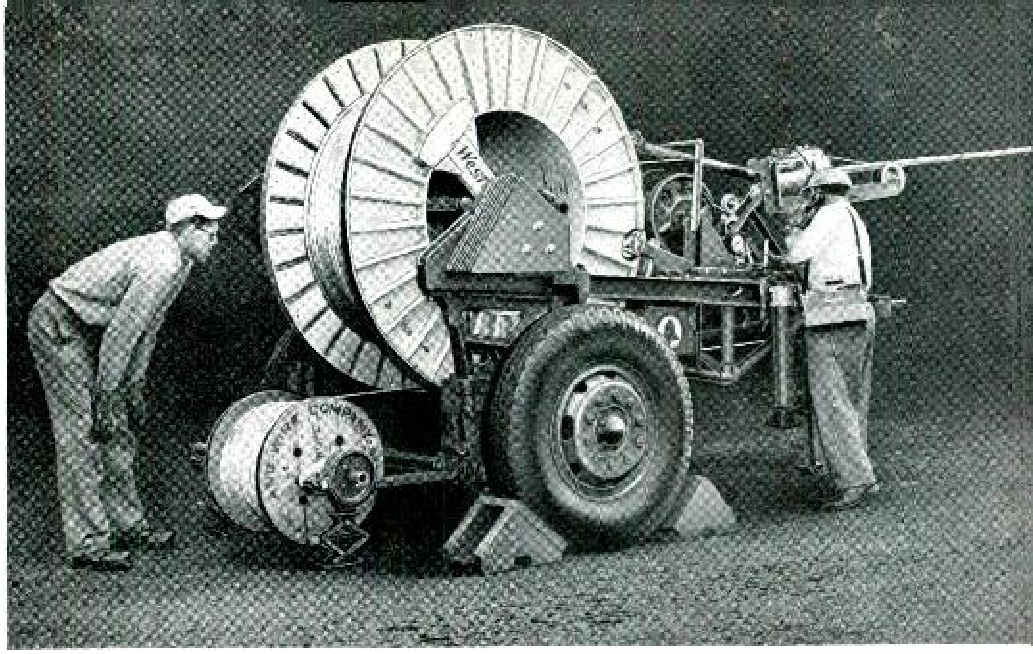
Prelashing Aerial Telephone Cable



F. V. HASKELL and O. L. WALTER *Outside Plant Development*

The Bell System has more than 300,000 miles of aerial cable in service, and more is being added each year. This cable, consisting of soft copper conductors and a lead or polyethylene sheath, does not have sufficient strength to be self-supporting in spans of reasonable length, and therefore is attached to a steel strand. A new method of attaching small sizes of cable to the strand, before it is placed on the poles, is called "prelashing." When more than a few hundred feet of small cable is to be installed in normal situations, prelashing can usually reduce the man-hours required for the job.

Within the past decade, the telephone business has gone through the greatest period of expansion in its history, more than doubling its size and spreading out into many areas that previously had no telephone service. This period of expansion has been one of mounting material and labor costs and hence an economic solution of many Bell System engineering problems has become increasingly important during recent years.

A proper balance between material and labor costs is essential to any industrial project, whether it be the factory production of completely assembled items or the field assembly of fabricated parts to form complete units. It is generally desirable that the labor factor of the materials-labor ratio be as low as possible. On many factory assembled units used in communications, the materials-labor ratio may be as high as five to one. However, for outside plant items, the materials-labor ratio may not be so favorable. Usually, the assembly of outside plant apparatus takes place in the field, often under extremely adverse conditions. As a result, outside plant construction crews must be highly trained, skilled workmen. These factors so influence the materials-labor ratio for outside plant installed equipment that it is now about one to one.

The job of increasing this ratio, especially through a reduction in field installation costs, has been a direct challenge to Laboratories engineers concerned with the development of outside plant apparatus and facilities. Much has already been done to this end and effort in this direction is continuing with even greater vigor at the present time. The job has involved intensive studies of installation and maintenance operations. Out of these studies has come a series of new developments, and others are now nearing completion. Outstanding examples are the cable lasher, rural distribution wire, the mechanical splice closure, and the prelashing method of installing aerial cable.

The prelashing method of aerial cable installation perhaps best demonstrates the efforts of outside plant development engineers to improve the materials-labor ratio of an established construction procedure. Substantial savings in aerial cable installation costs by the prelashing method have been realized through the design of special equipment which reduces the number of man-hours required for each length of cable installed.

Aerial telephone cables supported on poles located along a street, country road or on a cross-country right-of-way are a common sight. It may not be obvious, however, that these cables are not fastened directly to the poles but are supported from steel strands attached to each pole. This construction is necessary because telephone cable, with its soft copper conductors and lead or polyethylene sheath, is not strong enough to support itself in the span lengths commonly employed (100 to 600 feet). The supporting strand must be stretched tightly so that the "sag" resulting from the weight of the cable will be small enough to provide satisfactory clearance between line and ground on poles of reasonable height. Strand tensions, with the cable in place, are of the order of a thousand pounds or more, and pole structures must be sufficiently strong to support this load plus the added stresses imposed by wind and ice.

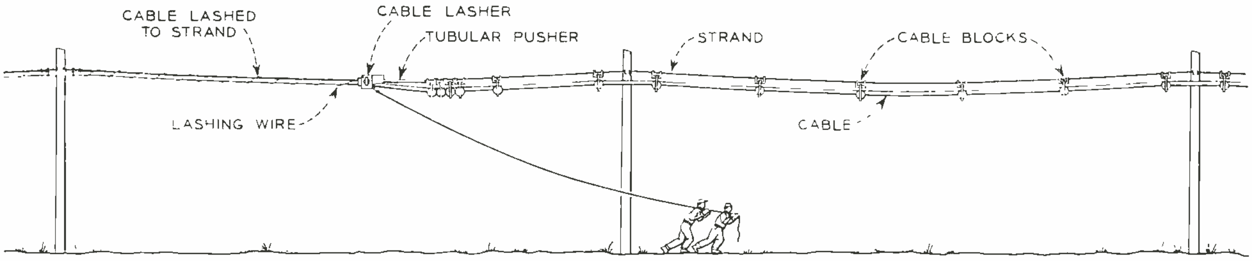


Fig. 1 — Cable and strand being lashed together on the field side of the poles. The lashing machine may be towed only from pole to pole, and must be transferred across the pole after the cable blocks are removed and the lashing terminated.

For many years, cable was hung from its supporting strand by cable rings that were snapped onto the strand at intervals of about 20 inches by a man riding along the strand in a cable car. A line through these rings was used to pull the cable into place. Today, common practice is to secure the cable to the strand by a helical wrapping of wire wound around the strand and cable with a cable lasher. With this lashed construction the time-consuming job of placing rings is avoided, and cuts in the sheath caused by chafing in the rings are no longer a problem. For these and other reasons, lashing has almost entirely supplanted rings in aerial telephone cable construction.

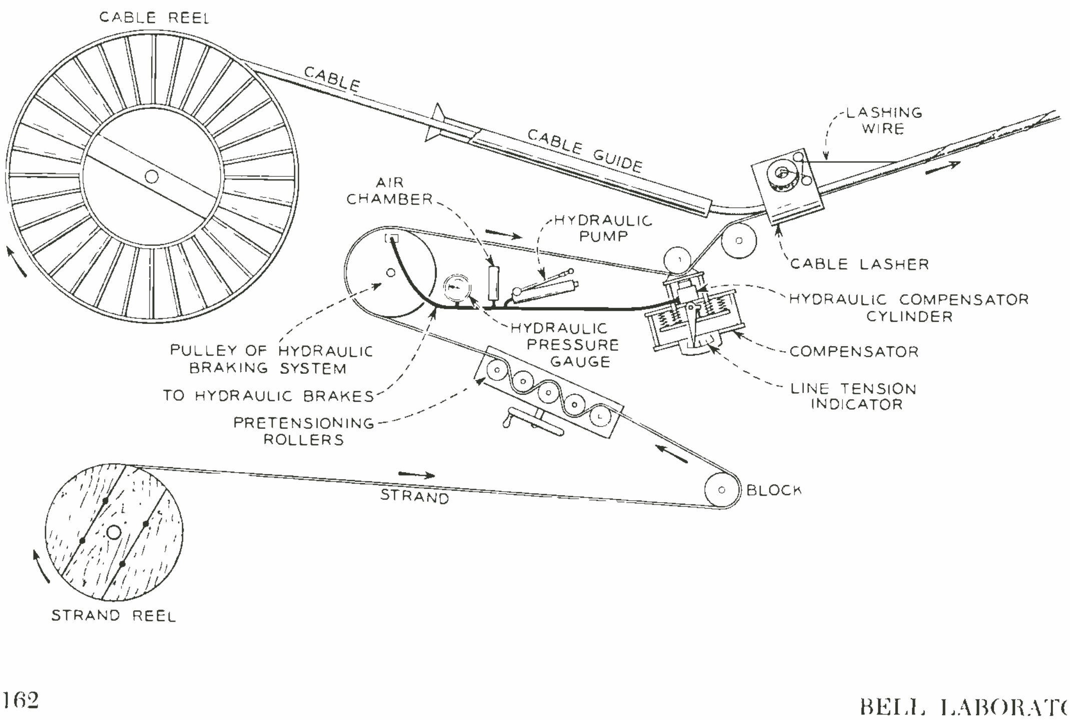


Fig. 2 — Schematic diagram showing the principal parts of the prelashing apparatus for cables.

Before describing the prelashing method of installing cable, it may be helpful to review briefly the sequence of operations followed in a typical aerial cable installation in which a conventional cable lasher is employed. After the poles are placed, a lineman climbs each pole and installs a cable suspension clamp that will be used for gripping the supporting strand. The strand is payed out in long lengths, perhaps one-half mile, and placed loosely in the clamps. It is pulled to its proper tension, and each pole must be again climbed to tighten the clamp. The procedure used from this point on depends on whether the cable is to be installed on the road side or the field side of the poles. In the first case, if there is sufficient clear space on the road side, the cable can be payed out from a cable reel trailer towed by a truck moving along the line. In the second case, or if there are trees or other obstructions on the road side, the cable must be pulled into place from a stationary reel. In one method of making such installations, cable blocks containing rollers are raised by means of a lifting tool and placed on the strand at frequent intervals in each span. A winch line is threaded through the blocks and attached to the outer end of the cable on the reel which is set up at a strategic point. The cable is pulled through the blocks so as to lie just below the strand, and the cable lasher is then placed over the cable and strand adjacent to the pole. The lasher is towed to the next pole by a truck or by workmen walking along the ground as shown in Figure 1. As it moves, the lasher wraps the lashing wire around the cable and strand to bind them together tightly. However, each pole must be climbed to remove the cable blocks which have been pushed ahead to the pole by the lasher, to lift the lasher across the pole from one span to the next, and to cut and terminate the lashing wire at the pole.

Road-side installation from a moving reel is somewhat simpler. The cable reel is placed on a trailer, and the end of the cable passed through a strand-supported guide and then fastened to the strand. As the trailer is moved ahead, paying out cable through the guide, which is towed along the strand, a lasher, located a few feet behind the guide, is also towed by the truck and lashes the cable to the steel supporting strand.

For either of the cable installation methods described above, each pole must usually be climbed three times, and several trips made up and down the line. The prelashing method of aerial cable installation was developed principally to reduce the amount of pole climbing and other labor incidental to cable installation by conventional lashing methods. With this method, a roller support is installed temporarily on each pole, and after the winch line has been pulled through all roller supports, the cable and strand are "prelashed" on the ground and long lengths of the composite structure, continuously maintained at the proper tension, are pulled through the rollers. The maximum number of times each pole must be climbed has been reduced to two and the number of trips that must be made along the line has been substantially reduced.

The principal equipment used in the prelashing is the trailer-mounted assembly illustrated in the headpiece. This equipment, designed for installation on a standard cable reel trailer, can be moved and placed as needed along the line by a telephone construction truck. A tension in the order of 1,000 pounds is applied to the strand and a lower tension of about 100 pounds is applied to the cable by this unit during the prelashing operation. This serves to keep the cable and strand clear of the ground and any obstructions along the pole line while the assembly is being placed.

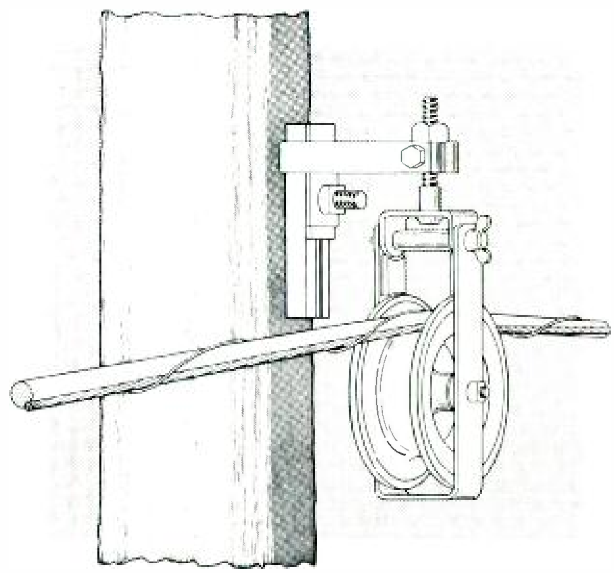


*Fig. 3 — **Diagram of temporary single roller and mount as used on poles that are in line.***

The main working components of the trailer equipment are illustrated schematically in Figure 2. As shown, the strand is first pulled forward from the strand reel over a block mounted on a footpost of the trailer. This reel is kept from overrunning by a mechanical brake. From the block, the strand passes toward the rear of the equipment through a set of pretensioning rollers where a degree of tension is introduced. The strand next passes around the pulley of a hydraulic brake assembly whose braking action increases the strand tension to its final pay-out value. From here, the strand passes forward under an idler roller that is part of an assembly used to indicate the strand tension and automatically control the effort of the hydraulic brakes. Finally the strand is joined by the cable coming from its reel and both pass through a stationary lasher, fixed to the trailer, where a tight helical wrapping of corrosion-resistant steel wire is applied to the combination. Mechanical brakes on the strand and cable reels are set manually, before a pull is started, to prevent the reels from overrunning. These brakes may be adjusted further at any time during the pull. The pretensioning rollers are also set in advance by means of a screw adjust-

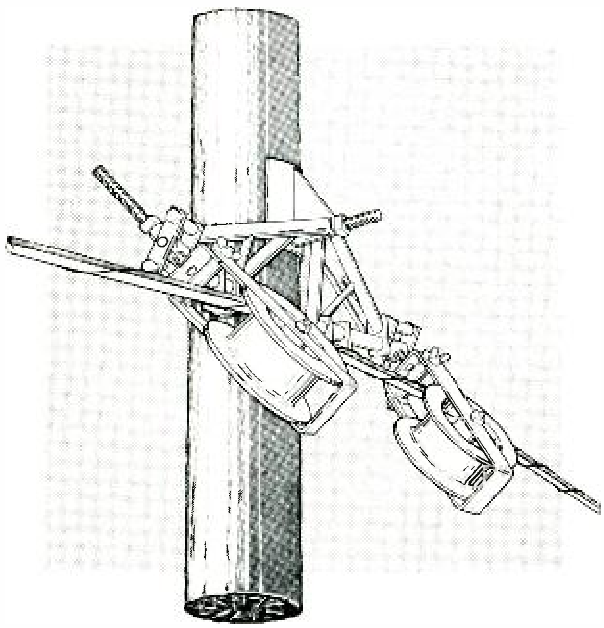


Fig. 4 — Double rollers as used on corner poles where the pull is away from the pole.

ment to provide sufficient tension to prevent the strand from slipping around the hydraulic brake pulley. Additional strand tension applied at the trailer is developed by resisting the turning motion of the pulley in the hydraulic brake system. This resistance is set manually by the operation of a pump and a release valve.

During the operation of the prelashing apparatus, the tension in the strand applies an upward force to the idler pulley in the tension-measuring device. This force is opposed by a set of springs which compress in proportion to the strand tension and actuate a pointer on a scale that is calibrated to show the strand tension in pounds.

The temporary rollers mentioned above are used on the poles to support the prelashed cable and strand combination while the pull is in progress. They consist of one or two rubber-covered cast aluminum pulleys mounted in a specially designed framework. When a pole is in an approximately straight line with adjacent poles, a single pulley and frame, as shown in Figure 3, is used. This pulley is mounted so that the roller bracket is free to rotate and thus relieve stresses that would otherwise be produced by slight changes in direction of the route. At poles marking a sharp change in direction, a pair of pulleys is mounted on one of two types of frames, depending on whether the pull is toward, or away from the pole. This form of assembly is used to divide the strain between two rollers and effectively reduce the angle where the sharp bend might result in damage to the cable or lashing wire. One such double roller assembly is illustrated in Figure 4 at a position where the pull is away from the pole.

There is a tendency in the prelashing operation for the strand and cable assembly to twist around each other as they are pulled over the temporary rollers under the tension provided by the trailer assembly. To overcome this, the lashed cable and strand combination is attached to the winch line through a "cable leader" as shown in Figure 5. This leader consists of a set of hinged weights that fold up into a frame as they pass through a pulley; a curved rod, called a "tipper bar," to the leading end of which the winch line is attached; and a connector at the trailing end to which the cable, strand, and lashing wire are secured. The tipper bar turns the leader as it enters each pulley so that the weights ride over the face of the pulley. These weights normally hang down in an extended position and develop a torque to resist the twisting tendency of the strand and the winch line. As the strand has a left-hand lay, it has been found that a left-hand lay in the winch line provides a further means of minimizing the twisting tendency. Each weight is spring-loaded and so returns from the folded to the extended position as it leaves a pulley.

After a pull has been completed, the strand is permanently attached to the pole at the winch end of the route and then brought to its final tension at the trailer end by workmen using a chain hoist; alternatively, the strand may be attached to the pole at the trailer-end of the route and then brought to final tension by means of the truck winch. The lashed combination is next transferred from the temporary rollers to permanent strand supports on each pole. A special tool, used to make this transfer, consists of a pair of hooks provided with grooves to fit the strand and a lifting screw that enables workmen to lift the strand and cable away from the roller. At poles that are in line, the tool is used to lift the prelashed combination upward, clear of the pulley, until the strand can be secured in a suspension clamp mounted on the same through-bolt used to support the pulley frame on the pole. After the strand is secured, the temporary assembly is removed and the permanent mount tightened in place.

At corner poles, the lashing wire is clamped, cut, and temporarily unwound from the prelashed combination for two or three feet on both sides of the pole, and the strand is lifted away from the pulley to within about three inches of the pole. A three-bolt corner suspension clamp is then placed on the strand between the hooks of the transfer tool, and a hole is bored through the pole in line with the center hole of the clamp for a cable suspension bolt. After the bolt has been installed, the clamp is secured to it and the temporary roller assembly is removed. The cable and lashing wire are secured to the strand in these positions with spacers, metal bands (lashed cable supports), and lashing clamps.

During prelashing, close coordination of all work operations is necessary. To achieve this, it is essential, except on short pulls where hand signals may suffice, that a man at the prelashing trailer and a patrolman observing the progress of the cable leader be provided with means for instant communication with the winch operator. Portable radio talking sets are used for this purpose, as illustrated in the headpiece.

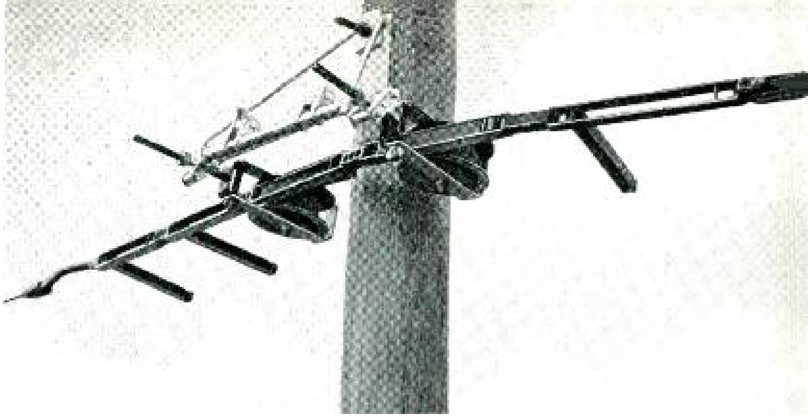


Fig. 5 — Model of cable leader passing through a double roller at a corner where the pull is toward the pole.

