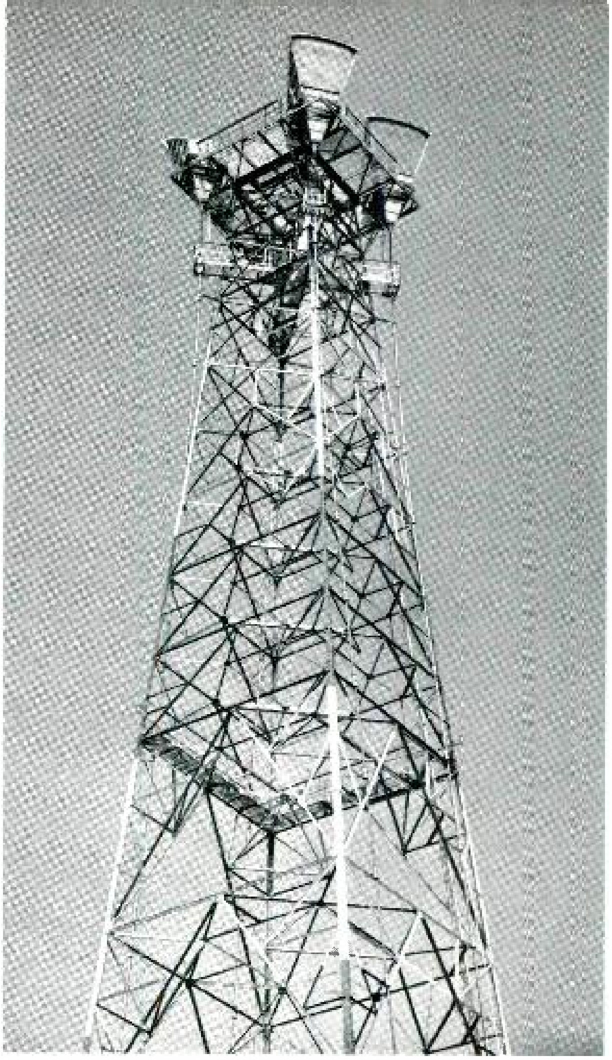
One of the chief objectives of transmission research and development at Bell Laboratories is to design equipment for the constantly growing number of channels required for telephone messages and television signals. Now that two new microwave radio-relay systems are being developed to supplement TD-2, a novel antenna invented at the Laboratories has also been developed. This antenna, which can be used for all three radio-relay systems, has already been incorporated into some recent TD-2 installations.



A. T. CORBIN AND A. S. MAY
Transmission Development

Broadband Horn Reflector Antenna

A new microwave antenna has been developed to improve the efficiency of the Bell System's long haul microwave radio relay systems. This antenna can operate simultaneously in the 4,000-, 6,000-, and 11,000-mc bands designated by the FCC for "common carrier" use.

Within a relatively short span of years, TD-2 radio relay* has interconnected most of the large cities throughout the United States and parts of Canada. At the end of 1954, about 100,000 channel miles were in operation and trends indicate that about 130,000 will be required by the end of 1955.

Many routes are already being used to the full six-channel capacity of the 4,000-mc TD-2 system and still more circuits are needed now or in the near future. To augment radio relay service, two new systems are in the development stage. These new systems, designated TH and TJ, will operate in the 6,000-, and 11,000-mc bands. The former will be suitable for long haul transcontinental service, while the latter will be designed for short route service and for spur routes connecting to a long haul system. The need for a wide-band antenna operating in all three common carrier bands was foreseen and has been fulfilled with the invention and development of a horn reflector antenna.

This antenna and its associated circular waveguide feed can transmit or receive, with high efficiency, signals polarized at 90 degrees with respect to each other in each of the three common carrier bands. That is, the lines of the radiated electric field can be oriented vertically for some signals and horizontally for others. The use of the circular waveguide with cross-polarized signals permits ad-

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

ditional discrimination between microwave channels. Systems designed to take advantage of such discrimination can make more efficient use of the frequency spectrum, leading to the possibility of a greater number of message and television channels in a given band than has been previously attainable.

Because of the broadband characteristics of the new antenna, the TD-2, TH, and TJ radio-relay signals can all be transmitted along the same route using only four horn reflector antennas at each repeater tower. A transmitting and a receiving antenna will be used for each of the two directions of transmission (see the illustration at the head of this article). On spur or light routes, where wider channel separation can be employed, one antenna may be used for both transmitting and receiving in one direction, thereby reducing the number of antennas needed per tower to two.

Basically, the antenna is a combination of an electromagnetic horn capped by a sector of a paraboloid of revolution. Figure 1 illustrates how the horn and sector are combined to form the antenna. It may be seen that the apex of the horn coincides with the focal point of the paraboloidal reflector. In the front side opposite the reflecting surface, the horn is cut away to form a 64½ square foot aperture. The antenna weighs about 1,700 pounds and is 20½ feet high, 11 feet wide, and 9 feet deep.

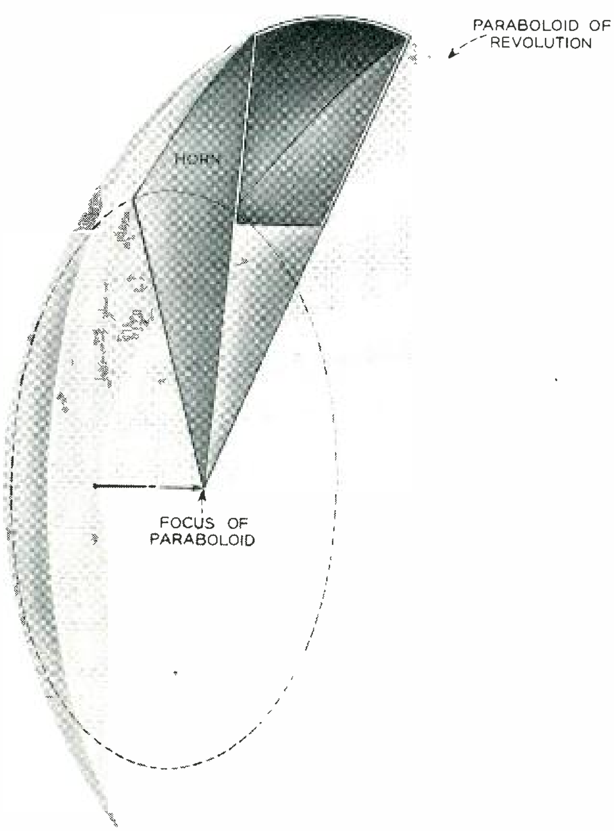


Fig. 1 — Geometry of the broadband horn reflector antenna: the apex of the horn coincides with the focal point of the paraboloidal reflector.

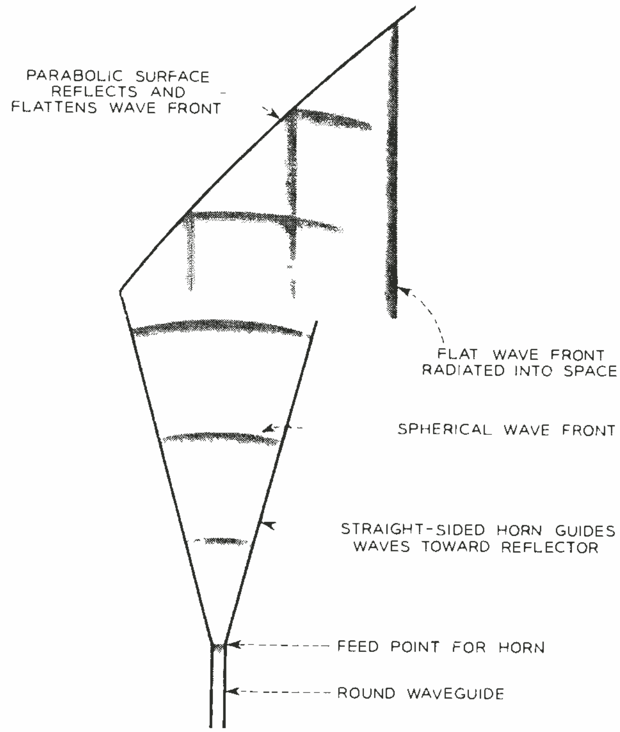


Fig. 2 — A spherical wave front, reflecting from the parabolic surface, becomes a plane wave front transmitted from face of antenna.

The reflector is made in two parts with the dividing line down the center. A reflecting "skin" for each half is formed by stretching an ⅛-inch thick aluminum sheet over a plastic die having the desired shape. The contour of the reflecting surface must be accurate to 1/16 of a wavelength or about 1/16 inch for the 11,000-mc band. The skins are attached to thick aluminum spars which have been machined to the proper shape, and to horizontal ribs. These spars and ribs stiffen the reflector to withstand ice and snow loads of 100 pounds per square foot or wind velocities of 150 miles per hour. The horn is made of 1/16 inch thick aluminum sheets and extruded aluminum stiffeners or braces that reduce movement of the aluminum sheet in high winds. The lower end of the horn is a precision aluminum casting, square at one end and round at the other to match the square horn to a circular waveguide feed. A four-ply polyester-impregnated glass fiber cover 0.040-inch thick protects the antenna aperture from the weather. A new seal has been developed for use in all seams of the antenna. The seal, made of non-vulcanized conducting rubber and a woven wire mesh, combines the important functions of protection against the leakage of radio frequency energy and making the structure weather-tight.

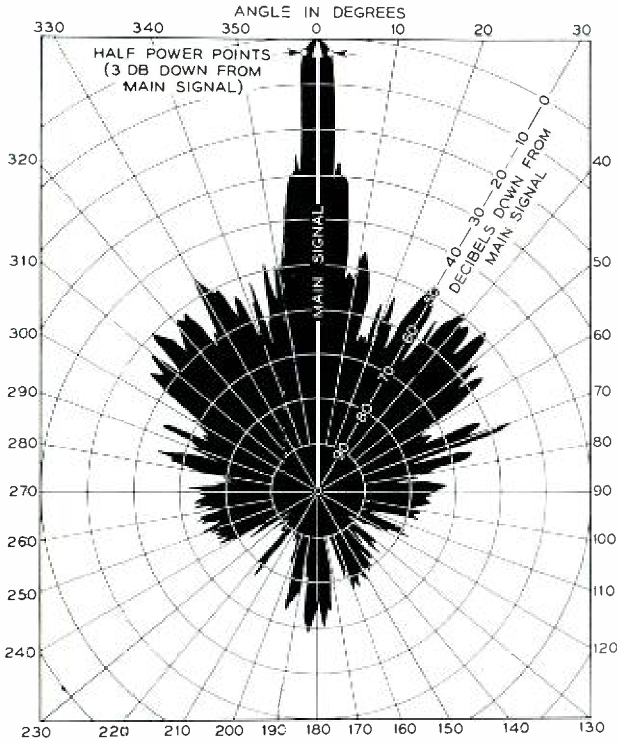


Fig. 3 — Radiated energy distribution of horn reflector antenna at 3,740 mc.

A cross-section of the antenna showing typical paths of radio waves as they leave the focal point is illustrated in Figure 2. The horn converts the electromagnetic energy propagated by the connecting circular waveguide into a spherical wave front to "illuminate" the reflector. Since the reflector has a paraboloidal contour, the spherical wave is changed to a plane or uniphase wave front.

Because the radiated energy is concentrated into a narrow beam instead of being allowed to diverge in all directions, the distant antenna receives more signal energy than it otherwise would. Thus, we say the antenna has gain. The gain is measured by the ratio of a received signal when a horn reflector antenna is used for transmitting the signal, to what the received signal would be if the transmitted signal radiated equally in all directions. The gain in the 4,000-mc TD-2 band is 40 db. In the 6,000- and 11,000-mc bands this gain is 43 db and 48 db respectively. The gain increases at the higher frequencies because the beam of radiated energy becomes narrower.

Figure 3 shows the radiated energy distribution on a 360 degree polar diagram for 3,740 mc. The energy of the main signal at 0 degrees is measured, and the number of decibels below this value is plotted for all other directions. It can be seen that most of the energy is concentrated in a narrow beam about 2 degrees wide at the half-power points. The beam width decreases as the frequency increases and has been measured as 1.5 degrees and 1 degree at 6,000 and 11,000 mc, respectively. For these higher frequencies, the energy distributions have the same general pattern as that seen in Figure 3, except that even more of the energy is concentrated in the desired direction of propagation.

Fig. 4 — L. C. Tillotson (left) and A. T. Corbin inspecting glass fiber cover on face of horn reflector antenna at the Holmdel Laboratory.

To determine the beam widths and radiation patterns accurately, it was necessary to design new measuring equipment using radar pulse techniques. With this equipment, reflections from nearby hills or buildings could be separated from the direct signal and thus a true plot of the radiation pattern was obtained.

To a reader unaccustomed to thinking in db terms, Figure 3 may not adequately portray the quality of the new antenna. The rear radiation is shown as 70 db below the main signal. This means that only one ten-millionth of the signal energy is transmitted or leaks from the back of the antenna.

A very important consideration in the design of the antenna was to maintain a good impedance match throughout the waveguide and antenna system. The 2.812-inch inside-diameter circular waveguide is carefully manufactured to precision tolerance; the internal contour of the 21-inch long cast feed-horn tapers down in a gradual hyperbolic transformation from the 11½-inch square aperture of the large horn to the circular waveguide; the weather cover across the output aperture slopes to minimize reflections back to the focal point; and there are no braces or projections on the interior surfaces of the antenna. As a result of this careful attention to design detail, the minimum return loss of the antenna over a 3,700- to 11,700-mc frequency range is 40 db. Thus only one ten-thousandth of the power transmitted through the waveguide feed is reflected back into the feed system.

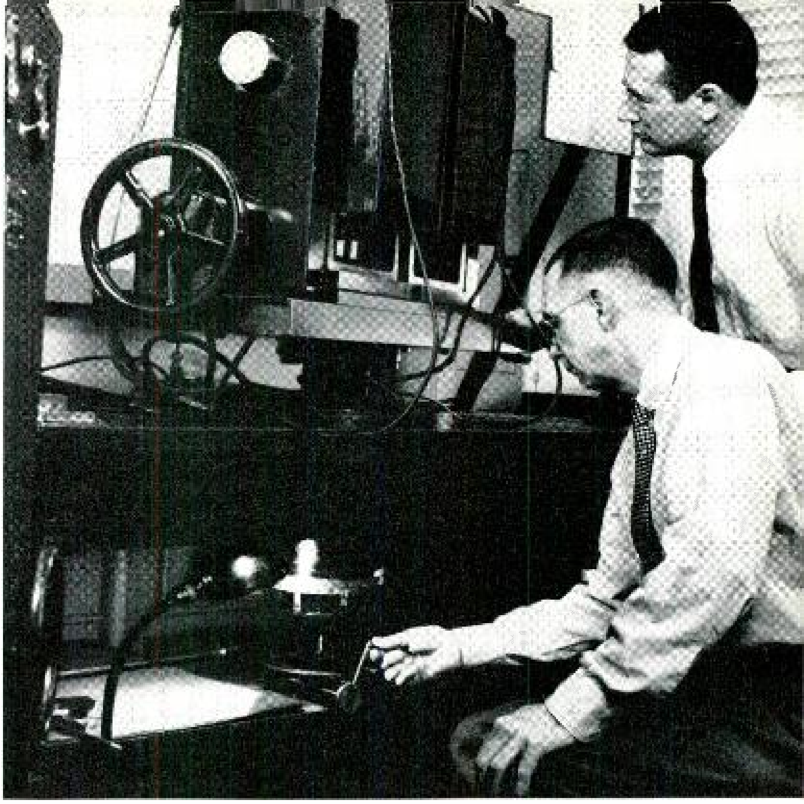
At the present time the broadband horn reflector antenna is being manufactured for use with all new TD-2 installations. Ultimately the new antennas can be used to replace existing delay lens antennas now in service when TH or TJ systems are added to existing TD-2 routes.

THE AUTHORS

A. T. Corbin joined the Southwestern Bell Telephone Company in 1942, and after a period of service with the Navy during World War II, rejoined that Company in 1949. He came to the Laboratories Transmission Systems Development Department on loan in 1952. While at the Laboratories, he was engaged in work on the TH system, horn reflector antenna, microwave systems testing, and safety engineering. Mr. Corbin returned to Southwestern Bell in December, 1954. He has attended the University of Oklahoma and Southern Methodist University.

Allen S. May joined the Laboratories in 1939 shortly after receiving the B.S.E.E. degree from West Virginia University. For two years he worked on trial installations of automatic teletypewriter switching systems and then he turned to the analysis of sections of a transcontinental carrier system. During World War II, he designed radar equipment for the armed forces and since the war he has been engaged in the design of microwave radio relay equipment for telephone and television transmission. Several years ago, Mr. May engaged in work on the TH radio relay system, and more recently, has been working on a TD-2 improvement program.

The Inner Structure of Alnico 5



E. A. NESBITT AND R. D. HEIDENREICH *Physical and Chemical Research*

Bell Laboratories' pre-World War II heat treatment of permalloy in a magnetic field showed that this process could greatly improve the properties of certain magnetic materials. Application of this treatment to permanent magnets was also effective, and led to the development of the amazingly powerful Alnico 5 which has found countless civilian and military applications. Now a new theory of the structure of this material, to which the Laboratories have made important contributions, has been confined experimentally. This may result in even more powerful magnets for the future.

Permanent magnets are playing an increasingly important role in our peacetime living. A modern home contains magnets in its telephone, kilowatt-hour meter, and in its television and radio sets. In war, the role of magnets is even greater. For example, a modern bomber may contain as many as 300 permanent magnets.

There are approximately twenty different permanent magnet alloys used commercially of the hundreds that are known to science. In fact, according to current permanent magnet theory, any ferromagnetic material may be made into a strong magnet. As we shall see later, the fabrication of such magnets requires that we somehow achieve a structure composed of extremely fine particles of a certain shape. Among the modern industrial magnets, Alnico 5 is the most powerful, and it accounts for approximately 90 per cent of commercial production. It is a complicated alloy containing 14 per cent nickel, 8 per cent aluminum, 24 per cent cobalt, 51 per cent iron, and 3 per cent copper. When heat treated in a magnetic field, it has excellent permanent magnet properties.

Because of the complex structure of Alnico 5, and because of the methods used to produce it, a number of interesting questions can be asked about the physical laws that give rise to the observed phenomena. For example, what causes the alloy to respond to heat treatment in a magnetic field? Alnico 5 is practically unique in this respect since its magnetic strength is increased threefold by the presence of a magnetic field during controlled cooling of the specimen from 1300°C. In addition, what causes the alloy to have a coercive force (ability to resist demagnetization) as high as 600 oersteds? Both of these important questions were successfully answered by our investigation.

When the physicist thinks of permanent magnets today, he visualizes the internal structure to be made up of very fine particles of ferromagnetic material which have dimensions of the order of one millionth of an inch. In a particle of this small size, the elementary atomic magnets all lie in the same direction and each individual particle is therefore a single "magnetic domain."* There are a number of methods of obtaining such particles. In one method, they are made by reducing oxide particles in hydrogen; the particles are then compacted to form a magnet. In another method, the particles are precipitated in the body of the material and no further handling is necessary. To date the latter method is by far the most useful.

