplished by subdividing the work, required to process each call, into segments and time-sharing the segments of other calls. The system's actions are determined by a program stored in semipermanent memory. Variations in features of different offices are accomplished in the stored program rather than in apparatus, wiring and equipment options. Office units, which are traffic dependent, are accommodated by a plan which minimizes engineering and installation efforts required for new offices and additions to existing offices. Wide use is made of transistors and other solid-state devices which operate more than 1000 times faster than conventional switching apparatus. The system's high speed and special equipment make possible a variety of new services which greatly increase the value and flexibility of each customer's telephone. Although ESS uses electronic components, it is comparable in many ways to the present common control switching systems, especially No. 5 Crossbar.

A. NO. 1 ELECTRONIC SWITCHING SYSTEM (NO. 1 ESS)

Succasuna, New Jersey was selected for the Bell System's first full-scale commercial electronic central office "Cutover" in May 30, 1965. It is a very sophisticated common control switching system which can serve as many as 65,000 station lines. Highly reliable and compact, this office has high-speed solid state devices that provide unlimited flexibility, great dependability and economy in every phase of its operation. A stored program that utilizes magnetic memory devices to direct the system, provides such unique "customer calling services" as:

1. Two and three-digit dialing for frequently called numbers
2. Automatic routing of incoming calls to another phone when the original called line is busy
3. Dialing a code to forward incoming calls to another telephone when the customer is away from home, and
4. Dialing a third telephone into an existing telephone conversation.

Taking full advantage of its data processing capabilities, this system has been programed for Automatic Message Accounting operation.

B. NO. 101 ELECTRONIC SWITCHING SYSTEM (NO. 101 ESS)

The first commercial trial for an electronic PBX, Centrex and other modern subscriber service features was inaugurated in November 1963 at Cocoa Beach, Florida. As in the No. 1 ESS, this system also utilizes high-speed solid-state electronic components in conjunction with a binary stored program control. Among the new features of this system are:

1. Abbreviated dialing in which frequently called outside numbers, either local or long distance, may be reached by dialing three digits.

2. Touch-Tone dialing in which extensions can be equipped with numbered touch buttons instead of a rotary dial.

3. Call transfer in which calls from the outside can be switched from extension without going through the switchboard operator.

4. Conference calling in which as many as two additional parties can be dialed into an existing conversation by the party originating the conversation.

1.6 CARRIER SYSTEMS

The carrier principle is a method of converting voice frequencies of a communication channel to a corresponding band of frequencies centered about a particular frequency beyond the voice range, known as the carrier frequency. By suitably spacing such carrier frequencies over a comparatively wide range, several communication channels may be combined to transmit signals or voice over a single pair or wires without interference from another channel. Thus, the carrier system is used to increase the capacity of open wire, cable conductors and microwave for carrying telephone, telegraph and video messages.

Early carrier systems provided up to three or four additional channels, as well as the original voice-frequency channel, on each pair of wires. The number of channels which a carrier system can accommodate is limited by the band of frequencies which can be transmitted economically over the conducting wires.

As a result of continuous improvements to carrier systems, we cannot realize utilization of the carrier principle which will permit the transmission of 3600 telephone conversations over a pair of coaxial cable conductors in the L-4 Carrier System. Yet, with the potential now offered by solid-state devices (repeaters using transistor amplifiers), it is possible that even wider band coaxial systems than the L-4 will be designed.

1.7 A NATIONWIDE AND WORLDWIDE COMMUNICATIONS NETWORK

Today, as the result of the efforts by Long Lines - the long distance operating unit of the A.T.& T. - which builds, operates and maintains the interstate network of circuits and other facilities in the United States that make possible nationwide and world wide communications, telephone users in the United States can be connected with almost all the telephones in the world.

A. LONG DISTANCE OPERATIONS

There are in the United States 2100 cities in which there are operating offices for handling long distance calls. These cities are called toll centers.

In order for a long distance call to be made, the call must travel from the local exchange at which the call originates to a nearby toll center, then (directly or indirectly) to toll center near the exchange at which the call terminates, and then to that local exchange itself. To facilitate the connection of any two of the 2100 toll centers, there is a special set of 210 toll centers that are called switching points and that perform a function in connecting the toll centers that is comparable to the function of a central office switchboard in connecting the subscribers whose lines are connected to that switchboard.