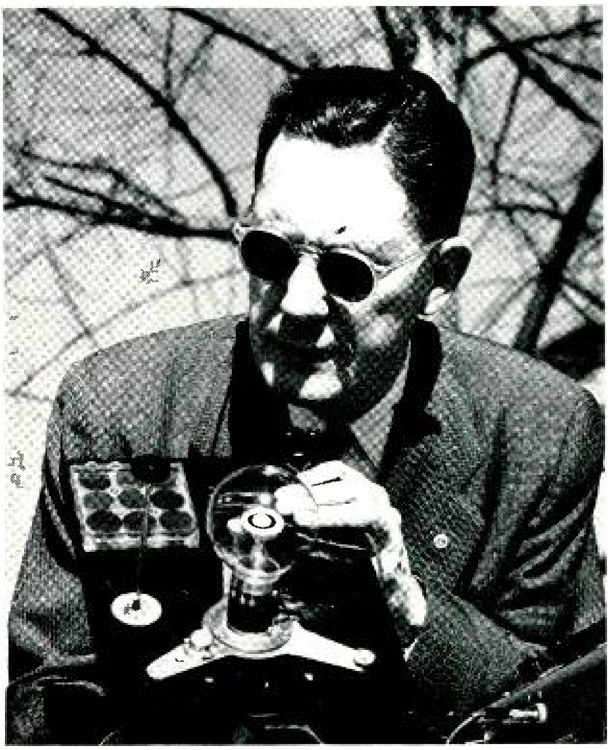
The prelashing method is applicable to the installation of lead sheathed cables up to 1.1 inches in diameter and composite sheathed cables up to 1.3 inches in diameter. The Bell System is now installing much aerial cable by prelashing and substantial savings are being realized in construction effort per unit length of cable placed. These savings in skilled manpower are especially important at present, when the Bell System's work load is at a maximum in an all-out effort to provide service for the great number of people desiring it.

THE AUTHORS

F. V. Haskell joined the Laboratories in 1929 after three years with the New York Edison Company. He has devoted most of his efforts to outside plant work, with particular emphasis on development engineering in aerial wire and cable systems. During World War II he worked on the preparation of several technical manuals and on the design of fault location test sets for the Signal Corps. More recently, he has been associated with the Systems Engineering Department and has engaged in systems planning for outside plant. Mr. Haskell received his B.S. in E.E. from Worcester Polytechnic Institute in 1926 and is a member of the American Institute of Electrical Engineers.

O. L. Walter joined the Laboratories in 1927 and was first engaged in the development of reproducing equipment for talking motion pictures and the design of public address systems. During World War II he worked on the design of auxiliary drive equipment for radar systems and was one of those who received Navy citations for helping to perfect the sonic torpedo. For the past several years he has worked on the design of equipment for the prelashing and placement of aerial cable. He received the B.S. degree in Mechanical Engineering from Oregon State College in 1927. He is a member of Sigma Tau.

Efficiency of Bell Solar Battery Almost Doubled



D. F. Ciccolella compares the electrical output of the battery with the total energy available from the sun as measured by a pyrheliometer.

The efficiency of the Bell Solar Battery has been practically doubled since its announcement by Bell Telephone Laboratories just a year ago. The battery is man's first successful device for converting sunlight directly into useful amounts of electricity.

Bell scientists, who had already achieved 6 per cent efficiency when the battery was first shown, have since steadily increased its efficiency until today they have experimentally obtained 11 per cent – an efficiency comparable to that of the best gasoline engines and more than twenty times higher than that of the best photovoltaic devices available.

The Laboratories team responsible for the increased efficiency and further development of the Bell Solar Battery includes K. D. Smith, E. J. Stansbury, C. J. Frosch and D. F. Ciccolella.

Trial models of the improved battery will have their first practical test as part of the telephone system this summer in Americus, Georgia, where controlled experiments will determine the usefulness of the battery in supplying power to amplifier stations on rural telephone lines.

The Bell Solar Battery is an extremely simple looking apparatus made of wafers of especially prepared silicon. Silicon, one of the world's most abundant elements, is a semiconducting material that is extremely sensitive to light. The improved "cells" or silicon wafers can now be electrically linked together to deliver power from the sun at a rate of up to 100 watts per square yard of silicon surface.

The increased efficiency of the battery has been achieved primarily by refinements in the fabrication process, aimed at reducing internal losses in the individual cells.

The battery was invented by a three-member team of Bell Laboratories scientists – Gerald L. Pearson, Calvin S. Fuller and Daryl M. Chapin.

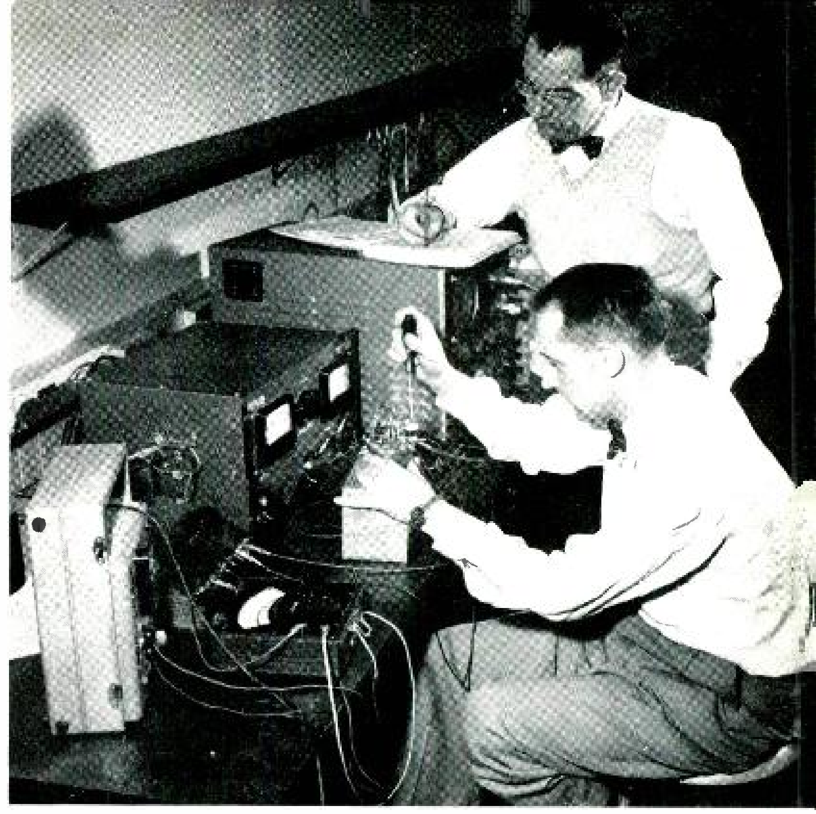
Although the Bell Solar Battery is a relatively new device and still in the research stage, small solar converters like those now being produced experimentally at the Laboratories hold great promise for future use in communication systems where there are small power requirements. Research also indicates that these batteries can be used as power supplies for low-power portable equipment.

Key to the Laboratories' technique for producing the batteries is the controlled introduction of a foreign element, boron, into a microscopic layer near the surface of a thin slice of arsenic doped silicon.

Treatment under gas at high temperature permits the introduction of minute traces of boron into the atomic structure at the surface of the silicon. Introduced at a precise rate and under carefully controlled conditions, the boron reaches a depth of less than 1/10,000 of an inch.

This thin layer and the remainder of the silicon wafer form what is known as a p-n junction, the heart of the battery. This same type of junction built into a single crystal of germanium is the basis for the junction transistor, another invention of Bell Telephone Laboratories.

The field-effect transistor, a completely new and fundamentally different type transistor, has been developed in the Laboratories' Physical Research Department. Experimental models of this higher frequency unit are already undergoing tests in amplifiers, oscillators, and frequency and amplitude modulation circuits.



The Field-Effect Transistor

I. M. ROSS *Physical Research*

The "field-effect" transistor is one of the latest additions to the transistor family. Although it operates on a principle quite different from that of the point-contact or junction type, it is capable of performing many of the same functions such as amplification or oscillation, and it has the advantages of small size and low power consumption common to the others. The development of the field-effect transistor is in an early stage; however, it has already been shown that it behaves as predicted by theory and, in particular, that it should eventually be capable of operating at appreciably higher frequencies than can the point-contact or usual junction type. It is the possibility of obtaining this higher frequency response that is the most interesting feature of the field-effect transistor.

Although the field-effect transistor is one of the most recent of the transistor family to be made into a practical amplifier, the underlying principle is quite old as transistors go. The original proposal for the device is illustrated in Figure 1. As shown, it consists of a thin sheet of conducting material with electrical contacts at each end and a metal plate close to, but not in contact with, one surface. The surface of the conductor and the metal plate then form a capacitor. By applying a potential to the plate, a field will be set up in the conducting slab and, if the polarity of the potential is correctly chosen, this field will tend to push the current carriers away from the surface of the material. The net result of this will be a decrease in the total number of carriers in the material and hence an increase in the resistance from end to end of the slab. If the device is connected as shown in Figure 1, when the key is closed, the current through the slab will decrease. It is therefore possible to control the current through the slab by means of the potential on the metal plate and, if the dielectric between metal and slab were perfect, this control would require no power. In the circuit of Figure 1, the current through the slab also flows through a load resistor. Thus, when the current changes, the potential drop across the load resistor changes and, if a large enough resistance is used, this potential change will be greater than

Above — The author (front) and G. C. Dacey, jointly responsible for this development, measuring the characteristes of a field-effect transistor.

that applied to the metal plate. In other words, it would be possible to obtain voltage amplification. Also, when the current in the load changes, the

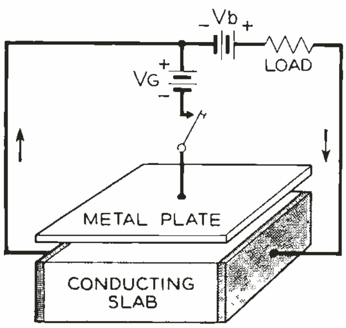


Fig. 1 — Schematic representation of a field-effect transistor in a circuit designed to illustrate how current through the slab can be controlled by applying a voltage to the metal plate.

power dissipated in it will change and, since the control power is essentially zero, there would be power amplification.

The principal problem in the realization of the field-effect transistor was to find a suitable material for the slab. Since the material had to be a conductor, all insulators were immediately ruled out. Metals, on the other hand, contain such high densities of current carriers — electrons — that it would require an impractically high potential to give an appreciable percentage change in the current flowing. Semiconductors, however, have densities of current carriers lying between those of insulators and those of metals and are ideally suited as "field-effect" transistor materials. In 1948, W. Shockley and G. L. Pearson of Bell Telephone Laboratories used germanium to make a structure similar to that shown in Figure 1. They found that they were able to affect the current through the germanium by means of the potential on the metal plate, but that the control sensitivity was much less than that predicted from a theory of the device. However, this was the first time that the "field-effect" mechanism had been observed.

It was proposed by J. Bardeen that the loss of sensitivity of the device could be attributed to conditions at the surface of the germanium slab. At the surface, the arrangement of atoms is different from that in the bulk of the material, and hence the electrical properties may also be different. In effect, what Bardeen proposed was that the free surface acted as an electrical screen that tended to prevent a field from penetrating into the body of the material, thus decreasing the effect of the field on the resistance of the slab. It was during an investigation to test this hypothesis that Bardeen and W. H. Brattain invented the now familiar point-contact transistor.

The field-effect transistor in its original form lacked sensitivity because of the effect of the germanium surface. The ideal would be to have a capacitor situated inside the germanium slab to eliminate surface effects. This can be achieved by using what is called a p-n junction.

In a semiconductor like germanium, there are two important ways in which conduction can occur. In the first, conduction takes place by the movement of electrons, which, being negatively charged,

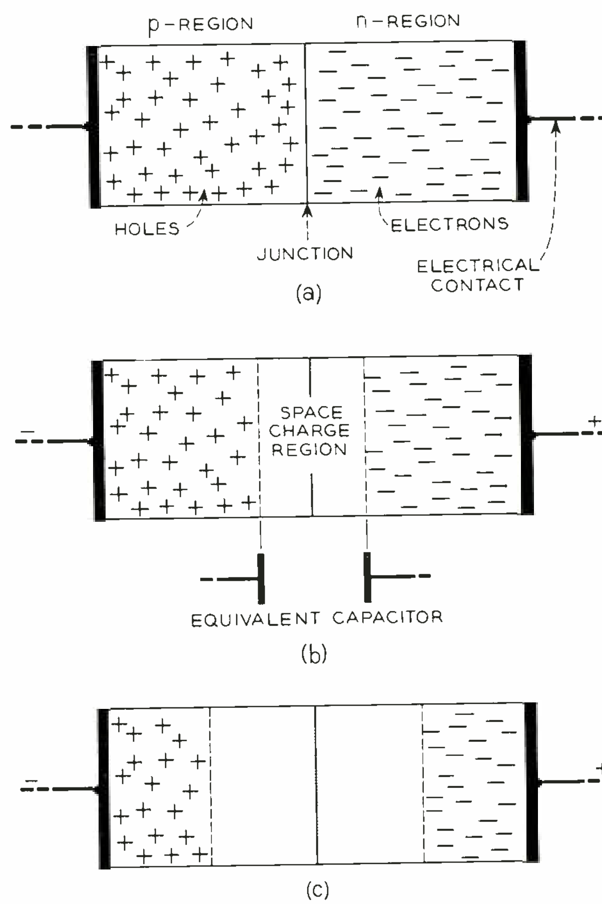


Fig. 2 — Distribution of holes and electrons in a p-n junction for: (a) no bias voltage applied; (b) a reverse bias where removal of charges produces a space-charge region and makes the junction equivalent to a capacitor; (c) a large reverse bias producing a wider space-charge region.

move in a direction opposite to the electric field. A semiconductor in which conduction is due primarily to the movement of electrons is called "n-type," the "n" standing for negative. In the second type, conduction is due to the movement of what are called "holes," which may be considered is particles having almost the same mass as that of an electron but having a positive charge. Hence, holes will move in the same direction as the electric field. A semiconductor in which conduction is due primarily to the movement of holes is called "p-type," the "p" standing for positive. It is possible to make germanium either n- or p-type, depending on the chemical elements that are added during growth of the crystal.

A p-n junction specimen may be defined as a piece of single-crystal semiconductor containing two regions, one having n-type conductivity, and the other p-type. The boundary at which the type of conductivity changes is referred to as "the junction." Such a p-n junction is shown in Figure 2(a), where the distributions of current carriers (holes and electrons) are represented schematically by the plus and minus symbols. If the p-side is made positive with respect to the n-side, then electrons will be pulled across the junction from the n- to the p-region, while holes will move in the opposite direction. Because of the motion of these charges, a current flows, and this current increases with increasing applied voltage. Under these conditions, the junction is said to be biased in the "forward" direction, and it has a low impedance. If, however, the p-region is made negative with respect to the n-region, both the electrons and holes are pulled away from the junction, and little or no current flows across the junction. Under these conditions, the junction is said to be biased in the "reverse" direction and it has a high impedance.

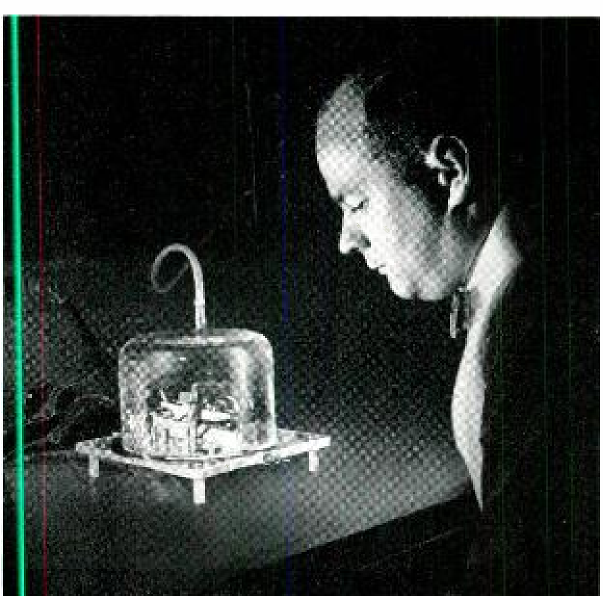


Fig. 3 — P. W. Foy operating a heater used in fabricating field-effect transistors.

Fig. 4 — W. Weigman assembling a field-effect transistor by means of a special jig.

A rigid analysis of a p-n junction biased in the reverse direction shows that there is a small but constant current flowing in the order of a few microamperes. This current is independent of the magnitude of the applied bias and is therefore called the "saturation" current. The analysis further shows that all the voltage drop occurs in a region close to the junction itself. In fact, the electric field in that region is sufficiently high to pull all the charged carriers (electrons and holes) out of it. This situation is shown in Figure 2(b) where the charged carriers have been removed from a region on either side of the junction. Such a region is called a "space-charge" region. Since it contains no current carriers, it cannot support conduction and will, therefore, act like an insulator. However, this insulating region is bounded by two conducting regions of p- and n-type conductivity. A p-n junction biased in reverse is, hence, equivalent to a capacitor with plate separation equal to the total width of the space-charge region as shown in Figure 2(b). If the voltage across the ends of the junction is increased, Figure 2(c), the charged carriers are pulled farther from the junction, increasing the width of the space-charge region and, thereby, increasing the plate separation of the equivalent capacitor. Thus, as the reverse voltage across a p-n junction is increased, the capacitance of the junction should decrease.

The p-n junction has the desired properties for use in a field-effect transistor, and Figure 5 shows the junction equivalent of the elementary field-effect transistor. Such a unit could be used as an amplifier. However, there is a more interesting and useful form of the transistor shown in Figure 6(a). This device, as shown, has an n-to-p junction on both sides of an n-type slab, and the two p-regions are connected. Consider what happens if the p-regions are short circuited to the left end of the n-region and a positive potential applied to the right end, Figure 6(a). A current, I, will flow in the direction shown, and this current consists of a flow of electrons from left to right. The left-hand contact is the "source" of these electrons, and the right-hand contact "drains" them out of the material. The contacts are referred to as "the source" and "the drain" and are marked accordingly in the figure. Because the n-type material has resistance, the flow of current will produce a potential drop in the material, the potential becoming more positive toward the drain. But, since the p-regions are connected to the source, the same potential will appear across the p-n junctions, and this potential is in such a direction as to bias them in reverse.

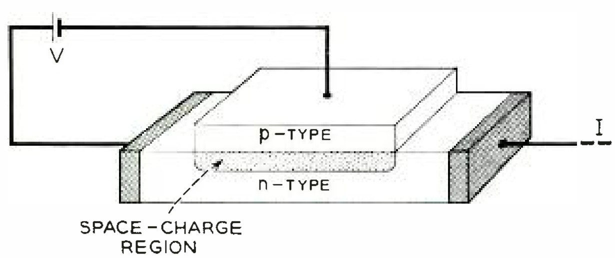


Fig. 5 — A field-effect transistor using a p-n junction to produce a "capacitor" within the body of the semiconductor. A voltage that is applied between the p- and n-type material causes a penetration of space charge, creating a region within the body of the n-type material that will not contribute to current flow through the semiconductor.

In consequence, a space-charge region will spread into the n-type material, getting wider toward the drain, as shown in Figure 6(a). The current is now constrained to flow in the center of the slab, called the "channel," and hence the resistance from source to drain is greater than with no potential applied. If the drain potential is increased, the space-charge regions will extend farther, and the source-to-drain resistance will further increase. The current versus voltage curve will, therefore, bend as shown in Figures 6(a) and (b). If the potential is further increased, a condition will be reached at which the space-charge regions from opposite sides meet, as shown in Figure 6(c). This is called the "pinch-off" condition, with current a maximum.

It is important to consider what happens when the drain voltage is increased above the value necessary for pinch-off. There are a number of ways of looking at this problem, but the following is possibly the simplest. At first sight, it would appear that the current would increase. But should this happen, the potential drop due to the resistance of the channel would increase causing the space-charge regions to meet over a finite length of the channel and thus introduce a very high resistance between source and drain. Hence, the current can-

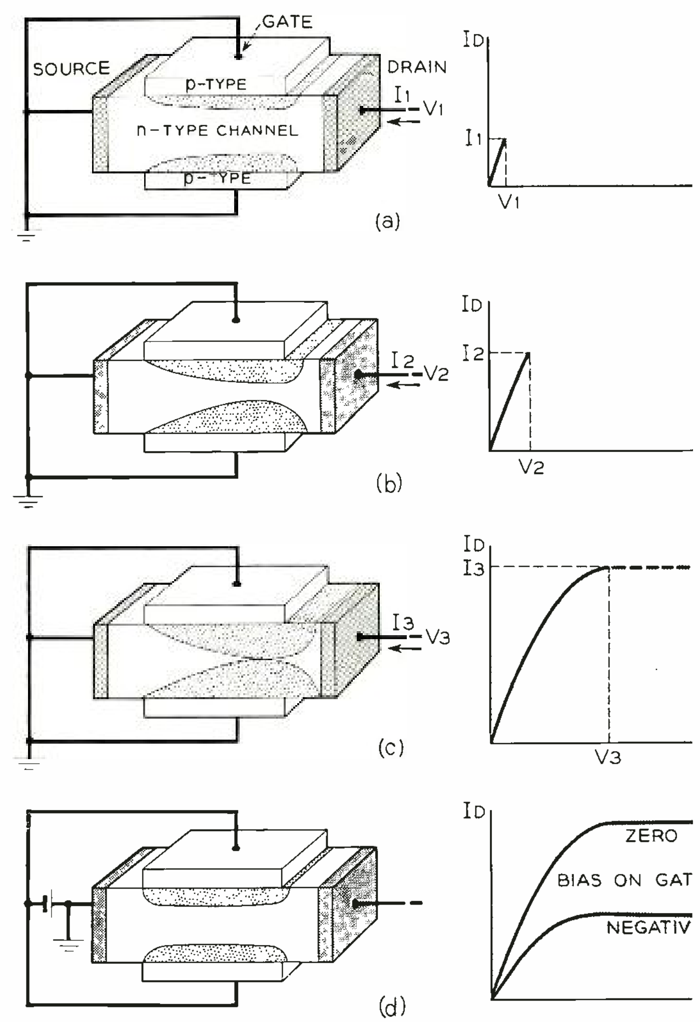


Fig. 6 — Schematic diagrams of a field-effect transisto showing the shape of the space-charge region and th current-voltage characteristic for: (a) zero gate voltag and small drain voltage, (b) larger drain voltage, (c) pinch off condition for zero gate voltage, and (d) voltages applie to both gate and drain.

not increase appreciably. On the other hand, the current might decrease. However, should this happen, the potential drop in the channel would decrease causing the space-charge regions to contract. This in turn would decrease the resistance from source to drain and cause the current to increase again; so the current cannot decrease. If it cannot increase and cannot decrease it must stay constant, and this is the case illustrated by the dashed line at the right in Figure 6(c). As shown, the presence of the p-type regions causes the conducting portion of the n-type material to be narrowed down. For this reason, the p-type regions are called "the gates."