According to current theory, the very small particles are necessary in order to limit the magnetization process to one of rotation, as shown by the arrows in the fine particles represented in the upper part of Figure 1. That is, in a magnet, we wish to change the direction of magnetization (lines of magnetic flux) by rotation alone, and this process will take place only when the particles are very small. The spherical particle A of Figure 1, in addition to its small size, must have crystal properties such that there is an easy direction and a hard

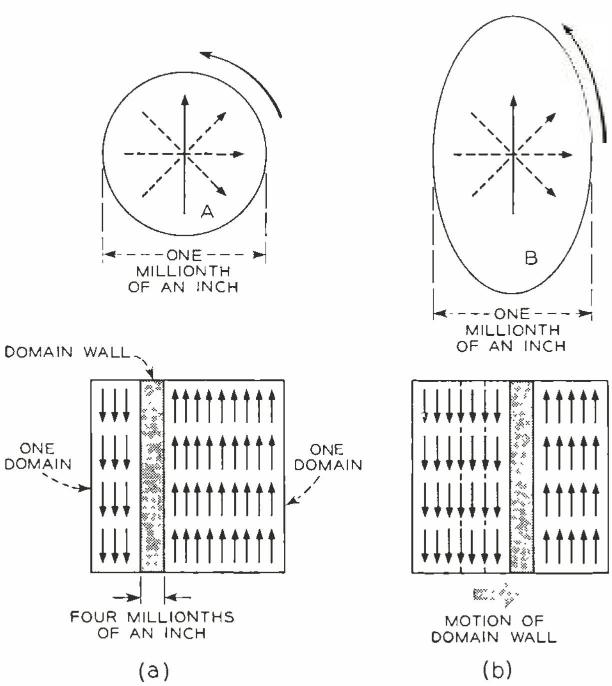


Fig. 1 — Above: in very small particles, reversing of magnetization is indicated by rotation of arrows; below: in larger particles, magnetization is reversed by motion of domain wall.

* RECORD, *October*, 1952, *page* 385.

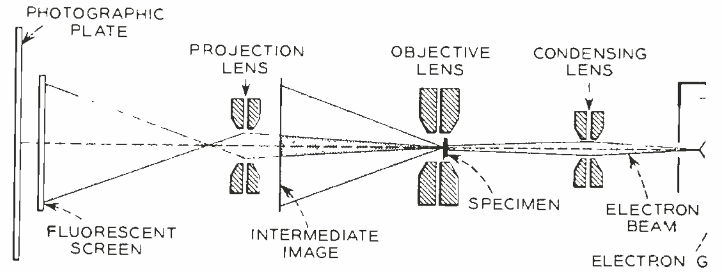


Fig. 2 — Principal parts of an electron microscope; electron beam replaces light used in optical microscope.

direction of magnetization. The degree of this difference in difficulty of magnetization is a measure of what is termed its "crystal anisotropy." High crystal anisotropy results in stronger permanent magnet properties. Further, as illustrated by particle B of Figure 1, the very small particle should be longer than it is wide; it will then be easy to magnetize along the long dimension and difficult to magnetize along the narrow dimension. The ratio of the length to the width of the particle is a measure of its "shape anisotropy." Since high shape anisotropy results in high permanent magnet properties, needle-like shapes of fine particles are very desirable.

If the particles are larger than the sizes indicated in the upper part of Figure 1, a change of magnetization will take place by what is called "domain wall motion." As shown in the lower part of the illustration, this mechanism requires the existence of a domain wall, which is a boundary or transition region about 4 millionths of an inch between domains, wherein the magnetization changes in direction from that of one domain to that of the adjacent domain. When the magnetization is changed in these larger particles, the wall moves across the particle in accordance with the change. This is the type of magnetization change that occurs in transformer cores. It is a low energy process, since the magnetization does not have to directly overcome any of the anisotropy of the material, as it does in the rotational type of change. For this reason, the particles are made smaller than the thickness of a domain wall. The wall therefore cannot exist, and the changes in magnetization must take place by rotation.

The experimental work was guided by a current theory of Alnico 5, to which the Laboratories has contributed. According to this theory, if we have a polycrystalline bar of Alnico 5, and if we heat treat it in a magnetic field, certain portions of the alloy will precipitate in the form of plates; these plates

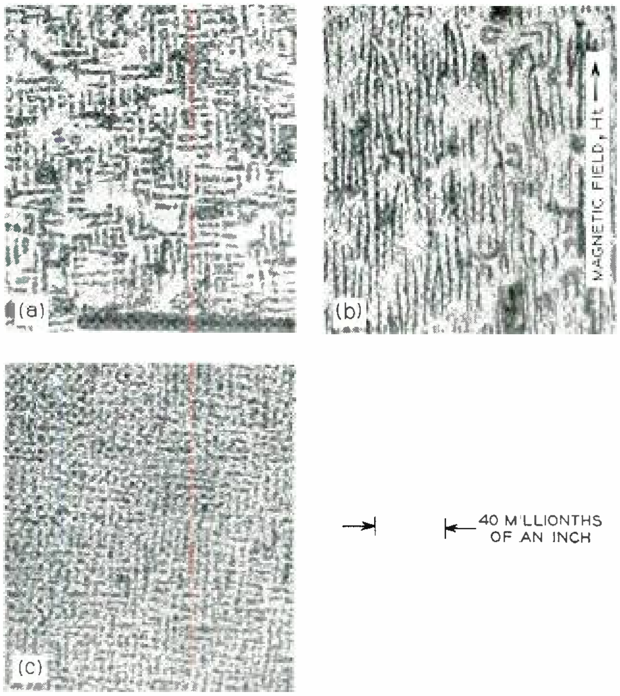


Fig. 3 — Electron microscope photos of Alnico 5 replicas: (a) molten alloy cooled without magnetic field, (b) cooled in magnetic field, and (c) a cross section of (b).

will be aligned parallel to the magnetic field but not at right angles to it. As a result, the bar will be divided into plates of precipitate imbedded in the main body or matrix of the material. The reason for this arrangement is that the nuclei, or small "seed" particles from which the plates grow, are formed parallel to the field, because in this direction they are easy to magnetize, whereas the nuclei at right angles to the field are difficult to magnetize and are suppressed.

Before describing some of the experimental verifications of this theory, it is worthwhile first to consider briefly the role of the electron microscope in this work, since the use of this instrument was crucial in elucidating the structure of Alnico 5. As is now generally known, an electron microscope operates by means of an electron beam and electromagnetic "lenses," instead of the light beam and glass lenses found in the more common optical microscope. As shown schematically in Figure 2, the electron microscope consists of an electron gun, condensing lens, objective lens, and projection lens. The condensing lens serves to focus the electron beam from the gun onto the specimen, which is located just above the objective lens. Electrons are scattered by the specimen, and some of these are focused to produce an enlarged intermediate image of the specimen. The projection lens further enlarges the image produced by the objective lens and yields a final image on the fluorescent screen, where it is viewed through a glass window. Photographs are taken by moving the fluorescent screen to one side and allowing the electrons to strike the photographic plate immediately below. The magnification of the final image can be varied from about 1,500 to 15,000 diameters by changing the strength of the projection lens. The instrument used in this work is the RCA-EMU, operating at 50-kv accelerating potential.

It will be noticed that the specimen to be observed is of the transmission type — that is, the electron beam must pass through it to produce the image. The penetrating power of electrons is so low, however, that only very thin layers of solid matter can be imaged by this method. Films of the order of one millionth of an inch in thickness are ideal for examination in the electron microscope. Thus it is necessary to "replicate" the surface structure of a solid body into a thin film of suitable material to study the surface. There are several techniques for doing this. The one particularly well adapted to the Alnico 5 study is the "oxide replica" method. The oxide replicas were prepared by oxidizing the polished and etched surface of an Alnico 5 crystal at 500°C in a molten

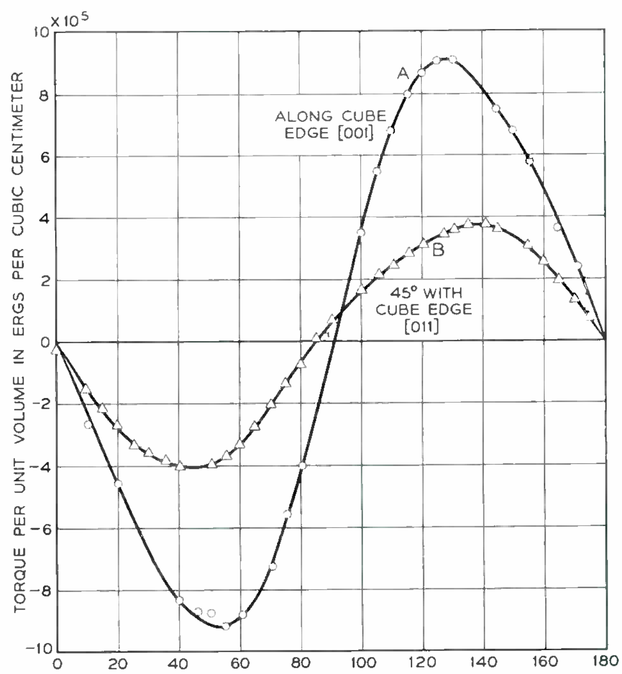


Fig. 4 — Torque curves for single crystal Alnico 5, with two different directions of magnetic field.

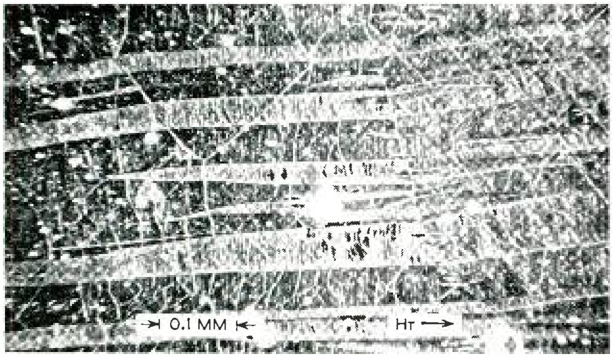


Fig. 5 — Magnetic powder pattern of Alnico 5, showing magnetic domains oriented in direction of magnetic field.

bath of potassium nitrate and sodium nitrate. The oxide layer so formed grows to about one millionth of an inch thick in 10 seconds. It is removed from the underlying metal by immersion in a bromine and methanol solution, which parts the film from the metal surface. These films are then mounted in the specimen holder and examined in the electron microscope. The image obtained from such a film depends upon differences in effective thickness from one point to another. For Alnico 5, these thickness variations are determined by the local rate of oxidation of the alloy.

Electron microscope photographs taken in this manner revealed a remarkable experimental confirmation of the theory of fine particles. Three such photographs are reproduced in Figure 3. In Figure 3(a), the crystal was heat-treated without a magnetic field, and the black precipitate present is seen to have grown in two directions at right angles to each other. In Figure 3(b) the crystal was heat-treated with the field (H_t) applied in the vertical direction as indicated. As predicted by the theory, the black precipitate is elongated in the direction of the field, and cross precipitation is prevented. The precipitate particles shown have been grown larger than the optimum size for permanent magnet properties so that the structure can be seen more clearly.

Figure 3(c) shows a cross-section of the same crystal seen in Figure 3(b). The plates of precipitate are now at right angles to each other, but they are still parallel to the field direction, which is now normal to the page. The experiment has added a refinement to the theory in that we can now see that the precipitate grows as rods which form into plates. Figure 3(b) is a side view of the rods and Figure 3(c) an end view. The spacing between the rows of rods (plates) is approximately one millionth of an inch, which is within the limits predicted by the theory. We do not know the chemical composition of the precipitate, but we have reason to believe that it is rich in cobalt and iron, and that it is the agent responsible for the permanent magnet properties of the alloy.

We can measure the degree of crystal or shape anisotropy by means of magnetic torque measurements. Briefly this consists of rotating single crystal disk specimens in a strong, uniform magnetic field and measuring the torque necessary to turn the crystal away from a direction of easy magnetization. The illustration at the head of this article shows E. A. Nesbitt (left) and A. J. Williams operating the large magnet used in torque measurements to determine the magnetic properties of Alnico 5. From these measurements, we find the easy direction of magnetization and the value of the anisotropy constant K, which measures the torque necessary to rotate the magnetization out of the easy direction. Then we can calculate the coercive force on the basis of the measured anisotropy constant K and compare this value with one obtained by direct measurement. Such comparisons enable us to check the theory.

Two typical torque curves obtained on a single crystal disk of Alnico 5 heat-treated in a magnetic field are shown in Figure 4. In curve A of Figure 4, the heat-treating field was directed along a cube edge of the crystal and in curve B the heat-treating field was directed along a 45° angle with this cube edge. It is evident that the maximum torque obtained in curve A is greater than that obtained in curve B. When we heat treat a polycrystalline sample of Alnico 5 in which the crystals lie at random, the maximum value of the lower torque curve will largely determine the coercive force. The fact that the torque curve repeats every 180° tells us that the torque results from particles having shape

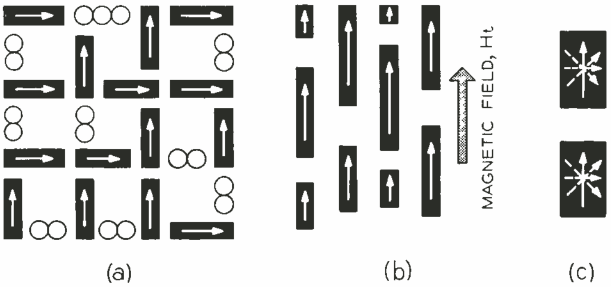


Fig. 6 — Without heat treatment in magnetic field, plates lie at right angles (a); with treatment, plates are aligned with field (b); and side view of plates (c) shows magnetic change by rotation only.

rather than crystal anisotropy. The relatively small effect that crystal anisotropy has upon the direction in which the domains lie is also shown by the magnetic powder pattern in Figure 5. In this experiment, a polycrystalline sample of Alnico 5 was cooled rapidly in a magnetic field so that the domains would be large enough to see. The photograph shows that the domains follow the direction of the magnetic field applied during heat treatment without too much regard for crystal orientation.

A simplified picture of the magnetic domains and the plates of precipitate in a single crystal of Alnico 5 are shown in Figure 6. The picture was deduced from torque measurements and electron-metallography. When the material is not heat treated in a field, the plates of precipitate grow in three directions mutually perpendicular to each other as shown in Figure 6(a). The circles in this figure represent the ends of the rods in the plates of precipitate. With this type of domain arrangement, we obtain 9,000 gauss for residual induction and approximately 13,500 for saturation. When the material is heat treated in a magnetic field, a much more efficient type of structure for permanent magnets is obtained as shown in Figure 6(b). Now the precipitate and consequently the magnetic domains all lie in the same direction, with the result that the residual induction is 13,000 gauss, which is almost equal to the saturation value. The coercive force of this structure is also higher because of greater length of the precipitate particles.

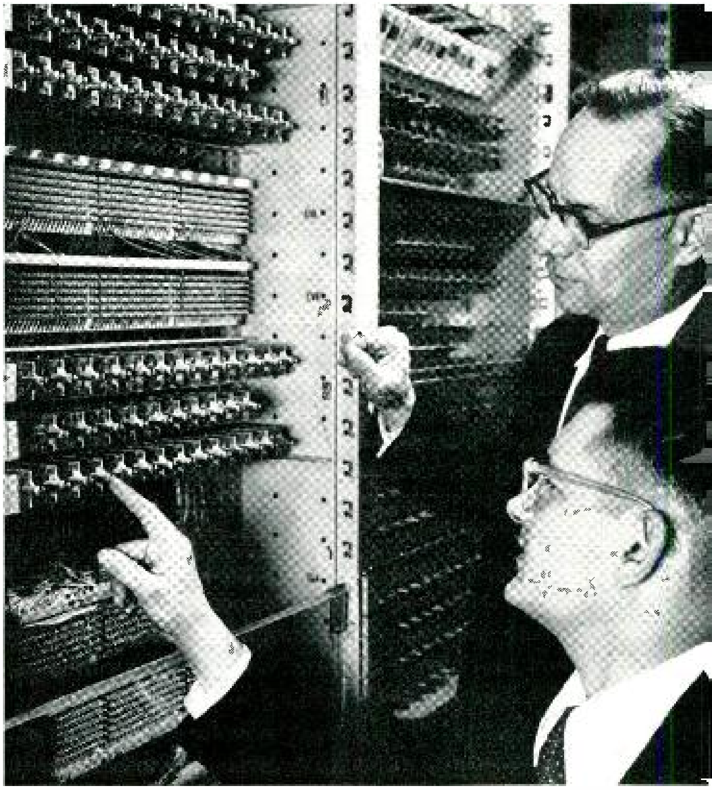
In Figure 6(c) we observe the side view of the plates of precipitate, which, as mentioned earlier, are single magnetic domains. It is the ratio of the length to width of the plates (in the side view) which determines the coercive force of the alloy. Electron metallography indicates that this ratio is approximately 2, and if it could be increased, the permanent magnet properties of Alnico 5 would be further enhanced. Investigation of these properties is continuing at the Laboratories, and it is to be hoped that the finer, needlelike particles can be achieved, which will in turn make Alnico 5 an even better magnetic material.

THE AUTHORS

E. A. NESBITT joined the Engineering Department of the Western Electric Company in 1924 and transferred with that Department to the Laboratories in 1925. In the early part of his telephone career, he worked with the magnetics group where he assisted in the development of the permalloys, Perminvar and Permendur. During World War II, Mr. Nesbitt worked for the Office of Scientific Research and Development and for the Naval Ordnance Laboratory. More recently, in the solid-state physics group, his work has been principally on the theory of permanent magnets, magnetostriction, magnetic alloys and magnetic phenomena in general. Mr. Nesbitt received his B.S. degree from Brooklyn Polytechnic Institute.

R. D. HEIDENREICH received a B.S. degree in Electrical Engineering from the Case School of Applied Science at Cleveland, Ohio, in 1938 and an M.S. degree in physics from the same school in 1940. That same year he went to work for the Dow Chemical Company, later applying the then novel electron microscope to metallurgical and chemical problems. Since joining the Laboratories in 1945, Mr. Heidenreich has been engaged in the Chemical Department in electron diffraction and electron microscope research on the structure of metals and alloys and, more recently, on oxide cathodes. He is a member of the American Association for the Advancement of Science and a Fellow of the American Physical Society.

Code Conversion in No. 5 Crossbar



F. P. CIRONE *Switching Systems Development III*

To be versatile enough to aid the expansion of direct distance dialing, the No. 5 crossbar switching system has built into it the feature known as code conversion. This feature permits customers or operators to dial standard telephone numbers even though special area codes or office codes are required for switching through step-by-step offices.

During its relatively short existence, No. 5 crossbar has developed into the most versatile local switching system we have. Among its functions, No. 5 plays an important part in the nation's long distance switching system, since, in addition to its role as a local office, it was designed to act as a tandem or toll office, and is at present an important factor in extending direct distance dialing.

With direct distance dialing, a telephone call will generally be given a routing through toll offices and/or tandem offices, and cases will arise where the pattern of digits needed to perform the switching functions will differ from the pattern dialed by the customer. To obtain flexibility, and at the same time to minimize the cost of adapting other types of equipment, No. 5 has built into it a code conversion feature, being checked in the illustration by G. T. Hornung (foreground) and W. I. McCullagh. This feature is used in several different ways as will be discussed later.

First, however, we should consider the simplified mechanics of a call made by a customer in a step-by-step office to a customer in another office, whose number is assumed to be MAin 2-9970. After the calling customer has picked up the telephone and his line has been found by the step-by-step equipment, he hears dial tone and proceeds to dial M (or "6" on the dial). As shown in Figure 1, this letter is used in the step-by-step office to step up a selector to the sixth level. The selector then hunts horizontally until it finds an idle terminal connected to a second selector. At this point the equipment is ready for the next digit. The second selector rises to the second level in response to the next dialed digit, in this case A (or 2). This selector then hunts horizontally until it finds an idle terminal to another selector, and the process is repeated until all digits that will be used in the step-by-step office are dialed. Figure 1 shows the connection in a step-by-step office from a customer to a trunk going to the

MA 2 office. The digits MA 2 are used to select the trunk, and the remaining digits, 9970, are repeated directly to the MA 2 office with no registering device in the originating step-by-step office. Although this example is somewhat simplified, it serves to show that the step-by-step system as ordinarily arranged does not remember digits and cannot take a given set of digits and translate them into other types of routing information.

