Important factors leading to Alexander Graham Bell's invention of the telephone were his devotion to the problems of the hard of hearing and his knowledge of the nature of speech and hearing. At the Laboratories, continuing studies of the fundamentals of sound and hearing have led to better telephone instruments and to more effective devices to help those whose hearing is impaired. In the 532-type telephone set there is a self-contained transistor amplifier — independent of local batteries — that offers improved service to these customers.

The New Volume Control Telephone

A. J. CHASE *Station Apparatus Development*

The junction transistor has made possible an entirely new approach to the design of a telephone set for the hard of hearing. Capable of operating as a high efficiency amplifier at low voltages, the junction transistor uses but a small fraction of the central office power supplied to the instrument at a customer's premises. Now for the first time it is possible to operate a practical receiving amplifier in a telephone set without the use of local batteries.

Over the years a number of developments have provided telephone service for those with impaired hearing. Some 50 years ago mechanical repeaters were used at the customer's premises, and by the late twenties an electron tube amplifier was available.[*] By 1941 the miniature mechanical amplifier developed for hearing aids was provided in a combined set.[†] Although some 50,000 installations of this set indicate some service improvement, performance limitations and manufacturing difficulties stimulated new design. Development of an electron tube replacement set was discontinued when the imminence of transistors indicated a more desirable solution.

When point-contact transistors became available, their small size and low power requirements prompted the development of a two-stage transistor amplifier. Despite reduced power requirements in this design, local batteries again had to be used to supply the biasing voltages of approximately 20 volts dc needed for satisfactory operation.

The introduction of the junction transistor not only reduced power requirements still further but also assured satisfactory operation of the amplifier at voltages low enough to eliminate the need for local batteries. Ideally suited, too, were such characteristics of the junction transistor as its small size, its long life expectancy, and its freedom from the effects of shock and mechanical vibration. Its low operating power and voltage levels facilitated packaging of the amplifier by permitting such miniaturization of all circuit components that in the final design the amplifier is housed in a cubic space approximately one inch on each side. Figure 1 shows one of the amplifiers with the metal case removed.

The circuit schematic of Figure 3 shows the junction transistor amplifier inserted in the receiver circuit of a 500-type telephone set. This amplifier provides adequate gain in a single stage, and the input impedance of the transistor is suitable for direct coupling into the receiver circuit shown at terminals R and GN. Resistor R1 and capacitor C1, shunted across the input, provide stabilization of the input impedance and suppression of radio interference. The transistor collector circuit is coupled to the U1 receiver by a miniature output transformer, whose impedance ratio is designed for maximum power gain with the low collector voltages available – usually 2 to 4 volts. The 20,000-ohm base resistor, R2, has been selected to provide transistor current which

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[*] RECORD, *October*, 1931, *page* 46.

[†] RECORD, *October*, 1942, *page* 45.

ranges from about 5 milliamperes on the shortest customer loops to two milliamperes on the longest.

Power for the amplifier is obtained by diverting a small fraction of the carbon transmitter current, causing a loss in transmitting level of less than one db. This operating current is filtered by a small inductor, L1, and by-pass capacitor, C2.

The voltage gain available in this single stage is too small to permit the use of stabilizing negative feedback when the amplifier is operating at full gain, but for operation at less than full gain, the volume control potentiometer provides negative feedback by inserting resistance in the emitter circuit.

At minimum gain, therefore, the resistance of the volume control in the emitter circuit is high enough to insure negligible speech distortion and serves to stabilize and minimize variations in transistor characteristics. Because performance at minimum gain is effectively that of a standard 500-type set, the design of the set is simplified and its maintenance minimized by omitting the customary arrangement for switching the amplifier out of the circuit when additional gain is not required. The expected long life of transistors justifies the use of the amplifier whenever the set is in use, irrespective of whether additional gain is required.

Since the bridging diodes at the input of the talking circuit protect the transistor against battery reversals or the accidental applications of manual ringing voltages on the line, the transistor is always biased properly for operation.

The design objective for the junction transistor amplifier was to provide a continuous range in gain from substantially 0 to at least 20 db. Power supply variations due to differing customer loop lengths have little effect on the maximum gain available.

Fig. 1 — The heart of the 151A amplifier is the junction transistor shown just beneath the pointing finger.

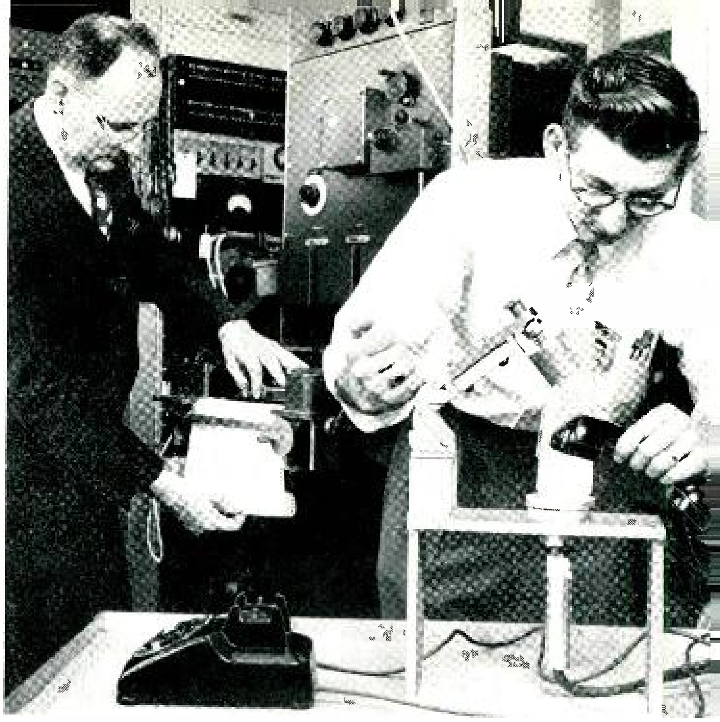


Fig. 2 — J. R. Ouellette couples the receiver to the "artificial ear" while the author prepares the level recorder for operation.