The case considered above was that in which the gates were short circuited to the source. If a potential is applied between the gates and the source in such a direction as to bias the junctions in reverse, the channel will be constricted even before drain bias is applied, as in Figure 6(d). The initial resistance from source to drain will then be higher and, when drain bias is applied, the current will always be smaller than in the case previously considered. In addition, it will now require less drain voltage to reach the pinch-off condition. A comparison of the drain characteristic for bias and no-bias is shown in Figure 6(d), where it is seen that, with gate bias, the current is always smaller, and pinch-off occurs at a lower value of drain voltage. A theoretical drain-characteristic with gate voltage as the parameter is shown in Figure 7. As the gate voltage becomes more negative, pinch-off occurs at a lower voltage, and the pinched-off current is correspondingly decreased.

Thus far only the drain-to-source current and the means of controlling it by the gate current have been considered. If it is to be possible to obtain power amplification, this control must require very little power, and therefore, the gate-to-source impedance must be high. This gate-to-source impedance is essentially that of a p-n junction biased in reverse and in practice it can be of the order of 10 megohms. Hence, it should be possible to obtain power amplification with this device. A circuit for this purpose, shown in Figure 8(a), contains a field-effect transistor having a reasonable characteristic for a practical design. If the value of V_G is adjusted so that the device is always operating in the pinched-off condition, a change of V_G from 0 to –5 volts produces a change in drain current of 5 ma; that is, 1 ma for 1 volt. Thus, if V_G were changed by one volt, by applying an ac signal for example, the drain current, I_D, would change by one ma, and the change in the potential drop across the 10,000-

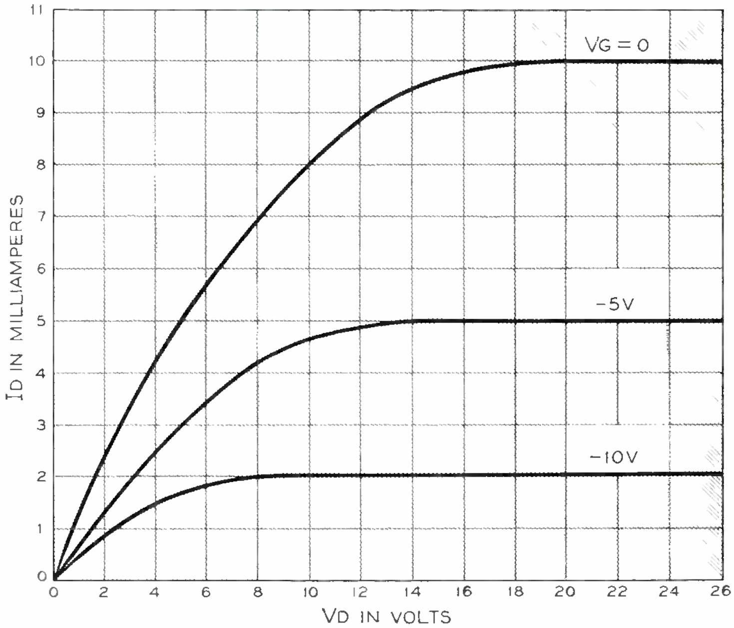


Fig. 7 — A theoretical characteristic curve for a field-effect transistor with gate voltage as the parameter.

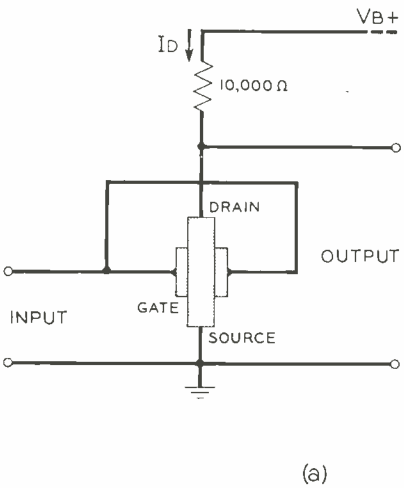
ohm load resistance would be ten volts. There would, therefore, be a tenfold voltage gain. If the gate-to-source impedance were taken to be one megohm (a very low value for a p-n junction biased in reverse), the change in input power would be $V^2/R_G = 10^{-6}$ watt while the change in output power would be $I^2R_L = (10^{-3})^2 \times 10^4 = 10^{-2}$ watt. Hence, there would be power gain of at least ten thousand or 40 db. A device with such characteristics would make a useful amplifier.

Field-effect transistors of the form shown in Figure 6 have been made at Bell Telephone Laboratories, and in every respect their performance has been found to be in good agreement with theory. For example, the characteristic shown in Figure 8(b) was taken from an operating unit, and it can be seen that its shape is very similar to the theoretical characteristic of Figure 7. A transconductance value — that is, change in drain current for unit change in gate voltage — of several milliamperes per volt has been achieved together with successful operation at frequencies as high as 50 megacycles per second. So far the work is still in an early stage and it is expected that much better performance will ultimately be achieved. Nevertheless, the initial results have been very promising. On an experimental basis, field-effect transistors have been used in amplifiers and oscillators as well as in frequency and amplitude modulation circuits.

How does the field-effect transistor compare with other electronic amplifying devices? As compared with electron tubes, the drain characteristic is very similar to the plate characteristic of a pentode tube. The high impedance input characteristic is also similar to that of the pentode tube, and the values of transconductance and frequency response are comparable. Thus, it appears that the field-effect transistor could perform many of the functions for which the pentode tube is now used. In addition, it has all the usual advantages of a transistor over an electron tube, being small, rugged, and light weight, requiring no heater power, and possibly having much longer life.

How does it compare with a junction transistor? There are a number of differences of practical importance. First, in the field-effect type, the current carriers are traveling in an electric field whereas in the junction transistor they are moving by diffusion. Since the velocity in a field is much higher than the velocity of diffusion, the transit time for transistors of the same size will be much shorter in the field-effect type. Since the maximum frequency of operation of both devices is limited by the transit time, the field-effect transistor is intrinsically capable of operating at higher frequencies. Second, the field-effect transistor has a high input impedance, whereas the junction transistor has low input impedance. This difference affects the associated circuitry and may make one or the other transistor more suitable in a particular application. The field-effect transistor, even with ultimate design conditions, would probably not be capable of operating with such high efficiency at such low power levels as the junction transistor.

It is too early in the development of the field-effect transistor to make definite statements as to its future uses. It would appear that it would find its main applications where considerations of size, weight, and power consumption dictate the use of a transistor, and where the required frequency response is higher than could be achieved with a simple junction transistor.



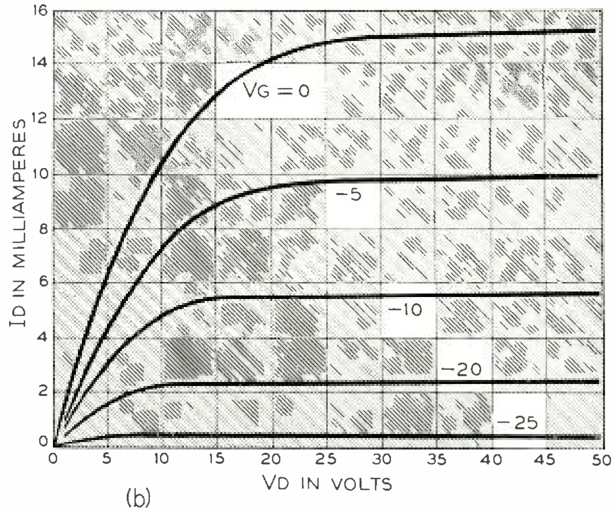
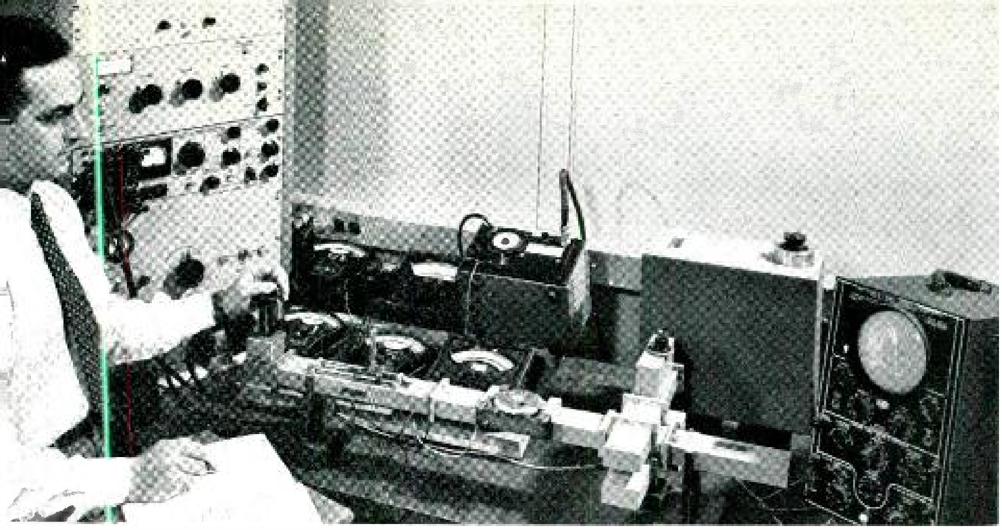


Fig. 8 — An amplifier using a field-effect transistor showing: (a) the circuit diagram, and (b), the characteristic of a suitable transistor. This characteristic, obtained from measurements on an actual transistor, is similar to the theoretical curve shown in Figure 7.

THE AUTHOR

IAN MUNRO ROSS joined Bell Telephone Laboratories in 1952, working first in transistor physics and then in solid state device development. He is primarily concerned with the design of transistors for switching apparatus. Mr. Ross, a native of Southport, England, received his Bachelor of Arts degree in 1948 from Gonville and Caius College, Cambridge University. He received his M.A. and Ph. D. degrees in 1952 from the same university. He is a graduate member of the Institution of Electrical Engineers (England).



Reflex Klystrons for Microwave Radio Relay Systems

E. D. REED
Electron Tube Development

Microwave radio relay has grown remarkably in recent years, thereby creating a need for improved microwave energy sources. Of these sources, reflex klystrons are perhaps the most commonly used and the Laboratories has maintained a continuous effort toward developing new designs and improving existing ones. Typical of post-war reflex klystron designs, the 419A is slated for service in the TD-2 radio relay system while the 431A has helped in the realization of the objectives of the TE system.

The rapid growth of microwave radio relay systems* during the past several years, with the attendant increase in the need for suitable energy sources, has led to considerable improvement in both the design and performance of microwave oscillators. Of these oscillators, reflex klystrons are perhaps the most useful. In their principal applications, these sources of microwave energy serve as final transmitting tubes, as beat-oscillators in microwave receivers, and as deviators in frequency modulation. In addition, they have found extensive use as laboratory oscillators. Reflex klystrons are particularly suited for these applications because of their low-voltage operation, simplicity, reliability, and the ease with which frequency can be changed both mechanically and electronically. Of importance, too, is the wide frequency spectrum in which various reflex klystrons operate – a frequency spectrum extending from a few hundred megacycles up to several tens of thousands of megacycles.

An inherently simple three-element device, a reflex klystron consists of an electron "gun" to supply a beam of electrons, a frequency-determining resonant cavity in which electrons interact with a high-frequency electric field, and a repeller electrode. Since it can be designed for operation at relatively low voltages – from 250 to 600 volts – and since it does not require magnetic focusing, it provides distinct economies in maintenance and initial cost.

The ability of a reflex klystron to be electronically tuned permits direct frequency-modulation of a microwave carrier by applying the intelligence to the repeller as amplitude variations. Since the repeller is always negative, it draws no power and the modulator can be simply a voltage amplifier. This electronic control of frequency also permits automatic frequency control (AFC) by various methods. Thus, a highly stable external resonant cavity may be used as a frequency reference and the klystron's output frequency "locked" to it by suitable circuits. Or, when used as the beat-oscillator in a microwave receiver, a klystron may be made to accurately "track" a varying incoming frequency.

Reliability and long life are, of course, important considerations in all Bell System applications. Here too, the reflex klystron measures up well. Since it

* RECORD, *November*, 1954, *page* 424.

operates at fairly low voltages and moderate emission densities, damage to the cathode by high-speed positive ions – encountered in many high voltage tubes – is not a serious problem and life spans well in excess of 5000 hours are the rule.

Two reflex klystrons, the 419A and 431A, developed at the Laboratories for specific system needs, are typical of post-war developments in this field. However, before the mechanical details and structural differences between these two tubes may be appreciated, the reader should be familiar with the basic principles of reflex klystron operation.* A good starting point might be a brief explanation of the evolution of a resonant cavity.

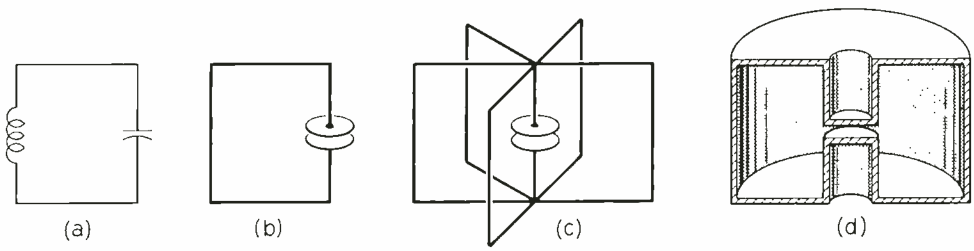


Fig 1 — Evolution of a cavity resonator.

The low-frequency equivalent of a resonant cavity is a conventional tuned circuit consisting of a coil (inductance) and a capacitor, their sizes depending on the frequency to which the circuit is to be tuned. As the frequency is raised, the size of both coil and capacitor must be reduced. The physical limit would be a capacitor consisting of only two small plates and an inductance consisting of a single turn of wire, Figure 1. What happens, then, as the frequency is raised still further? Although the capacitance is already a minimum, the inductance can be further reduced by adding more turns in parallel. The ultimate limit is reached when the parallel turns form a continuous cavity wall.

In the 419A and 431A klystrons, the cavities are shaped somewhat differently from that shown in Figure 1. They resemble a round "pill box" with the center portion of one side pushed in so as to almost touch the opposite side, Figure 2. The narrow space between the two sides is called the "interaction gap", because it is here the electrons interact with the high-frequency electric field of the cavity. To permit the passage of electrons through this gap, apertures are provided in its two bounding surfaces, covered only by fine wire grids.

An electron "gun" is the source of electrons; by means of a properly shaped cathode and a system of beam-focusing electrodes it projects a beam of electrons through the two grids toward the repeller electrode. This beam, passing through the interaction gap, provides the energy that is required for driving the klystron.

Conversion of the dc energy in the electron beam into microwave energy is achieved by velocity modulation. In this process, a positive dc accelerating voltage is applied to the cavity, attracting electrons emitted by the cathode so that they arrive at the first grid with a high velocity and then enter the interaction gap. Since both grids are at the same dc potential, the electrons are not affected by this dc voltage while in the gap. However, assuming for a moment that the cavity has been previously excited, the RF field existing between the grids has a decided effect on electron velocities. Electrons traversing the gap when the RF field aids the accelerating voltage, will be further accelerated; When the RF field opposes this voltage, they will be

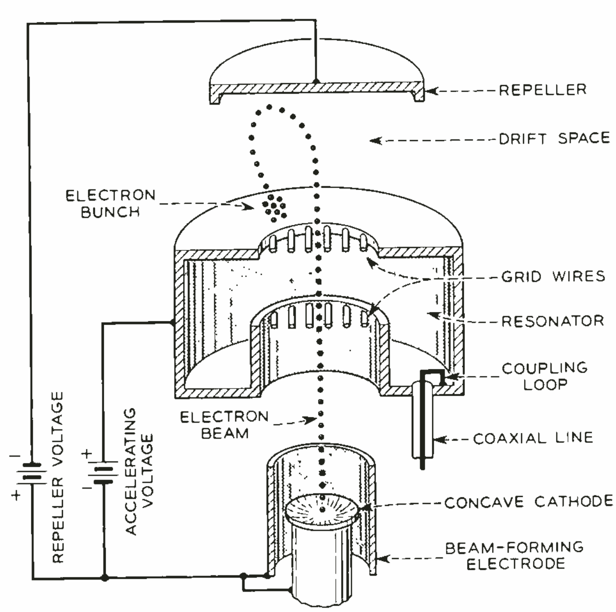


Fig. 2 — Exploded view of a reflex klystron showing the general arrangement of the basic tube elements (not drawn to scale).

* Record, *August*, 1945, *page* 287.

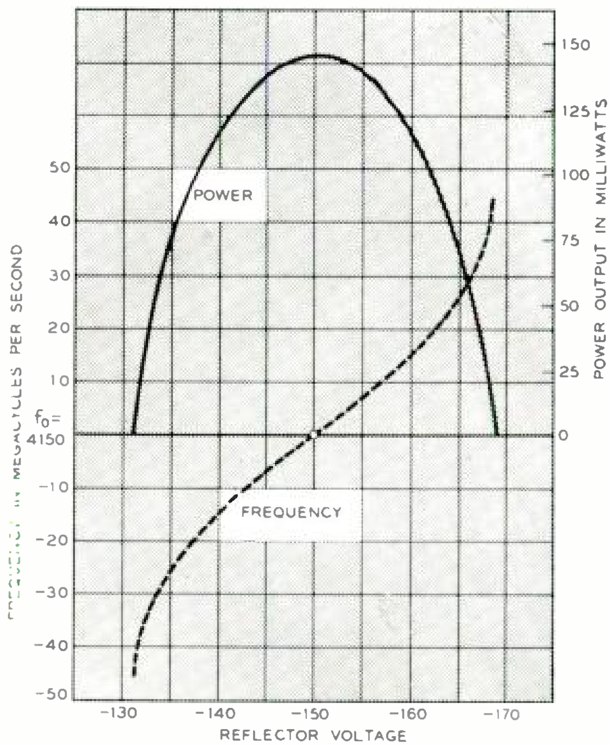


Fig. 3 — Power output versus frequency for a typical reflex klystron oscillator.

slowed down. The result is that electrons leaving the second grid and entering the retarding dc field of the repeller have differing velocities.

In the repeller space all electrons are slowed down, brought to a standstill, and returned to the gap for a second and final transit. During this "drift" period in the repeller space, the varying velocities imparted to the electrons cause them to form "bunches" as they return to the gap for a second traversal. For these bunches to deliver maximum energy to the cavity, they must arrive at the gap in the proper phase; this occurs when the returning bunches encounter a maximum retarding RF field — three-quarters of a cycle after the first traversal. Obviously, the same conditions would hold if the bunches returned a full cycle plus three-quarters of a cycle later, or two plus three-quarters, or N + ¾ cycles later, N being any integer. The time it takes for electrons to traverse the repeller "drift space" and return is determined by the repeller geometry, its spacing from the interaction gap, and the applied negative repeller voltage. Depending on this drift time, a reflex klystron is said to operate in the 1 + ¾ mode, 2 + ¾ mode, or the N + ¾ mode. For a 4,000-mc klystron operating in the 1 + ¾ mode, the drift time is about 4×10^{-10} second.

For a klystron oscillator to be useful, energy must be extracted from the excited cavity. One method is to provide an iris in the outer cavity wall to feed energy into a waveguide. In the other method — used in the 419A and 431A — a loop of wire links with the RF magnetic field and carries RF power to the external load via a coaxial line, Figure 2.