At this point, let us examine some possible ways that two customers, served by two different central offices, can be connected together. Figure 2, though incomplete, shows six ways customers in an originating office A can be connected to customers in a terminating office B. Most actual telephone connections will fall in the Figure 2(a), (b), (c), or (d) classes; Figure 2(f), is a highly improbable, but nevertheless possible connection. Further, existing trunking schemes are much more flexible than those indicated in the diagram, and can include almost any combination of local, tandem and toll offices. Also, the offices may use different types of switching equipment, but only step-by-step tandem and toll offices are considered here.

The diagram can be used, however, to illustrate the important part code conversion plays in such routing patterns. Figure 2(c) demonstrates a call having a routing through two step-by-step tandem offices. Without code conversion, a customer in office A might have to dial several extra digits to reach another customer served by office B. These digits would be used to select paths through the tandem offices. Now with the coming of direct distance dialing and a systematic numbering scheme, when a No. 5 crossbar system must complete calls through SxS systems, it must be able to take a directory code and, when necessary, convert it into an arbitrary code. Under conditions such as these, a nationwide numbering system without code conversion would entail extensive alterations of many of the step-by-step "intertoll" offices. Many offices would also have to be enlarged to provide extra selectors.

Some step-by-step offices use only two selectors per path, and if it were necessary to select an MA 2 trunk, the office would have to be modified to accept three digits. Also, a step-by-step office may not have paths corresponding to MA 2, but may have paths corresponding to codes which customers do not dial, such as 012 and 140. Such codes beginning with 0 or 1 are not available to customers because dialing 0 would reach an operator, and because a 1 is considered as a preliminary pulse caused by switchhook jiggling. Therefore, if efficient use is to be made of the selectors in such step-by-step offices, the MA 2 code must be changed to a more convenient code. Since No. 5 crossbar was designed to work not only as a local office, but also as a tandem or toll office, it will often have to work through step-by-step tandem and intertoll offices to complete calls. For this reason, No. 5 has built into it a "code conversion" feature.

In the No. 5 crossbar system, code conversion is actually two operations — digit deletion and digit substitution or addition. The marker (controlling element of No. 5 crossbar offices) is able to delete from one to six digits from the beginning of any given series of numbers, starting with the first digit in all cases, and is able to add as many as three digits. A few simple calculations will show that the marker is theoretically capable of code conversion for a very large number of situations. In practice, however, the marker is endowed with the ability to code convert for a maximum of 100 of the possible combinations. These 100 code conversions can cover routes to all areas, if necessary, or routes to one area, or any combination of area and local routes.

As an example, when a step-by-step tandem office

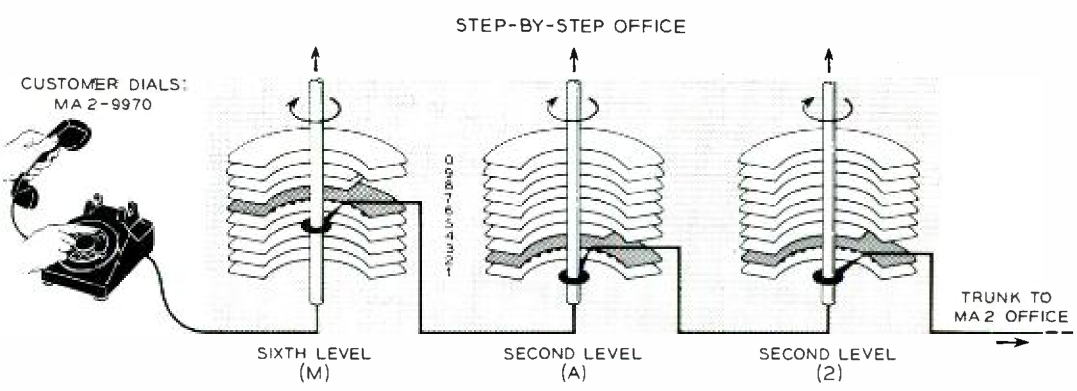


Fig. 1 — Simplified diagram showing how "MA 2" path is selected through a step-by-step office.

uses only two switching stages to select a trunk, the marker recognizes that MA 2-9970 must be converted to a number with two digits preceding the customer's number (9970), and would perhaps delete the MA 2 code entirely, or just delete the M if A2 were usable. If the marker deletes all three digits of the code, it then substitutes one, two or three digits, as required, for switching through whatever step-by-step equipment is to be used.

Figure 3 shows how the same call, MA 2-9970, can be code converted to use existing equipment in a step-by-step office. In this example, it is assumed that the step-by-step office does not have an available MA 2 path, but does have a 125 path. The No. 5 crossbar office will therefore convert the MA 2 code to 125 (the 125 route in the step-by-step office must be connected to trunks which go to the MA 2 destination), and no changes will be necessary in the equipment installed in the step-by-step office. The terminating office, MAin 2, connects to the called customer's line to complete the call.

Figure 5 is a simplified diagram showing how the marker functions during code conversion. When the customer has completed dialing, the marker receives the full complement of digits. The first three digits, MA 2 (622), cause a terminal called a "code point" to be grounded. Normally, this code point would operate a route relay, which would have wired into it all the routing instructions necessary to complete the call to the next office, whether tandem, toll, or local. With code conversion, however, this

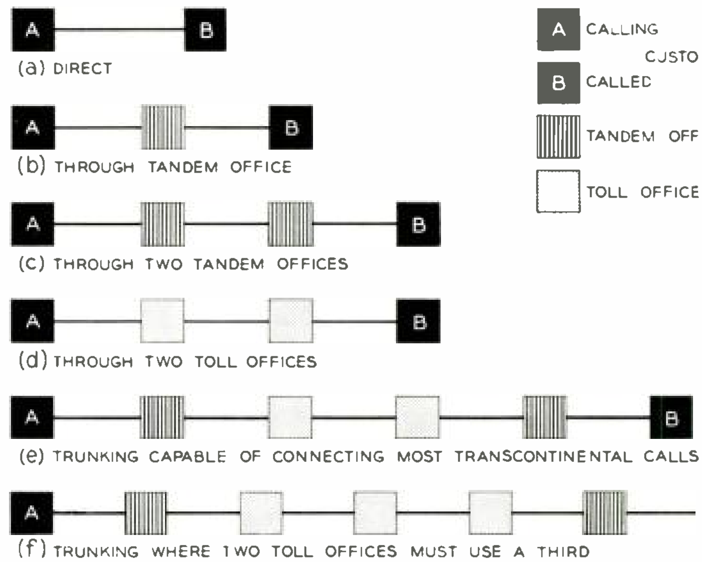


Fig. 2 — Some possible methods of connecting office A t office B.

particular code point does not operate a route relay, but instead operates a "conversion relay". The function of this relay is to cause the operation of a route relay and the proper "arbitrary number relays" through a flexible cross-connection system.

The conversion relay in Figure 5 is activated by the 622 code point, and causes the operation of three arbitrary number relays in the marker. These in turn operate three sets of digit registration relays in the outgoing sender, and the sender thus registers 125 ahead of the MA 2-9970 digits. At the

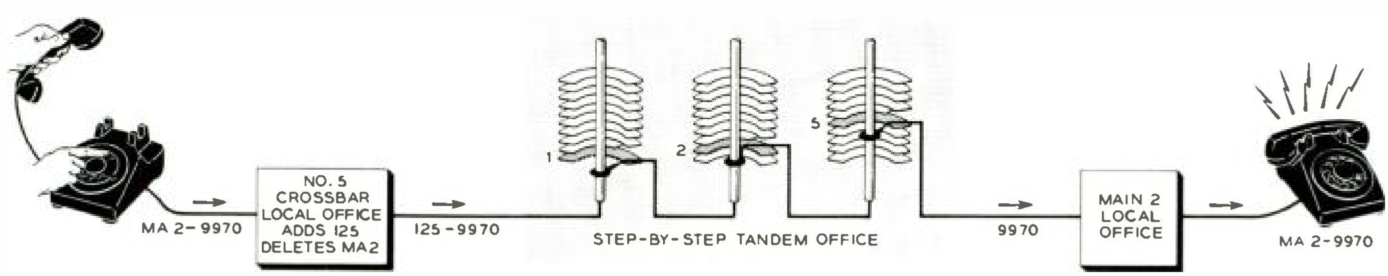


Fig. 3 — Code conversion used for finding "125" path through step-by-step office.

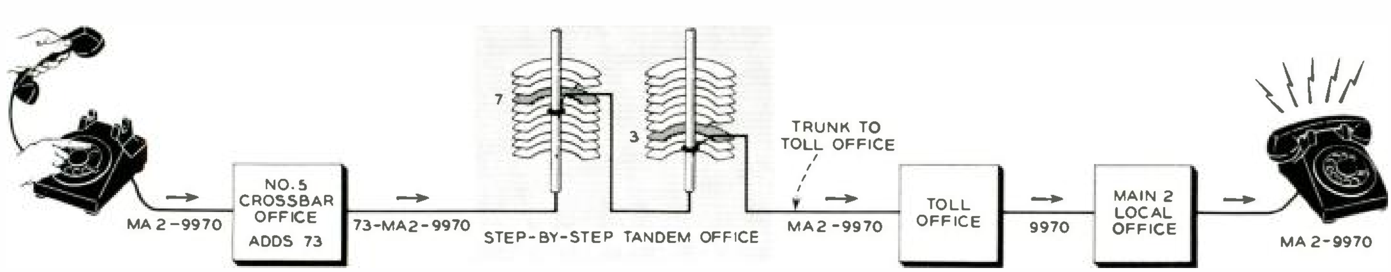


Fig. 4 — Use of code conversion when the two local offices are in the same numbering area with no direct trunks.

same time, the conversion relay causes the operation of the route relay.

The next operation causes the sender to ignore the MA 2 portion of the code. This is done by having the route relay of the marker transmit a "delete 3" signal to the sender. The delete 3 relay operated in the sender does not affect the arbitrary numbers put there by the marker but does affect the original digits. The sender now has on its digit registers 125-MA 2-9970. The delete 3 relay causes the MA 2 to be ignored during sender pulsing. The sender will therefore send 1-2-5, then skip over the will operate when associated arbitrary digits are registered.

These steering relays are controlled by three factors. First, the marker must have passed to the sender a digit so that the associated steering relay may operate. Second, the deletion relays control the steering relay in such a way as to by-pass the unwanted steering relays and consequently skip the associated digits. Third, each steering relay is assigned in a "sequence chain" so that arbitrary digit steering relays have highest preference. This means that each steering relay is controlled by

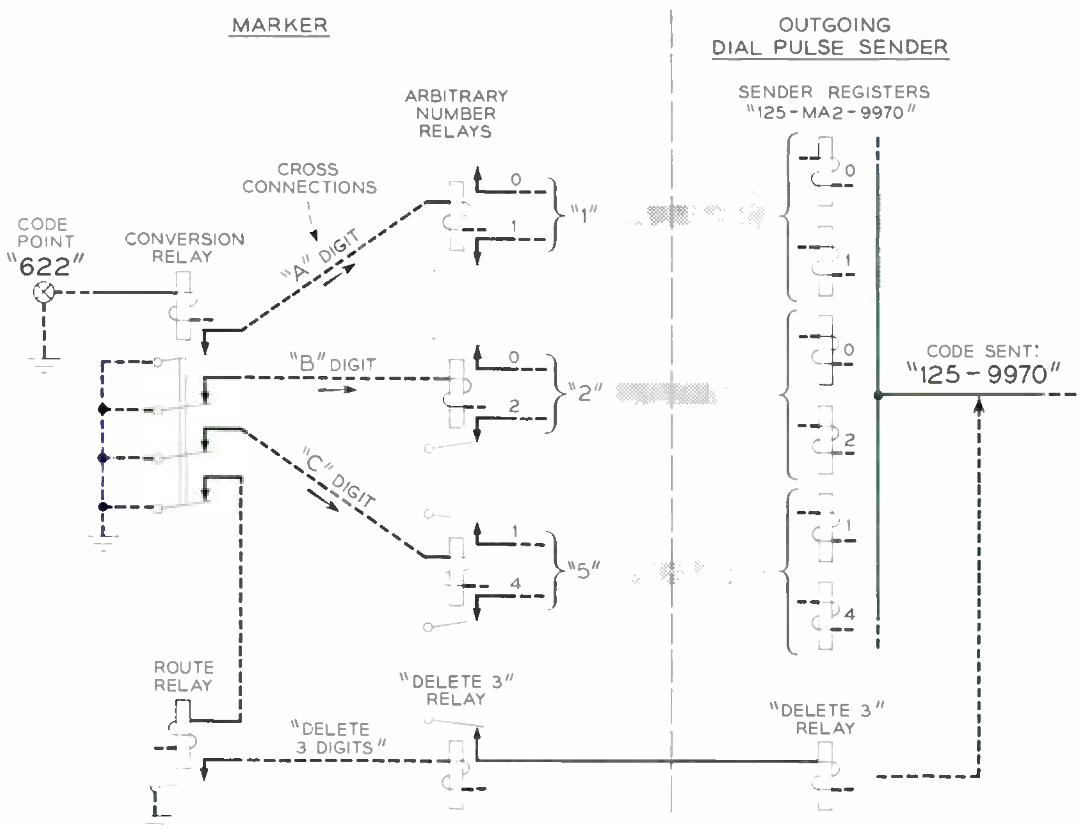


Fig. 5 — Simplified diagram showing system of code conversion by addition and deletion of digits.

M-A-2, and proceed with 9-9-7-0. Here one might ask why the unwanted digits are passed to the sender. The reason is that billing information is controlled from the sender, and the standard codes are used for this purpose although they are not pulsed out.

This pulsing sequence is accomplished by means of "steering relays" – relays that direct the sender to pulse out digits in the correct order. There is one steering relay for each digit, and each operates when its respective digit is to be pulsed out. These relays are the key to code conversion, for when a particular steering relay is not operated, the associated digit is omitted. Conversely, steering relays previous steering relays except the first, which is controlled directly by the digit register in the sender.

It should be noted that if only one arbitrary digit were to be added, the marker would put it in the third arbitrary digit register. This permits the digit-steering unit to be simpler and more economical. Similarly, if two arbitrary digits were to be added, they would be put in the second and third arbitrary digit registers.

While code conversion was intended primarily for the use explained in this discussion, it has another function. Although the marker can delete from one to six digits and add or substitute from one to three digits during code conversion, it is possible to add one, two or three digits without deleting any digits. This function is useful when it is necessary to complete a call by going through an additional step-by-step office. Figure 4 shows how a customer can call MA 2-9970 by going through No. 5 crossbar, step-by-step tandem, and toll offices to reach the MA 2 central office. The customer dials MA 2-9970, but since there are no direct trunks available to the MAin 2 central office, or to the toll office, the calling office must select a trunk to the step-by-step office, which in turn connects to the toll office to complete the trunking. In this case, the local office must code convert to add digits for selecting a path through the step-by-step tandem office to the toll office. The originating office adds the digits 7-3 to the called number, and these digits select a path through the step-by-step office to the toll office, which then extends the trunk connection to the MA 2 office for completion of the call.

The conditions under which a route will require code conversion may vary, but in all cases code conversion enables No. 5 crossbar to function with other systems at minimum cost and effort. This and other features of the No. 5 crossbar system are helping to bring the day closer when most long distance telephone calls will be made without the assistance of an operator.

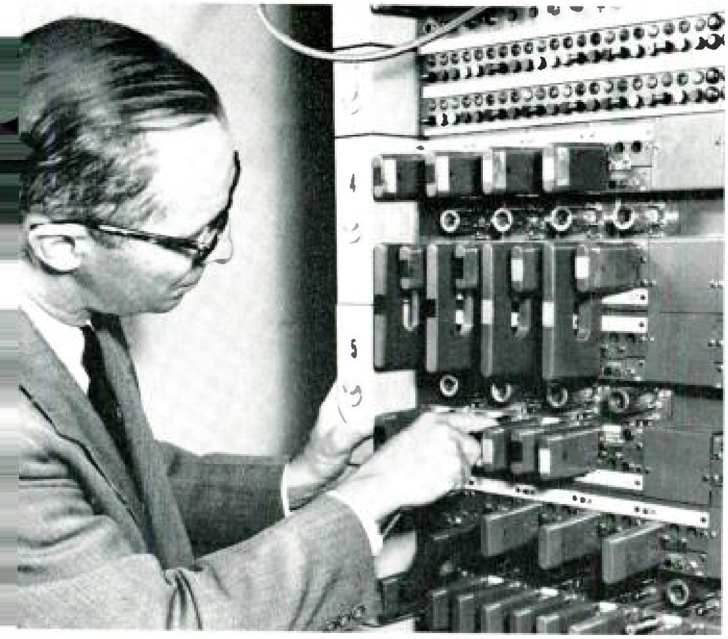
Fig. 6 — The author inspecting code register relays in Laboratories installation of No. 5 crossbar outgoing sender.

THE AUTHOR

FRANK P. CIRONE joined the New York Telephone Company in 1951 as a switchman in the No. 1 crossbar system. The following year he transferred to the Laboratories, where his first assignment was assisting in the analysis and testing of the foreign area translator in the No. 5 crossbar system. Upon completion of this job, he was then concerned with the analysis and testing of senders and registers in the No. 5 crossbar system. At present, Mr. Cirone is doing exploratory work looking forward to electronic switching systems. Mr. Cirone has completed three years of Electrical Engineering at the City College of New York and is planning to complete his studies at the Newark College of Engineering.

First Transoceanic Telephone Cable Spans the Atlantic

The Long Lines Department of the A.T.&T. Co. has announced that the final splice in the transatlantic cable was made on September 26, 1955, some two miles offshore from Oban, Scotland, which will be the eastern terminus of the new communication system. The splicing operation linked the long stretch of deep-sea cable with a short, shore-end section laid from Oban some weeks previous. The cable, 1950 nautical miles in length, is the first link in a twin-cable system that will provide a 36-channel voice path between North America and the United Kingdom. The second cable, needed to provide the two-way channels for telephone conversations, will be laid next year. The system is scheduled to be placed in service by late 1956. The historic cable project is a joint undertaking of A.T.&T., the British Post Office, and the Canadian Overseas Telecommunication Corporation.



Program Switching in TD-2 Radio Relay

W. O. FULLERTON
Transmission Systems Development I

Most people today know that television programs are transmitted between cities over microwave radio relay and coaxial cable. Few of them realize, however, that the complex program switching requirements of network television are also a Bell System responsibility. To provide improved, more flexible switching facilities economically, the Laboratories has developed a new simplified arrangement for program switching that uses recently developed coaxial switches and bridging amplifiers.

You sit at home, on a cold winter evening, comfortably watching a program on your television set. Perhaps the program originates in snowy New York City; suddenly the scene shifts to Hollywood, or to sunny Miami. You may be one of the viewers who realize that the Bell System supplies the transmission facilities that make such programs possible, but you probably never think of the intricate switching problem presented by such network requirements. The Bell System is also responsible for most of the switching facilities that make it possible for your TV program to emanate from first one city, then another.

Most network TV programs are transmitted at least part of the way over TD-2 microwave radio relay. Originally, switching equipment for the TD-2 system was based on electronic designs of rather complex nature.* However, in the development of automatic protection switching for TD-2, a new coaxial switch and a simple one-tube bridging amplifier were designed. These two equipment items have been utilized in a new, simplified arrangement for program switching.