Each toll center is connected directly with at least one of these switching points. In turn, each switching point is connected, directly or indirectly, with each of the other switching points.

B. DOMESTIC TELEPHONE MESSAGE SERVICE

Long Lines' responsibility is to handle interstate calls which originate in the territory of one Associated Company and terminate in the territory of another. Long distance calls other than the type just defined are handled by the Associated Companies.

Consequently, most intrastate long distance calls are handled by the Associated Companies. Also, most interstate long distance calls that originate and terminate within the same Associated Company are handled by the Associated Companies.

In general, the Long Lines Department provides circuit facilities for the longer haul interstate traffic of the Bell System. During 1966, long distance interstate telephone messages - jointly handled by Long Lines and the Associated Companies - totaled 1,780,300,000. This traffic amounted to 5,706,000 messages per average business day. To assure a smooth flow of communication - particularly in times of especially heavy traffic, disaster, or equipment failure, the Long Lines Department and the Associated Companies have established twelve regional network control centers as well as an overall control center in New York.

Each of the twelve regional centers is divided into several sectional centers, then, in turn, into smaller areas called primary centers and, finally, toll centers containing the switching machines where calls first enter or leave the long distance network.

Together, the staffs at these centers act as a network management team, handling the interstate network of circuits and switching equipment that serves customers with about 95,000,000 telephones - and about 55,000 teletypewriter machines.

Under a master switching plan, the network, like a computer, is programmed to handle calls in a systematic, economical manner with alternative routes provided when normal ones are not available. It is seldom that a "no-circuit" tone or announcement must be made in order to ask the customer to try his call again later.

The success of this management of the flow of calls depends upon automatic switching equipment, a system of alternative routings, and full knowledge of the second-by-second state of the network as noted briefly in the material on communication systems.

C. OVERSEAS SERVICE

The Long Lines Department furnishes service by means of ocean telephone, satellite, radiotelephone, and over-the-horizon radio to countries and territories overseas and by radiotelephone to ships on the high seas and to airplanes. The volume of overseas messages handled by Long Lines was about 10,000,000 during 1966. Overseas telephone service, together with service to points on this continent, makes it possible for telephone users in this country to reach more than 97 percent of the telephones in the world.

Overseas telephone facilities are also used in transmitting television and radio programs to and from countries abroad. Long Lines also makes circuits available to the international telegraph carriers for their use for their own customers. Many of the underseas telephone cables were laid across the ocean floor by the Bell System cable ship, C.S. LONG LINES (Figure 1-6).

In addition, circuits for overseas communications are leased from the Comsat Corporation, which provides the service via orbiting satellites. The Bell System pioneered communication by earth satellites with the Echo balloon and TELSTAR[R] satellites.

1.8 THE BELL TELEPHONE LABORATORIES

The Bell Telephone Laboratories has the reputation of being the finest industrial laboratory in the world. A large part of this reputation is due to the work of the scientists noted thus far. Further indication of the importance of the research work can be found also in the fact that Bell Laboratories is an industrial labortory whose researchers have won two Nobel prizes. One was awarded to Clinton J. Davisson in 1937 for the codiscovery of electron diffraction and the wave properties of electrons. Another, in 1956, went to William Shockley, John Bardeen, and Walter H. Brattain for their investigations into semiconductors and for the discovery of the transistor effect.

The invention of the transistor opened the era of modern electronics, an era in which Bell Laboratories has played a significant role. Another invention was the solar battery, which has been the source of power for many long-lived earth orbiting satellites. The principles of the laser were first described by a Bell Laboratories researcher, Dr. Arthur Schawlow, working with Dr. Charles Townes of Columbia University. Later, the first continuously operating gas and solid-state (ruby) lasers were created by Bell Laboratory scientists.

Figure 1-6 C.S. Long Lines

Communications achievements which have come from Bell Laboratories include: two-way transoceanic radio-telephone service, the coaxial cable, microwave radio relay systems, the nationwide television network, over-the-horizon microwave transmission, transoceanic telephone cable systems, direct distance dialing, and electronic switching systems.