It might seem that the frequency of a klystron is fairly well fixed once the size and shape of the cavity have been chosen. It is not difficult, however, to physically change the cavity. Small plungers in the cavity wall may be inserted to various depths to change the inductance. Or, as in the tubes to be described, the flat face of the cavity may be a flexible diaphragm that permits the gap spacing to be changed, with resulting changes in effective capacitance. This method is generally used when the cavity is contained inside the vacuum envelope, because of the smaller physical motions required.

When the repeller voltage is so adjusted that the drift period is exactly N + ¾ cycles, a klystron is said to be operating in the center of its mode and the frequency of oscillation will be the resonant frequency of the cavity. Under such conditions, electron bunches returning to the interaction gap deliver repeated "kicks" to the RF energy in the cavity at the proper times. If the repeller voltage is made more or less negative, the bunches will arrive a little too soon or too late for perfect timing. This is equivalent to adding a small inductance or capacitance in parallel with the cavity and will shift the frequency up or down. Electronic tuning is thus simply the shifting of frequency by changing the

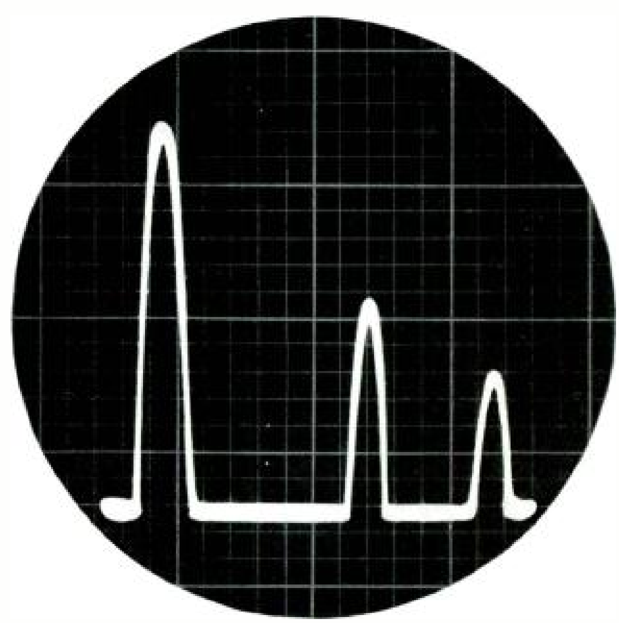


Fig. 4 — An oscilloscope picture of three modes.

repeller voltage. Unfortunately, as the repeller voltage is varied about its mid-mode value, power output will decrease, since optimum energy interchange occurs at mid-mode. A typical curve relating power output with repeller voltage, Figure 3, looks very much like the impedance-frequency curve of an ordinary low-frequency tuned circuit.

The mid-mode power output of a reflex klystron is a function of the mode number N. It is usually highest for small values of N and becomes successively less as N increases, Figure 4. On the other hand, the electronic tuning range increases with N, so that the choice of operating mode must necessarily be a compromise between the conflicting requirements of power output and electronic tuning. Once a mode has been chosen, the coupling loop is designed for maximum power transfer in that particular mode, with the result that maximum power output will not be obtained for other modes unless an external transformer is used.

To achieve wide electronic tuning, the ratio I_0/V_0C must be maximized. This requires that the accelerating voltage V_0 be small, the cathode current I_0 be as large as practical, and the effective shunt capacitance C be small. Since this capacitance is primarily that between the grid planes, they should be of small diameter. A high-current, low-voltage beam normally calls for a large-diameter grid aperture, conflicting with the requirements for low capacitance. To reduce the capacitance, a highly convergent beam is desired, but is difficult to attain with a low accelerating voltage.

Once a proper design compromise has been reached, another problem is encountered. A highly convergent beam will produce electron bunches of high density so that the repulsive forces between electrons will cause the bunches to "explode"; the repeller, then, must be shaped to offset this tendency. In addition, it must assure that all electrons arrive back at the gap in the proper phase. When wide electronic tuning is desired, the gun, resonator, and repeller elements must all be considered a single complex design problem.

Two possible solutions to these design problems are exemplified by the Western Electric 419A and 431A reflex klystrons. They are integral-cavity tubes of identical external appearance, and both use the same mechanical tuning mechanism and basic mechanical structure, Figure 5. In electrical performance, however, and in the type of service they render, they are quite different.

The 419A was designed as the FM deviator in terminal equipment of the 4,000 mc TD-2 transcontinental microwave radio relay system. In this application, the modulating intelligence is to be applied to the repeller as amplitude variations, deviating the microwave carrier some 4 mc in each direction. The principal requirements for the 419A are wide electronic tuning and good frequency stability with respect to changes in ambient temperature; only minor emphasis is placed on power output. The high-perveance* electron gun developed for this tube operates on only 250 volts and uses a concave cathode and accelerating grid to aid in converging the beam. The low-loss cavity has a very small gap

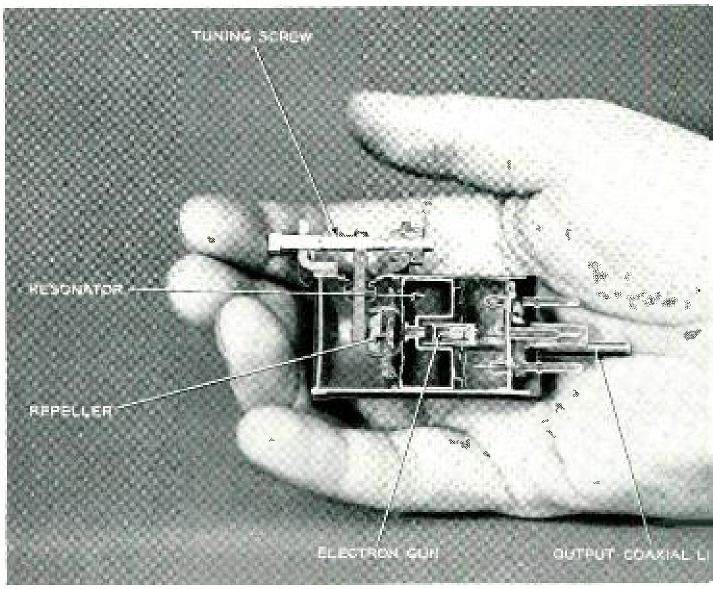


Fig. 5 — The central portion of the 431A klystron contains the cavity, cathode, and adjustable diaphragm.

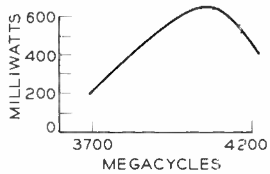
capacitance. Power is taken out of the cavity by a short 50-ohm coaxial line that terminates in a coupling loop inside the cavity. The outstanding properties of the tube are its wide electronic-tuning range and low temperature-coefficient, Figure 6.

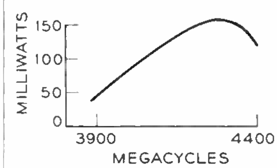
In the 4,000-mc TE short-haul radio relay system, the 431A tube has served for some time as the frequency-modulated final transmitting oscillator. In this application it really constitutes the heart of the system. Feeding directly into the antenna, it must deliver about ½ watt of microwave power yet have sufficient electronic-tuning range to permit linear frequency modulation. To meet the requirement of higher power, 450 volts was chosen as the accelerating voltage and a medium-perveance gun was developed, using a cathode similar to the one in the 419A. The higher voltage permitted elimination of the

* Perveance is defined as the ratio of Cathode Current to (Accelerating Voltage) $^{3/2}$.

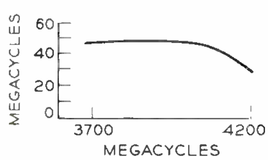
	431 A	419 A
RINCIPAL PLICATION	TRANSMITTING OSCILLATOR FOR TE RADIO RELAY SYSTEM	FM-DEVIATOR FOR TD-2 RADIO RELAY SYSTEM
ECHANICAL NING RANGE	3700-4200 MC	3900-4400 MC
ESONATOR VOLTAGE	450 VOLTS	250 VOLTS
CATHODE CURRENT	30 MA	30 MA
REPELLER MODE	$2+\frac{3}{4}$ CYCLES	$2+\frac{3}{4}$ CYCLES

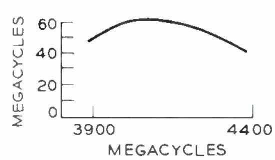
WER OUTPUT OVER ECHANICAL NING RANGE (ERAGE OF 12 ABORATORY UILT TUBES)



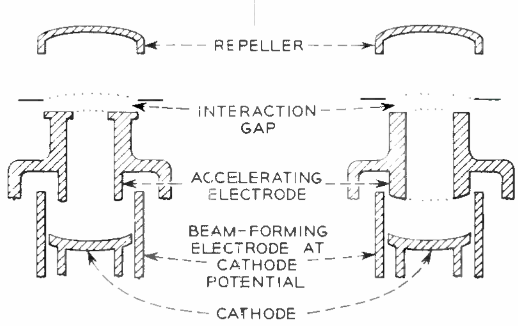


LECTRONIC NING RANGE BETWEEN ALF-POWER POINTS





LECTRON-OPTICAL SYSTEM



ig. 6 — Typical characteristics of laboratory prototypes f the 431A and 419A klystrons. These characteristics do not epresent the performance of factory-made tubes.

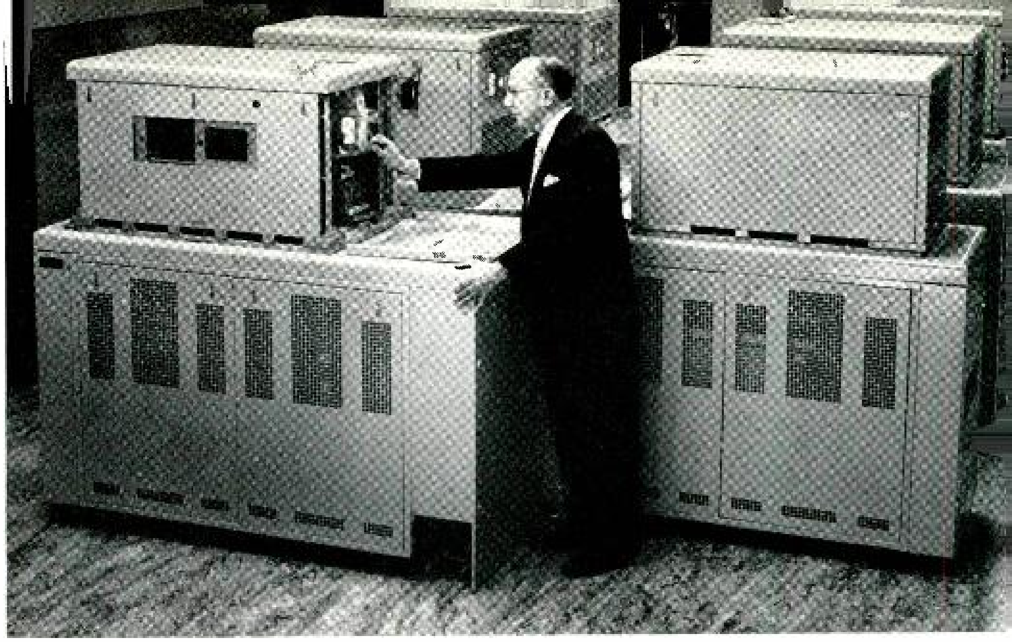
accelerating grid; this not only simplified the tube structure, but gave rise to a more highly convergent beam, capable of passing through a smaller diameter grid. In the recommended 2+¾ mode, the maximum efficiency is about 5 per cent. In the 1+¾ mode, efficiency runs as high as 8 per cent but the electronic-tuning range is too small for the intended radio relay system application.

The high degree of thermal stability achieved in both tubes is a result of the mechanical structure and choice of materials. In older tubes, the resonator-diaphragm forms part of the vacuum envelope, exposing the tuning mechanism to the atmosphere so that changes in atmospheric pressure or temperature can cause the frequency to shift. In the 419A and 431A, the gun, cavity, reflector, output coaxial line, and stem form a self-supporting mount that may be readily inspected. This is inserted in and brazed to an outer steel shell containing the external tuning mechanism. Since the diaphragm is no longer exposed to the atmosphere, it is not affected by atmospheric changes; it is thinner, more flexible, and can withstand many more flexures than the older types. Moreover, since most of the tube elements are within the steel shell, the shell acts as an oven tending to keep the elements at a constant temperature. Those parts of the tuning mechanism external to the vacuum are in intimate thermal contact with the shell, virtually eliminating frequency sensitivity to drafts. The frequency variation with changes in ambient temperature has been reduced to the point where automatic frequency control is no longer required in some applications. For example, a change in ambient temperature of 20°C will cause a shift of 0.5 mc in the operating frequency of the 419A — less than 0.0125 per cent.

THE AUTHOR

E. D. Reed received his B. Sc. degree from the University of London in 1941 and the M. S. and Ph. D degrees in electrical engineering from Columbia University in 1947 and 1953. Upon completion of his military service with the U. S. Army and a year of graduate study at Columbia University, he joined the Laboratories in 1947. Here Dr. Reed has been engaged in the design and development of microwave oscillators. He is a member of the Institute of Radio Engineers and Sigma Xi.

Card Translator Equipment



R. S. SKINNER *Switching Systems Development*

The growth of the card translator from an idea to a reality is a good illustration of the research and development that go into the components of a switching system. In addition to the circuitry involved, engineers also had to consider such problems as floor space, mounting and packaging of parts, and ease of maintenance. As solutions to these problems were found, the card translator evolved through many design changes and through a series of preliminary models.

Operators now dial about two out of every five long distance calls straight through to the distant telephone. This fact has an interesting background, for each element of today's vast telephone network is a product of years of systems engineering, research and development work. This work involves new inventions and constant improvement in designs to obtain maximum efficiency and minimum cost. It is impossible to describe briefly all of the new switching features that have made the newer automatic telephone systems possible, but the equipment of the card translator, a vital part of the No. 4A toll switching system,* provides a typical example of the development of new features.

As its name implies, this machine "translates" telephone numbers; that is, information is received in the form of groups of pulses (or digits) and is translated into the information needed to route the call through the office and pass it along toward its destination. The large number of variables met in this job of translating necessitated a new device — a device radically different from the relay type translators used in other crossbar systems. The relay translators require the code digits to operate a group of relays which select a single terminal (a code point) corresponding to the called code. Cross connections from the code points and route relay contacts are used to supply information for routing the call. When routings are altered, or when equipment is relocated for a trunk group, the cross connections must be changed.

Direct distance dialing requires, however, that when routing patterns are altered, or when new offices are placed in service, translating arrangements must be modified in many toll crossbar offices, some of them remote from the scene of the change. In any one office such changes will be frequent, and the use of equipment having route relays would therefore require frequent re-running of cross connections. The card translator, however, uses punched cards instead of relays, making it possible

Above — O. Myers, Bell Telephone Laboratories, inspecting the card translators installed in the Newark 4A toll crossbar office. The back-to-back arrangement of translators permits ease of cabling.

* RECORD, *October*, 1953, *page* 369; *December*, 1953, *page* 481; *March*, 1954, page 93.

to effect routing changes simply by removing old cards and inserting new ones. The equipment is therefore out of service only a short time.

These are the reasons for adopting the card method of translation, but to develop an actual machine, engineers first had to solve many preliminary problems. The development of such devices as the card translator requires close cooperation between switching apparatus engineers, who design them, and switching system engineers, who have the problem of incorporating the new device into a switching system.

An early model of the card translator (Figure 1) was mounted on a wheeled laboratory table, with some of the signal channel equipment and control relays mounted below for convenience in testing. While this model was being built and tested, both switching groups studied and discussed the problem of how best to design the machine and associated equipment as components of a toll crossbar office. The need for maintenance access to all four sides of the machine made it desirable to continue the table-type mounting for central office use, but presented problems in floor space economy and cabling. These were met by designing a cabinet which mounted the machine, housed the associated control and signal equipment, and provided space at one end for sorting and terminating cables. As shown in the headpiece, the cabinets are located adjacent to each other, with alternate cabinets fac-

ig. 1 — Early model of the card translator.

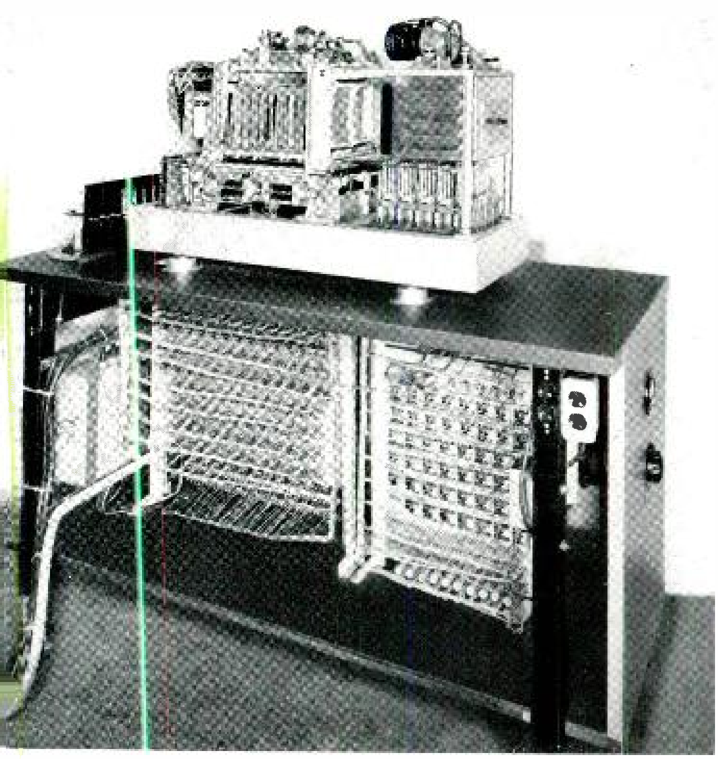


Fig. 2 — The author inserting a 680A input transformer into a Bell Laboratories' card translator.

ing in opposite directions. This arrangement permits a continuous cable run for the translators and a cable entry point at one end of the translator group.

The cabinet is made of sheet steel and supports the load of the translator machine and the cards. At the same time it provides mounting space for the signal channel and control equipment. To minimize the transmission of vibration caused by raising and lowering of the card stack, the machine rests on shock-resistant mountings contained within the top cover of the cabinet.

The problem of separating all leads and apparatus which could induce unwanted noise into the signal channels was solved by running the signal channel wiring in a separate local cable using shielded wire for all low-level signal channel leads. Battery filters are provided in the cabinet for signal channel supplies; and the a-c vibrator, used as the emergency power supply for the motor which modulates the light source in the machine, is located at one end of the cabinet within an end cover. Since the transistor amplifiers used in the channels are somewhat heat sensitive, this same end compartment is used to contain the code bar series resistors, which generate a substantial amount of heat. The use of a large number of shielded leads required a shielded wire having a small diameter. This wire also had to be flexible so that maintenance personnel could occasionally replace phototransistors and check the light channels in the machine.

The problem of accommodating the signal channel apparatus within a limited space was solved by packaging the two major groups of channel elements. After these had been designed, a number of units of each type were built and tested to insure proper operation of the signal channels and to determine requirements of margin and tolerance needed for manufacture. These two channel elements are now coded as the 149A amplifier and the 680A input transformer, and are shown in Figure 3.

These two units illustrate two forms of packaging technique. In the case of the 680A input transformer, studies showed that it would be simpler and

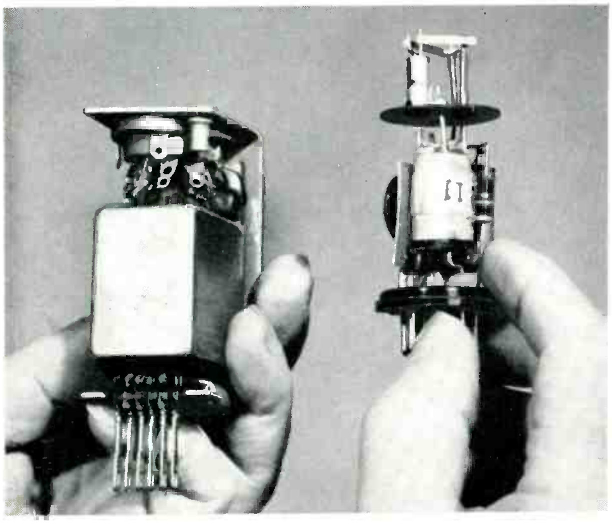


Fig. 3 — 680A transformer (left) showing arrangement of components on bracket, and 149A transistor amplifier with case removed.