The curves of Figure 4 illustrate the performance of the set in terms of sound pressure delivered to the ear by a close-coupled telephone receiver. Measurements were made by means of the "artificial ear" shown in the foreground of Figure 2 and the level recorder in the background. The lower curve of Figure 4 represents pressures delivered by a standard 500-set receiver over the important portion of the audio range when a steady signal is applied to the line at a typical incoming level. When the amplifier is adjusted for maximum gain, the sound pressures are raised as indicated; the slight increase in gain at the higher frequencies is a desirable characteristic. The top curve shown by the dotted line represents the "threshold of feeling," beyond which sounds are felt rather than heard; it is obviously desirable that sound pressures in the ear be kept below this level. Since both the overload characteristic of the transistor amplifier and the click-reducing characteristic of the varistor built into the receiver serve to limit sound pressures in the ear, safe operation is assured regardless of the level of incoming sounds or sharp clicks on the line, and the pressures on the ear cannot exceed those shown in Figure 4 by more than a few db.

A model of the new set has been designated as the 532-type. (The illustration at the head of this article shows Mrs. M. S. Aamodt operating the plastic knob to adjust the volume of this set.) The amplifier is housed in a metal case riveted to the base of the set, with all components mounted to the terminal plate which forms the cover of the case. The diode bridge, the 419A varistor, is housed in the terminal plate cartridge mounted between the legs of the dial bracket, and the potentiometer gain control mounts in the corner of the set for easy access. In outward appearance the set resembles a single-button key set.

Assembly of this transistorized set is simplified by the fact that all components may be readily added to the base plate of a standard 500-type set. The amplifier housing mounts in holes originally provided for the filamentary type equalizer of the earlier 500-type series; the potentiometer bracket utilizes holes provided for the key in the 510-type set; and the varistor assembly replaces the terminal strip of that set. All other components are standard with the sets in the 500-type series, and installation of the set is as simple as that for the 500-type. Another type known as the 533 is available for selective ringing party service.

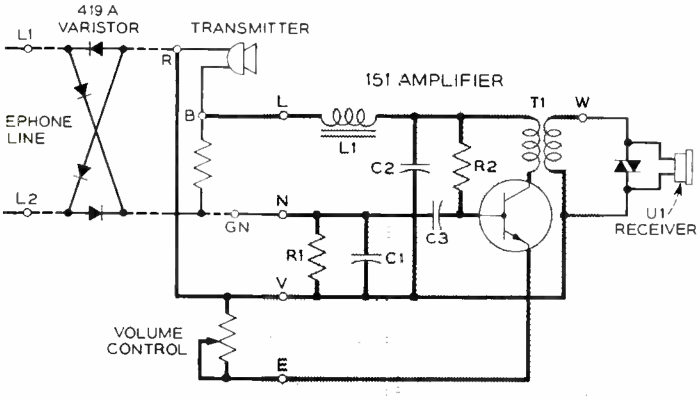


Fig. 3 — *Simplified schematic of the 151A amplifier inserted in the receiver circuit of a 500-type telephone set.*

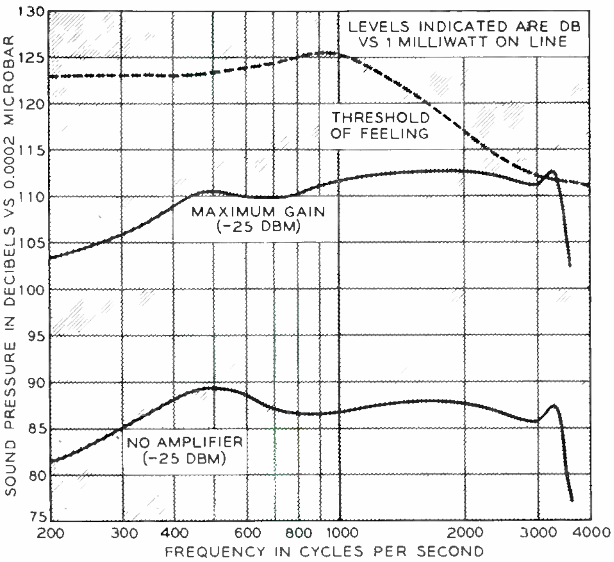


Fig. 4 — Sound pressures delivered to the ear by a close-coupled telephone receiver.

Measurements made at the San Francisco World's Fair in 1939 revealed that about 0.7 per cent of the people tested had hearing losses which experience has indicated require some amplification for satisfactory hearing over the telephone. Assuming that this distribution applies to the telephone population and that there are an average of two telephone users for each of the fifty million stations in the United States, it would appear that there might be 700,000 customers with impaired hearing, who would benefit by such a telephone set.

In this regard the potentialities of the set are evident, including the fact that it is simpler to install and maintain than previous types. It is the first of many applications of the junction transistor to the station set which will undoubtedly be made to improve service for the customer.

THE AUTHOR

A. J. Chase joined the Laboratories in 1930. Until 1938 he was concerned primarily with telephone transmitter carbon tests and transmitter maintenance, and from 1938 to the start of the war he was engaged in economic and maintenance studies of the station dial. During World War II Mr. Chase took part in the design, development, and testing of underwater sound reference instruments and an electronic-mechanical system for guiding torpedoes. Since the war he has been responsible for the maintenance of appraisal facilities for special tests of telephone apparatus and has engaged in the design, development and maintenance of service observing equipment. Mr. Chase received a B. of E.E. degree from New York University in 1938.

"Time of Day" Goes Magnetic

John McCarty, of the Audichron Company, points out the new features to Laboratories' Vice President M. H. Cook and A. D. Knowlton, Director of Design Engineering.

"Time of day" announcements to telephone customers calling a listed number started out modestly in the Bell System in the early 1920's. In the first system, a single telephone operator announced the correct time, as read from a regulated clock, into a network extending to each central office in the city.[1] Shortly, afterward, the Audichron Company of Atlanta, Georgia pioneered in the development of an automatic time-announcement machine to bring economical around-the-clock time service to smaller cities. Early models of this machine used the optical sound-on-film method and the machines were mounted in a low cabinet in the central-office operating room. These machines have been used both with and without a commercial announcement in some 180 cities throughout the country,[2] and answer approximately 3 million requests per day for the correct time.