The 223-type coaxial switch uses four glass-sealed mercury switch elements housed by a die-cast unit in such a way as to maintain the characteristics of 75-ohm coaxial cable, permitting the switch to be used at 70 mc with reasonably small losses. The bridging amplifier is a small, one-tube amplifier, so arranged that two 75-ohm outputs can be derived from a single input. It is used where a signal is to be tapped off a 70-mc line without affecting the through transmission. Only passive circuit elements are used in one branch, and this branch is preferred for the through circuits where reliability is paramount. The other branch incorporates an amplifier adjusted to give unity gain so that the two outputs are at the same level.

In the TD-2 system, a TV program (or several hundred telephone conversations grouped together) is considered as a base band of frequencies, and is frequency-modulated onto a 70-mc

* Record, *April*, 1952, *page* 153.

carrier. This modulated carrier is further modulated up to microwave frequencies for transmission. For economic and practical reasons, most of the amplification is done at 70 mc instead of at microwave frequencies. At each station, the incoming microwave signals are demodulated to 70 mc, amplified, modulated back to microwave frequencies, and transmitted to the next station. All switching in the system is done at 70 mc – between the receiving and transmitting microwave equipment.

Closely associated with program switching is terminal maintenance switching. Each TD-2 terminal station includes several FM transmitters and receivers, to convert the video signals to 70 mc and to demodulate incoming FM signals to video. Spare transmitters and receivers are provided at each terminal; connecting these spares in place of regular equipment is part of the over-all switching job.

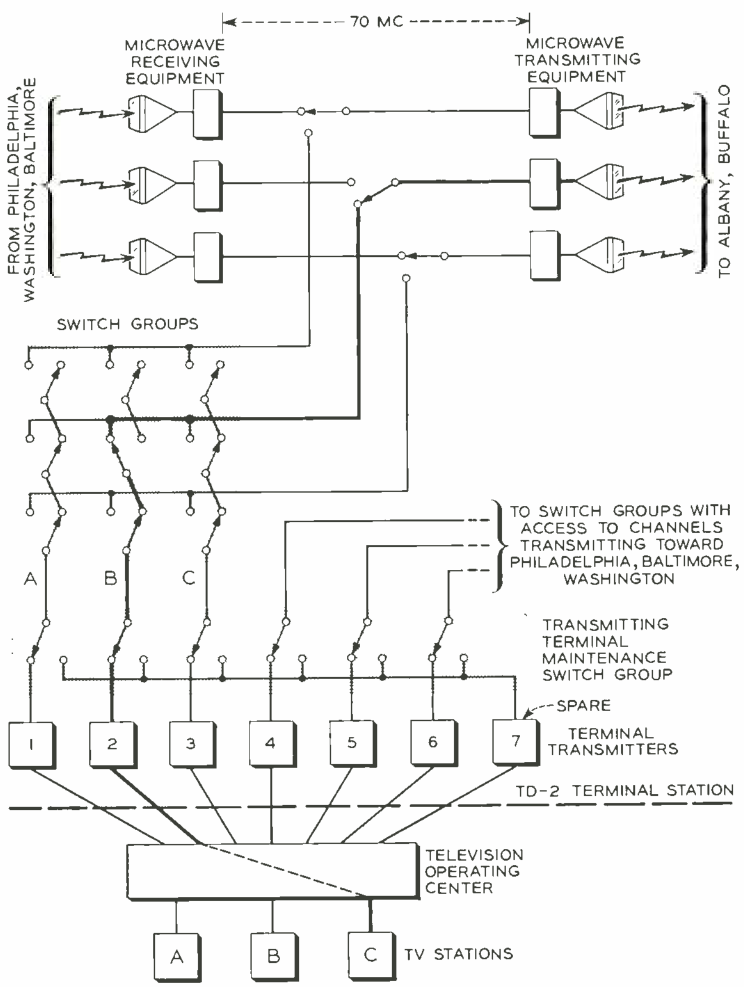


Fig. 1 — Typical arrangement of transmitting switches in a city such as New York.

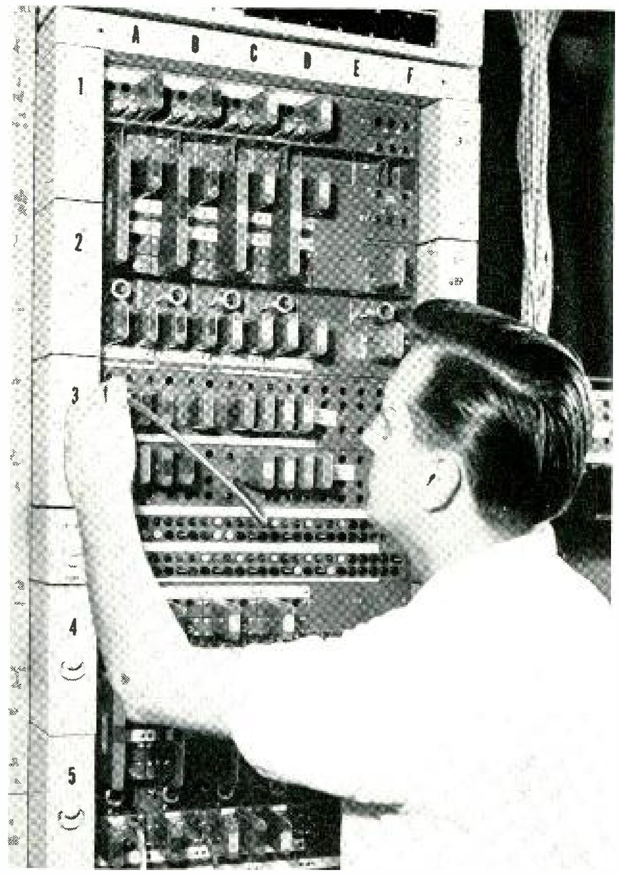


Fig. 2 — E. J. Alfredo Jr. of Long Lines checks the program switching bay at Washington, D. C.

Perhaps the best way of showing how such switching is done is to take a typical example, Figure 1. One of the TV stations in New York City is to originate a program. The video signal is fed from the station over Bell System video pairs to the television operating center (TOC) where it is distributed throughout the country via different transmission media. If it is to be transmitted, say, to California and the rest of the country over the TD-2 system, it is distributed to the TD-2 radio station at the Long Lines Building in New York City. The particular radio transmitter used there is determined at the TOC.

Suppose the signal is trunked to FM terminal transmitter No. 2 where it is modulated up to 70 mc. This 70-mc signal is fed through a coaxial switch in the transmitting terminal maintenance switching group. If transmitter No. 2 should become inoperative, operation of maintenance switch No. 2 in this group would connect spare transmitter No. 7 to the radio channel in its place. At the TOC, the video signal would then be sent to transmitter No. 7 instead of No. 2. From the terminal maintenance switch group, each 70-mc signal is fed to a second switch group. The signal from transmitter 2, for example, would go to switch group B. From here it has access to any of the outgoing TD-2 microwave channels, provided the proper switches are operated in both the switch group and the microwave channel. The arrangement is such that one and only one transmitter can be connected to a given channel at a time, and only one channel can be fed by a given transmitter.

and more bridging amplifiers, so arranged that each channel feeds an FM terminal receiver. As in the case of the terminal transmitters, a spare terminal receiver can be substituted for any regular receiver. Number 7 is the spare.

From the receiver, the TV program is sent at baseband frequencies to the TOC, where it is distributed to a local station for broadcasting. Programs may also be sent directly to local TV stations, but ordinarily they are trunked to the TOC for local

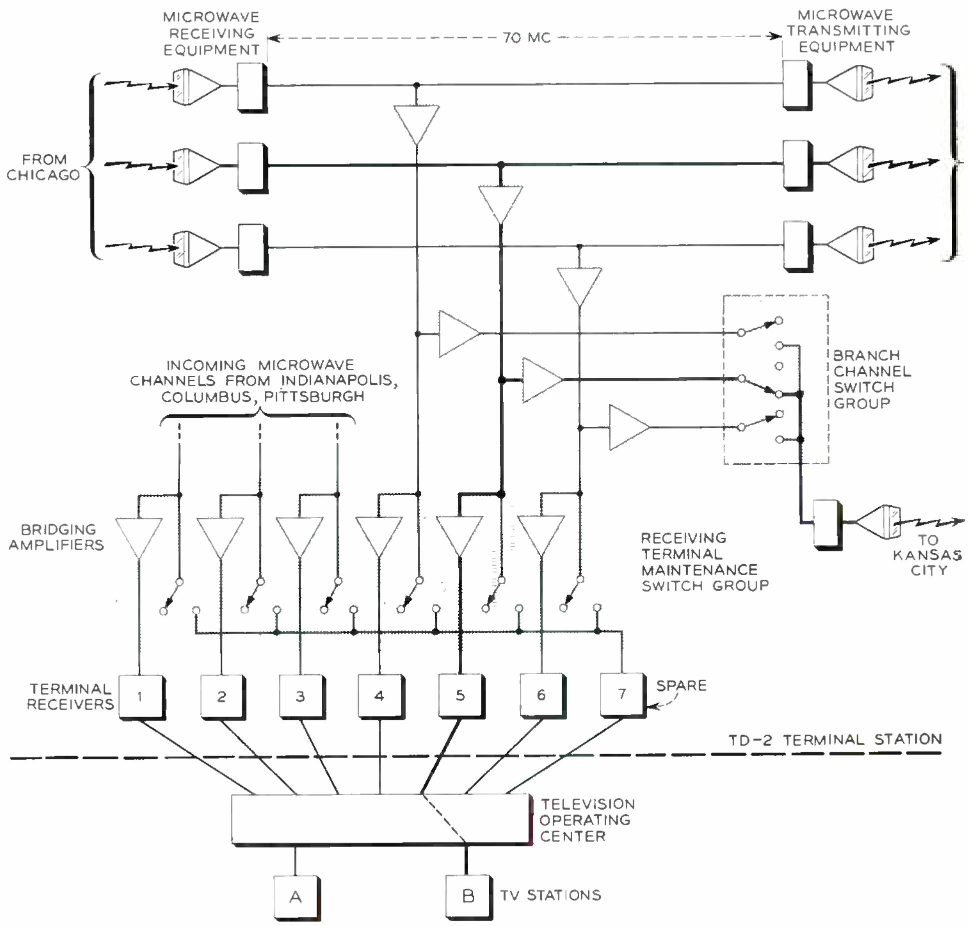


Fig. 3 — Possible arrangement of receiving switches for a city such as St. Louis.

At any city on the microwave route, the program can be repeatered along the main line, tapped off and transmitted on a branch line, or demodulated to base band and sent to a local TV station for broadcasting. Figure 3 shows possible switching arrangements in a city such as St. Louis, where the program is repeatered, picked up and used locally, and at the same time is beamed toward Kansas City on a branch channel. Bridging amplifiers permit the microwave signals to be tapped off and fed to the receiving terminal maintenance switch group, without affecting through transmission along the main line. This switch group consists of coaxial switches

distribution. The control of switches is generally exercised by the associated TOC. However, when programs are fed directly from a TD-2 station to a television station, the switching controls may be located in some other telephone office. Switching controls may also be provided at the TD-2 microwave station when it is considered advantageous for maintenance reasons.

Figure 3 also shows how a branch channel, in this case to Kansas City, is derived. Supplementary bridging amplifiers feed the signals to a branch-channel switch group where coaxial switches permit selection of the desired channel. No provision is made for substituting spare equipment since no terminal receiver is used.

Where programs must be tapped off the main line at an auxiliary repeater not having program and terminal maintenance switching facilities, bridging amplifiers and coaxial switches are used to give access to the desired channels without affecting through transmission. The arrangement is the same as for a branch channel at a terminal or main station. Where programs must be originated locally, coaxial switches are inserted in the through line in as many channels as desired. When a switch is operated, the microwave receiver is disconnected from the transmitter and the local 70-mc signal is substituted.

The bridging amplifiers and coaxial switches are mounted in a nine-foot bay of the type used for other TD-2 equipment. Terminal strips at the top permit the control leads for the switches to be cross-connected to their controlling relays as conditions require. Fuses are provided to protect the amplifiers. To permit patching the various channels through the station or to terminal equipment, all incoming and outgoing channels appear on a patching jack field. A die-cast housing with a multi-contact plug-in connector at the rear will mount either switches or bridging amplifiers, and six housings can be installed across the bay.

This new program and terminal maintenance switching equipment is now in service in TD-2 stations at some of the more important locations. Not only is it less expensive than the equipment previously used, but it has already demonstrated a high degree of flexibility and considerably greater operating convenience.

THE AUTHOR

William O. Fullerton joined the Northwestern Bell Telephone Company in 1921 while attending Iowa State College. After receiving the degree of B.S. in E.E. in 1923, he entered the Western Electric Hawthorne Works; he transferred in 1924 to the Engineering Department in New York which later became the Laboratories. Mr. Fullerton's experience includes toll lines, switching trunks, and switchboards and one of the first uses of the crossbar switch, call distribution equipment for toll trunks. He was engaged in the No. 4 toll switching system development and the first installation of the system in Philadelphia. During the war his work involved military airborne radar equipment, and since then he has been engaged in the design and development of microwave equipment for intercity communication networks.

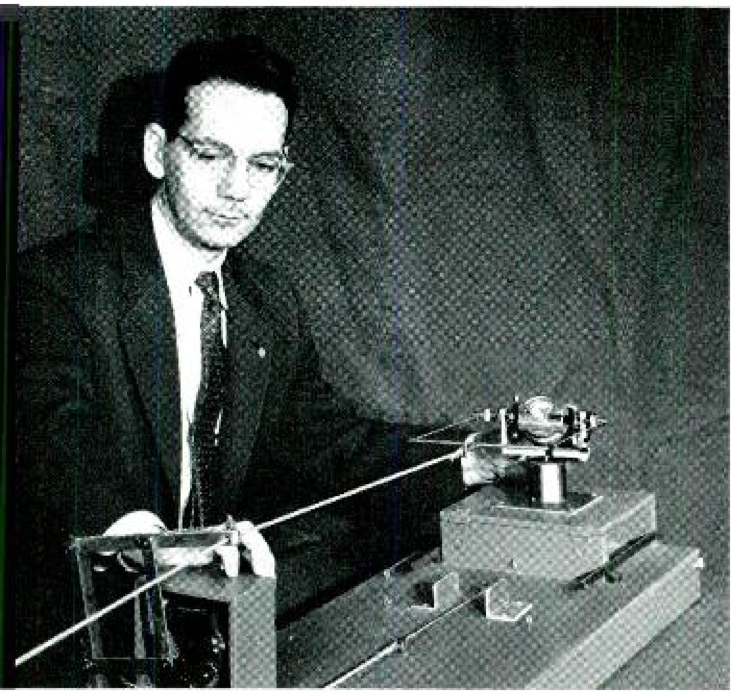
Dr. Kelly to Serve on "Atoms For Peace Awards" Committee

Dr. Mervin J. Kelly has been named a member of the Organization and Planning Committee of "Atoms For Peace Awards." Dr. James R. Killian, Jr., president of Massachusetts Institute of Technology, will serve as chairman of the Committee.

Atoms For Peace Awards, announced by Lewis Strauss, chairman of the Atomic Energy Commission, in Geneva on August 8, was established as a memorial to Henry and Edsel B. Ford by a Ford Motor Co. Fund appropriation of $1,000,000. It will provide $100,000 annually for ten years, to be spent in helping to provide incentive for the world's scientists, inventors, and engineers – without regard to nationality or political belief – toward finding new ways in which the atomic energy science can be used for the welfare of mankind.

The Organization and Planning Committee, under the leadership of Dr. Killian, has agreed to undertake the planning and organization of the Atoms For Peace Awards that will best assure the use of its funds during the next ten years toward the application of atomic energy for mankind's benefit.

Other members of the Committee are: Dr. Detlev W. Bronk, president of the Rockefeller Institute for Medical Research and president of the National Academy of Sciences; Dr. Ralph J. Bunche, undersecretary general of the United Nations; Dr. Arthur H. Compton, professor and former chancellor, Washington University; Mrs. Douglas Horton, former president of Wellesley College, and Dr. Alan Waterman, director of the National Science Foundation.



The magnetic material known as "ferrite" has the property of rotating the plane of polarization of microwaves that are transmitted through it in the presence of an applied magnetic field. This phenomenon — which provides the basis for the development of important new techniques for the control of microwaves — results from interaction between the waves and spinning electrons in the ferrite. By means of a gyroscope and a vibrating rubber cable, various interactions required by theory may be vividly portrayed.

Gyro Model of Electron Behavior in Ferrites

A. G. FOX *Radio Research*

In transmission circuits a broad distinction is made between "active" components like electron tubes, transistors, and relays, and "passive" components like coils, resistors, and capacitors. In the past, all transmission circuits using passive components could transmit equally well in either direction; to take a very simple instance, a filter consisting of a coil and a capacitor will perform its filtering action regardless of whether we impress a signal on one or the other side of the circuit. Such a filter is termed a passive "reciprocal" device. Now, however, it has become possible for the first time to build a variety of passive "*non*-reciprocal" or "one-way" devices of great value to the art of microwave radio transmission. These make use of a relatively new ceramic-like magnetic material known as "ferrite," which can be arranged to exhibit a non-reciprocal or "one-way" transmission behavior.

An important property of radio waves is the state of polarization, that is, the direction of vibration of the electric field. It is well known, for example, that when a rectangular wave guide is used in microwave transmission the electric field in the guide is perpendicular to the broad dimension of the wave guide. In a circular wave guide the polarization can be set up in any desired direction.

In 1950, C. L. Hogan of Bell Laboratories observed that one can produce a large rotation of polarization in a circular wave guide with a thin rod of ferrite inserted along the axis and longitudinally magnetized, Figure 1. The rotation of polarization observed with microwaves in ferrites is similar to that observed by Faraday in 1845 with light waves in other materials. Hogan, however, showed that the Faraday rotation in ferrites could be used to build a practical gyrator – a hitherto hypothetical transmission element with non-reciprocal properties.

In both the optical and microwave applications, the same physical principle is involved. The direction of polarization of the wave is rotated when it passes through the magnetized device. The amount of rotation can be adjusted and might be, for example, 45 degrees in a clockwise direction when viewed from the sending end.

The unique phenomenon occurs, however, when we pass the radiation back through the device in the opposite direction. The wave is rotated another 45 degrees, and *in the same angular direction*. In reciprocal optical and microwave devices, the returned wave would be rotated in the opposite direction and would be restored to the original orientation; but here the returned wave is now oriented 90 degrees to the original. We can therefore design a circuit element which will pass the original wave but will

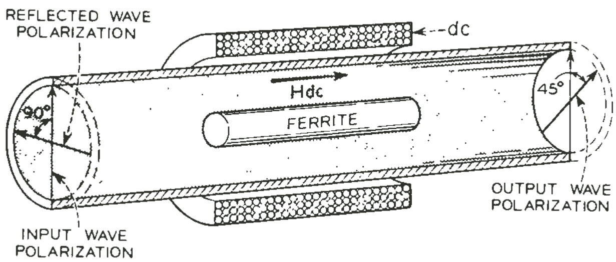


Fig. 1 — In a longitudinal magnetic field a ferrite rod rotates the plane of polarization of microwaves flowing along the waveguide.

block out the returned wave. Such an element, termed an "isolator," has actually been built, and has been incorporated into an experimental short-haul radio-relay system (Figure 2).* The transmitted wave passes to the antenna, but undesirable reflections from the antenna are blocked out by the isolator.