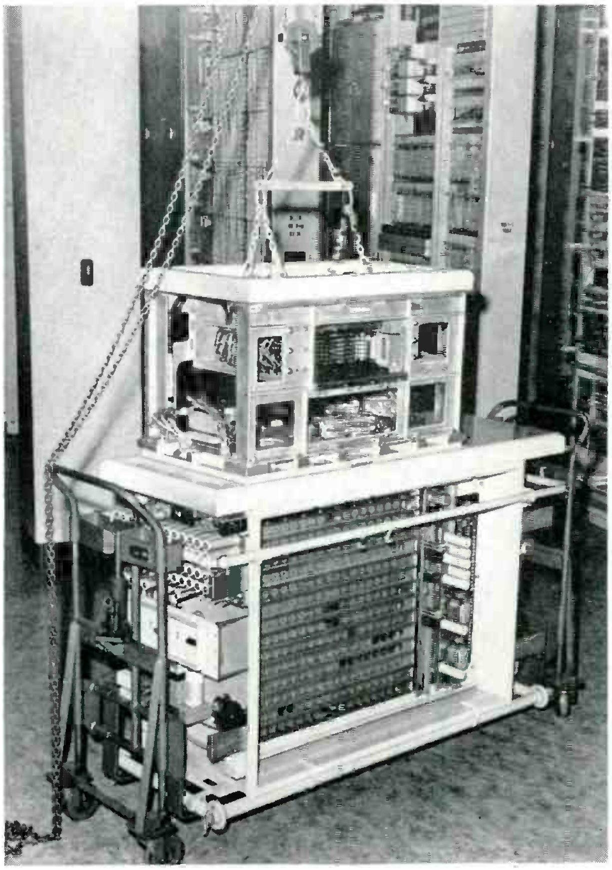
cheaper to manufacture in the form shown with all components mounted on a simple sheet metal bracket and all wiring run along the surface of the bracket. In the case of the 149A amplifier, however, similar studies showed that a potted assembly having a removable cover to provide access to the transistor would be a better design.

Maintenance checks of the signal channels indicated the need for a new device to simplify the measurement of photocell output as well as amplifier output. This need resulted in the 100A test set (Figure 4) which provides test access to permit these measurements. The test set is simply inserted in place of the amplifier or cold cathode tube of the channel in question.

Once the solutions to these design problems had

Fig. 4 — E. J. Donohue replacing a 149A transistor amplifier (left hand) with a 100A test set in a Bell Laboratories' card translator.

Fig. 5 — Card translator prior to installation at the Pittsburgh toll office — the first translator equipment of this type to be put into service.



been agreed upon, models incorporating them were constructed and placed in operation in a skeleton version of a No. 4A toll switching system in the toll switching laboratory.

Tests of this system not only permitted an operating check of the translator design but showed the need for further development work. One such case was the problem of heat conduction and transfer from the code bar coils and the pull-up and pull-down magnets in the machine to the phototransistor bank in the machine. This problem required the redesigning of the coils to use series resistances which could be mounted in the end compartment of the translator, thus diverting 480 watts from the phototransistor area. It was also necessary to provide ventilated side covers on the cabinet and ventilated end and top covers on the machine. In addition, it was found desirable to use a blower to provide forced air circulation over the phototransistors in those offices which are subject to high ambient temperatures.

The production design of the translator and cabinet are shown on page 178, taken in the Newark, New Jersey, toll switching office. Figure 5, taken at Pittsburgh, Pennsylvania, during the installation period, shows a translator after having been mounted on the cabinet prior to wheeling the cabinet into position on the floor. This equipment, the first of its type to be put into commercial use, was placed in service March 29, 1953.

THE AUTHOR

ROBERT S. SKINNER joined the Southwestern Bell Telephone Company in 1939 soon after receiving a B.S. in E.E. degree from the University of Kansas. After working in the outside plant engineering and equipment engineering groups he transferred to the Laboratories in 1942. Mr. Skinner first was concerned with the construction of pre-production units of radar and crew trainer equipment. From 1943 to 1946 he was assigned to the development of airborne radar equipment and video line equipment for local television program distribution. More recently he has worked on the design of equipment for No. 5 crossbar and 4A toll switching systems. He is now engaged in the program to develop an emergency reporting system. He is a licensed professional engineer in New York, a member of the A.I.E.E., and Triangle Fraternity. Mr. Skinner is also engaged in graduate studies at Stevens Institute of Technology.

Patents Issued to Members of Bell Telephone Laboratories During the Month of February

Barney, H. L. – *Semiconductor Oscillation Generator* – 2,701,309.

Bowen, A. E. – *Wave Guide Phase Shifter* – 2,701,344.

Bowen, A. E., and Mumford, W. W. – *High Frequency Directional Couplers* – 2,701,341.

Doba, S., Jr. – *Ground Speed and Distance Meter* – 2,701,358.

Eich, N. J. – *Method of Manufacture of Incapsulated Electrical Apparatus* – 2,701,392.

Fox, A. G. – *High Frequency Directional Couplers* – 2,701,342.

Haynes, J. R. – *Semiconductor Signal Translating Devices* – 2,702,838.

Head, G. A., and Norton, E. L. – *Accelerometer* – 2,702,186.

Hopper, A. L. – *Recognition Circuit* – 2,701,305.

Kock, W. E. – *Wave Filters of Extended Area* – 2,701,617.

Lange, R. W. – *High Q Resonant Cavities* – 2,701,343.

McGuigan, J. H., see Lovell, C. A.

Lovell, C. A., and McGuigan, J. H. – *Multifrequency Signaling System* – 2,701,279.

Miller, S. E. – *High Frequency Directional Couplers* – 2,701,340.

Mumford, W. W., see Bowen, A. E.

Newby, N. D. – *Capacitive Commutator Transmitter* – 2,701,357.

Norton, E. L., see Head, G. A.

Oliver, B. M. – *Signal Predicting Apparatus* – 2,701,274.

Pfann, W. G., and Theuerer, H. C. – *Semiconductor Translating Devices* – 2,701,326.

Theuerer, H. C., see Pfann, W. G.

Townes, C. H. – *Concealed Ground Target Computer for Aircraft* – 2,701,098.

Townsend, M. A. – *Multicathode Gaseous Discharge Devices* – 2,702,357.

Wells, H. A. – *Drop Wire Clamp* – 2,700,808.

Repeaters in the L3 Coaxial System

C. G. ARNOLD *Transmission Systems Development*

Increased long-distance telephone service and the need for transmitting television signals between widely separated cities have resulted in the development of a coaxial carrier system with greatly increased bandwidth. As the bandwidth is extended, however, there is increased signal loss at the higher frequencies. In the L3 system with transmitted frequencies extending to about 8.5 mc per second, this loss is compensated for by repeaters located at four-mile intervals along the line. Improved repeaters were required to accommodate the wider L3 frequency band and to meet the stringent transmission requirements established for this system.

Every four miles along some of our national coaxial cable network, small cement block huts can be seen. Some are located along busy highways, some in residential towns; some have unfinished block exteriors, and some brick veneer. Each houses repeater equipment which plays a significant role in providing more and better long distance telephone service. These auxiliary repeaters, together with main repeaters, terminal equipment, and coaxial cable, comprise the L3 coaxial cable carrier telephone system.

The primary function of repeaters in any long distance communication system is to compensate for the loss in the transmission medium. In the L3 system, however, they must also perform several other major tasks. First, various telephone channels must be dropped at points along the cable route. The L3 system is designed to transmit 1,860 one-way channels over one coaxial from New York to California; however, only a small portion of this number will actually be used for transcontinental circuits. Consequently, to use this long multichannel system efficiently in meeting traffic demands, flexible facilities must be provided for dropping and reinserting various channels at intermediate repeater points along the cable route.

Above — Main repeater voltage measurements are an important part of L3 maintenance.

Another function performed by some repeaters is to compensate for the accumulated difference between the loss of the cable and the gain of several auxiliary repeaters in tandem. It is impossible to develop repeaters which compensate exactly for loss in a specific length of cable. Though the repeaters developed for this system are unusually accurate and stable, there are small residual deviations which cumulatively become intolerable on long circuits unless some corrective means is provided. In the L3 design it has been found economically desirable to allow deviations from a number of repeater sections – four miles of cable and an associated repeater – to accumulate, and to correct for the resulting distortion by means of equalizers at only a few repeaters in a long route.

A third function of the repeaters is to assure service reliability. Facilities must be provided to observe system operation and to minimize the number of service interruptions due to cable or equipment failure. Obviously, the reliability of a system with a large capacity is extremely important, and particular emphasis has been placed on this factor in the design of the L3 system.

Repeaters used in this system may be divided into two general classes: those that receive power over the cable and those that obtain power locally. The first group includes the auxiliary and equalizing auxiliary repeaters. In general, these repeaters are located in small, unheated and unattended buildings. Included in the second general group are the equalizing main, the switching main, and the terminal repeaters which usually are located in central office buildings. A typical arrangement of these various types of repeaters on an L3 route is shown in Figure 1.

The auxiliary repeater is the basic unit of the system and its performance largely determines the economics and capabilities of the system. A simplified block diagram of this repeater showing equipment required for transmission on a pair of coaxials is given in Figure 2.

The power separation filter (PSF) is a six-terminal, high-pass, low-pass filter. As the name implies, it separates the high frequency signals from the low frequency power that is transmitted over the center conductor of the coaxial to provide the primary power for operation of the auxiliary repeater. At the input of the repeater the low frequency current is diverted to a power supply and the high frequency currents are directed through passive equipment to the input of the amplifier. At the output, the signals and power current are recombined for transmission to the next repeater. The design of the power separation filter was complicated by the fact that not only must the unit pass high frequency signals with little distortion, but it must also be capable of passing power currents of 1.5 amperes along the cable at a potential as high as 2,000 volts rms.

The nominal spacing of auxiliary repeaters on 0.375 inch diameter coaxial is four miles. Where it is not physically possible to place repeaters four miles apart, they are spaced closer together and artificial lines are used to build out the electrical length of the repeater section to the nominal value.

The gain in the repeater is supplied by the line amplifier* whose gain is controlled by either a pilot-controlled or a thermometer regulator.†

By means of the pilot alarm unit, indications of troubles at or near a repeater equipped with a pilot-controlled regulator are obtained at the nearest attended repeater office. The alarm unit, operating under the control of the regulator, short circuits an alarm pair in the cable when the 7,266-kc pilot frequency deviates a specified amount from its nominal value. Resistance measurements on the alarm pair are made at the main repeater to locate the auxiliary repeater from which the alarm originates, for maintenance purposes.

For reasons of economy and reliability, primary power for the auxiliary repeaters is obtained over the center conductors of the coaxials from an adjacent main repeater. A pair of coaxials is used to form a constant-current power loop. Power for the repeaters is obtained from the loop through high voltage transformers; the required heater, plate, and bias voltages are developed in a power supply at each repeater. For such a power arrangement to operate satisfactorily, several factors must be carefully controlled: (1) line current variations along a power section, which may be as long as

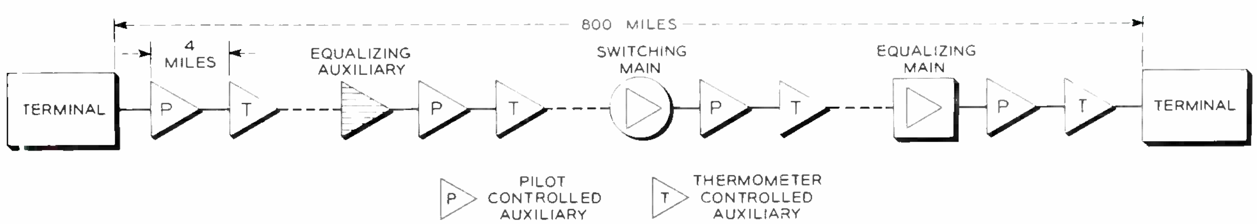


Fig. 1 — Typical arrangement of repeaters along an L3 route.

* Record, *April*, 1954, *page* 139. † *October*, 1954, *page* 385.

84 miles, must be minimized; (2) the waveform of the power current must be relatively free of harmonics; and (3) the power factor of the load at each repeater must be near unity. A constant line current throughout a power section is maintained with a systematic pattern of inductive loading. The second and third factors are satisfactorily controlled by the use of a unique design of repeater power supply which presents a resistive load to the power loop of the two coaxial tubes.

The auxiliary repeater equipment required for a pair of coaxials is usually mounted on a 6-foot cable-duct type framework as shown in Figure 3. The transmission panel for one coaxial is shown with the regulator and amplifier in place and appears in the upper third of the bay. Similar equipment is located immediately below for the other coaxial; power units are mounted in the bottom of the bay.

After the signals pass through a maximum of 32 auxiliary repeater sections in tandem, the accumulated gain distortion must be equalized for satisfactory transmission. Equalizers for this purpose are provided at the equalizing auxiliary repeater. A block diagram of this repeater (one direction of transmission) is shown in Figure 4. As illustrated, the transmission units at the input of the repeater are identical with those used in the auxiliary repeater. The equalization mentioned is provided in the "A" equalizers where fixed, manually adjustable and pilot-controlled networks are provided. The flat amplifiers shown compensate for the losses in the equalizer units.

Three regulators are required at this repeater for adequate automatic control of the transmission characteristic. They are named, for simplicity, from

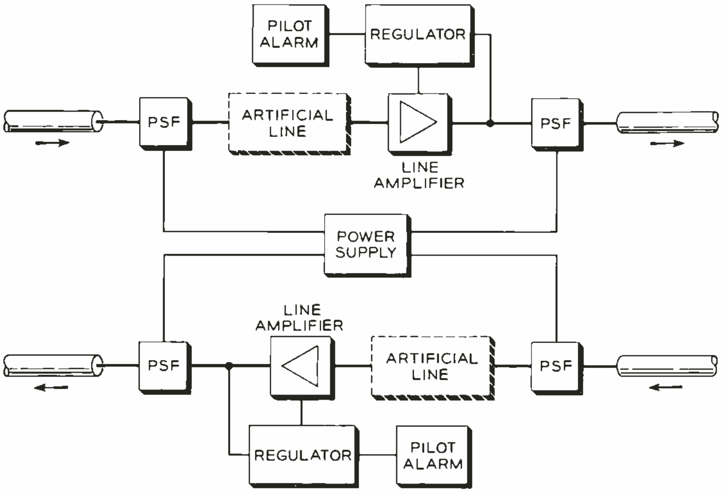


Fig. 2 — Block diagram of an auxiliary repeater.

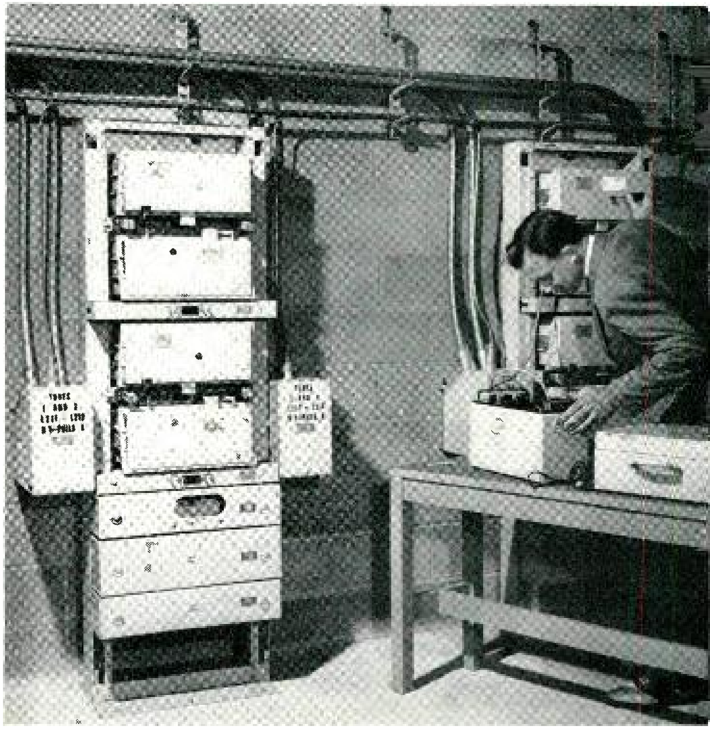


Fig. 3 — Mr. Arnold checks transmission levels at an auxiliary repeater of the L3 system.

the pilot frequencies which are used for their control – 308, 2,064 and 7,266 kc – and are similar in design to the pilot-controlled regulator provided at the auxiliary repeater. Each regulator adjusts the loss of an equalizer network by controlling the dc flowing through a thermistor in the network.

With these regulators and equalizers not only are changes in cable loss equalized, but also changes in system gain caused by the aging of electron tubes in the amplifiers and by shifts in the ambient temperatures within the repeater huts. The gain versus frequency characteristics of these effects cover the entire frequency range. Consequently, a change in any one affects the magnitude of all pilots. The interaction which would exist if each regulator independently controlled an automatic equalizer is eliminated by a computer unit.*

The pilot signals that govern the operation of the regulators at the equalizing auxiliary repeater are picked off the high frequency line by means of a hybrid transformer which isolates the input impedances of regulators from the through transmission path. It also provides a low impedance circuit between the regulators and the line, having approximately the same loss at all pilot frequencies.

* Record, *October*, 1954, *page* 385.

This hybrid differs from the more common design which provides two equal outputs from an input signal. It presents a low transmission loss to the through signals at the expense of a relatively high loss in the regulator circuit where loss can be tolerated more economically.

The pilot alarm unit here, very much like the one provided at auxiliary repeaters, operates when any one of the three controlling pilots deviates beyond a given limit. Power for this repeater is obtained from the cable with arrangements very similar to those used at the auxiliary repeater.

All the transmission components and the heater and bias supply unit for one coaxial are mounted in one 7-foot shop-wired bay. The plate and primary ac power equipment for two of these bays is mounted in another 7-foot bay.

The third type of L3 repeater – the equalizing main – is identical to the equalizing auxiliary as far as transmission components are concerned. It differs, principally, in the power arrangements provided. Instead of obtaining power from the coaxial, as do the auxiliary types, this repeater includes equipment to generate and feed power to the cables. In addition, a number of special features are provided in main repeaters to improve system reliability and to expedite maintenance. These include special alarm circuits to indicate and isolate trouble conditions, test equipment for locating equipment and cable faults, and order wire circuits which provide communication paths to maintenance centers and to other repeaters in the coaxial cable route.

The switching main repeaters are the fourth and most complex type used in the system. In addition to supplying power for operation of the auxiliary repeaters, they include provision for dropping telephone and television signals from the through route, as well as means for automatically switching service from a working line to a standby line in the event of trouble in the system.

In order that these functions may be performed satisfactorily, the equalization provided at the equalizing auxiliary repeaters is augmented by additional manual and automatic equalizers. The amount of additional equalization provided depends somewhat on the type of service being transmitted. Requirements are considerably more stringent for television transmission than for message transmission and not only is gain distortion an essential factor, but so also is delay distortion. The general plan employed at this repeater for equalizing gain deviations is similar to that already described. For adequate automatic control of long systems, six pilot-controlled regulators are required, the three already mentioned and the 556, the 3,096 and the 8,320-kc regulators. Normally, all the gain equalization is provided in each line in the receiving portion of the repeater.

At the output of this equipment, all lines transmitting in the same direction are connected to the "receiving line switch." This switch operates under the control of a pilot indicator unit. It substitutes a standby line in place of a working line whenever any one of the six pilots deviates a specified amount from its nominal value. As many as four working lines may be protected by one standby line.

At the output of the switch, branching facilities are provided. The branching equipment, or "line connecting equipment" as it is called, which is available for use in an all-telephone system, is shown in Figure 5. This equipment provides an

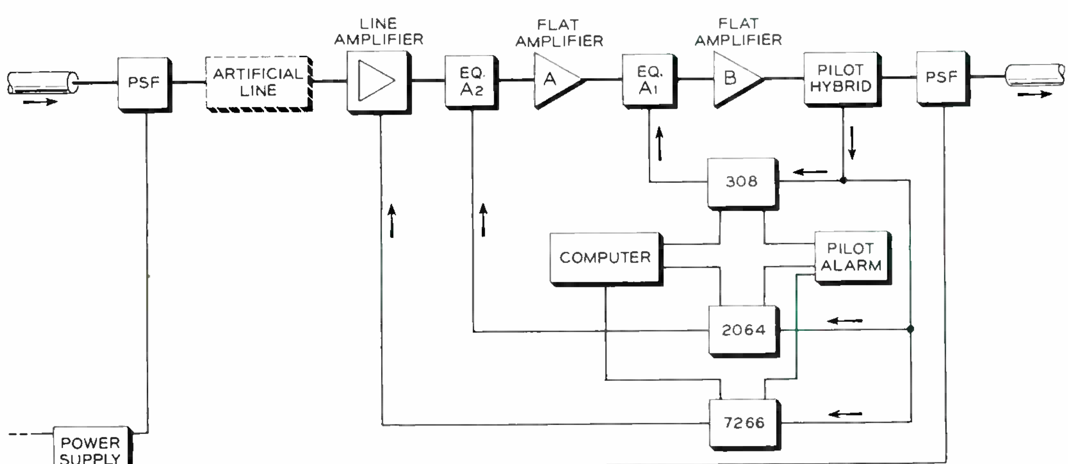


Fig. 4 — Block diagram of an equalizing auxiliary repeater.

economical method of dropping and inserting telephone channels at various points along an L3 route. Only desired channels are blocked and through circuits are passed at line frequencies. Pilot signals which are in the blocked band are passed around the blocking filter by means of filters having very narrow pass-bands. The specific arrangement shown provides for blocking master group 1 and supergroup 2, or 660 channels.* It is planned, ultimately, to provide several types of blocking filters for dropping various numbers of channels. These will provide the flexibility which is so essential for efficient use of the system in the field.