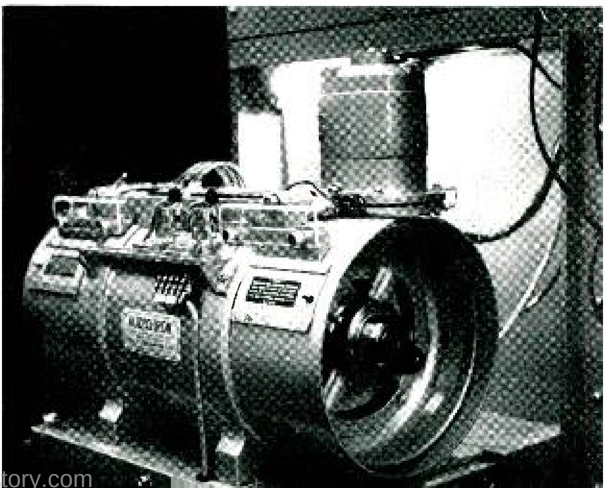
Recently, the Audichron Company completed the development of a new machine using magnetic recording to replace the sound-on-film technique formerly employed, and a model was recently demonstrated to members of the Laboratories, Western Electric Company, and the American Telephone and Telegraph Company. The magnetic recording medium used on the new machine is the "talking rubber"[3] developed by the Laboratories. The machine not only provides superior speech quality, but gives more flexibility in meeting the individual requirements of the various Associated Telephone Companies. The relatively large cabinet required for the older optical equipment is eliminated and the compact new design mounts within the framework of a standard telephone relay rack.

The cylindrical housing shown below contains a single drum on the right side and two drums on the left side with a drive mechanism in between. The right-hand drum can be used to reproduce any one of twelve different pre-recorded messages as a preamble to the time message, and can be replaced with another pre-recorded drum without stopping the drive motor. The two left-hand drums carry the hours and minutes recordings and are arranged to move into proper register with the passage of time to repeat the appropriate message. The center mechanism is driven by a synchronous motor connected to a precisely-controlled power supply.[4] A typical announcement might be, "Please do not dial until you hear the dial tone. The time is 3:47."

It is expected that the new magnetic time of day machines will be used in all new time bureaus and will gradually replace the older, less flexible optical machines in existing time bureaus.

R. F. MASSONNEAU
Special Systems Engineering

Drums on each end are driven by the vertical synchronous motor through the drive mechanism in the center.



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[1] RECORD, *March*, 1931, *page* 335; *December*, 1938, *page* 131; and *May*, 1931, *page* 272. [2] *September*, 1953, *page* 356. [3] B.S.T.J., *May*, 1954, *page* 530. [4] RECORD, *August*, 1954, *page* 308.

Emergency Radio Telephone System

F. B. COMBS *Transmission Systems Development I*
R. W. COLLINS *Switching Systems Development II*

Modern America leans so heavily on the telephone that temporary interruptions of telephone service can mean business failure, financial loss, or even the difference between life and death. Long interruptions might even mean military disaster should we be attacked. One of the means by which the Bell System can maintain continued telephone service during emergencies is a new VHF radio telephone system that provides practically static-free two-way communication over line-of-sight paths up to 25 or 30 miles long.

Modern telephone lines can withstand all but the most unusual situations, such as hurricanes, earthquakes, floods, and similar disasters. Most wires are now in either overhead or underground cables, and alternate routes are available in all but the most sparsely settled areas. Nevertheless, nature does go on the rampage occasionally and telephone circuits are temporarily put out of service. To meet these situations, various forms of radio communication have been used in the past, including a special emergency radio telephone system developed by the Laboratories in 1938.

One of the earliest uses of radio for emergency telephone service was in 1933 when a hurricane disrupted service between Palm Beach and Miami, Florida. For two days all telephone calls were handled in limited numbers via radio circuits. However, it took the New England hurricane of 1938 to really prove the value of radio for emergency telephone service. Radio equipment of all descriptions was brought into temporary service, since wire circuits were out for several days. Among the various types of equipment was the developmental model of the Laboratories' 221-type emergency radio telephone. This system operated in the range of 2 to 3 megacycles, and used voice-controlled relays to determine the direction of transmission. Having proved its worth, 221-type systems were made available to the Operating Companies and many were located at strategic points throughout the country. Since then, they have been "life-savers" during sleet storms, forest fires, submarine cable failures, explosions, landslides, and the occasional fall hurricanes along the East Coast. In 1953 alone, 853 hours of operating time were reported in 40 instances where they were used for this type of work.

As telephone service has grown, the need for emergency radio facilities has become correspondingly greater, prompting the design of a new system that would take advantage of various improvements in the radio art since the thirties. This new system operates in the band between 152 and 162 megacycles, and uses frequency modulation (FM) of two separate carriers for transmitting and receiving. The higher operating frequencies and the use of FM provide quieter circuits with less susceptibility to interference, and the separate transmitting and receiving frequencies permit simultaneous transmission in both directions. One of the first uses for the new system was as part of the vast telephone communica-

Fig. 1 — E. J. Henley operates the control unit of an emergency radio telephone terminal during Laboratories field tests of the system.

tion arrangements required during President Eisenhower's six-day trip to New England last June.

The radio channels used by the new system are those allocated for common-carrier mobile telephone service, making it possible in most cases to predetermine the extent of interference by operating on frequencies not in use in the locality. Since most mobile-service antennas produce vertically polarized signals, the antennas of the emergency system are arranged to provide horizontally polarized signals; this further reduces the possibility of interference.

When normal wire circuits are interrupted, emergency facilities must be capable of operating in almost any location. Transmission over the new system is effectively line-of-sight, up to about 35 miles, and it is therefore often necessary that the equipment be located on roof-tops or relatively inaccessible hills. Since portability and ease of installation are necessarily of prime importance, the equipment is so packaged that each unit can easily be handled by two men.

Weatherproof interconnecting cables permit the control terminal to be located up to 25 feet from the radio equipment if desired. The system operates from 117-volt, 60-cycle commercial power; since, however, power lines often fail under conditions that disrupt telephone circuits, a 750-watt gasoline-engine-driven alternator is included as one of the packages. An entire transmitting and receiving terminal, including the antenna and alternator, weighs approximately 1,000 pounds and can be transported to the required spot in a station wagon or two ordinary passenger cars, as shown in the illustration at the head of this article. Under favorable conditions, a radio terminal can be installed and placed in operation in approximately an hour by two trained men.