Since we have never before had passive circuit elements capable of non-reciprocal behavior, it has become extremely desirable to obtain a clear physical picture of what goes on in ferrites to produce these effects. Ferrites are magnetic materials which, like iron, derive their magnetic properties from the presence within them of a multitude of spinning electrons which, because they have mass, behave like little tops. Because of their charge and spin, they also behave like elementary current loops giving rise to a magnetic flux directed along the axis of spin. By virtue of certain forces between the electrons known as "exchange forces" some of these electrons line up in groups with their spins in parallel. These groups, the so-called domains, may easily be oriented in a given direction by the application of a relatively small magnetic field and produce a total flux through the material very much greater than if the electrons had not been present.† This is what makes the material appear ferromagnetic.

Unlike iron, the ferrites are ceramic-like materials having extremely low conductivities. A radio wave can therefore pass through a block of ferrite several inches thick without being substantially attenuated, whereas a block of iron would completely reflect it. In passing through the ferrite, the magnetic field of the wave interacts with the spinning electrons by twisting them from their original direction of alignment. It is this interaction between the wave and the spinning electron "tops" which gives rise to the many non-reciprocal properties of ferrites, of which the Faraday rotation is one.

To help give a sound physical understanding of microwave ferromagnetic effects, the author has devised a model of a spinning electron shown in the headpiece and in Figure 3, in which the electron is represented by the gyroscope at the right of the illustration. If this gyro were free to twist in any direction and could, at the same time, have applied to it torques corresponding to the dc magnetizing field and the alternating field of the radio

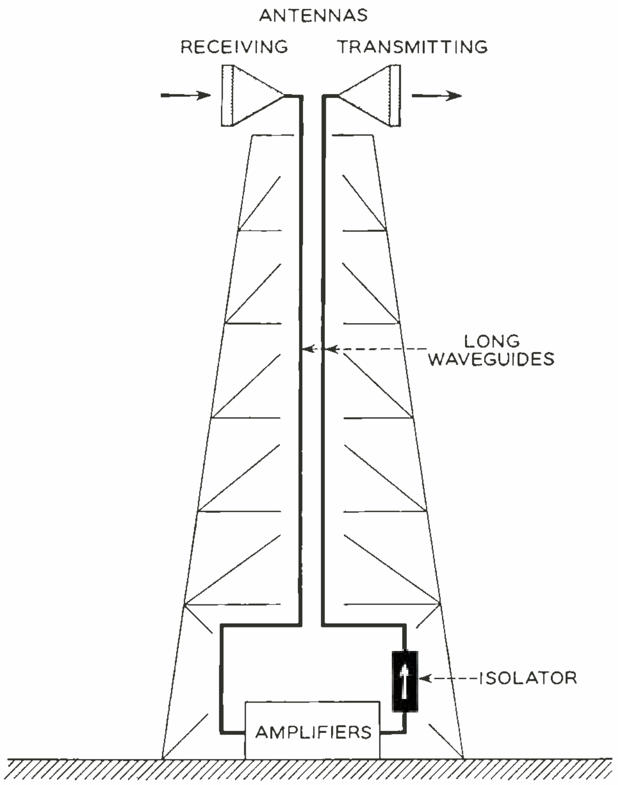


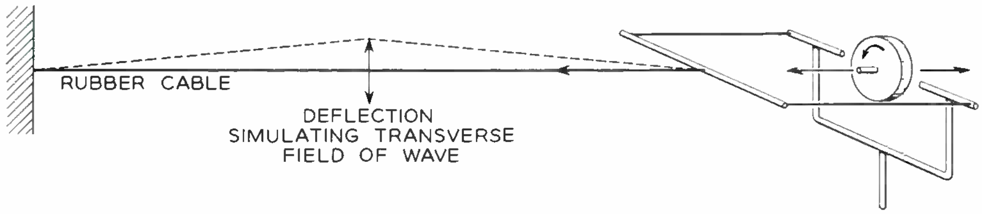
Fig. 2 — Ferrite "isolator" in waveguide of radio relay station insures one-way transmission path from the output of the amplifier to the antenna. The isolator does not attenuate appreciably the signal transmitted from the amplifiers to the antenna, but any reflections from the antenna are blocked out by the isolating action of the ferrite.

* RECORD, *April*, 1955, *page* 131 and *October*, 1955, *page* 385. † RECORD, *October*, 1952, *page* 385.

wave, we would observe a precession of the gyro similar to that of the elementary electronic magnets within the ferrite. Unfortunately it is not possible to mount a gyro with complete freedom, but a fairly good compromise has been obtained for the motions that are desired.

The pull on a rubber cable attached to the gyro represents the action of a dc magnetic field lining up the electrons in a horizontal direction. We assume that the field is strong enough to align all of the electrons which can be oriented, corresponding to magnetic saturation. A radio wave is assumed to have produced at this point in free space only vertical components of magnetic flux, the electron motion is producing horizontal components of magnetic flux as well. This, together with the motions of all the other electrons, tends to generate a new wave having a horizontally polarized magnetic field. Thus, energy is abstracted from the vertically polarized wave and re-radiated as a horizontally polarized wave. As the wave passes on through the medium encountering other electrons, this process becomes cumulative so that after a certain distance, all of the vertically polarized magnetic field may be converted

Fig. 3 — Diagram of the gyroscope model.



travel along the direction of the rubber cable. At the left (in the photograph at the beginning of this article) a motor can produce periodic lateral deflections of the cable simulating the transverse magnetic field of this wave. Up and down deflections represent a wave with a vertically polarized magnetic field. Circular deflections represent a circularly polarized wave.

into a horizontally polarized field, corresponding to a rotation of the plane of polarization by 90 degrees.

If no wave is present and if the gyro is momentarily deflected from its horizontal alignment, it will not return immediately to proper alignment, but will precess circularly around the axis of the dc magnetic field. The frequency of this precession around the dc field is dependent upon the angular momentum of the gyro and the strength of the dc field. As the dc field is increased, the precession frequency is also increased. For any given applied dc field, the frequency of precession of the gyro is called its "resonant" frequency; and the behavior of the gyro in the presence of a wave depends upon whether the frequency of the wave is above or below the resonant frequency.

One way to demonstrate why the plane of polarization of the wave is rotated is to apply the equivalent of a vertically polarized magnetic field to the gyro by means of vertical deflections of the associated rubber cable.

Figure 4(a) is a time exposure of the model with switchboard lamps attached to an extension of the gyro axis and to the cable deflection point. As may be seen the gyro responded to the vertical deflections of the cable with an elliptical motion of its axis. This means that although the wave would

An alternative explanation which gives us additional insight into electronic behavior may be obtained by examining the behavior of the gyro when driven by the equivalent of circularly polarized waves. Figure 4(b) is a time exposure during one half a radio frequency cycle for a wave circularly polarized in a (+) sense (clockwise looking along the dc field). The applied dc field is weak so that the resonant frequency of the gyro is less than the frequency of the applied wave. As can be seen, the motion of the "top" is approximately 180° out of phase with the applied dc field.

This means that when a radio wave attempts to force magnetic flux in one direction, an electronic magnet responds with its magnetic flux in the opposite direction, resulting in a net transverse flux smaller than would have been produced in free space. The permeability of the magnetic medium is therefore less than one. This may appear surprising since at low frequencies permeabilities are always greater than one. At high frequencies, however, they are frequently less than one, and sometimes even negative. The explanation is simply that the spinning electrons with which the medium is filled are opposing the applied field so effectively that the resultant flux is diminished or even reversed in direction relative to what it would have been with no electrons present.

In Figure 4(c) we have the equivalent of (+) polarized waves, as in Figure 4(b), but the dc magnetic field has been increased so as to make the

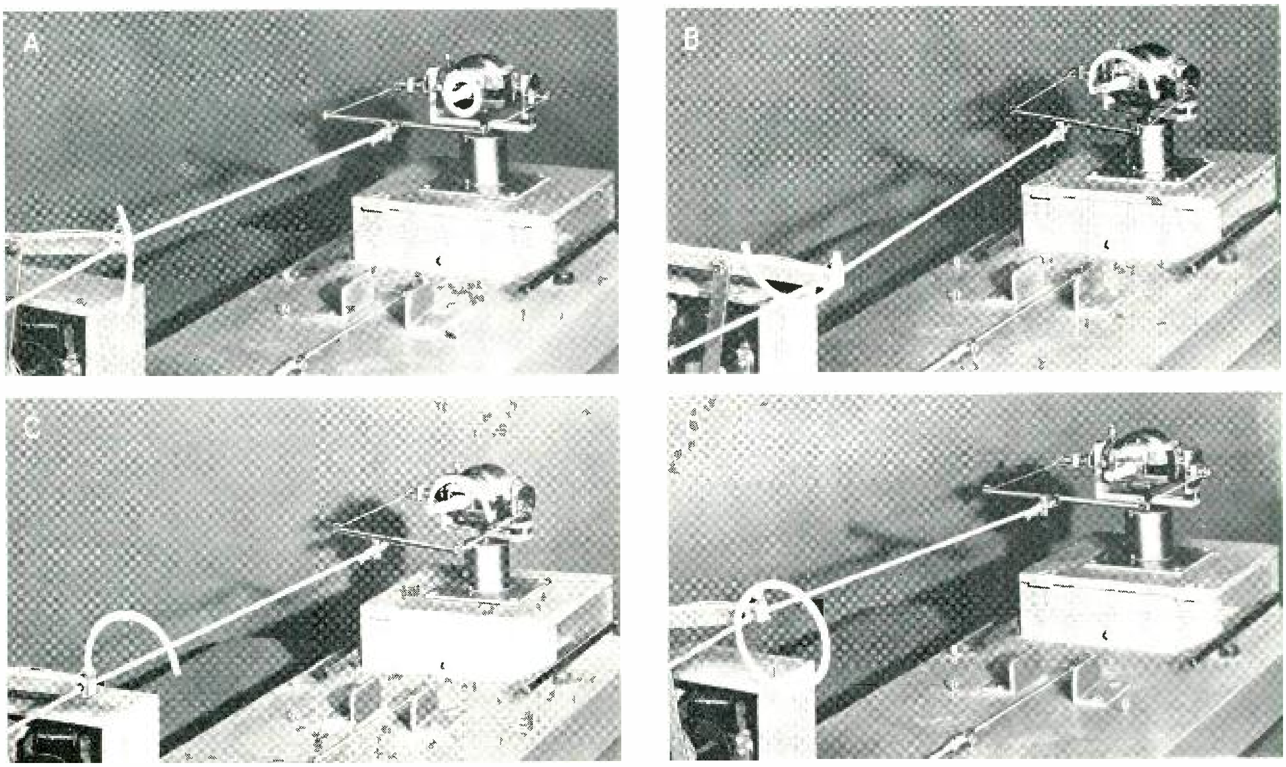


Fig. 4 — (a) Elliptical precession of gyro in vertically polarized field indicates the re-radiation of a horizontally polarized field. (b) Response to a (+) circularly polarized wave having a frequency higher than the resonant frequency. Precession of gyro is out of phase with field of wave, thereby reducing total field. Thus, the permeability is less than unity.(c) Response to a (+) wave having a frequency lower than the resonant frequency. Precession is in phase with field of wave, thereby enhancing total field and giving a permeability greater than unity. (d) Response to (—) wave is very slight. Thus, wave is little affected by the electrons, and the permeability is unity.

resonant frequency of the gyro higher than the frequency of the wave. Here the motion of the gyro is in phase with the cable deflection. This means that the transverse flux produced by the electron is aiding that produced by the wave, and we conclude that the permeability is greater than one.

In Figure 4(b) and Figure 4(c) the precession angle of the gyroscope was fairly small. In Figure 5 is shown a situation where the dc magnetic field has been adjusted to make the resonant frequency equal to the frequency of the applied (+) polarized wave. The gyro starts from alignment with the dc field, and spirals outward through ever-increasing precession angles until it points nearly in the opposite direction to the dc field. As may be seen from the illustration, the mounting of the gyroscope had to be changed in order to permit this latitude of motion. A complete reversal of the "top" was not permitted but would have occurred, had it been possible. This motion corresponds to a large absorption of energy from the wave which causes the electron to turn against the force of the dc field. It is believed that the actual electron precessions never assume the large angles illustrated in Figures 4(b) and (c) and Figure 5, since before the electron has time to acquire these angles, starting from alignment with the dc field, some sort of "collision" causes precessional energy to be removed and converted into heat. This limits the maximum angle of precession and causes a continuous conversion of radio frequency power into thermal energy. At resonance the conversion of wave power into heat is so great that the wave is wholly absorbed in passing through a very short length of the medium.

In Figure 4(d) is shown the motion of the top when excited by a (—) circularly polarized wave (counter-clockwise looking along the dc field). The dc field is adjusted to the same value which produced the resonant condition of Figure 5 for the (+) polarized wave. As may be seen, the motion of the gyro is very slight indeed. Obviously the electrons are very selective as to the sense of the circular polarization to which they will respond. We conclude that for (—) waves the permeability is approximately one.

We can now show from these observations why the Faraday rotation should take place. We have seen that with a dc field which produces a resonant frequency lower than the frequency of the radio waves, the permeability for a (+) polarized wave will be less than one while the permeability for a (—) polarized wave is approximately equal to one. Since the velocity of waves in a medium is inversely proportional to the square root of the permeability, (+) waves will travel at higher speed than (—) waves. We may think of a linearly polarized wave as being composed of two oppositely rotating circularly polarized waves. These components will travel through the medium at different velocities. At some point further along in the medium, they will add together to produce a new linearly polarized wave whose polarization axis will be rotated with respect to the original axis by an amount depending upon the difference in velocities and the distance traveled in the medium. In particular, if the (+) component travels at higher speed, the linearly polarized resultant will be rotated in a (+) sense. This corresponds with what is actually observed in microwave Faraday rotation.

This reasoning is independent of any assumption as to the direction of travel of the wave; it depends only upon how the radio wave field varies at the point where the electron is stationed. For this reason, we conclude that regardless of the direction of transmission, (+) waves will always travel faster than (—) waves, and the rotation of polarization will be in the same sense for both directions of transmission. Thus, a wave which travels down and back will be rotated by twice the angle of a one-way transit. This is the key to the anti-reciprocal properties of ferrites.

This explanation is valid for waves in an infinite ferrite medium. When we are concerned with waves in hollow metal tubes, the situation is complicated by the geometry and the type of wave used. Also, ferrites can be employed in a number of other ways using transverse magnetizing fields. Nevertheless, this picture of the precessing electron tops is basic for all applications.

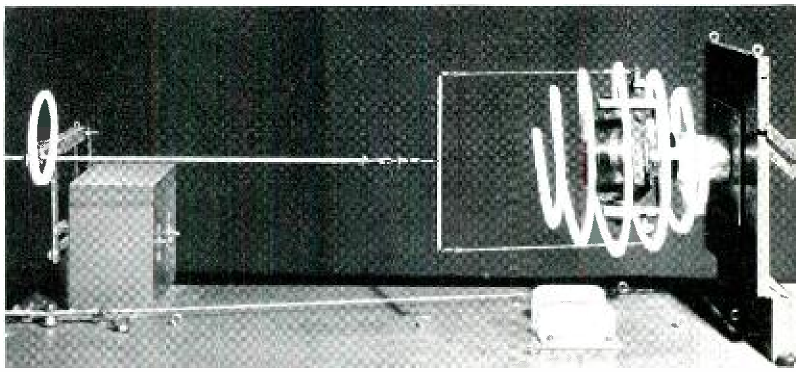


Fig. 5 — Large precession angles result when (+) wave is at the resonant frequency.

THE AUTHOR

A. Gardner Fox received the S.B. and S.M. degrees in electrical engineering from Massachusetts Institute of Technology in 1934 and 1935, respectively. He joined the technical staff of Bell Telephone Laboratories in 1936 and for the next three years was engaged in the development of mobile and airborne radio transmitters, and in early radar development. In 1939 he transferred to the Radio Research Department, where for three years he conducted research on waveguide techniques. From 1942 to 1944 he was again occupied with the development of radar systems. Since 1944, Mr. Fox has been engaged in the design of radio frequency amplifiers and in research on millimeter waves at the Holmdel radio laboratory, where he is in charge of a group specializing in microwave physics. For the last four years he has been particularly concerned with studies of the microwave properties of ferrites. Mr. Fox is a Senior Member of the Institute of Radio Engineers and past chairman of its Committee on Antennas and Waveguides.

Circuit Features of the No. 2 Telegraph Serviceboard

J. R. DAVEY *Military Development (formerly Telegraph Development)*

Teletypewriter services have expanded so rapidly in recent years that lines and equipment could not be switched and tested as easily as was required. No. 2 serviceboards are now efficiently providing these needed facilities, with savings in time and labor. This was made possible in the new serviceboards through the use of electronic coupling units and loop repeaters with a new electronic "hub" circuit — all developed at the Laboratories.

Bell System teletypewriter services have expanded at such a rate in recent years that switching and testing of the various lines and equipment posed a serious problem. The No. 2 telegraph serviceboard* is the Laboratories' latest answer to the problem, combining into one-man switchboard-type positions the switching and testing functions required for private-wire teletypewriter networks. These new serviceboards provide the same functions for trunk lines of the Bell System teletypewriter exchange (TWX) service, but not for TWX customer loops.

Originally, lines and loops (called legs) were connected together through the use of a simple dc series circuit. Obviously, each time the private-wire network was changed by the addition or removal of a leg, the current in the series circuit had to be readjusted to the correct operating value. In a serviceboard, the series arrangement is replaced with a parallel circuit, where additions and removals do not require readjustments. The parallel circuit is known as a "hub," with the lines and loops radiating from it like the spokes of a wheel. A No. 2 serviceboard, the latest development utilizing the hub principle, uses electronic coupling units and electronic loop repeaters and each hub can accommodate up to about twenty "spokes" or connections.

In the No. 2 serviceboard, the hub arrangement is used only for those interconnections where it is economical. Most two-leg networks, such as private-wire terminals and all TWX circuits, are still directly connected by a simple series circuit because they require little service attention. These economical direct-leg (D-L) connections take care of a large proportion of the switching required at serviceboards, but networks with three or more legs, and those requiring regeneration of the signals, are connected through hub circuits. D-L connections are handled at a "facilities" position of the serviceboard, while connections utilizing hub circuits are handled at a "service" position.

This newest use of a hub circuit was made possible by the development at the Laboratories of

*Record, *March*, 1955, *page* 100.

electronic coupling units and electronic loop repeaters. These operate to transform current pulses from a relay-type repeater or customer loop into varying voltages on the hub leads; for outward signals they transform hub voltages into current pulses. Figure 1 shows a 144A1 coupling unit connected to a hub.

A hub circuit consists essentially of a receive lead RH, a send lead SH and a potentiometer as a high-impedance source of voltage. When regeneration is not required, the two leads are strapped together (option A) to form a single lead that is above ground by the voltage supplied by the potentiometer. During a "mark" pulse, which is the normal condition of an idle teletypewriter, the hub lead (RH and SH tied together) is held at 60 volts above ground by the potentiometer. The 144A1 coupling unit has no effect on the hub-lead voltage as long as the receiving relay of the line repeater is in the mark or normal condition, because varistor VR does not conduct and the coupling unit is essentially an open circuit between the relay and the hub leads.

When the relay changes to a "space" or signaling condition, the varistor does conduct and the coupling unit draws current from the potentiometer. The voltage of the hub lead falls to –30 volts, the condition of the hub for a space. This negative voltage

about 2,000 ohms, low enough to permit up to 10,000 feet of switchboard wire to be used in a hub circuit without causing excessive distortion of the teletypewriter signals or crosstalk into other hubs in the switchboard.