When the system is used for transmitting both television and telephone signals, the line connecting equipment is more extensive (see Figure 6).

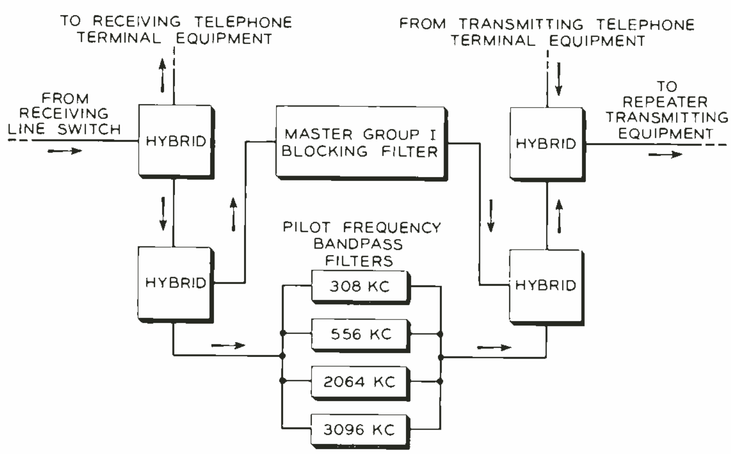


Fig. 5 — Telephone line connecting equipment.

Branching filters are required to separate the television and telephone bands so that the signals can be transmitted to their respective branching or

* Record, *February*, 1955, *page* 72.

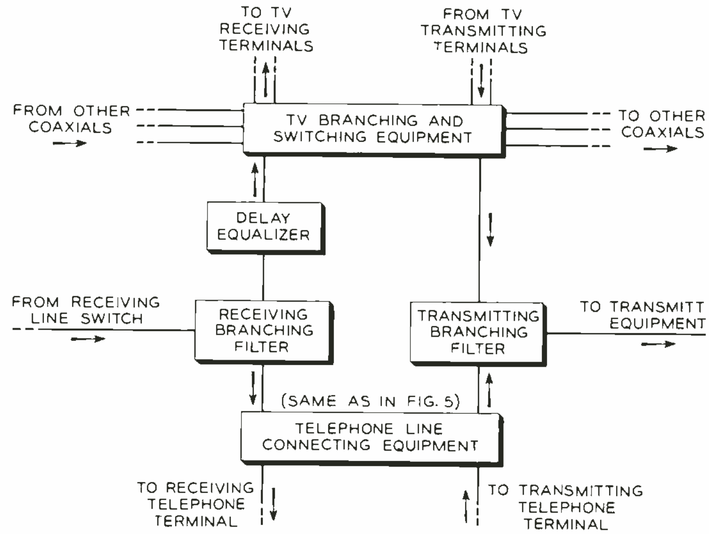


Fig. 6 — Combined system line connecting equipment.

terminal equipment. In addition, delay equalizers are required to compensate for the delay distortion accumulated in the line sections. These equalizers are located only in the television path since the amount of delay distortion involved is not vital to transmission of telephone conversations.

The transmission requirements for the line connecting equipment are very severe. This arises from the fact that there may be as many as 35 of these arrangements in a 4,000-mile circuit; and since this equipment is not a part of a switching section, any transmission deviations originating in it are not compensated for by the equalizers in the switching section. Also the equipment must be reliable, as it is not protected by line switching and a failure could cause interruption of service on 1,860 telephone channels, or one television program and 600 telephone channels plus one network television program.

The transmitting portion of a switching main

THE AUTHOR

C. G. Arnold received the degree of B.S. in electrical engineering from Pennsylvania State University in 1942 and joined the Laboratories in the same year. During World War II he was engaged primarily in the design of equipment for aircraft radar. In 1946 he was transferred to the Transmission Development Department where he worked on problems in the L1 carrier system and was associated with the design of high-frequency echo test equipment. More recently, he has been concerned with the design of the L3 coaxial system and with the problems of arranging the system to meet field needs. Presently he is working on a new light route radio system. Mr. Arnold is a member of Phi Kappa Phi, Tau Beta Pi, and Eta Kappa Nu.

repeater follows the line connecting equipment and consists of a balanced hybrid transformer and a flat amplifier. The hybrid performs two functions. It provides a means for inserting line pilots where they are required and also a method of energizing a working and standby line with the same signals so that line switching can be accomplished satisfactorily. The flat amplifier compensates for the loss of the line connecting equipment in the through path and amplifies the weak signals, received directly from terminal equipment, to the proper magnitude for transmission on the coaxial cable.

The terminal main repeaters are identical to the type just described except for differences in the line connecting equipment, and the fact that pilot signals are always introduced at terminal repeaters. Since all message signals are passed directly into telephone terminal equipment, the telephone line connecting equipment consists of pads only.

Reliability and ease of maintenance have been stressed in the design of the L3 system. Facilities have been provided to monitor its operation and to minimize service interruption due to cable or equipment failure. Appropriate test sets and procedures have been developed to locate and replace aging equipment. Critical units can be demounted without tools and their operation observed while they are in service. These features, which improve reliability and reduce maintenance costs, also improve L3 system performance and, consequently, the long distance telephone service supplied by the Bell Telephone System.

Co-inventors of Transistor Receive John Scott Medals

Dr. Walter H. Brattain (left) of the Physical Research Department, and Dr. John Bardeen (right), formerly of the Laboratories and now professor of physics and electrical engineering at the University of Illinois, have been awarded John Scott Medals for the invention of the transistor. They are shown here with G. Curtis Pritchard at the banquet of the American Physical Society in Baltimore.

The medals, accompanied by a premium of $1,000 each, were presented on March 18 in Baltimore at the banquet of the American Physical Society. Ernest T. Trigg, vice president of the Board of Directors of City Trusts of Philadelphia, which administers the award, presided at the award presentation ceremony.

The medal is named for John Scott, a chemist of Edinburgh, Scotland, whose will in 1816 established the award and entrusted its administration to the City of Philadelphia. He instructed that the award be given "to ingenious men and women who make useful inventions," and that the bronze medal be inscribed "To the most deserving."

During its 139-year history, the John Scott Medal has been awarded to more than five hundred men and women of many nationalities. Orville Wright, Thomas A. Edison, Madame Curie, Guglielmo Marconi, Lee de Forest, Dr. Irving Langmuir, Dr. Vannevar Bush, and Sir Alexander Fleming are among the previous recipients, as well as William G. Housekeeper, Gustav W. Elmen, Herbert E. Ives, Robert R. Williams, and Harold D. Arnold of Bell Telephone Laboratories.

Converting Toll Crossbar Offices for Nationwide Dialing

S. J. BRYMER *Switching Systems Development II*

Earlier crossbar toll offices using the No. 4 or A4A switching systems must be converted to include the features of the new 4A system needed for nationwide dialing. In the No. 4 systems, changes and replacement of major equipment units are necessary. In the A4A, these changes were anticipated and the replacements have been reduced to a minimum. Six No. 4 and thirteen A4A offices will be changed to include the new features as conditions require, to implement the toll dialing plan and expedite the widespread use of direct distance dialing by telephone customers.

Described in a series of earlier RECORD articles,* the 4A toll crossbar switching system is the product of a long-term plan looking toward nationwide customer dialing. This has been a continually growing process, both in conception and implementation, closely paralleling the growth of local mechanical switching of customer lines. As the local dial plant expanded, it was a natural step for operators to use similar methods to complete toll calls to nearby towns. As "nearbys" increased in distance, the demand grew for more suitable facilities for operator toll dialing. This demand was answered in the 1920's and 1930's by the development of "step-by-step" type toll dialing equipment, and a number of networks were set up in various parts of the country using this equipment. Subsequently, the increasing use of common-control principles in the 1930's provided such a high order of versatility and reliability that their use was a "natural" for toll switching applications.

The first development of common-control equipment for toll switching was the No. 4 toll crossbar system, and the first office of this type was installed in Philadelphia in 1943. Since that time, five others have been installed – in the larger metropolitan areas of New York, Chicago, Cleveland, Oakland, and Boston. The system was designed to permit operator dialing into areas having local equipment of the panel or crossbar type, but it could also interconnect with step-by-step areas. The fundamental coding plan, however, was the same as that

* RECORD, *Oct.*, 1953, *page* 369; *Dec.*, 1953, *page* 481; *Aug.*, 1954, *page* 295; *Nov.* 1954, *page* 431; *Feb.*, 1954, *page* 65; *Mar.*, 1955, *page* 93; *Apr.*, 1955, *pages* 141 and 149.

Above — Conversion of the A4A office at Dallas illustrates the use of both the older trouble indicator, seen in the foreground, and the new trouble recorder used with the 4A system. When conversion is complete, the trouble indicator is removed.

used in the previous step-by-step intertoll dialing system. Codes represented trunk-groups rather than destinations, and toll operators calling a given telephone from different remote points would, in general, use different codes to correspond with the different trunk groups selected. As in the step-by-step system, a trunk-group code was absorbed at each switching point and the number of digits dialed by the various operators was, therefore, proportional to the number of switching points involved in establishing the connection. In the No. 4 system, a maximum of fourteen digits was used, comprising three, three-digit trunk-group codes plus the called customer's number. The connections were therefore limited to three toll offices in tandem plus the terminating local office. This coding plan, not being universal, precluded the use of full automatic alternate routing.

Even before the later No. 4 offices were installed, the broad outlines of a nationwide dialing plan were beginning to take shape in the minds of the toll system planners. The foundation of this plan is the use of destination codes to give each customer a distinctive ten or eleven digit number not conflicting with that of any other customer in the nation. This universal number is used regardless of the point of origin of the call and permits full automatic multi-alternate routing. Other requirements, such as six-digit translation, code conversion, and the variable spilling of digits, followed naturally. However, some time would elapse before all these features could be developed for the forthcoming 4A system. In the meantime, the increasing toll business demanded immediate expansion of automatic switching facilities. Although it was realized that all early installations would later be integrated into the nationwide dialing system, it was felt that the flexibility of the common-control equipment would permit future conversion to 4A operation. The five installations of No. 4 equipment after Philadelphia were therefore authorized with certain far-sighted arrangements for facilitating these future conversions.

Within two to three years, certain of the nationwide dialing features had been developed, and it was decided to include them in interim installations known as the A4A (Advance 4A). This system incorporated some Control Switching Point (CSP) features, such as limited code conversion, variable spill forward, and limited automatic alternate routing, thereby permitting part of the operating advantages and economies of the final design to be realized early. In addition, certain of its equipment components were designed so that they could be modified for CSP operation, rather than entirely replaced as in No. 4. The conversion requirements, therefore, differ for No. 4 and A4A offices.

Conversion of these offices centers on the common-control equipment, and provision was made for this in the engineering and installation. In both the No. 4 and A4A system, a marker obtains the called code from a sender and, with its associated route relays, performs all functions necessary to locate an idle trunk, select a path through the link frames, and instruct the sender on what to pulse outward. In the 4A system, a decoder and card

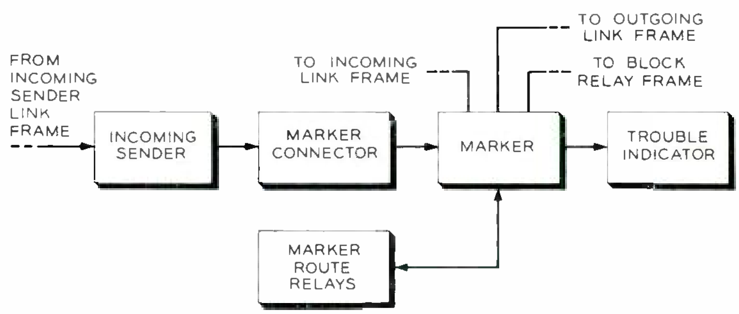


Fig. 1 — The circuit units of a No. 4 or A4A system. The marker route relays are used for limited alternate routing.

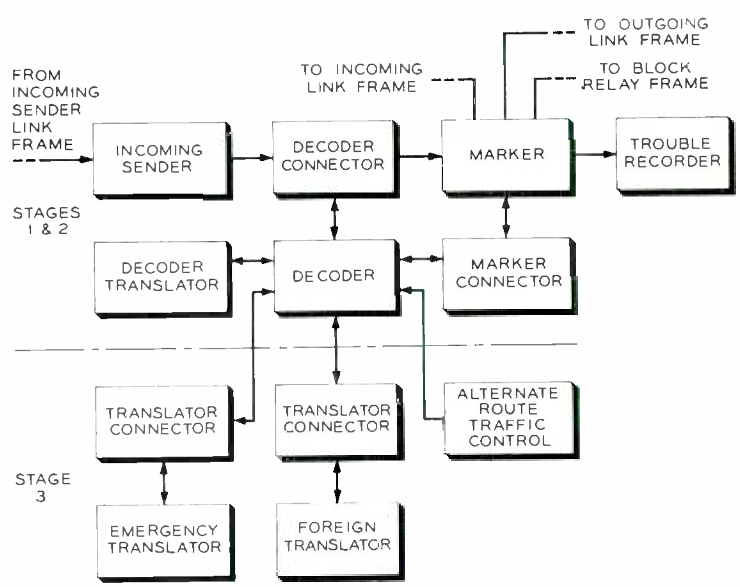


Fig. 2 — When a No. 4 or A4A office is converted, the marker connector becomes a decoder connector, the trouble indicator becomes a trouble recorder, and the marker route relays are replaced by several equipment units. A decoder and decoder translator provide limited alternate routing in stage 1, and foreign translators and associated equipment enlarge this function in stage 3.

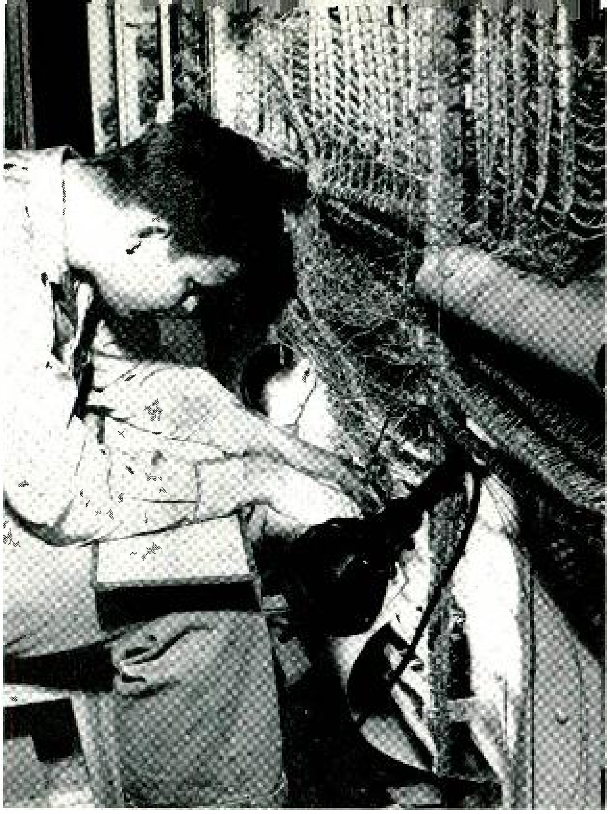


Fig. 3 — Some of the cables and hundreds of wires to be changed in converting a marker connector to a decoder connector for 4A operation.

translator do the work implied by their names, and a marker only locates and sets up the connections to the called trunk. Figures 1 and 2 show the differences between the common-control components of earlier systems and of the 4A system.

In a working office, the replacement of certain No. 4 or A4A common-control equipment by the 4A equivalent must be done without impairment of service. To accomplish this, the original installations omit the two lowest-numbered markers in each switching train, reserve some floor space for future 4A equipment, and loop certain office cables at these locations for later use with the new equipment. Figure 4 indicates this looping of cables in a typical A4A installation.

Omitting two markers in each train provides "elbow room" for substituting the 4A equipment without loss of traffic capacity. Markers connect to the incoming and outgoing link frames and block relay frames. Each of these frames has connectors for ten markers, and omitting two No. 4 or A4A markers permits connecting like-numbered 4A markers in their places so that both types of common control units have access to the links and block relays. Installing the associated senders, decoders, card translators, and other equipment permits operation as a combined No. 4 (or A4A) and 4A office, limited to traffic operating practices and routing codes of the earlier system. The new equipment allows systematic replacement of the remaining No. 4 or A4A common-control equipment by 4A components.

Conversion of a No. 4 or A4A office is divided into three main stages:

(1) Two 4A markers are added per train, along with two decoders and decoder translators, as shown in Figure 2, and approximately thirty new senders plus the associated connectors and test equipment. The senders are added into the sender link multiple as though they were senders of the old type. Whether a call is completed by the No. 4 (or A4A) or the 4A common-control equipment depends entirely upon the random selection of one or the other type of sender at the sender link frame. Naturally, the traffic operating practices and routing codes used must be uniform and will, therefore, be limited by the earlier marker and sender capabilities.

(2) Individual markers and groups of approximately fifteen No. 4 senders are replaced (A4A senders are only modified) in successive steps by corresponding 4A equipment. As each intertoll or combined 4A marker is installed, another decoder and its associated decoder translator are added.

(3) Other equipment required to provide 4A CSP features is added. This includes foreign-area translators as needed, the alternate-route traffic-

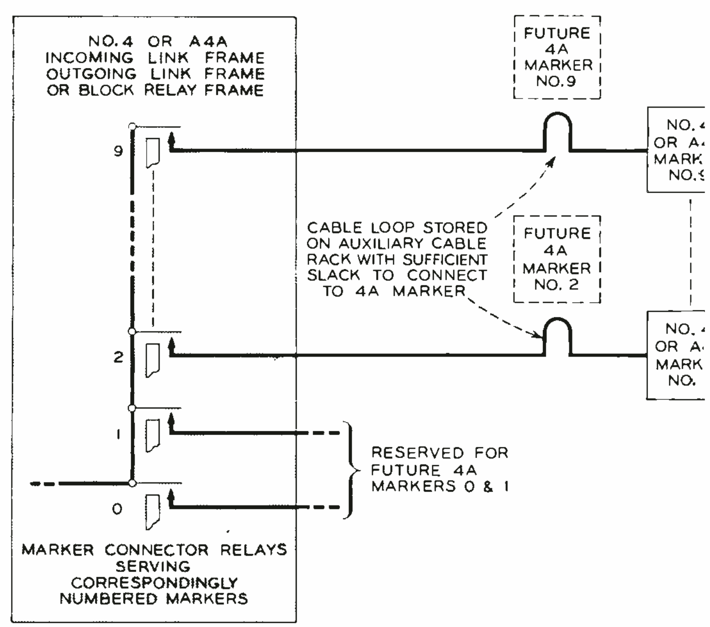


Fig. 4 — Excess cable is looped on auxiliary racks to provide for connecting to future 4A markers.

control frame, and group-busy relay circuits, to permit six-digit translation and full automatic multi-alternate routing as trunks are made available.

Relatively minor modifications in some of the previously installed frames and racks are also made in stage 1, for operation with the 4A common-control equipment. During stages 1 and 2, when the mixed common-control equipment is in operation, it is necessary to use both the 4A trouble recorder and the No. 4 or A4A trouble indicator for maintenance of their respective equipments, and a special lockout circuit is provided to avoid interference over their common connections to the link frames. This period of dual operation, and the final location of the larger trouble recorder frame in the maintenance center lineup in place of the trouble indicator frame, required special provision in the original installations. Extra space was left alongside the trouble indicator and sufficient slack was left in the cables to permit moving it to the location shown in the headpiece. At the end of the second stage, the trouble indicator is no longer required and can be readily removed.

To provide sufficient sender capacity during the periods when the older senders are being converted, so-called "interim" or "swing" senders of the new design are furnished for temporary substitution. These senders appear on their own decoder connector frames, but are temporarily connected into the sender link multiple in the locations of senders being converted and thus out of service. When this latter group is restored to service with the new features, the interim sender connections at the sender link frames are "swung" to the locations of a second group and so on. At the end of the conversion, these interim senders are connected permanently into the multiple.

Thus far, conversion procedures have been described broadly enough to apply to either a No. 4 or A4A office. As mentioned earlier, however, these offices differ in the extent of their built-in CSP features. A4A senders differ in only a few respects from the 4A senders, and require only relatively minor modifications for CSP operation. The A4A marker connector was designed with 4A decoder connector requirements in mind so that it too could be converted in the field. These modifications are much more extensive than those for the senders, but are confined within the frame so that the office cabling can be reused without change. A converted A4A office, therefore, is in all major respects the same as a 4A office.

This is not true for a converted No. 4 office.

Fig. 5 — Three of the many senders at Dallas.