One package comprises the control terminal, effectively the "nerve center" of the system. This unit performs the essential functions of connecting the wire circuits with the radio equipment, and determining what types of connections can be used. It also provides metering, monitoring, and signaling facilities. A line-selector switch on the control unit panel permits a choice of three general types of circuits to be set up, taking care of most requirements. Because it was felt that simplicity and portability were of more importance than the ability to connect to all types of circuits the design does not include provision for certain circuits and signaling methods.

Figure 2 shows a typical use of the emergency radio telephone. Two central offices are normally connected by a 2- or 4-wire trunk employing voice-frequency, 20-cycle, or dc signaling. Suddenly the circuits are "out" — perhaps ice and falling trees have caused breaks over a twenty-mile section of line and it is estimated that hours or even days will be required to repair them. The radio equipment is immediately rushed to each end of the damaged section to provide communication between the two offices until the lines are repaired.

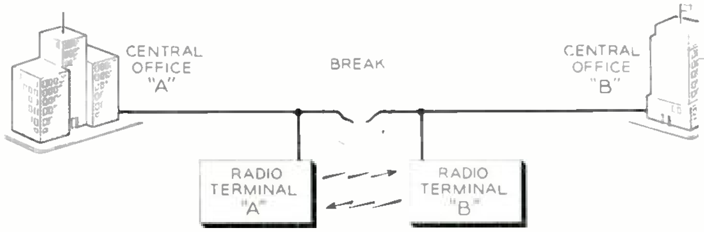


Fig. 2 — Radio replaces a missing section of a telephone trunk.

In the telephone business, the term "supervision" means certain signals and their use — signals that tell an operator or equipment in a dial central-office when to connect and disconnect. On trunks using single-frequency supervision, the emergency radio system carriers are radiated continuously. These trunks may employ either single-frequency (SF) dial pulsing or multifrequency (MF) key pulsing for signaling, and since the pulses are within the voice-frequency range, they are transmitted over the radio the same as the voices. However, even though MF key pulsing can be transmitted, it cannot be used in combination with dc supervision since there is no provision for relaying the dc over the radio link. Because of the wide variety of dc signaling in use, it was considered uneconomical to provide for relaying dc signals in the emergency radio set.

"Ring-down" trunks using 20-cycle ringing are handled by a special circuit arrangement. Supervision on these trunks is not automatic – the calling operator must ring the called operator to establish a connection, and then ring again when the call is finished, to tell her that the trunk may be disconnected. To provide this operation, the radio carriers are radiated continuously as before, but the 20-cycle ringing signal temporarily interrupts the one at the originating end of the radio circuit. Interruption of the carrier at the receiving equipment causes a 20-cycle generator to operate, ringing the distant operator.

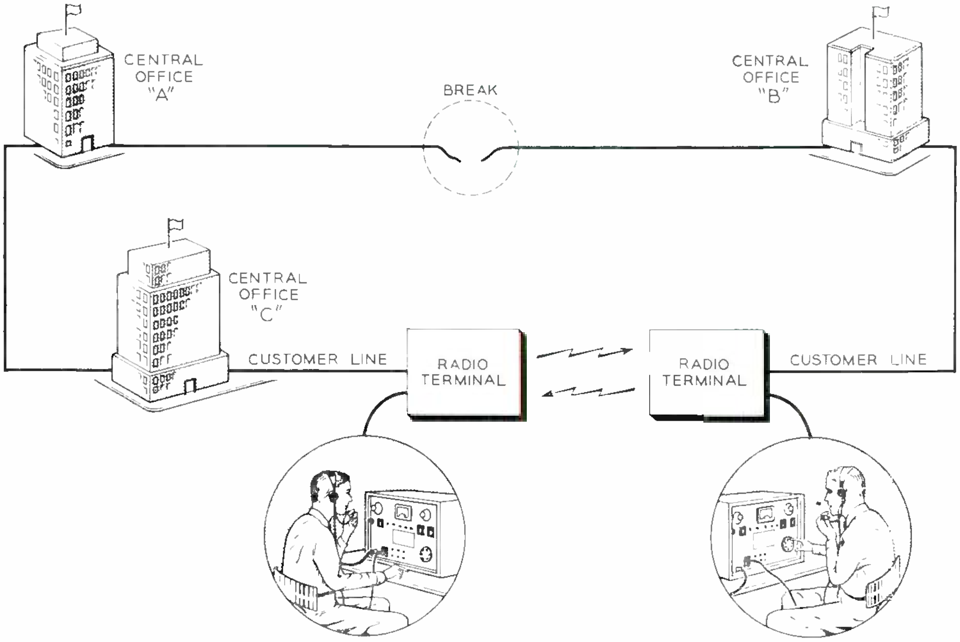


Fig. 3 — Two customer lines may also be used for emergency service. Two technical operators are required for this.

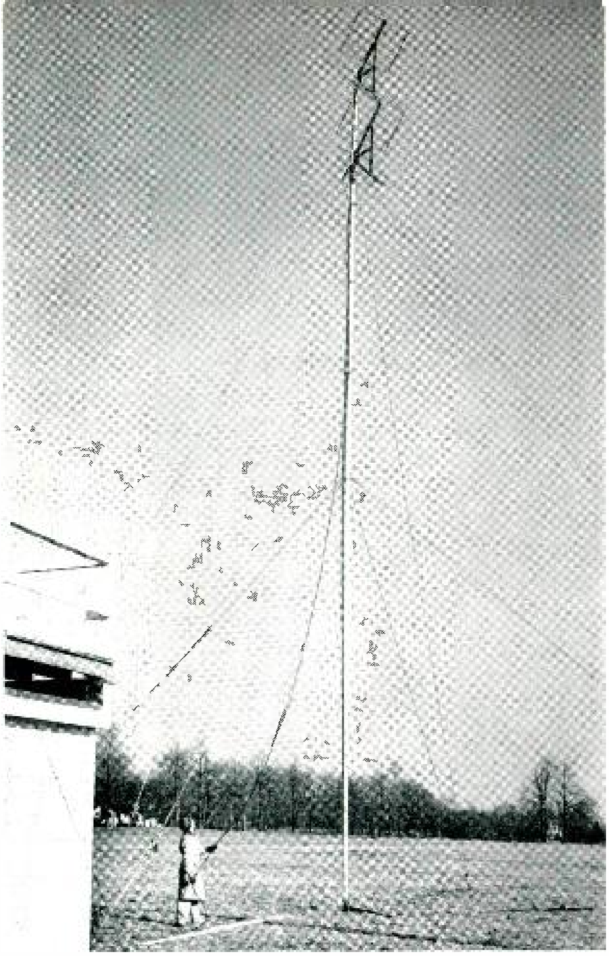
Sometimes it is necessary or desirable to maintain contact between a telephone office and a strategically located customer, such as a forest ranger. In this arrangement, the radio carrier is normally off but can be put on the air by the customer's lifting his handset, and then turned off by his replacing the handset. If the line connects to a manual office, this supervision is sufficient. Whenever a dial office is involved, an attendant is required at the radio terminal nearest the dial office. A buzzer and lamp on the control unit panel alert the attendant when a call needs assistance, and a dial permits him to send the necessary dial pulses to complete the call. He also provides any "on-hook" or "off-hook" signals that are necessary.