Transmission to a line from a coupling unit is through a line-repeater send relay in the cathode circuit of electron tube V1. When the hub is in a mark condition (+60 volts) V1 conducts and the send relay is held operated in the mark condition. A space condition on the hub (–30 volts) cuts off V1 and releases the send relay. Shunting of the hub is negligible because of the high input impedance of V1. A directional control feature is included in the coupling unit to assure that incoming signals will not be re-transmitted back to the originating line. A directional control circuit maintains point P sufficiently positive to hold the send relay operated, except when a space condition on the hub is the result of some other leg. The illustration on the opposite page shows the author adjusting a 144A1 coupling unit.

Since the coupling units are effectively out of the circuit when in the normal or mark condition, several units may be connected to a hub without shunting it except for distributed capacitance. What happens, however, if two control units receive

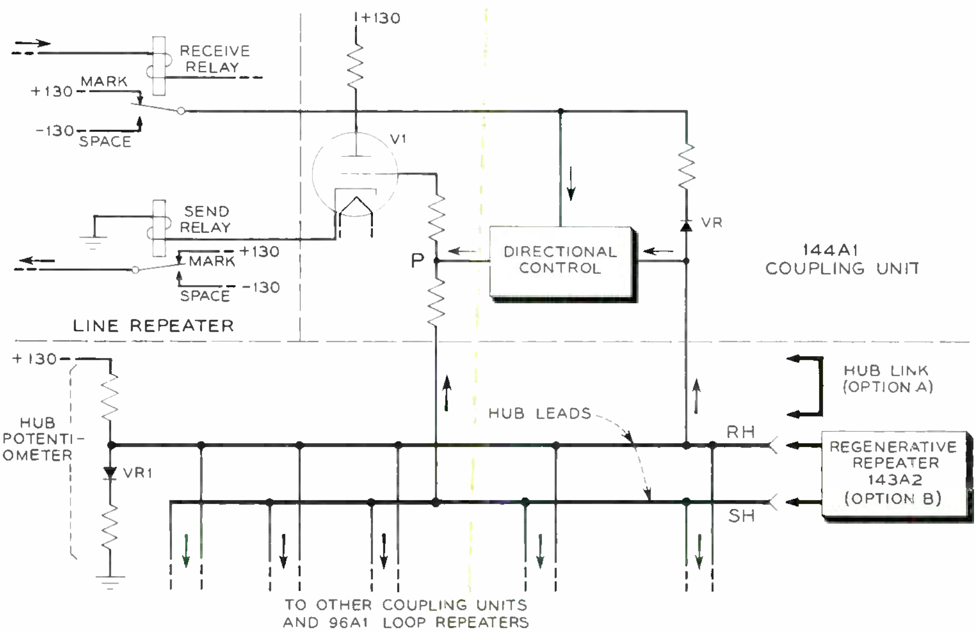


Fig. 1 — Diagram of 144A1 electronic coupling unit connected to a hub circuit.

causes varistor VR1 in the potentiometer to stop conducting, and the output impedance of the coupling unit becomes the lower part of the potentiometer. Replacement of an impedance rather than shunting one across another tends to maintain the hub impedance to ground at a constant value. This is

spaces at the same time? The hub voltage is reduced to –60 instead of –30 volts, and this condition is recognized by the directional control circuit as a "double space." It then unblocks the outward paths of those units receiving the spaces, so that *all* legs connecting to the hub receive a space. This "double-space by-pass" insures that all incoming spaces (each letter code starts with a space pulse) are transmitted to all legs and are not lost because of a prior space condition on the hub. Local copy becomes garbled, indicating to a teletypewriter operator that someone else is also sending.

For a customer loop, a 96A1 loop repeater provides the hub with exactly the same voltage conditions (see Figure 2). With the loop in a mark or receive condition, the loop current is 60 milliampers and the dc plate-to-cathode impedance of V2 is such as to cause the voltage at its plate to be about –50 volts.

When the hub lead goes to –30 volts for a space, V2 is cut off and the loop no longer is supplied with current to hold its teletypewriter relay operated; the machine then recognizes a space. The high dynamic plate resistance of V2 permits it to act essentially as a constant-current source to operate the loop relay reliably even over twenty-five miles of a cable pair.

Transmission of a space to the hub by the customer causes the plate voltage of V2 to drop from its normal –50 volts to nearly –130 volts. This decrease in voltage is inverted in an electron-tube interstage unit and applied to V3 as an increase of voltage. The increase causes V3 to draw current from the hub and lower the hub voltage from its normal +60 (mark) to –30 (space) as does the coupling unit. A directional control circuit blocks the hub voltages from the grid of V2 to prevent the signals being fed back to the customer loop. Loop repeaters are not required to recognize a double space.

When regeneration is required, the jumper (option A, Figure 1) is removed and the RH and SH leads operate separately. A 143A2 regenerative repeater is connected (option B) in place of the jumper, providing the SH lead with a duplicate of the voltage conditions existing on the RH lead. How-

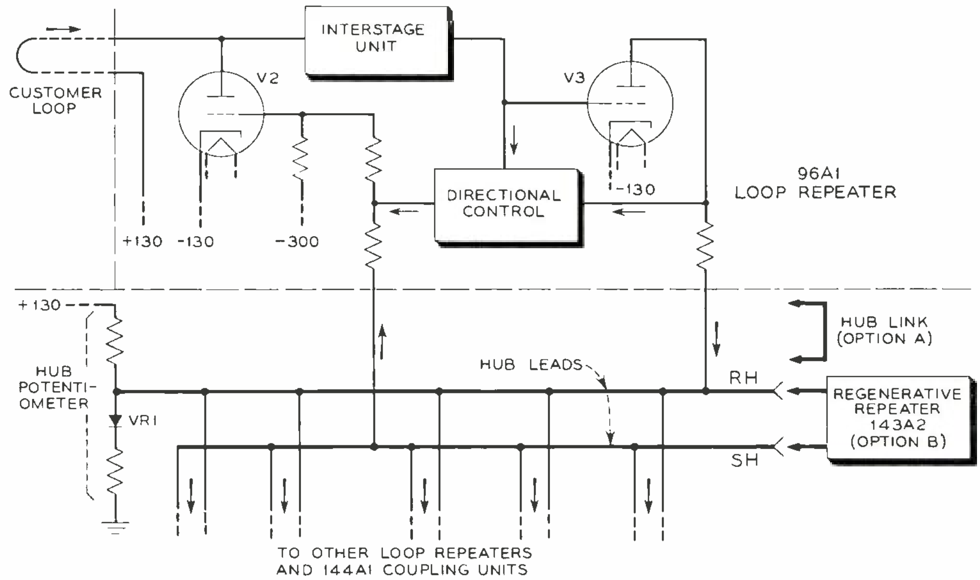


Fig. 2 — Diagram of a 96A1 loop repeater connected to a hub circuit.

THE AUTHOR

J. R. DAVEY became a member of the Laboratories in 1936 after receiving the degree of B.S.E. from the University of Michigan. He has been engaged in circuit development of voice-frequency carrier and dc telegraph equipment and of telegraph switchboards, as well as military high-frequency radio teletypewriter systems. At present, he is engaged in the development of military data communications systems. Mr. Davey holds several patents dealing with telegraph transmission and is the author of several published papers. He is a member of Tau Beta Pi and Sigma Xi.

ever, there is a time-lag of one-half a pulse between the two leads and, part of the time they are at different voltages. During such periods, the directional controls continue to prevent signals being re-transmitted back to the originating leg.

These small, compact, electronic units are mounted in sheet-metal boxes, with their tops and bottoms open. Mounted in vertical rows on a bay, they provide a channel for rising air currents, and are therefore partially self-cooling. A coupling unit uses three electron tubes and several varistors to provide the necessary operating functions. A loop repeater uses five electron tubes instead of three because it requires an additional interstage inverting unit, and because two tubes are paralleled to provide sufficient current to operate a customer's teletypewriter. All varistors are mounted outside the boxes at the rear to isolate them from the heat of the electron tubes. The units are of the plug-in type for rapid replacement in the event of trouble. Centralized test facilities are available in each serviceboard office for the various electronic units.

Dr. Kelly Honored by Polytechnic Institute of Brooklyn

"In recognition of distinguished achievements in the field of science and engineering," Dr. M. J. Kelly was awarded the honorary degree of Doctor of Engineering by Polytechnic Institute of Brooklyn on October 8, at an academic convocation closing the Institute's centennial year.

In conferring the degree, Dr. Harry S. Rogers, president of the Institute, cited Dr. Kelly as follows:

"Head of the largest electrical engineering research organization in the United States, a research scientist of exceptional personal achievement, you play one of the most important roles today in the field of American science and technology. Because of your inspired leadership of the Bell Telephone Laboratories, vast reservoirs of information in basic areas of electrical and materials research have been created. You have been particularly sensitive to the needs for close cooperation between industry and universities, and this awareness has contributed immeasurably to the advancement of scientific thought. There is probably no advisor to the government on matters of research of greater magnitude than yourself. Polytechnic Institute considers it an honor to number you among its sons from this day forward."

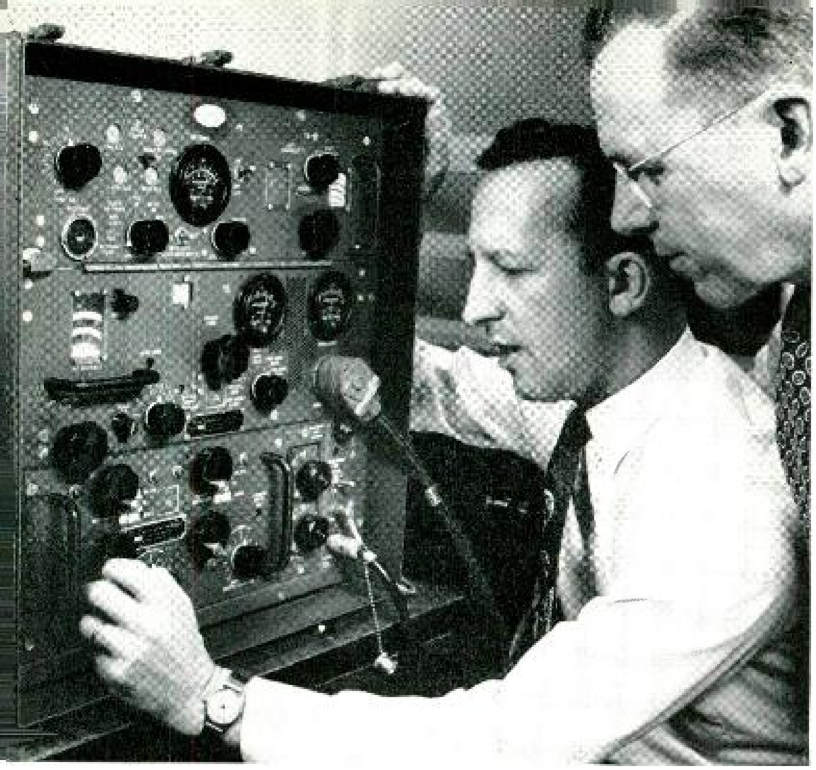
Polytechnic Institute of Brooklyn was chartered in 1854 and opened classes in September, 1855, for 250 boys. Its registration has now grown to more than 6,000 students. Many members of the Laboratories are numbered among its graduates.

"Science, Engineering, Research for Human Well-Being" was the theme of the Institute's 100th anniversary celebration, held throughout the 1954-55 academic year. The centennial was marked by more than 30 major scientific, engineering and educational conferences, as well as meetings of many professional societies.

Dr. Harry S. Rogers, President of the Polytechnic Institute of Brooklyn (right) congratulating Dr. M. J. Kelly on his receiving honorary degree of Doctor of Engineering.

In addition to Dr. Kelly, others who received honorary degrees at the convocation included Professor Linus Pauling of California Institute of Technology; Thomas E. Murray, commissioner of the Atomic Energy Commission; Professor F. W. Zachariasen of the University of Chicago; Professor H. M. Morse of the Institute for Advanced Studies, and E. V. Murphree, president of the Standard Oil Development Company.

Among the official delegates at the ceremonies were members of the Laboratories K. K. Darrow, representing the American Physical Society and the American Institute of Physics, G. R. Gohn, American Society for Testing Materials, and R. I. Wilkinson, Eta Kappa Nu Association.



AN/TRC-24 Radio Transmitter

W. G. HENSEL AND C. G. REINSCHMIDT

Transmissions Systems Development and Military Design Engineering

Like all components of the AN/TRC-24 radio-relay military communication system, the transmitter had to meet demanding electrical performance requirements, yet had to be ruggedly mounted in an easily transportable case. This transmitter is now being used by the Armed Forces to carry either four or twelve telephone message channels on any of a large number of carrier frequencies in the 100- to 400-mc range.

The general features of the AN/TRC-24 military radio-relay communications system have been described in three earlier articles,* and at this point we begin the discussion of some of the specific components. The present article describes the AN/TRC-24 transmitter, and later articles will deal with such units as the receiver, the antennas, and several of the subassemblies.

Signal Corps requirements determined many of the transmitter's unique electrical and mechanical design features. Electrically, it provides an RF output of approximately 100 watts on any one of a large number of discrete frequencies in the 100 to 400 mc range. It employs frequency modulation and is designed for use with cable-carrier telephone equipment to supply twelve message channels and one maintenance channel. Distortion introduced by the transmitter circuits is extremely low, and the built-in metering facilities make it easy to adjust the various tuning and level controls.

Mechanically, the transmitter is designed to withstand the severe shock and vibration encountered under adverse transportation conditions. Structural materials, finishes, and lubricants were carefully selected to permit operation under varying temperature and climatic conditions anywhere in the world.

The circuit arrangements are indicated in block diagram form in Figure 1. A base-band amplifier first delivers the message material to a reactance-tube modulator. This modulator uses two pentode tubes to provide a variable reactance for frequency modulating the RF oscillator. This reactance-tube modulated oscillator combination provides a relatively large frequency swing or deviation over a wide radio frequency operating range.

Severe frequency stability requirements made it necessary to use an automatic frequency control circuit to maintain the center or "rest" frequency

* Record, *July*, 1955, *page* 274; *August*, 1955 *page* 290; and *October*, 1955, *page* 382.

of the RF oscillator at the desired value. The circuit used for this purpose is indicated in the lower part of Figure 1. Under control of a crystal oscillator, the pulse generator produces repetitive pulses that are fed to a tuned regenerative amplifier or pulsed oscillator. The output of the pulsed oscillator is a spectrum of accurately controlled reference frequencies. The mixer stage and subsequent circuits are used to compare the actual frequency of the RF oscillator with the desired reference frequency and to deliver to the AFC motor an alternating current whose phase and amplitude are a measure of the direction and amount of error. The motor turns a variable capacitor to keep the center or rest frequency at the desired value.

The controlled RF oscillator is followed by two buffer amplifiers which amplify the signal and isolate the oscillator from possible interaction effects from the later power amplification stages. A driver stage provides the further amplification necessary to drive the power tubes located in one of two "RF tuners." These tuners cover the present frequency range in two bands – band "B" from 100 to 225 mc and band "C" from 225 to 400 mc. It will be noticed in Figure 1 that the driver doubles the basic 50-112.5-mc range to provide the "B" frequencies, and that these are further doubled in the "C" band tuner to provide the 225-400-mc range.

High-frequency beam-power tubes are used in the driver and RF tuner stages, and all other transmitter tubes are of the low-power receiver type. Variable inductance tuning is used in all cases except for the tuned circuits of the RF tuners. Here, the coaxial cavity type of tuning is used, in which a cylinder with a central conductor replaces the more conventional types of tuners using coils and capacitors. The electrical length of the cavity is varied in tuning it to the correct resonant frequency. This arrangement results in low power losses and a wide frequency range, which is especially important in achieving high power levels at the higher frequencies. Band-pass filters are used between the power amplifier stages and the antenna cable to attenuate carrier harmonics and, where present, subharmonics of the carrier.

Metering facilities are provided for use in tuning the RF oscillator to the desired operating frequency and for measuring and adjusting the modulation sensitivity of the transmitter. This may be accomplished by the use of a built-in 1-kc test oscillator or by using incoming test signals or pilot tones sent over the line. Another meter circuit measures the power delivered to the antenna cable as well as the reflected power if the antenna is not a proper match for the cable impedance. An alarm circuit gives a visual and audible indication if the power delivered to the antenna cable falls below a predetermined value.

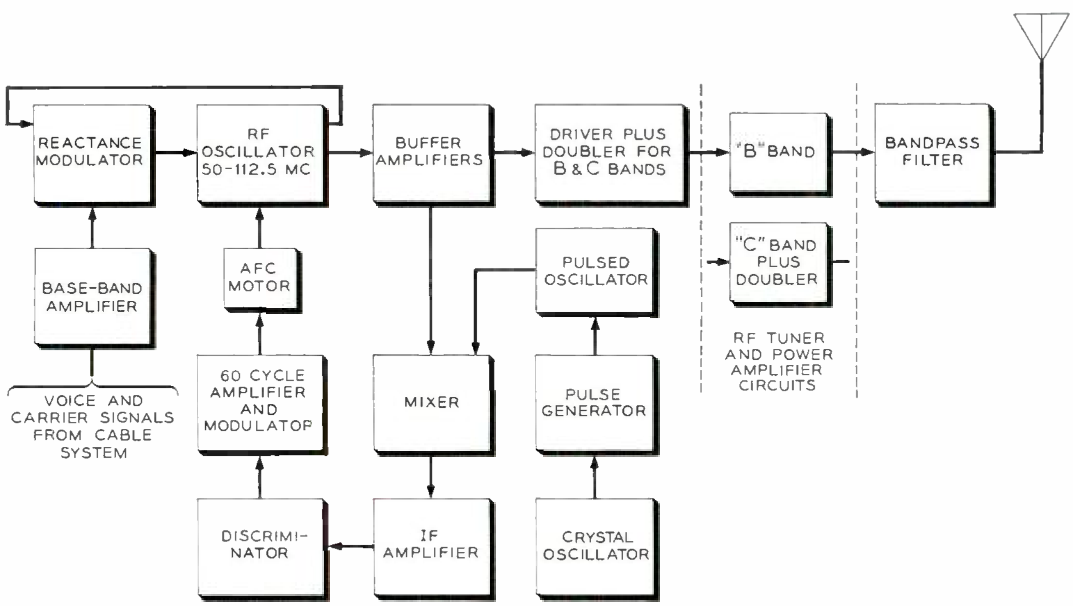


Fig. 1 — Block diagram of AN/TRC-24 Radio Set transmitter.