There is a basic difference in the outpulsing arrangements between the No. 4 system, on the one hand, and the A4A and 4A on the other. In the latter, incoming senders are equipped for outward dial-pulsing, while in No. 4 they can outpulse only MF (multifrequency) or dc key pulses and require the services of an outgoing sender for dial-pulsing. Changing to the 4A arrangement from the No. 4 conversions would have required modifications of all trunk circuits handling this traffic, removal of all the associated outgoing senders and sender links, and provision of additional floor space for the larger 4A incoming senders. Retaining the No. 4 outpulsing arrangements permitted the design of new incoming senders that are physically interchangeable with the No. 4 senders.

These new senders not only mount in the space on the frames formerly occupied by the No. 4 senders, but re-use their terminal strips. Sender replacement involves disconnecting the No. 4 sender local cable from these strips and reconnecting the terminal strips to leads furnished in the new sender local cable. The office cables remain connected to the terminal strips during these operations, and senders are therefore replaced without removing frames or major recabling.

These basic differences in the conversion arrangements for No. 4 offices preclude calling them 4A offices when converted, even though the CSP features and many equipment components are identical. It has been decided, therefore, to identify them as 4M toll switching system offices, the "M" stemming from early discussions on modifications for CSP operation. For the 4M offices, new senders and 4A decoder connectors are required, in addition to the other 4A common-control equipment furnished for A4A conversions. A further requirement for the 4M conversions is the necessity for certain preconversion changes, occasioned by differences between the in-pulsing arrangements of the No. 4 and 4M senders and by the rapid growth of some of the existing No. 4 offices.

Since the No. 4 and 4M senders are mixed in the same sender link frame groups during conversion, it is imperative that they be compatible in regard to types of pulsing and the number of digits receivable. No. 4 senders can receive dial, MF, and dc key-pulsed, fourteen-digit codes, with three digits being absorbed at each switching point. 4M senders are arranged only for dial and MF eleven-digit codes that can be pulsed on to the next switching point, either completely or in part, as in the 4A system. The pulsing of the complete received code has recently been developed for No. 4 systems and it is necessary to provide this "spill-forward" feature prior to conversion. Traffic operating practices must be changed before any 4M senders are put in service to use codes with an eleven-digit maximum, and it is also necessary to modify those switchboard positions and connecting trunks arranged only for dc key-pulsing, to outpulse MF to operate with the 4M senders.

Growth in toll traffic has resulted in the equipping of some No. 4 offices with more than eight markers, thus eliminating the "elbow room" for the conversion. This elbow room must be restored and toll traffic carried by the office must be reduced, to permit removal of the extra markers. This will be accomplished by various measures, such as the installation of No. 4A, crossbar tandem, or trunk-concentrating equipment in the areas served by No. 4 offices.

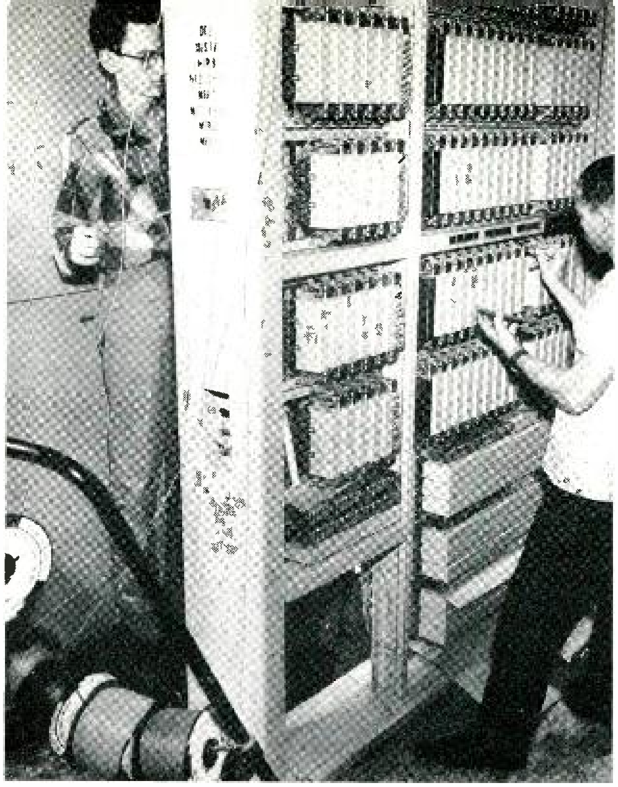
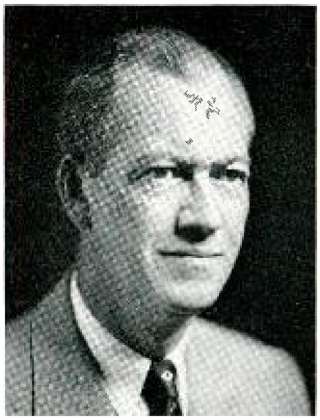


Fig. 6 — The multicontact relays of a marker connector are changed to decoder-connector operation.

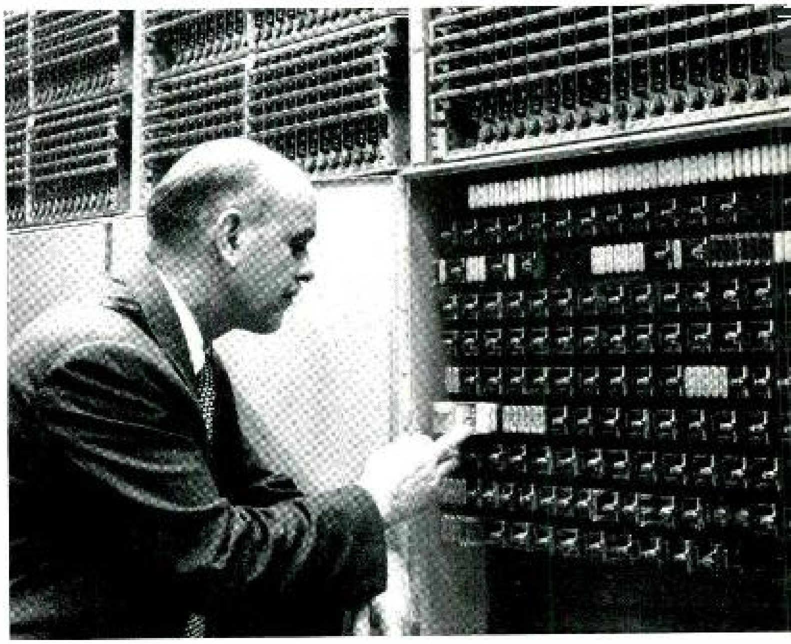
Converting the earlier crossbar toll switching offices to CSP operation is a rather delicate and prolonged process, since it involves a major change in working equipment while service is being furnished. It is estimated that a conversion will take about twice as long as a new installation of a like-size No. 4A office. Conversion of three of the thirteen A4A offices is now complete; these offices are at Pittsburgh, Dallas, and Washington, D. C. The first of the six No. 4 offices to be converted to 4M will be Cleveland, with the installation already started. Plans provide for the conversion of all nineteen No. 4 and A4A installations by about 1965.



THE AUTHOR

S. J. Brymer joined the Laboratories in 1920 as a technical assistant in the Systems Development Department after graduating from the Brooklyn Boy's High School. He spent nine years in the drafting room and then transferred to the special equipment group to work on trial installations and current development problems. He received the degree of E. E. in 1933 from the Brooklyn Polytechnic Institute, and in 1938 began work on common systems equipment. During World War II, he was concerned with multi-channel telephone systems using microwave transmission, and for a year and a half after the war he concentrated on short-wave overseas radio. Since then he has been involved in the design and development of the 4A crossbar toll switching system.

CAMA— Position Link Circuit



C. E. GERMANTON

Switching Systems Development II

The centralized automatic message accounting system required a number of new circuits and several modifications of previous crossbar and AMA practices. One of these circuits is the operator's position link — a link circuit that uses common control techniques to connect high-calling-rate telephone operators to high-calling-rate crossbar switching equipment.

Several of the component parts of the centralized automatic message accounting system have been described in a current series of RECORD articles. It will be recalled that CAMA is a system for achieving the benefits of automatic message accounting by arranging one centrally located office to serve the recording needs of as many as 200 surrounding offices. The recording of information required for billing the customer is entirely automatic except that an operator must be connected to obtain the calling number and to key it into the CAMA equipment.

To permit the CAMA operator to talk to the customer and obtain his number, a link circuit is required. Each link consists of a number of wires, with ends terminating at the crosspoints of crossbar switches. Its utility results from the manner in which the connection is established; in this case, as illustrated in Figure 1, its purpose is to connect the operator to a sender (and thence to the calling customer).

Each CAMA position link frame has two controllers and 80 links and serves a maximum of 40 senders. It can connect any sender to any one of as many as 100 operators. The controller, as will be seen later, determines the order and preference for setting up the link connections. It includes a storage or memory ability necessary in making the correct selection of link paths. A typical office with about 100 senders and 40 operators would require three position link frames.

The CAMA operator is connected to the customer for only a very brief period – probably not more than ten seconds on the average. To insure minimum delay, linkage paths are provided liberally. Duplicate controllers are used, each having a complete set of links, and on any call either of the two controllers may be used.

Distribution of traffic posed a new problem, and its solution constitutes a unique feature of the CAMA position link. Most link controllers are so designed that on the average they distribute the work load evenly among the various circuits to which connections are being made. Even so, for a brief time during relatively slack periods, a par-

Above — The author inspecting a controller in a bay of position link frames in the New York city office.

ticular circuit may be used over and over again while the others remain idle. This is tolerable to switching machines, which are usually content to do all the work assigned to them at the highest possible speed, even though their fellow machine workers may for a time be getting a statistical break. However, dissatisfaction is engendered if one operator receives a number of calls in succession while the adjacent operator is idle. The CAMA position link therefore requires an equitable distribution of traffic, so that successive calls go to different operators, even over a brief period.

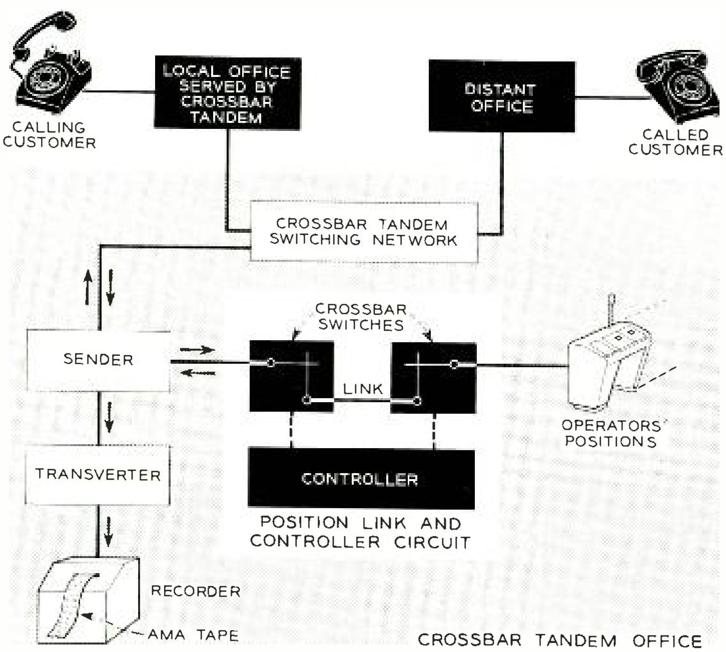


Fig. 1 — Block diagram showing role of position link and controller circuit in CAMA crossbar tandem switching.

The fact that this circuit uses crossbar equipment complicates the attainment of equitable distribution of traffic. The problem is basically one of memory. To find an operator who should serve the next call, the circuit must remember who handled the previous one. With rotary switches, as illustrated in Figure 2(a), the task is quite easy. The control circuit causes the selecting and connecting means to hunt over a group of terminals until it finds an idle one. The connecting means then "stays put" on the selected terminal, even after the circuit has relinquished the terminal electrically at the end of the call. When a subsequent call is handled, hunting starts at the next terminal.

With crossbar equipment, however, the connecting means does not lend itself to use as a "stay put" type of memory. As illustrated in Figure 2(b), the control circuit, in making group selection, first gains exclusive control (so far as the test for availability is concerned) of a group of operators, and then selects an idle operator within that group. After the control circuit has decided which operator will be given the call, it operates the crossbar linkage (not shown) to connect the operator to the circuit requesting the connection. The controller must therefore be provided with a two-stage memory to record both the group and the position within the group selected on the call. These are then used as the starting points in selecting an operator for the succeeding call.

This two-stage memory arrangement is illustrated in Figure 3. Operator positions are considered in groups of ten (the ten horizontal rows of contacts on a crossbar switch), and each controller has access to five groups of ten each. In the controller, therefore, there are two groups of relays — ten for the ten position numbers and five for the five group numbers. These relays are arranged so that only one in each group will remain operated at any one

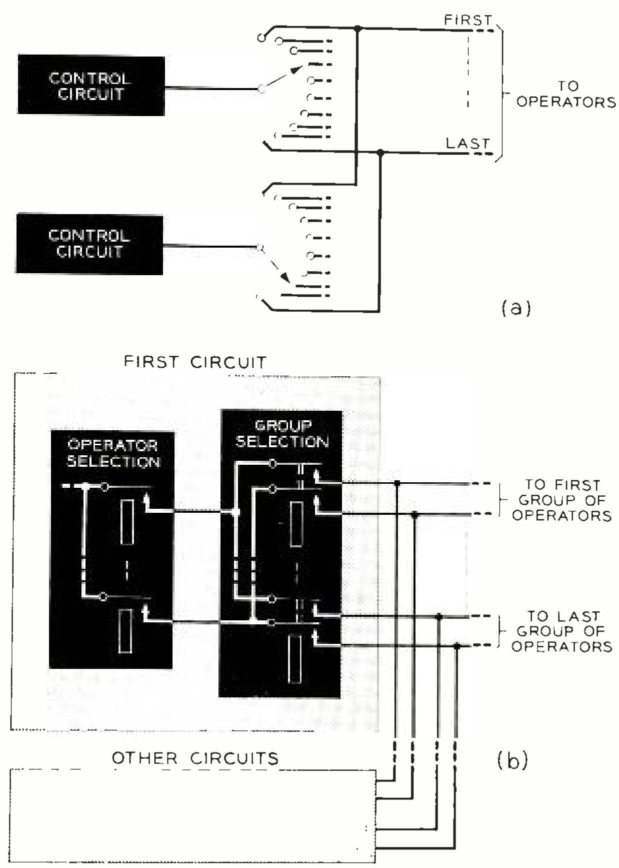


Fig. 2 — (a) Selection by the use of rotary switches. (b) Selection by the use of crossbar equipment requiring memory circuits.

ime. Whenever a second relay in a group is operated, the previous relay is automatically released. Thus, in Figure 3, after operator No. 6 in group No. 3 has been selected to handle a call, only No. 5 (the next down from the one selected) will remain

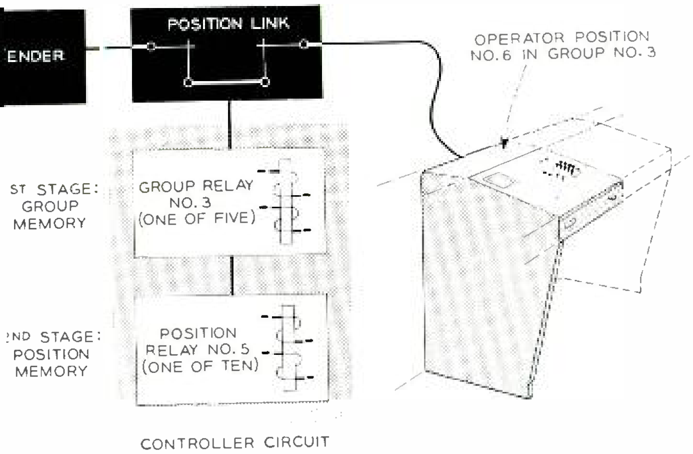


Fig. 3 — Diagram illustrating two stages of memory in controller circuit for CAMA position link.

operated, and the controller will attempt to place the next call with operator No. 5. While trying to place the next call, however, the controller may find that group No. 3 and position No. 5 have already been seized by another controller. It will then "hunt down" through successively lower numbers until an idle position is found.

In selecting the group and the position, and in resetting the memory, it is important that only one group and one position be considered. The checking network controlling such operations provides a path if one and only one relay in the set of relays is operated. The principle behind this type of network is illustrated in very simplified form by the arrangement commonly used in the home where two switches control a single light. Assuming it is wired so that the light is off with both switches in the "down" position, then the light is turned on when one and only one of the switches is up.

Also important in the distribution of calls is a circuit in the controller called the "handicap allotter." During periods of heavy CAMA traffic, all operators will be continuously busy, and besides the calls currently being handled, there may also be calls waiting to be served in each of the controllers in the office. When one operator becomes idle, each controller competes with the others, and without a second distribution feature, one controller might always "win the race" and leave calls waiting for an objectionably long time in the others.

Such monopolization is prevented by the handicap allotter, which is another type of memory circuit. As illustrated in Figure 4, the "position group gate" relay controls the search for a group of operator positions. Normally, when operators are not continuously busy, the operation of the position group gate relay is dependent upon four intermediate relay operations after the controller starts to serve the call. When traffic increases, however, and the controllers begin to compete for groups of operators, one controller will win the first race on a random basis. All other controllers will remember their chagrin by operating their "false start" relays. The next time an operator in any group becomes available, all controllers will again attempt to seize that group by operating their position group gate relays. The next controller following the previously successful one, however, will find a path through two "false start" relays — its own in the operated condition, and one in the previous controller (not operated). This controller will therefore win the second race because the path via the "false start" relay in the previous controller is closed and is ef-

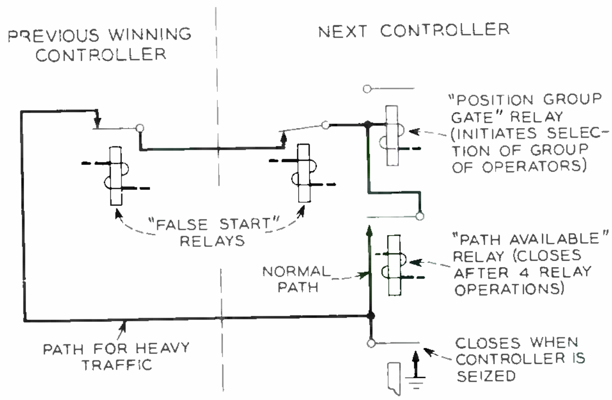


Fig. 4 — Relay operation of handicap allotter, which prevents monopolization of group of operators by a single controller.

fective as soon as the controller is seized. In this way, the controllers take turns seizing control of the group of position test leads.

The controllers are arranged to prevent double connections due to either electrical or mechanical trouble. Selection of the individual position is made by "looking at" (testing) the selecting lead. In addition, before the sender is connected to a position, a look is also taken at the "sleeve" or holding lead of the position. If the position sleeve lead is grounded, as it would be if the position were already busy, the controller sounds an alarm and restores to normal. Since the request for the connection has not been withdrawn, the same con-

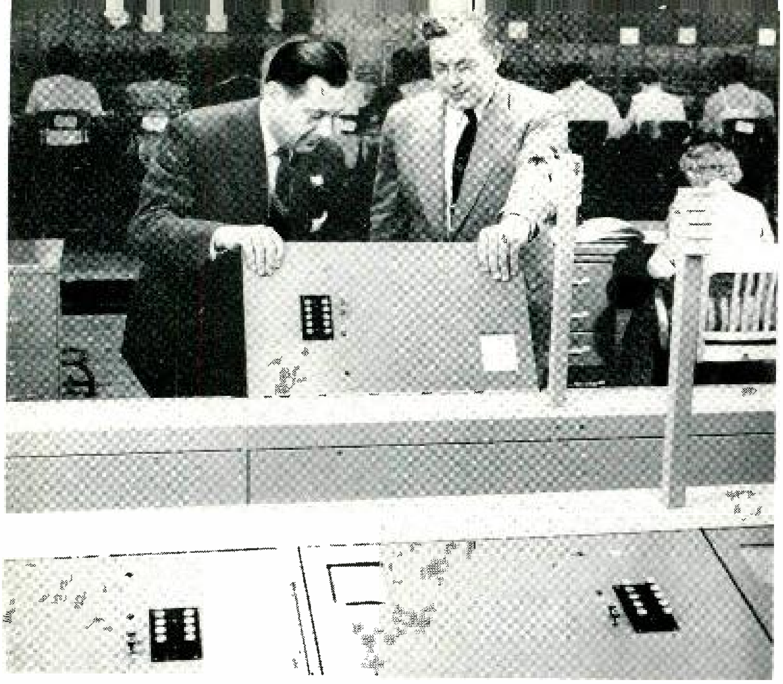


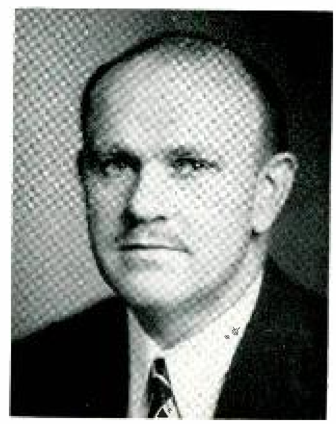
Fig. 5 — At the New York city office during installation of CAMA equipment, J. J. Cozine (right) of the Laboratories inspects operator switchboard positions with W. A. Davis, Central Office Foreman, New York Telephone Company.

troller or its mate will make a second attempt to set up the connection.