The concept of communications by satellite was first proposed scientifically by Dr. John R. Pierce of Bell Laboratories. Later, the TELSTAR experimental communications satellite, which stirred the world when it first spanned the Atlantic with live television in 1962, was engineered, constructed, and successfully tested by Bell Laboratories development engineers. They continued their experiments with the second TELSTAR satellite, which was put into orbit in 1963.

1.9 NEW DEVELOPMENTS

A. HOLOGRAPHY

Recently, the Bell Telephone Laboratories have been pioneering in Holography which holds great potential for important communications functions. Holography, sometimes called "lenseless photography" of "wavefront reconstruction photography" is a way of recording the unfocused light reflected or transmitted by an object or objects. The recording, called a hologram, is usually made by exposing a photographic plate to light reflected from a subject and a reference source. The subject and the reference source (often a mirror) are illuminated with laser light. Two aspects of holography that are of primary interest at the Laboratories are:

1. The recording and transmitting of pictoral information, including possible uses in PICTUREPHONE and television services; especially, the three dimensional imaging capability of holography.

2. Utilization as a memory device.

Holography is still in its infancy. The advent of the laser, with its intense, coherent output (light waves) has given great impetus to its progress. Its potential however, in the final analysis, to the communications media must be evaluated in terms of its economic feasibility.

1.10 DIGITAL COMMUNICATION

Transmission systems carrying all types of communications in a digital pulse stream are gradually being introduced into the Bell System. Eventually, they will be connected together in a digital hierarchy to form a nationwide digital communications network.

For some years Bell Telephone Laboratories has been planning a digital network that will carry all types of communications signals, including:

1. Voice
2. Digital Data
3. Facsimile
4. PICTUREPHONE Service
5. Television

These signals will be mulitplexed together and transmitted on high-speed pulse streams.

Although the complete concept of a digital communications network includes digital switching as well as transmission facilities, most of the effort has been on the latter. T1 Carrier, the first digital transmission system to be designed, is now used commercially in many of the more heavily populated areas. At present, a medium-speed system and a commercial high-speed system are being developed. An experimental high-speed system has been built. The domestic communication satellite system, recently proposed by the Bell System to the FCC, would employ digital transmission and would be interconnectable with the digital network.

With the rapid development of solid state electronics and its application technologically to digital transmission, it may not be too far in the future when a digital network will be capable of:

1. Operating over any distance, and
2. Carrying several thousand calls, several television channels, or many data signals on a single pulse stream.

As time goes on, digital communication systems are expected to assume an increasingly important role in the Bell System, but analog systems will continue to provide the bulk of communication for many years.

1.11 FUTURE TRENDS

The past history of communications has been studded with developments that have contributed significantly to man's progress. At the turn of the century, the Bell System mobilized its resources to bring about a nationwide telephone network. It was a period in which the ground work was prepared for the transition from the manual system to the switching system. Later, we saw the advent of the solid state era in which the transistor, communication satellite and the computer made their entries. Today too, we are witnessing the increase in the variety and number of products, systems and services.

What will be the demands of the future? The following are comments by two world-renowned Bell Telephone Laboratory scientists.

Dr. John R. Pierce - Executive Director, Research Communications Sciences Division:

> "I see a great extension of satellites using radio frequencies for both domestic and foreign communication. It's a way of getting a lot of circuits quickly. And of course television is now extending through the ultra-high frequency as well as the high frequency. Ultimately, you run into an end as the air waves become full. But you never run into an end in the demand for communication. Thus, I think that communication--even mass communication--will eventually outgrow the air waves. We will have more and more of it by wire, or by millimeter waves going through hollow tubes called waveguides, or through laser beams that can carry tremendous amounts of communications, but which will have to be protected from the weather by pipes. I think that ultimately a large fraction of communications, even those that now ordinarily go by radio, will probably have to go by some guided means."

Dr. William O. Baker - Vice President, Research:

"In the coming years we must prepare to anticipate and meet customer needs for communications facilities of ever-increasing quality and quantity ... which will involve the transmission of new magnitudes of communications, including intermixed batches of data, works and graphics beyond anything conceived hitherto ....

"The new technology should enable us to enhance the usefulness of all our service offerings."