Fig. 4 — R. M. Wheatley operates the chain hoist to raise the antenna into position.

In extreme cases, two central offices can be connected together by using customer lines. Each line, Figure 3, is connected to an emergency radio set instead of to the customer, making the lines effectively parts of a trunk between the offices. When this is done, an attendant is required at each radio terminal to take care of all signaling and supervision.

Aside from the control unit, two other packages are of major interest – the radio transmitter and receiver units. The transmitter and receiver panels are of the types presently used in low-powered mobile telephone base stations. The transmitter is frequency modulated, with a power output of about 50 watts. Modulation-limiting circuits prevent the frequency deviation from exceeding the ±15 kc maximum permitted by the Federal Communications Commission. A carrier-operated relay signals the local attendant that the transmitter is "on the air" or warns of failure.

The receiver is of the double-superheterodyne type using crystal-controlled oscillators. A toggle switch on the panel permits a choice of two predetermined receiving frequencies in the 152-162 megacycle band, as well as two other predetermined



transmitting frequencies. A cavity-type filter in the receiving antenna circuit rejects the carrier from its companion transmitter, permitting simultaneous transmission in both directions.

Two aluminum corner-reflector antennas, one for receiving and one for transmitting, mount on a 55-foot sectional tubular aluminum mast. The antennas, mast, and a lifting boom are assembled on the ground, and the mast and antenna are then raised and held in position by guy wires. One man operates a chain hoist, Figure 4, while the other watches the guy wires to see that they are equally taut. After the mast is erected, Figure 5, the antenna can be rotated to its operating position from the ground. Where elevated sites are available or when the radio path is very short, half the mast may be used.

A spare-parts box includes a complete spare set of all electron tubes and fuses used in the terminal. Installation and maintenance tools, test equipment for general testing and for adjusting the radio transmitter for maximum power output, and interconnecting cables and instruction books are also carried in this box.

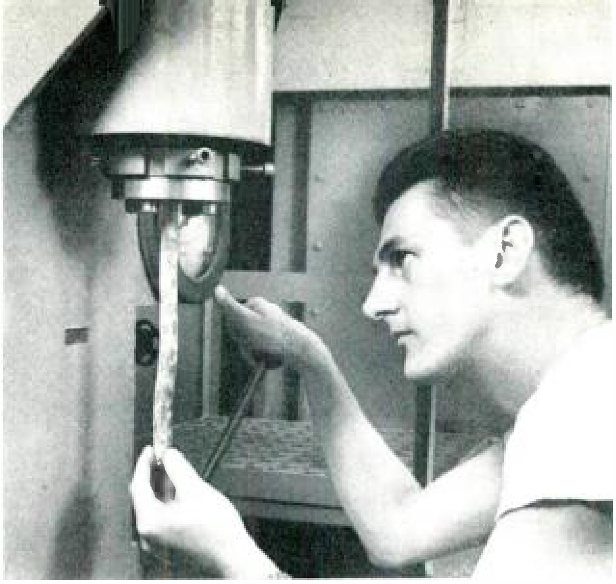
Fig. 5 — The complete antenna mast is 55 feet high.

THE AUTHORS

Frederick B. Combs joined the Laboratories in 1935 as a member of the Commercial Products Development Department. Until World War II, he was engaged in the mechanical design of aircraft and marine radio equipment, and the emergency radio telephone. In 1941 he transferred, on loan, to the Manufacturing Relations Department as the Bayonne and Jersey City representative of the Commercial Products Department. He was also concerned with the establishment of a manufacturing relations group at the Burlington, N. C., plant. Mr. Combs spent three years with the mobile radio group at Whippany, and since 1950 has been a member of Transmission Systems Development at Murray Hill. He attended Pratt Institute, receiving a certificate of mechanical engineering in 1925, and a certificate of industrial electrical engineering in 1936.

R. W. Collins received the degree of B.S.E.E. from the University of Notre Dame in 1928, and joined the New York Telephone Company in that same year. He engaged in the design and maintenance of outside plant and the maintenance of toll central office equipment until 1942, and joined a project of the National Defense Research Committee at Duke University during the war years. After the war, Mr. Collins developed maintenance methods for radio, television, inductive coordination, transmission, and plant protection for the New York Company, transferring to the Laboratories in 1952. He has since been concerned with the design of switching and control circuits for radio-telephone systems.

Precision Ceramics



W. F. JANSSEN *Chemical Research*

For many years processes in the manufacture of ceramic components could not be controlled rigidly enough to insure the desired electrical and chemical properties, nor could they be produced with the precise physical dimensions required in many modern Bell System applications. Now, research at the Laboratories has largely overcome these limitations, and precision ceramics are certain to be used widely in the communications industry.

The Laboratories has recently developed new applications for established ceramic formulas as well as new formulas for ceramics having special uses. Ceramic parts with the desired electrical and chemical properties can now be formed with dimensions as precise as those obtained in metals and other materials. Such precise components are especially useful in the construction of apparatus because of their great mechanical strength, their ability to withstand temperature extremes, and their wide range of electrical characteristics. The dielectric loss of ceramic materials, for example extends from very high to very low; their conductivities vary greatly; and their resistivities vary with temperature and voltage in unusual ways. Equally important is the fact that, within limits, these properties can be controlled and varied as desired.