If a mechanical defect, such as a bent selecting finger on a crossbar switch, produces a double connection, this will be detected by a polar relay which looks at the link sleeve before the signal is given to the sender to apply holding ground. The circuits are arranged so that under normal conditions this polar relay operates. If mechanical or electrical trouble is encountered, however, and if the link is connected to a connection previously established, the current in the relay will flow in the opposite direction, thus preventing its operation and blocking completion of the call.

This circuit also provides several checking features to insure proper ground connections of the sender and position relays and proper closure of crosspoints. The checks are automatically performed during the handling of a call, and if no fault is detected, the controller restores to normal and is ready for the next call.

THE AUTHOR



C. E. Germanton was graduated from Lafayette College in 1926, receiving the B.S. degree in E.E. He then joined the Technical Staff of Bell Laboratories where, as a member of the Systems Development Department, he has since been principally engaged in the development of panel and crossbar switching circuits. During World War II, he contributed also to the design of operational flight trainers which were built by the Western Electric Company for the Navy. More recently he has been designing circuits for the No. 5 crossbar system and for the crossbar tandem centralized automatic message accounting system. He is the holder of a number of patents in his fields of activity, and is a member of Tau Beta Pi and Phi Beta Kappa honorary fraternities.

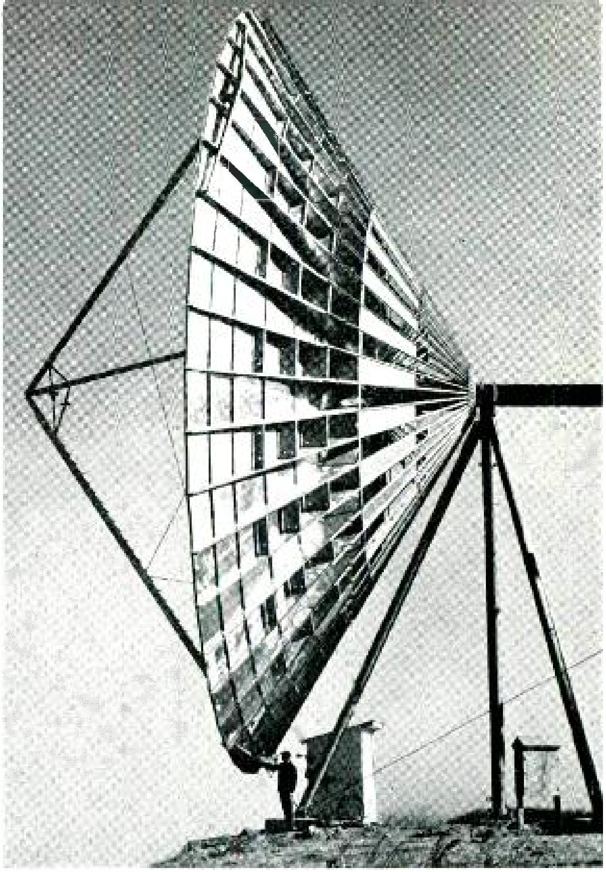
Over-the-Horizon Microwave Transmission

Direct television and multi-channel telephone transmission through space for as much as 200 miles — without relay stations and at ultra-high frequencies — has been accomplished, Bell Telephone Laboratories and the Massachusetts Institute of Technology announced recently.

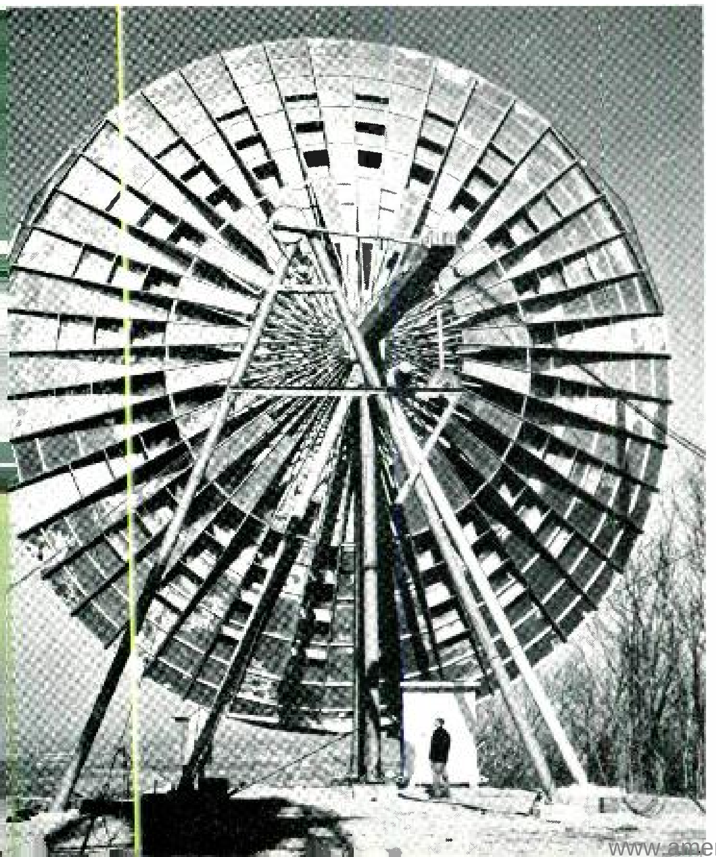
Television pictures, as well as radio and telephone conversation can be sent over-the-horizon on ultra-high frequencies in an extension of a transmission technique recently applied to the continental defense system.

Principal virtue of over-the-horizon transmission is that longer communications bridges are possible over water and rugged terrain. In the present microwave radio relay network across the United States, relay stations are 30 miles apart.

Standard AM radio broadcasting employs waves that follow the earth's curvature, but waves used in television and telephone relays were presumed to travel in a straight line. For many years, "line of sight" transmission between antennas placed on towers on the horizon (about 30 miles apart) was thought to be the only practical means of transmitting by radio the wide bands needed for television and multi-channel telephone service.



Side view of new 60-foot experimental antenna, largest in the world for super high frequencies, which can pick up television and telephone signals sent directly through space for 200 miles. Signals are sent over the horizon in a transmission technique developed by Bell Telephone Laboratories and the Massachusetts Institute of Technology. A rear view of the antenna is shown below.



This was disproved after years of research at M.I.T. and the Laboratories. The Laboratories research stemmed from its success with transcontinental microwave systems for carrying telephone conversations, radio and television programs from coast to coast and its continued interest in radio propagation. The M.I.T. interest was stimulated by work for the Government in radar and overseas radio broadcasting.

Scientists knew that ultra-high frequencies traveled over the horizon under certain conditions but believed them to be too weak and undependable for practical use. In the course of investigating occasional interference attributed to these waves, however, the scientists discovered that many actually overshot the relay towers they were aimed at and arrived at points farther along the radio path with remarkable consistency.

The next step was to provide reliable long distance transmission over-the-horizon. M.I.T. and Laboratories engineers did this by erecting larger antennas and using higher power than is employed in the conventional microwave system. In this way they put to use the weaker signals that drop off a straight radio beam beyond the horizon and are reflected or scattered to distant points by the earth's atmosphere.

The effect of the new system is very much like that of a powerful searchlight, which casts a beam in a straight line. A searchlight aimed at the sky can be seen from the ground miles away, even when the searchlight is behind a hill. This is possible because some of the light is reflected to the ground by the atmosphere.

In order to make use of over-the-horizon transmission, 10-kilowatt transmitters and 60-foot-diameter antennas are being used. This is 20,000 times the power and 30 times the antenna area used in the present transcontinental microwave system. It was found necessary to employ the lower frequencies (in the UHF band) to develop with available equipment sufficient power to attain a satisfactory degree of reliability.

Even after scientists learned that transmission was possible over-the-horizon, they were not certain that this medium would support the broad band of frequencies needed for multi-channel telephone or television transmission. In the fall of 1953, they found that they could transmit twelve voice channels over-the-horizon.

Television was first successfully transmitted over-the-horizon in 1954 between the Holmdel, N. J., laboratory of the Bell Telephone Laboratories and the M.I.T. Round Hill Research Station near New Bedford, Mass., a distance of 188 miles.

Laboratories and M.I.T. scientists emphasize that this success with over-the-horizon transmission will probably result in a supplement to, rather than a replacement of line-of-sight radio relay systems.

Over-the-horizon signals are not to be confused with a similar type of transmission known as "ionospheric scatter," which is useful in long distance transmission of telegraph signals at relatively low frequencies. Unlike ionospheric signals, the over-the-horizon technique provides signals that are useful for the wide bandwidths required for a television picture or by many telephone channels.

Papers Published by Members of the Laboratories

Following is a list of the authors, titles, and place of publication of recent papers published by members of the Laboratories:

Callaway, Joseph, Orthogonalized Plane Wave Method, Phys. Rev., **97**, pp. 933-936, Feb. 15, 1955.

Cooper, H. G., Koehler, J. S., and Marx, J. W., Irradiation Effects in Cu, Ag, and Au Near 10°K, Phys. Rev., **97**, pp. 599-607, Feb. 1, 1955.

Cutler, C. C., and Hines, M. E., Thermal Velocity Effects in Electron Guns, Proc. I.R.E., **43**, pp. 307-315, March, 1955.

Cutler, C. C., and Saloom, J. A., Pin-Hole Camera Investigation of Electron Beams, Proc. I.R.E., **43**, pp. 299,306. March, 1955.

Davey, J. R., Hanley, F. H., and Purvis, M. R., A New Telegraph Serviceboard Using Electronic Circuits, A.I.E.E. Commun. and Electronics, **17**, pp. 30-37, March, 1955.

Ewing, N. S., Patent Law as a Career, The Bent of Tau Beta Pi, Feb., 1955.

Geller, S., Note on the Structure of Dimethylamine-Boron Trifluoride, Acta Crystallographica, Letter to the Editor, **8**, p. 120, Feb., 1955.

Geller, S., and Wolontis, V. M., The Crystal Structure of Co_2Si, Acta Crystallographica, **8**, p. 83, Feb., 1955.

Gilman, G. W., see Kelly, M. J.

Hines, M. E., see Cutler, C. C.

Hohn, Franz, Some Mathematical Aspects of Switching, Am. Math. Monthly, **62**, pp. 75-90, Feb., 1955.

Kelly, M. J., Radley, Sir Gordon, Gilman, G. W., and Halsey, R. J., A Transatlantic Telephone Cable, Elec. Eng., 74, pp. 192-197, March, 1955.

Kelly, M. J., Radley, Sir Gordon, Gilman, G. W., and Halsey, R. J., A Transatlantic Telephone Cable, A.I.E.E. Commun. and Electronics, **17**, pp. 124-136, March, 1955.

Kohn, W., see Luttinger, J. M.

Mendel, J. T., Magnetic Focusing of Electron Beams, Proc. I.R.E., **43**, pp. 327-331, March, 1955.

Mertz, Pierre, Transmission Line Characteristic and Effects on Pulse Transmission, Symposium on Information Networks, pp. 85-114, Jan., 1955.

Purvis, M. R., see Davey, J. R.

Read, W. T., Jr., Scattering of Electrons by Charged Dislocations in Semiconductors, Philosophical Magazine, **373**, pp. 111-131, Feb., 1955.

Saloom, J. A., see Cutler, C. C.

Scales, Miss E. M., and Chapanis, A., Effect on Performance of Tilting the Toll-Operator's Keyset, J. Appl. Psychology, **38**, pp. 452-456, Dec., 1954. (Listed in March issue as published by the J. Appl. Phys.)

Southworth, G. C., The Challenge, I.R.E. Transactions, MIT-3, No. 1, pp. 2-3, Jan., 1955.

Tien, P. K., Walker, L. R., and Wolontis, V. M., A Large Signal Theory of Traveling-Wave Amplifiers, Proc. I.R.E., **43**, pp. 260-277, March, 1955.

Vogel, F. L., Jr., Dislocations in Polygonized Germanium, Acta Metallurgica, Letter to the Editor, **3**, pp. 95, Jan., 1955.

Walker, L. R., see Tien, P. K.

Wolontis, V. M., see Geller, S., and Tien, P. K.

Talks by Members of the Laboratories

During March, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and places of presentation:

I.R.E. National Convention, New York City

Aaron, M. R., The Use of Least Squares in Network Design.

Andreatch, P., see Thurston, R. N.

Bangert, J. T., Influence of Computing Machines on Network Design.

Bown, R., Spurious Radiation.

Bullington, K., Characteristics of Beyond-the-Horizon Radio Transmission.

Cook, J. S., and Fox, A. G., Tapered Velocity Couplers.

Douglas, V. A., An Experimental Mobile Dispatching Service.

Fox, A. G., see Cook, J. S.

Haus, H. A., see Robinson, F. N. H.

McMillan, B., The Mathematics of Information Theory.

Pierce, J. R., Orbital Radio Relays.

Robinson, F. N. H., and Haus, H. A., The Minimum Noise Figure of Microwave Amplifiers.

Shannon, C. E., Rate of Approach to Ideal Coding.

Thurston, R. N., and Andreatch, P., Characteristics of Torsional Transducers.

Tidd, W. H., Demonstration of Bandwidth Capabilities of Beyond-Horizon Tropospheric Radio Propagation.

Warner, A. W., Parameters Affecting the Q of Quartz Crystal Units.

Weiss, M. T., Behavior of Ferroxdure at Microwave Frequencies.

American Physical Society, Baltimore

Brown, W. L., Surface Potential and Surface Charge Distribution from Semiconductor Field Effect Measurements.

Brown, W. L., see Montgomery, H. C.

Feldmann, W. L., see Pearson, G. L.

Fletcher, R. C., Merritt, F. R., and Yager, W. A., Cyclotron Resonances in Germanium at 1.4°K.

Lundberg, J. L., Molecular Weight Distributions of Polymers: Speculations on Polymerizations to Equilibrium.

Mays, J. M., see Slichter, W. P.

Merritt, F. R., see Fletcher, R. C.

Miller, P., Work Function Difference of Gold and Gold Oxide from Contact Potentials with Respect to Germanium and Platinum.

Montgomery, H. C., and Brown, W. L., Field Effect in Germanium.

Montgomery, H. C., see Pearson, G. L.

Pearson, G. L., Montgomery, H. C., and Feldmann, W. L., Noises in Silicon p-n Junction Photocells.

Slichter, W. P., and Mays, J. M., Proton Magnetic Resonance in Polyamides.

Van Roosbroeck, W., Theory of the Photo-magnetoelectric Effect in Semiconductors.

Yager, W. A., see Fletcher, R. C.

Other Talks

Arlt, H. G., Standardization of Materials, Standards Engineers Society, New York City.

Bacon, W. M., Systems Engineering, Cornell University Graduate Seminar, Ithaca, N. Y.

Barstow, J. M., Television Transmission, South Dakota School of Mines, Rapid City, S. D., and University of Nebraska, Lincoln, Neb.

Bescherer, E. A., Miniaturization – Recent Developments in Components and Applications, A.I.E.E. North Carolina Section, Winston-Salem.

Besfary, V. F., Logic of Relay Circuits, Ramapo Reformed Church, Adult Fellowship, Mahwah, N. J.

Bradley, W. W., Corrosion – Problems and Preventive Measurers in the Telephone System, Newark College of Engineering, Newark.

Chapin, D. M., Recent Discoveries in Solid State Physics, New Jersey Science Teachers Association, Somerville, N. J.

Chapin, D. M., Theory, Development and Properties of the Bell Solar Battery, A.I.E.E.-I.R.E. and American Institute of Chemical Engineers, New York City.

Darrow, K. K., The Hall Effect, Rohm and Haas Chemistry Club, Philadelphia.

Doherty, W. H., Careers in the Communication Field, Career Conference on Engineering and Applied Science, Harvard University, Cambridge, Mass.

Doherty, W. H., New Pathways in Communication, Columbia University, Men's Faculty Club, New York City.

Flaschen, S. S., see Garn, P. D.

Foster, F. G., The Microscope – Its History and Development, Stevens Institute of Technology, Hoboken, N. J.

Fox, A. G., Measurement Techniques in the Millimeter Wavelength Range, I.R.E. Long Island Section, Garden City, Long Island.

Frost, H. B., Diffusion Transient in Oxide Cathodes, M.I.T. Physical Electronics Conference, Cambridge, Mass.

Garn, P. D., and Flaschen, S. S., Detection of Polymorphic Phase Transformations by Continuous Measurement of Electrical Resistance, American Chemical Society, Cincinnati.

Garn, P. D., and Halline, E. W., Polarographic Determination of Phthalic Anhydride in Alkyd Resins, Conference on Analytical Chemistry and Applied Spectroscopy, Pittsburgh.

Talks by Members of the Laboratories, Continued

Hagstrum, H. D., Electron Ejection from Metals by Ions, New York University, Physics Department Colloquium, New York City.

Halline, E. W., see Garn, P. D.

Hammann, P. L., Project NIKE, Kiwanis Club, Summit, New Jersey.

Harrower, G. A., Fine Structure of the Energy Distribution of Secondary Electrons from Molybdenum and Tungsten, M.I.T., Physical Electronics Conference, Cambridge, Massachusetts.

Holbrook, B. D., Electronic Computers, Columbia High School, South Orange-Maplewood Adult School, Maplewood, New Jersey.

Ingram, S. B., Training and Orientation in a Large Company, Summit Chamber of Commerce, Personnel Group, Summit, New Jersey.

Jakes, W. C., Jr., Microwave Antennas – Theory and Practise, Northwestern University, Evanston, Ill.

Karlin, J. E., What Psychologists Do at Bell Telephone Laboratories, New Jersey Psychological Association, Princeton, New Jersey.

Keefauver, W. L., Patent Law as a Profession, University of Pennsylvania, Electrical Engineering Seminar, Philadelphia, Pennsylvania.

Keister, W., Mechanized Intelligence, Student A.I.E.E.-I.R.E. Section, Agricultural and Mechanical College of Texas, College Station, Texas.

Kelly, H. P., Measurement and Equalization of Amplifiers and Transmission Systems for Color TV Service, I.R.E. Philadelphia Section Color Symposium, Philadelphia.

Kudlich, R. A., A Set of Transistor Circuits for Asynchronous Direct-Coupled Computers, Western Joint Computer Conference, Los Angeles.

Mason, W. P., Ultrasonics, Joint Meeting of Oklahoma Geological Society, American Association of Petroleum Geologists, American Petroleum Institute and Society of Geophysicists, Oklahoma City; and Oklahoma Geological Society, Tulsa Chapter, Tulsa.

Morrison, J., Some Effects of Gases on Thermionic Oxide-Coated Cathodes, M.I.T. Physical Electronics Conference, Cambridge, Mass.

Nelson, C. E., Microfilm Experience and Application at Bell Telephone Laboratories, National Microfilm Convention, Boston.

Nesbitt, E. A., Fine Precipitated Particles in Permanent Magnets, Edison Laboratories, West Orange, N. J.

Pedersen, L., Aluminum Die Castings for Carrier Telephone System, Electrical Utilization of Aluminum Conference, Pittsburgh.

Pfann, W. G., Application of Zone-Melting Techniques to Metals and Semiconductors, Metallurgy and Physics Department Colloquium, University of Illinois, Urbana, Ill.

Pfann, W. G., Zone-Melting, American Chemical Society, North Jersey Section, Physical Chemistry and Industrial Chemistry Groups, Newark.

Pierce, J. R., Interplanetary Communication, American Museum of Natural History, American Astronautical Association, New York City.

Raisbeck, G., The Bell Solar Battery, A.I.E.E.-I.R.E. Meeting, Kimball Hall, Chicago; Purdue University, West Lafayette, Ind.; and Armed Forces Communications and Electronics Association, Philadelphia.

Schaefer, J. W., Some Characteristics of Guided Missiles, Morris County Engineers Club, Dover, and Plainfield Engineer's Club, Plainfield, N. J.

Schawlow, A. L., Structure of the Intermediate State in Superconductors, Columbia University Physics Colloquium, New York City.

Schimpf, L. G., Transistor Circuit Applications, Tri-County Radio Club, Plainfield, N. J.

Shannon, C. E., Reliable Circuits Using Crummy Relays, Holmdel Colloquium, Holmdel, N. J.

Smith, K. D., The Bell Solar Battery, I.R.E. Subsection, Greensboro, N. C.

Talley, H. E., Positron Annihilation in Solids, Lehigh University Physics Colloquium, Bethlehem, Pa.

Thatcher, H. E., Project NIKE, Naval Research Reserve Unit, Princeton, New Jersey.

Vogel, F. L., A Metallurgical View of Dislocations, American Institute of Mining & Metallurgical Engineers, Chicago Section, Chicago.

Williams, H. J., Ferromagnetic Domains, Edison Laboratories, West Orange, N. J.