For military use, all of these circuit components had to be mounted in a rugged transit case. The final design, shown in Figure 2, measures 20⅝ inches wide, 21 15/16 inches high, and 18 1/16 inches deep, and weighs about 105 pounds complete. The severe temperature requirement of —80°F to +132°F dictated the use of special materials in some instances, such as silicone rubber for vibration-control

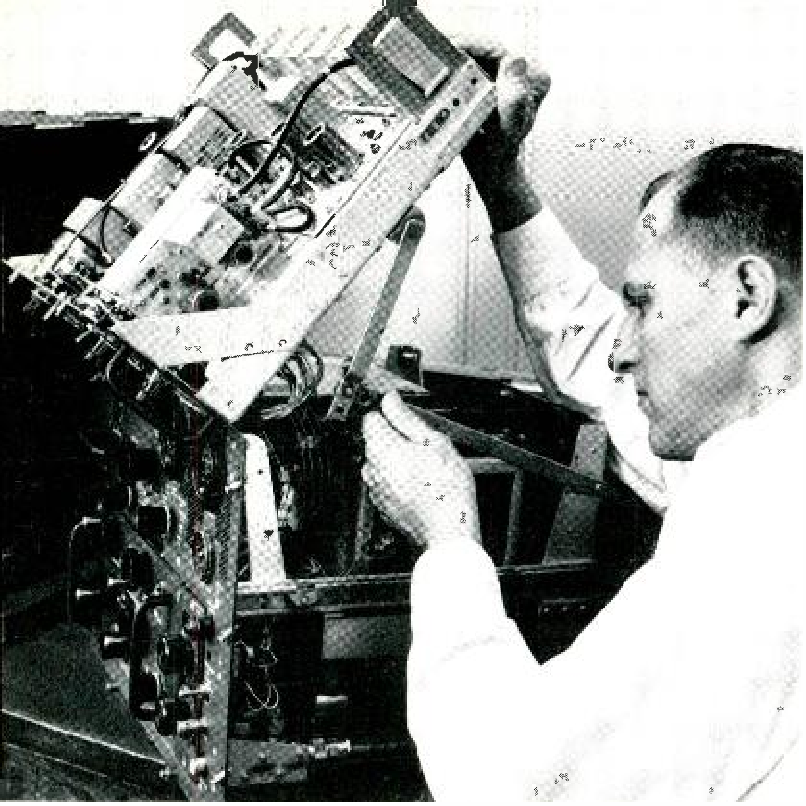


Fig. 2 — C. G. Reinschmidt inspecting internal components of transmitter. Top chassis has been raised on piano hinge in front panel.

mountings. The atmospheric requirements led to the use of hermetically sealed components, moisture and fungus resistant varnishes, and corrosion resistant materials and finishes. In many cases, special apparatus and hardware were designed specifically for the unit.

As seen in the illustrations, the transmitter is divided into two basic parts – an upper chassis attached to a lower chassis by means of a piano hinge at the front panel. A subassembly termed the "exciter unit" (modulator, oscillator, buffer amplifiers, and AFC motor), is mounted in the lower chassis, and the base-band amplifier is mounted directly above in the upper chassis to permit short leads to the modulator. Similarly, the RF tuner unit plugs into the lower chassis below the exciter to permit a short coaxial lead between the two. Other units, dials, and meters were also positioned so that as far as possible they reflect the natural flow of the circuitry. The entire transmitter slides out of the transit case on roller drawer slides, and the upper chassis can be raised on the piano hinge to provide access to components (see Figure 2).

The case assembly consists of an inner and an outer aluminum box. The outer box or transit case has reinforced corners, and the front removable cover has synthetic rubber shock mounts on its inner surface. The inner case has shock mounts on its outer surfaces, so that when the two are nested together and the front cover is attached for transporting, the transmitter is completely protected on all sides.

A blower, mounted in the upper right side of the lower chassis, is used to cool the power tubes in the driver and RF tuner stages. A small amount of air is also diverted to the antenna filter. Air is drawn in through a removable dust filter in the top of the inner case. It passes over the plug-in units of the upper chassis and is sucked in through holes in the rear of the inner case via a duct leading to the intake of the blower. The cooling air is directed to the appropriate spots and the heated air is finally expelled through a duct at the bottom of the inner case.

Considerable care was devoted to the design of dials so that they would be easy to operate and to read. The dial on the exciter – used for selection of channels – has a double scale, one for odd-numbered and one for even-numbered channels. Two separate dials are used on the pulsed oscillator for the odd and even channels. A combined switch and window slide makes the appropriate circuit selection between the two dials on the pulsed oscillator, exposes the correct one, and covers up the other window. The actual dial markings are spiraled on the dial face, and a pointer follows the markings in a spiral slot in the dial to give an equivalent of about 22 inches of linear marking space. The exciter dial also features an adjustable index to permit correction of dial settings for variations in alignment with the controlled inductive tuner. Anti-backlash gears are provided between the dials and the tuner shafts. To prevent accidental contact with hazardous voltages, interlock switches and disconnect plugs are located at strategic places. Removal of the transmitter or power supply from their cases, or removal of the RF tuner from the transmitter, opens a relay in the power supply which interrupts power to the high voltage transformer, thus removing the hazard.

The transmitter power supply is a separate unit and is housed in a similar case. This unit was designed by G. W. Meszaros and R. R. Gay of the Power Development Department. It operates from a 115-volt ac source, but an additional transformer may be used for 230-volt operation. Regulated plate voltages are supplied to the low-power and beam-power tubes, and the plate voltage for the power tubes is adjustable over a wide range to compensate for tube variations and to permit the radio frequency output of the transmitter to be reduced to a low value if desired. The unit is equipped with circuit breakers for overload protection, time delay circuits to prevent premature application of high voltage to the power tubes, and metering facilities for measurement of the dc output and ac input voltages. The main elements are supported by an aluminum frame and chassis, and a fan is included for cooling. For ease of maintenance, the low voltage rectifier is incorporated as a separate plug-in unit.

The transmitter and its power supply are currently in full scale production at the Marion Shops of the Western Electric Company. Many have reached the field and are being used in conjunction with the companion receiver by the military for radio-relay communication systems.

THE AUTHORS

W. G. HENSEL received the B.S. degree in electrical engineering from Ohio Northern University in 1929, and joined the Commercial Products Development Department of the Laboratories that June. Since then he has been engaged in the development of radio transmitting equipment of various kinds, including equipment for long-range transatlantic telephony and VHF equipment for aircraft. Engaged in the design of aircraft and vehicular communication equipment for the Signal Corps during the war, he was later concerned with the design of vehicular radio telephone transmitters for Bell System use. More recently, he participated in the AN/TRC-24 development, and is now concerned with mobile radio development work.

C. G. REINSCHMIDT entered the Laboratories in 1929 as a draftsman in the apparatus design group. Shortly thereafter, he was transferred to the Commercial Products Development Department where he was engaged in the design of radio broadcast transmitters and aircraft radio equipment. In 1943, he was made a member of the technical staff and was concerned with the development of radio equipment for the armed forces. Later he engaged in the development of mobile radio telephone equipment, microwave equipment, and the AN/TRC-24 radio set. In 1953, he was made a supervisor in the Military Branch Laboratories at the Marion Plant of the Western Electric Company, responsible for mechanical engineering problems on the AN/TRC-24 radio set during manufacture. Mr. Reinschmidt is a graduate of Pratt Institute in Industrial Electric Engineering with post graduate work in electronics and mechanical engineering.

Members of Laboratories Active in A.I.E.E., 1955-56

A number of Laboratories people will serve the American Institute of Electrical Engineers in official capacities for the fiscal year 1955-56.

Board of Directors: J. D. Tebo. General Committees: *Board of Examiners*, R. A. Heising, Chairman, E. C. Molina (retired), H. M. Trueblood (retired). *Code of Principles of Professional Conduct*, G. D. Edwards. *Edison Medal*, O. B. Blackwell (retired). *Planning and Coordination*, E. I. Green, J. D. Tebo. *Prize Awards*, R. M. Bozorth, E. I. Green, E. F. Watson. *Publication*, J. D. Tebo. *Public Relations*, R. K. Honaman. *Safety*, L. S. Inskip. *Standards*, R. D. de Kay, R. B. Shanck (liaison representative of Telegraph Systems Committee); Standards Committee appointments to ASA Sectional Committees, S. B. Ingram (alt.), L. S. Inskip (alt.), R. D. de Kay. *Technical Operations*, J. D. Tebo, Chairman, H. A. Affel, E. I. Green.

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Dr. M. J. Kelly and Sir Gordon Radley Receive New Communication Prize

United Press Photo

Dr. M. J. Kelly (right) and Sir Gordon Radley, Director General of the British Post Office, after receiving the first Christopher Columbus International Communication Prize in Genoa, Italy.

Dr. Mervin J. Kelly and Sir Gordon Radley, Director General of the British Post Office, were named by the City of Genoa, Italy, to receive the first Christopher Columbus International Communication Prize. The award was conferred in Genoa on Columbus Day, October 12.

Dr. Kelly and Sir Gordon Radley received the prize in recognition of "the planning, now being placed into practice, of the submarine telephone cable which will make it possible to establish 36 telephone circuits across the Atlantic between Scotland and Canada with extension to New York, 'intending furthermore to reward hereby the numerous scientists, research workers and engineers who have contributed in the planning, production and placing in operation of the intercontinental submarine telephone line'."

The Christopher Columbus International Communication Prize awarded to Dr. Mervin J. Kelly and Sir Gordon Radley.

In his letter of acceptance, Dr. Kelly emphasized that this pioneering venture in transoceanic telecommunication has been shared by many of his associates. "In receiving this honor," he said, "I am mindful of the fact that I am doing so as the representative of the many scientists and engineers of Bell Telephone Laboratories whose work during the past decade or more has contributed to the technology that has made the intercontinental repeatered submarine cable possible."

Dr. Kelly declared that "the same imagination and spirit of venture Columbus exhibited almost 500 years ago have been the driving forces in the transatlantic submarine cable project now nearing completion."

He pointed out that some 20 years ago, Bell Telephone Laboratories initiated research programs that have provided the technology for the 2,000-mile deep-sea section extending from Newfoundland to Scotland. In this section lying on the ocean's bed there are at intervals of 40 miles highly complex electronic repeaters. In these repeaters there are some 300 thermionic high-vacuum amplifying tubes and more than 7,000 associated circuit components. The researches made possible the development of amplifying tubes and components with expected lives without failure of more than 20 years, a reliability never before achieved in vacuum tubes and associated components.

"I am confident," he said, "that this pioneering cable is only the first of many broadband communications paths that will link the major land bodies of the world. Already under way is a similar link between the West Coast of the United States and Hawaii.

"While in the early years the technology will permit only band widths adequate for multichannel telephony, the time is not too far distant when cables with band widths sufficiently broad for television transmission will be possible. These communication links connecting continents will make large contributions to international business and social life and to world unity."

Sir Radley and Dr. Kelly each received a gold medal and 2,500,000 Italian lira, about $4,000. Dr. Kelly is giving his share of the monetary prize to the Massachusetts Institute of Technology and has written to Dr. James R. Killian, Jr., its President:

"After careful consideration, I have decided that a contribution to the Building Fund for the Karl Taylor Compton Laboratories and the Nuclear Reactor at Massachusetts Institute of Technology will be a most appropriate use of the monetary element of the prize. In the years to come, many of the scientists and engineers who will participate in the programs of Bell Telephone Laboratories will receive their training in physics and research in the Compton Laboratories."

The Christopher Columbus International Communication Prize was instituted recently in Italy, under the auspices of the City of Genoa, as a memorial to Christopher Columbus, a native of Genoa. The annual prize is intended to honor any outstanding discovery or research work completed in the previous four years to aid communications among men.

The award will be conferred each year in one of four categories of communications: Maritime, Air, and Land Communications, and Telecommunications. Awards will be based on recommendations of the Italian Higher Institute of Telecommunications and the Superior Research Council, and may be given to an individual, an organization or, collectively, to a group of persons. Presentation of the prize will take place each October in Genoa, on the occasion of the International Meeting of Communications.

E. J. McNeely Executive Vice President; H. I. Romnes O. & E. Vice President at A. T. & T.

E. J. McNeely

H. I. Romnes

The American Telephone and Telegraph Company has announced the appointment of Eugene J. McNeely as Executive Vice President. He also was elected a member of the Board of Directors and appointed a member of the Executive Committee. This change is due to the desire of Hal S. Dumas, Executive Vice President since 1951, to retire next summer.

Mr. McNeely will assist the President in the over-all operation of the business and perform such other duties as the President may assign to him. He will be in charge in the absence of the President and Executive Vice President Dumas.

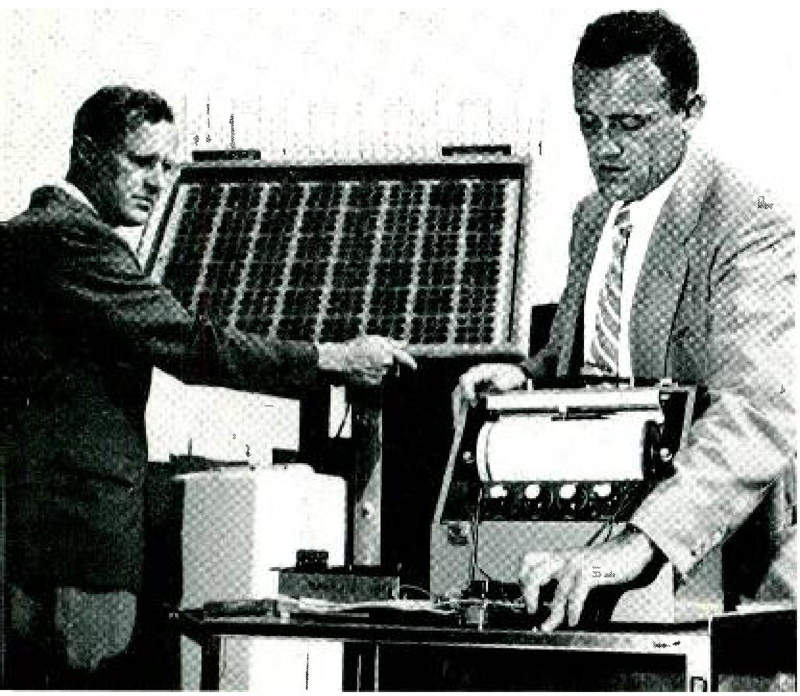
H. I. Romnes has been elected a Vice President of the A. T. & T. Co. and will be in charge of the Operation and Engineering Dept., succeeding Mr. McNeely. Mr. McNeely, a native of Missouri, joined Southwestern Bell Telephone Company as a student engineer thirty-three years ago. Before becoming an A. T. & T. Vice President in 1952, he was President of Northwestern Bell. At A. T. & T. he has headed first, Personnel Relations, and then the Operation and Engineering Dept.

Mr. Romnes has been Chief Engineer in A. T. & T. Operation and Engineering since 1952. He began his telephone career in 1928 as an installer for Wisconsin Telephone Co. Since then he has held various engineering posts with the Laboratories, Illinois Bell and A. T. & T.

Bell Solar Battery in Experimental Service

The Bell Solar Battery* was placed in experimental service on October 4, 1955, and for the first time, the sun began furnishing power directly to a telephone line. Use of the battery is a part of Laboratories experiments being conducted near Americus, Georgia, 135 miles south of Atlanta, to develop more and better rural telephone service. The tests have been arranged with the co-operation of Southern Bell Telephone Company.

The Bell Solar Battery was invented by a three-member Laboratories team, G. L. Pearson and D. M. Chapin, physicists, and C. S. Fuller, chemist. Very pure silicon is first treated with a small amount of an impurity so that it becomes n or negative-conductivity material. Then thin slices of the n-type silicon crystals are placed in a gaseous atmosphere and heated to a high temperature so that a controlled amount of a p or positive-conductivity impurity will diffuse into a very shallow layer on the surface of the crystal. This layer must be very accurately determined and is only about 1/10,000 inch in depth. The process results in what is known as a p-n junction, which is very sensitive to light. Solar energy falling on the surface of the crystal is converted into useful amounts of electrical power, with efficiencies of conversion up to 11 per cent.



Tests of the Bell Solar Battery being made at Bell Laboratories location. W. D. Gerdsen (left) is adjusting the position of the battery, as R. A. Coradeschi makes electrical tests.

By connecting such silicon solar cells in series and in parallel, it is possible to get a wide variety of current and voltage outputs. In the Bell Solar Battery used in the Americus experiments, the cells are assembled in modules of nine, and the modules are further grouped together in an aluminum housing less than a square yard in area. This unit contains a total of 432 silicon cells, cushioned in oil and covered by glass. In experimental service, the Battery is mounted on top of a telephone pole and is oriented to receive a maximum amount of sunlight. When exposed to the sun, it supplies more than the small amount of power necessary for the operation of the telephone equipment. The extra current from the solar unit not needed for immediate use feeds into a storage battery which provides power at night and over periods of bad weather.

The Bell Solar Battery has no moving parts or corrosive chemicals and therefore should last indefinitely. It is at least fifteen times more efficient than the best previous solar energy converter. Further, its efficiency of conversion remains essentially constant even in poor light where other types of converters fail. This means that in poor light the current output decreases, but the voltage stays nearly constant and the solar unit therefore continues to charge the storage battery.

The rural telephone system now under trial at Americus uses transistors instead of the traditional vacuum tubes. The system, termed the P1, uses the "carrier" principle, which allows several telephone conversations to be sent simultaneously over a single pair of wires. Since each conversation is sent at a different frequency, they do not interfere with each other. Electrical filters separate the conversations at the receiving end. Such multifrequency transmission has been used for years – with vacuum tubes – on longer distance calls. The system on trial at Americus, however, operates economically over shorter distances such as those on rural telephone lines.

* Record, *July*, 1955, *page* 241.

Bankers "Visit" Murray Hill Via TV

Members of the Investment Bankers Association recently heard Dr. Mervin J. Kelly declare that in "the spirit of exploration which burns brightly at the Laboratories lie many of our hopes in this critical age.

"By extending and furthering communications around the globe," he said, "we hope to contribute to the international understanding that men must achieve for permanent peace."

Dr. Kelly spoke at the Association's annual meeting at the Waldorf-Astoria on October 19, introducing a closed circuit television show which was transmitted directly from the Murray Hill Laboratories to the Waldorf. The TV show was part of the "Hour of Industry" program that the A. T. & T. Co. presented at the invitation of the investment bankers.

The bankers saw and heard vice president Ralph Bown and a group of Laboratories members display and explain Laboratories achievements in terms of their impact on the future – of the telephone business and of the nation. The theme of the TV program was how fundamental research breathes new life into creative technology.

A number of current Laboratories projects were spotlighted. Dr. Bown traced the research and development of semiconductors from the study of radio crystals and the cat's whisker detector to the invention of the transistor and the Bell Solar Battery. The camera showed the process of zone refining, which Dr. Bown explained makes "the purest substance ever achieved by man . . . germanium with a measurable impurity of one part in ten billion."

Dr. Bown illustrated the low power requirements of the transistor in connection with a new experimental telephone system. "Using transistors, we are actually substituting tones for bells in some telephones now being tried under field conditions," he said. In these experiments the tones are transmitted with the same amount of power that is needed to transmit a telephone conversation – considerably less than is needed to make a telephone ring. Subscribers whose telephones are being used in this field trial hear a distinctive tone instead of a ringing bell.

Use of the transistor in direct dialing, the volume control telephone, radio receivers and transmitters and in hearing aids was described. The bankers also saw the silicon power rectifier, the Bell Solar Battery, "Mr. Meticulous," tiny capacitors, resistors, thermistors, varistors, ferrite transformers and printed circuits.

Over film inserted into the live transmission by means of the Laboratories-developed film scanner, Dr. Bown touched on the role of the Laboratories in the television broadcasting industry: "The television network of radio-relay stations was built on the invention here in the Laboratories of the 'wave guide' – a sort of electronic plumbing that carries radio microwaves around corners," he told the bankers.

The TV program opened with a camera focused on the statue of Alexander Graham Bell in the Murray Hill reception room, bringing the famous "Leave the beaten track" inscription to the screen of the Waldorf. At the end of the program the camera returned to the same scene and Dr. Bown said:

"We have shown you many things. You see, we have left the beaten track – not once but many times, and we shall keep on doing so. In that way we expect to improve further the things you already have, and to find new things no one has ever seen or known before.

"We have an enormous respect for the future and we are confident that people, free to grow, will make it greater than we dare predict."

The first half of the evening's program consisted of a panoramic picture presentation that traced the development and growth of communications in the United States. The slides, cast on a screen 40 x 11 feet, emphasized many of the newer services being offered by the telephone companies such as color telephones, automatic answering sets, illuminated dial telephones for use in dark places and the speakerphone – a telephone that can be used without being picked up.