Difficulties encountered in producing precision elements are inherent in the nature of ceramic materials, which are composed of one or more powdered minerals or other inorganic compounds intimately mixed. This mixture is made plastic by adding water or an organic plasticizer which may serve also as a temporary binder, and the resulting mass is pressed into shape by some molding process. The element is then hardened by "firing"—baking at high temperatures.

Variations in the raw materials and molding pressures during manufacture result in variations in the densities of the ceramics before firing. In ceramic terminology these are called "green" densities.

During firing, chemical changes cause the molded elements to shrink by various percentages depending on the proportions, kinds and particle sizes of the raw materials. This shrinkage is dependent upon the "green" density and makes it difficult to produce ceramic components with highly reproducible characteristics and precise dimensions.

The Laboratories has taken two steps toward overcoming these difficulties: first, sound chemical and engineering principles have been established so that each component produced will have the electrical and chemical characteristics required for the intended applications. Raw materials are selected on the basis of their chemical composition and freedom from undesirable impurities. They must meet stringent requirements with respect to both density and particle size, shape and distribution. The manufacturing processes are closely controlled to yield very intimate mixing and a very large surface area for the inorganic ingredients. The temporary organic plasticizers and binders are also carefully chosen and distributed through the mixture. All of these factors affect the rate and amount of solid state reactions which occur during firing and thus the quality of the product. Second, this program has

Fig. 1 — The author examining an assembly fixture. On the table are additional finished components compounded of a variety of ceramic materials.

provided means whereby the finished components, even those of complex shape, can be ground or fabricated to dimensional tolerances more precise than any previously available. Generally speaking, conventional grinding and other machine shop equipment has been adapted or converted to the use of wet diamond wheel grinding. However, special chucking arrangements are frequently needed and many new types of diamond tools have been devised and used. Some finished components are shown in Figure 1.

The five principal types of ceramic materials now used in the communications industry are:

1. The steatites, composed principally of talc (magnesium silicate), used for low-loss insulation at higher voltages, frequencies, and temperatures.

Typical examples are: spacers, bushings and grid frames in electron tubes, bearing and switch plate brackets, capacitor rotor shafts, crystal filter and electron tube sockets, coil forms and terminals.

2. Titanates, composed mainly of titanium and barium oxides, possibly with small additions of other oxides or silicates. Their principal uses are as capacitor or piezoelectric materials.

3. Fused silica made from quartz, high silica and borosilicate glasses for applications requiring low dielectric constants and extreme dimensional stability with temperature changes.

4. The ferrites, compounds formed with iron and other oxides, used as magnetic core materials in high frequency circuits.

5. The high alumina bodies containing more than 85% aluminum oxide. Their dielectric properties are similar to those of steatites but they have both higher temperature resistance and much higher mechanical strength. The illustration at the head of this article shows C. D. Parker testing the workability of an experimental mixture.

These five materials have different applications depending on their basic properties. Although in most cases the primary consideration is their effect on circuit characteristics, their role as structural members is also important. Both functions are often aided by the availability of metallic or glassy coatings which may be applied without degrading the dielectric properties or distorting the material.

Metallic coatings may be applied by various means. Vapor deposition, sputtering, and conducting paints may be used for pressure type electrodes. For soldered connections, fired-on compositions of noble metal and glass or sintered-on base metals are available. The sintered-on base metals and also base metal coatings formed by the dissociation of certain metallic hydrides, such as titanium or zirconium hydrides, are especially well bonded and are suitable for brazing. This last mentioned technique is used in assembling ceramics to metals by positioning the components in fixtures and using the hydrides as wetting agents for high temperature solders. Glasses are used as coatings and bonding agents in many ways. Their principal use as coatings is to protect surfaces against contamination by dirt or moisture, although conducting glazes are used sometimes to reduce corona on high voltage bushings. As bonding agents they are compounded to have a wide range of expansivities to match those of the materials to be joined and chemical stability in the reducing atmospheres used to protect the metallic elements from oxidation during assembly.

The techniques for making metallized precision dimensioned ceramics or other brittle material have

Fig. 2 — N. H. Bagley spraying glaze on a submarine cable component.

aided various fundamental studies. These include ferrites as pole pieces in tape recording equipment, and unusual shapes of brittle germanium for the study of the Hall effect.* Contributions to the research and development work in electron tubes have been particularly numerous. The development of fired metallic coatings adherent to the ceramic surface and chemically stable in electro-plating baths has made it possible to construct noise free and thermally stable induction coils and transformer windings. A transformer design based on these techniques is described in a previously published article.* By employing similar techniques and close matching of expansivities of ceramic and metal components performance variations due to changes in temperatures have been minimized in electrical measurement equipment.

Precision ceramics have found increasingly wide use in the communications industry. Further study of the nature of ceramic materials, coupled with refinements in shaping techniques, should result in many additional new applications.

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* Record, *March*, 1955, *page* 85.

* Record, *August*, 1954, *page* 292.

THE AUTHOR

W. F. Janssen began his career with the Bell System in 1930 as an instrument maker's apprentice in the Laboratories' Development Shop. He became a Technical Assistant in 1936, and until 1939 he was engaged in research on silicon carbide varistors and oxide thermistors. For a number of years he was active in experimental work on low loss ceramic insulators and on the design of crystal growing equipment. More recently he has devoted his time to the development of methods for producing precision ceramic components. Mr. Janssen became a Member of Technical Staff in 1945. He attended Cooper Union and Polytechnic Institute of Brooklyn.

Dr. Kelly Names New Members to the Bell System Technical Journal Committee

Dr. M. J. Kelly recently named four new members, including a Chairman, to the Editorial Committee of The Bell System Technical Journal. The memberships became effective September 1.

Brockway McMillan was named Chairman succeeding W. H. Doherty, who recently accepted a position as Assistant Vice President in Merchandising with the American Telephone and Telegraph Company. Other new members are John R. Pierce, who succeeded Mr. Doherty as Director of Research in Electrical Communications, and R. L. Dietzold, Director of Military Systems Studies, who replaces Vice President E. I. Green, in representing the Whippany laboratory. Mr. Green will remain as a member of the Committee, however. The other new member is K. E. Gould, Director of Facilities Development, named to the Committee in anticipation of the retirement of G. D. Edwards, Director of Quality Assurance.

Continuing on the Committee are A. J. Busch, Director of Switching Development, and A. C. Dickieson, Director of Transmission Systems Development I, as well as H. I. Romnes, Chief Engineer, and R. G. Elliott, Assistant Chief Engineer, who will continue to represent the American Telephone and Telegraph Company, and Vice President F. R. Lack and H. V. Schmidt, Engineer of Manufacture, who will continue to represent the Western Electric Company.

J. B. Fisk, Executive Vice President of the Laboratories, and Vice President G. N. Thayer, have been relieved of their duties on the Committee because of the pressure of other work.

Continuing to serve on the Advisory Board of the Journal are Dr. Kelly, F. R. Kappel, President of Western Electric Company, and E. J. McNeely, Vice President, American Telephone and Telegraph Company.

The author snips a worn spring from a wiper in service in the Laboratories.

Improvements in Wiper Springs for Step-by-Step Switches

In the maintenance of step-by-step dial systems, the wiper springs on 197-type switches require frequent replacement because of wear. On heavily used switches, such as line finders, wiper replacement has sometimes been necessary within one year. Wiper replacements were anticipated, however, since the materials used have been selected so as to wear out rather than to cause wear on the bank contacts over which they travel. Replacement of a switch bank is a costly, time-consuming operation and it is therefore preferable to replace the wipers.

For many years, wiper replacement was also a somewhat difficult job — although easier than replacing a switch bank. A complete wiper assembly consists of two contact springs, three insulators, a cord-guide holder, and a metal hub and set-screw. This assembly, Figure 1, is positioned on the operating shaft of the switch so that the two springs are held under tension against the upper and lower contacts on each level of the switch bank. Replacement of the complete assembly required that flexible leads be unsoldered from the springs, the set-screw loosened, and the assembly slipped off the shaft; then, of course, the new one had to be properly positioned and the leads soldered to it. In the meantime, the switch was out of service.

Experience showed that, in most cases, dirt accumulating on the upper bank contacts caused the upper spring to wear out first. Usually there was considerable life left in the lower spring. In 1940, a

Fig. 1 — A wiper assembly installed in a step-by-step switch.

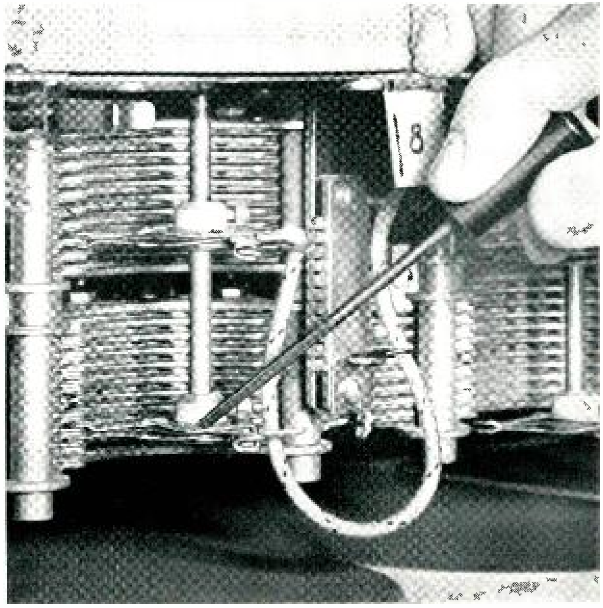

Fig. 2 — A replaceable spring is inserted into a wiper assembly.

replaceable spring, Figure 2, was made available at only a fraction of the cost of a complete wiper assembly. Moreover, a spring could then be replaced without the assembly being removed from the switch shaft or the leads unsoldered. Out-of-service time was greatly reduced. Both the original and the replaceable springs were stamped from plated brass.

In 1944, a further improvement was made in the replaceable springs by using a bi-metal material of phosphor-bronze and No. 1 metal. No. 1 metal is a contact material composed of 69 per cent gold, 7 per cent platinum, and the balance silver. A wedge-lay method was used where a block of precious metal was inlaid between two pieces of phosphor-bronze and the whole sheet was rolled to the correct thickness. The springs were then stamped out in such a way, Figure 3, that the No. 1 metal became the spring tip. Field studies showed that the life of wiper springs was increased by a factor of three to one.

Such increased life made it desirable that all wipers supplied on new switches be made with No. 1 metal tips. However, the cost was prohibitive since the wedge-lay stock was expensive. Accordingly, Western Electric Company sought some less expensive means of applying the precious metal. In 1954, a new replaceable spring was made available, stamped out of nickel-silver or brass, with No. 1 metal welded directly onto the tip, Figure 4.

Although the cost of a spring with a welded tip is still greater than that for one of brass, it is less than half the cost of one using the wedge-lay tip. Therefore, the use of tipped springs on original assemblies is now justified by the increased life and lowered maintenance, and all switch wipers delivered to the Telephone Companies since early 1955 have the welded tips.

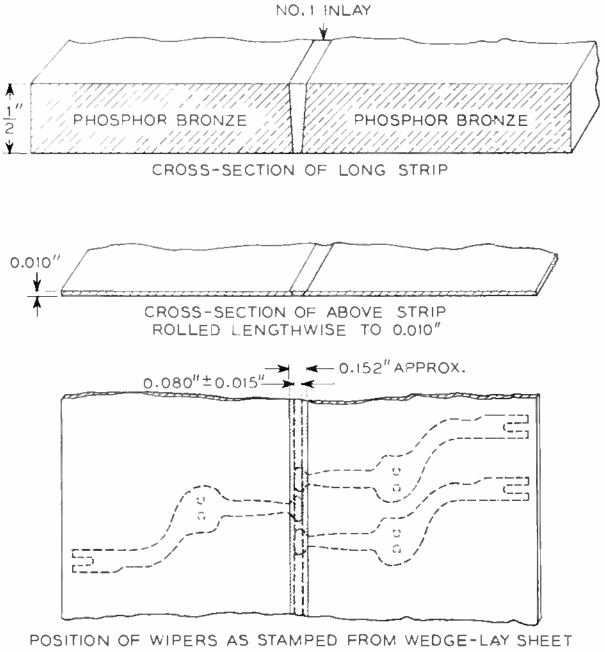

Fig. 3 — The wedge-lay material is rolled into a thin sheet and the replaceable wipers are stamped so that the No. 1 metal forms the tips.