By means of arrangements made in cooperation with the New Jersey and New York Telephone Companies, the television signal was transmitted from an experimental radio relay tower on the Murray Hill Laboratories property to the Empire State Building in New York City, and from there was carried by coaxial cable to the Waldorf-Astoria Hotel. Audio went directly to the hotel by cable. With these arrangements, Dr. Kelly in New York City was able to see and to converse with Dr. Bown at Murray Hill throughout the program.

W. O. Baker Named Vice President in Charge of Research

Dr. William O. Baker, Director of Research in Physical Sciences of the Laboratories, has been elected Vice President in charge of Research, effective October 1. In his new post he succeeds Dr. James B. Fisk, who became Executive Vice President on June 1. Dr. Baker will report to Dr. Fisk.

Dr. Baker joined the Laboratories as a research chemist in 1939 after receiving his doctoral degree in physical chemistry from Princeton University and

W. O. Baker

his bachelor's degree from Washington College, Md. During his graduate years at Princeton, he held a Harvard Fellowship and a Proctor Fellowship, and conducted pioneering investigations of the electrical properties of solids.

His research work has been primarily concerned with investigation of the molecular structure and physical properties of polymers, particularly the fundamental constitution of synthetic rubbers and plastics. His ideas concerning microgel as a highly cross-linked giant molecule of distinctive properties, a concept new to science, have led to a better fundamental understanding of the behavior of man-made polymers, particularly synthetic rubbers. This concept has also suggested the process that may be employed by nature in the synthesis of proteins. There have been many practical by-products and related aspects of this work and Dr. Baker's investigations have had considerable impact, both on chemical theory and the chemical industry as a whole.

Because of his outstanding contributions, Dr. Baker was asked during World War II to serve with the Office of Scientific Research and Development and the Office of Rubber Reserve for the government, and since the war he has served in several governmental consultant posts.

Before becoming Director of Research in Physical Sciences in 1954, Dr. Baker had served as Assistant Director of Chemical and Metallurgical Research from 1952. Previously he had been in charge of the Laboratories' work in synthetic rubbers and plastics.

He is a member of a number of professional societies, including the American Chemical Society, the American Physical Society and the American Society for Testing Materials.

Dr. Hendrik W. Bode, Director of Mathematical Research, has been named to succeed Dr. Baker as Director of Research in Physical Sciences.

Dr. Fisk to Head Disarmament "Task Force"

Dr. J. B. Fisk, has been named to head a communications "task force" in connection with a U. S. plan for international inspection and control of disarmament before the United Nations. Harold Stassen, Special Assistant to the President on Disarmament, announced recently that the Government has had eight "task forces" at work on inspection and control problems.

Dr. Fisk's task force is concerned with "rapid, continuous, reliable communications, without interference, necessary to implement an international inspection and reporting system." Mr. Stassen told a UN disarmament subcommittee that the disarmament problem "required a new, fundamental and extensive, expert study of the methods of international inspection and control by the most competent authorities in American life. Accordingly, we selected outstanding men to head up task forces in the appropriate fields of inquiry."

Claude E. Shannon Receives Stuart Ballantine Medal

Dr. Claude E. Shannon of the Mathematical Research Department was the recipient of the Stuart Ballantine Medal of The Franklin Institute of the State of Pennsylvania. Awarded for outstanding achievement in the field of communication, the citation and medal were presented to Dr. Shannon at The Franklin Institute's Annual Medal Day Ceremonies on October 19.

The Institute cited Dr. Shannon for "his recognition of communication as essentially a statistical process, his identification of the elements of communications systems with the appropriate statistical functions, and his welding of mathematical statistics into a comprehensive theory of communication which permits precise and rapid evaluation of proposed new communication systems, and points the way for significant new developments."

Dr. Shannon was graduated from the University of Michigan in 1936 with a B.S. degree in electrical engineering; he subsequently received an S.M. degree and a Ph.D. degree in mathematics in 1940 from Massachusetts Institute of Technology. While at M.I.T., he was awarded a Bowles Fellowship in 1939. The American Institute of Electrical Engineers presented him with the Alfred Nobel Prize in 1940. During 1940-41, he was a National Research Fellow. He joined Bell Telephone Laboratories in 1941.

In 1949 the Morris Liebmann Memorial Prize of the Institute of Radio Engineers was awarded him for his "original and important contributions to the theory of the transmission of information in the presence of noise." The following year he was made a Fellow of that Institute.

Dr. Shannon is a member of the American Mathematical Society, Sigma Xi, and Phi Kappa Phi.

W. T. Wintringham Becomes Fellow of S.M.P.T.E.

William T. Wintringham of the Television Research Department has been named to the rank of Fellow by the Society of Motion Picture and Television Engineers. The award was made on October 4, at the Society's 78th Convention, at Lake Placid. Members of the Society are eligible for elevation to the grade of Fellow when "by their proficiency and contributions they have attained to an outstanding rank among engineers or executives of the motion picture or television industries."

Mr. Wintringham joined the Development and Research Department of the A.T.&T. Co. in 1924 and transferred to the Laboratories ten years later. Since 1945 he has been primarily occupied with television research and is in charge of the television research group.

Horn Reflector Antennas in New Radio Relay Route

A new Bell System radio relay route, equipped with Laboratories invented and developed horn reflector antennas (see page 401), has been placed in service between Jackson, Mississippi, and Dallas, Texas.

The 430-mile route, a joint undertaking of the Long Lines Department of American Telephone and Telegraph Company and Southern Bell Telephone and Telegraph Company, will provide expanded long distance telephone and network television service in the area. It connects with the nationwide Bell communications network. The route includes 16 towers and equipment buildings at intervals of about 30 miles, stretching from western Mississippi, across northern Louisiana and into Texas.

The new antennas have been designed to handle up to 15,000 telephone conversations and 10 television programs at one time – a much greater transmission capacity than older models.

Western Electric Turns Over Cable to Air Force

A new undersea telephone cable, serving as the communications backbone of a test range for guided missiles, has been turned over to the United States Air Force by the Western Electric Company. Stretching between Florida and Puerto Rico, it makes possible the continuous study of guided missiles in flight, and thus puts into Air Force hands one of the most important military test facilities in the world.

Until the completion of the Atlantic Cable, this will be the world's longest telephone-type submarine cable. It has required 1370 nautical miles of cable to interconnect the land-based repeaters and terminal stations spaced at intervals on the coast of Florida and islands in the Caribbean. While the design is essentially that of a telephone system, communication facilities are provided for the transmission of telegraph, timing, telemetering and other data transmission, all of which are required for the administration and operation of this great testing range.

In engineering, furnishing, and laying the cable, which required four years to manufacture and lay, Western drew extensively upon the combined skills and experience of other Bell System units including Bell Laboratories and Long Lines. The selection and survey of repeater sites, the study and choice of cable routes, and the deep-sea cable-laying work were carried out under Bell Laboratories supervision. Bell Laboratories engineers were responsible for the design, line-up, and adjustment work on repeaters, terminals, and power equipment.

Missiles launched from the Missile Test Center in Florida are guided on a straight course that crosses the Bahama Islands and the western tip of Puerto Rico in what the Air Force terms "the world's longest outdoor laboratory." Radar installations at the several terminal stations gather word of a missile's position as it passes down the range at speeds reaching upward to thousands of miles an hour, and flashes it back to the test center via the cable.

Signals transmitted from the missiles are picked up by radio receivers at the cable stations and then are relayed by the new cable to Florida for analysis. These signals contain information relative to the missile's fuel consumption, skin temperature, internal temperature, flight attitude, performance of components, and related data. The news of the missile is thus communicated to its launching site as soon as it happens. This makes possible, for the first time, the study of guided missile performance over an extended range.

First Semi-Automatic Teletypewriter Relay System Now in Service

A new semi-automatic teletypewriter relay system, first of its kind, has been placed in service for Consolidated Freightways by the Bell System. It is another special service that has been tailor-made for customers.

Heart of the system, which stretches through twelve states, is a relay center located in Portland, Ore., Consolidated Freightways' headquarters. The Portland center serves as an electronic brain which controls the sending and receiving of teletypewriter messages from sixty-five locations of the motor transport carrier.

The new communications system was developed by the Long Lines Department of A.T.&T. and by Pacific Telephone to expedite messages dealing with dispatch of Consolidated's vehicles.

To send a message from the Consolidated office in Chicago to Seattle, and several other points in the Northwest, the Chicago attendant prepares a perforated tape in the same manner a message would ordinarily be written on a teletypewriter. The complete tape is placed in the Chicago transmitter. From this point on, the operation of the apparatus is automatic.

At Portland, the message receiving equipment is constantly sending out electronic impulses along the eleven circuits to see if there are any messages in transmitters at the outlying stations ready to be relayed.

Finding there is a message ready and waiting at Chicago, this electronic device connects the Chicago transmitter to the circuit and turns it on.

Automatically, then, the message is "pulled" into the Portland center and recorded on a receiving machine. When the transmission is completed, the

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

Anderson, A. B. – *Electrical Switch* – 2,716,164.

Andrews, F. T., Jr. – *Electrical Information System* – 2,715,656 and 2,715,657.

Avery, R. C. – *Counting Circuit* – 2,715,996.

Dunlap, K. S., and Lovell, C. A. – *Electrical Information System* – 2,715,658.

Foster, O. C. – *Method and Apparatus for Coating Articles* – 2,716,622.

Hall, N. L., Korn, F. A., and Powell, H. E. – *Ringing Generator and Interrupter Using Electron Tubes* – 2,714,632.

Houtz, C. C. and McLean, D. A. – *Stabilization of Electrolytic Capacitors* – 2,716,721.

Kinsley, T. G. – *High Speed Relay of Electromechanical Transducer Material* – 2,714,642.

Korn, F. A., see Hall, N. L.

Little, J. B. – *Microwave Amplifier Electron Discharge Device* – 2,716,202.

Locke, G. A., Mellnish, L. E., and Ostendorf, B. Jr. – *Private Line Intercommunicating Teletypewriter System* – 2,714,626.

Lovell, C. A., see Dunlap, K. S.

McLean, D. A., see Houtz, C. C.

Mellnish, L. E., see Locke, G. A.

Miloche, H. A. – *Method and Apparatus for Forming Cables* – 2,715,922.

Ostendorf, B., Jr., see Locke, G. A.

Pitt, R. S. – *Brake for Telephone Calling Dials* – 2,716,160.

Powell, H. E., see Hall, N. L.

Power, J. R. – *Flux Modulated Ringer* – 2,716,232.

Shockley, W. – *Circuits Including Semiconductor Device* – 2,714,702.

Shockley, W. – *Transistor Circuits with Constant Output Current* – 2,716,729.

Portland receiver automatically turns off and disconnects the transmitter in Chicago.

To relay the message to Seattle and other desired points, the Portland message center people take the incoming tape and place it on a transmitter. Then the stations for which the message is destined are selected by pushing buttons on a board above the transmitter. When the circuit, or circuits, needed to relay the message are available, the message is automatically sent on its way.

Advantages of the new communications setup over the former system include the fact that personnel at outlying stations simply put a message on their transmitter, then go away and leave it with the knowledge that it will be automatically transmitted. (Under the former system, they had to wait around with a message until the circuit was clear, and then "get on" the circuit before another station did.)

Similarly, personnel in the Portland message center can set up a message for transmission, leave it, and devote their time to another duty. As a result, more messages can be sent faster with less working time for personnel involved.

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

Basseches, H., and McLean, D. A., Gassing of Liquid Dielectrics Under Electrical Stress, Ind. and Engg. Chem., **47**, pp. 1782-1794, Sept., 1955.

Becker, J. A., The Life History of Adsorbed Atoms, Ions, and Molecules, Annals N. Y. Acad. Sci., **58**, pp. 723-740, Sept. 15, 1955.

Bridgers, H. E., and Kolb, E. D., Rate-Grown Germanium Crystals for High-Frequency Transistors, J. Appl. Phys., Letter to the Editor, **26**, pp. 1188-1189, Sept., 1955.

Calbick, C. J., Surface Studies with the Electron Microscope, Annals N. Y. Acad. Sci., **58**, pp. 873-892, Sept. 15, 1955.

Fewer, D. R., Blackwell, J. H., Allen, L. J., and Cass, R. S., Audio-Frequency Circuit Model of the 1-Dimensional Schroedinger Equation and Its Sources of Error, Canadian J. of Phys., **33**, pp. 483-491, Aug., 1955.

Francois, E. E., see Law, J. T.

Davis, J. L., see Suhl, H.

Galt, J. K., see Yager, W. A.

Gianola, U. F., Application of the Wiedemann Effect to the Magnetostrictive Coupling of Crossed Coils, J. Appl. Phys., **26**, pp. 1152-1157, Sept., 1955.

Hines, M. E., Hoffman, G. W., and Saloom, J. A., Positive-Ion Drainage in Magnetically Focused Electron Beams, J. Appl. Phys., **26**, pp. 1157-1162, Sept., 1955.

Hoffman, G. W., see Hines, M. E.

Kelly, M. J., Training Programs of Industry for Graduate Engineers, Elec. Engg., **74**, pp. 866-869, Oct., 1955.

Kolb, E. D., see Bridgers, H. E.

Law, J. T., and Francois, E. E., Adsorption of Gases and Vapors on Germanium, Annals N. Y. Acad. Sci., **58**, pp. 925-936, Sept. 15, 1955.

McLean, D. A., see Basseches, H.

Merritt, F. R., see Yager, W. A.

Meyer, F. T., An Improved Detached-Contact Type of Schematic Circuit Drawing, Comm. & Electronics, **20**, pp. 505-513, Sept., 1955.

Miller, S. L., Avalanche Breakdown in Germanium, Phys. Rev., **99**, pp. 1234-1241, Aug. 15, 1955.

Neisser, W. R., Liquid Nitrogen Cold Traps, Rev. Sci. Instr., **26**, p. 305, Mar., 1955.

Pedersen, L., Aluminum Die Castings for Carrier Telephone Systems, Comm. & Electronics, **20**, pp. 434-439, Sept., 1955.

Peters, H., Hard Rubber, Ind. & Engg. Chem., Part II, pp. 2220-2222, Sept. 20, 1955.

Pfann, W. G., Temperature-Gradient Zone-Melting, J. Metals, **7**, p. 961, Sept., 1955.

Poole, K. M., Emission from Hollow Cathodes, J. Appl. Phys., **26**, pp. 1176-1179, Sept., 1955.

Saloom, J. A., see Hines, M. E.

Slichter, W. P., Proton Magnetic Resonance in Polyamides, J. Appl. Phys., **26**, pp. 1099-1103, Sept., 1955.

Smith, B., and Boorse, H. A., Helium II Film Transport. II. The Role of Surface Finish, Phys. Rev., **99**, pp. 346-357, July 15, 1955.

Smith, B., and Boorse, H. A., Helium II Film Transport. IV. The Role of Temperature, Phys. Rev., **99**, pp. 367-370, July 15, 1955.

Suhl, H., Van Uitert, L. G., and Davis, J. L., Ferromagnetic Resonance in Magnesium-Manganese Aluminum Ferrite Between 160 and 1,900 Mc., J. Appl. Phys., Letter to the Editor, **26**, pp. 1181-1182, Sept., 1955.

Tien, P. K., and Walker, L. R., Large Signal Theory of Traveling Wave Amplifiers, Proc. I.R.E., **43**, p. 1007, Aug., 1955.

Ulrich, W., see Yokelson, B. J.

Van Uitert, L. G., see Suhl, H.

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

Yager, W. A., Galt, J. K., and Merritt, F. R. Ferromagnetic Resonance in Two Nickel-Iron Ferrites, Phys. Rev., **99**, pp. 1203-1209, Aug. 15, 1955.

Yokelson, B. J., and Ulrich, W., Engineering Multistage Diode Logic Circuits, Comm. & Electronics, **20**, pp. 466-475, Sept., 1955.

Talks by Members of the Laboratories

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

Anderson, P. W., and Talman, J. D., Line Shapes in Pressure Broadening at General Pressures, Conference on the Broadening of Spectral Lines, University of Pittsburgh.

Arnold, S. M., Metal Whiskers – Their Growth and Properties, Research Laboratories, American Smelting and Refining Company, South Plainfield, N. J.

Brattain, W. H., The Physics of Transistors, A.I.E.E., New York City.

Currie, A. A., Antiaircraft Fire Control System – M33, I.R.E. Piedmont Subsection, Burlington, N. C.

Dodge, H. F., and Torrey, Miss M. N., Sampling Plans for Continuous Production, Rutgers All-Day Conference on Quality Control, New Brunswick, N. J.

Finch, T. R., Semiconductor Junction Devices and Circuit Applications, A.I.E.E. Section, Minneapolis, Minn.; A.I.E.E.-I.R.E. Student Sections, University of Nebraska; Engineering Students, University of Omaha; and I.R.E. Section, Omaha, Nebraska.

Fisher, C. E., Effective Use of Statistical Quality Control by Management, American Society for Quality Control, St. Louis.

Geballe, T. H., Morin, F. J., and Maita, J. P., Some Low Temperature Thermometric Properties of Germanium, The International Conference on Low Temperature Physics, Paris.

Geballe, T. H., and Hull, G. W., Jr., The Size Dependence of Thermal Conductivity and Thermoelectric Effect in p-Type Germanium, International Conference on Low Temperature Physics, Paris.

Goldman, M., Subalgebras of Certain Banach Algebras, American Mathematical Society, Ann Arbor, Mich.

Hannay, N. B., Mass Spectroscopy of Inorganic Materials, Rutgers University, New Brunswick, N. J.

Hull, G. W., Jr., see Geballe, T. H.

Kudlich, R. A., TRADIC, A Tubeless Air-Borne Computer Using Semiconductor Diodes and Transistors, I.R.E. Northern New Jersey Section, Murray Hill.

Lewis, W. D., Electronics in Telephone Switching, A.I.E.E. Tulsa, Oklahoma, and Oklahoma City.

Lundberg, J. L., Molecular Clustering in Solutions of High Polymers, American Chemical Society Meeting, Minneapolis.

Maita, J. P., see Geballe, T. H.

Mason, W. P., Dislocation Relaxations in Metals and Crystals and the Determination of the Limiting Shearing Stress, International Union of Theoretical and Applied Mechanics, Madrid, Spain.

Matthias, B. T., Superconductivity of Zirconium Alloys, International Conference on Low Temperature Physics, Paris.

Morin, F. J., see Geballe, T. H.

Pearson, G. L., Silicon in Modern Communications, I.R.E. Monmouth Subsection, Holmdel, N. J.

Pietenpol, W. J., Transistors Today, I.R.E. Chicago Section, and I.R.E. Buffalo Section.

Ross, I. M., A Semiconductor Counting Device, Services Electronic Research Laboratory, Baldock, and University of Reading, England.

Rowen, J. H., Ferromagnetism and Its Application to Microwaves, Engineers Club, Philadelphia.

Ruwell, R. G., Automatic Message Accounting, Connecticut Chapter of Systems and Procedures Association, New Haven, Conn.

Schumacher, E. E., Communications Metallurgy, Idaho Mining Association, Sun Valley.

Slepian, D., A Class of Binary Signaling Alphabets, Third London Symposium on Information Theory.

Stansbury, E. J., Semiconductor Devices, I.R.E. Montreal Section, and National Research Council, Ottawa.

Talman, J. D., see Anderson, P. W.

Torrey, Miss M. N., see Dodge, H. F.

Trumbore, F. A., Method for the Determination of Vapor Pressures over Liquidus and Solidus Alloys. Vapor Pressure of Arsenic over Germanium-Arsenic Alloys, American Chemical Society, Minneapolis.

Williams, I. V., History of Preferred Decimal Thicknesses for Thin Flat Metals, Seminar of Standards Engineers Society, Hartford, Conn.