F. W. Clayden
Switching Apparatus Development

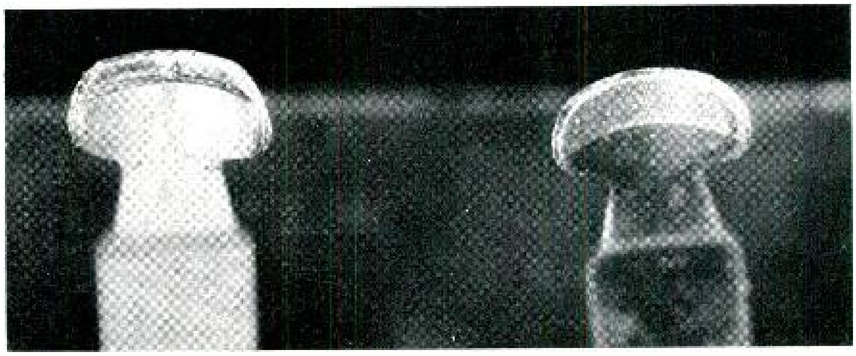

Fig. 4 — Comparison of a welded tip (left) and a wedge-lay tip.

Grown Junction Transistor Development

K. D. SMITH *Transistor Development*

With junction transistors the electronics art is carried into new and hitherto unreached micro-power levels and operating efficiencies. A junction transistor can oscillate or amplify at a level of total power consumption of less than one microwatt, and with a ratio of useful power output to total power consumed exceeding that of any electron tube. This and similar devices are expected to fill many needs where small size and limited available power are the important design considerations.

Application of the 4A germanium grown junction transistor in a special customer's set for persons with impaired hearing marks the first use of a transistor in telephone equipment installed in the home.* This n-p-n transistor, which acts as a voice amplifier, requires so little battery power that it can be supplied from the "talking current" sent along the wire from the central office. The 4A, along with other grown junction transistors which have been developed for many purposes in the telephone system, has opened the door to a wide variety of possible improvements in telephone service. Several of these are already in the design stage. In the illustration above, the author (right) and D. F. Ciccolella are shown inspecting a rack of n-p-n grown transistors that are used in various laboratory tests.

The construction of an n-p-n grown junction transistor begins with the preparation of a single crystal of germanium which has the two p-n junctions grown into it.† In the growing process, a seed crystal is slowly withdrawn from a bath of molten germanium in such a way that more germanium solidifies onto the seed, which then grows into a good-sized crystal. The molten germanium is n-type at the start. At the proper moment in the withdrawing process a small pellet of an acceptor (p-type) impurity is added, to be followed a few seconds later by a somewhat larger pellet of a donor (n-type) impurity. These impurities dissolve in the melt and control the type of the germanium subsequently grown. The resulting crystal then has a thin layer of p-type material sandwiched between terminal sections of n-type material. This structure is sketched in the upper left hand part of Figure 1. The p-type layer may be about a thousandth of an inch in thickness. The crystal is sliced, leaving the thin p-layer in the center of the slice, which is then cut into rectangular bars, square in cross section. Each bar is fabricated into a transistor, as illustrated, by soldering its ends to supporting and conducting leads comprising a stem assembly. The germanium bar is etched to re-

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* See page 361. † RECORD, *February*, 1955, *page* 41.

duce undesirable electrical effects caused by irregular surfaces, a very fine gold lead is then welded to the central p-layer, and finally the transistor is encased in a hermetically sealed can.

Some of the finer points of the fabrication techniques will be discussed later, in connection with the important effects they have on the transistor's characteristics, but it is useful now to discuss the principles of operation of this device. A preliminary discussion of the physics of p-n junctions has been given by M. Sparks in an earlier issue of the Record[*], and the following paragraphs will further develop some of the pertinent concepts.

A descriptive analogy is drawn in Figure 2 between a junction transistor and a waterfall. Both can be used as power amplifiers. Suppose the waterfall to be provided with a dam which can be moved up or down to control the flow of water. Raising or lowering the dam can be accomplished by the use of a small amount of mechanical power, while much more power is obtained from the wheel at the bottom of the fall. In the transistor, the left hand, or emitter, section acts as a reservoir for free electrons. The flow of these electrons over the left-hand junction is controlled by raising or lowering the electrical potential difference between the emitter and the central, or base, section of the transistor. This control requires the expenditure of only a small amount of electrical power, which is furnished by the signal to be amplified. These electrons then deliver much more power, in the form of an amplified replica of the input signal, as they flow over the electron potential fall at the right-hand collector junction. The extra power of this amplified signal comes from the battery in the collector circuit.

With certain reservations, the waterfall analogy can be pushed still further. In an actual waterfall, all the water flowing over the dam does not reach the water wheel, even in an ideal situation; some is lost by evaporation and as spray. In the transistor, losses occur in the current flow between emitter and collector because some of the electrons recombine with positive holes, which are plentiful in the base sandwich layer. By making the base layer very thin, one can keep this loss down to less than one percent of the current flowing over the emitter junction. The ratio of electron current collected to the total current entering the base layer is called the current transmission factor, alpha (α). As will be pointed out later in this article, this quantity is an important measure of transistor performance.

The analogy becomes fuzzy, however, if one tries to push it too far. In the waterfall, there is nothing that corresponds to the base layer of the transistor; water flowing over the dam at once enters the fall. In the transistor, a physical separation of the emitter and collector is necessary to provide for applying electrical voltages separately across the two junctions. Closer examination of the operation reveals also that the water flow losses occur in the fall, while in the transistor the electron current losses occur, not in the collector junction, but in the base layer.

The circuit performance characteristics of a transistor are directly related to its structure and fabrication. In the grown junction transistor it is possible to control the electrical properties of the emitter, base, and collector regions by proper additions of impurities to the molten germanium in the preparation of the crystal. The thickness of the base region is regulated by very precise temperature control and by careful timing of the impurity additions. The physical size and structure of the transistor are important design parameters also. The larger the transistor, the greater the power it can dissipate without overheating. Since the electrical capacitance of a p-n junction is directly proportional to its area, however, increasing the size of the transistor increases its collector capacitance. But this, in turn, reduces its useful frequency range.

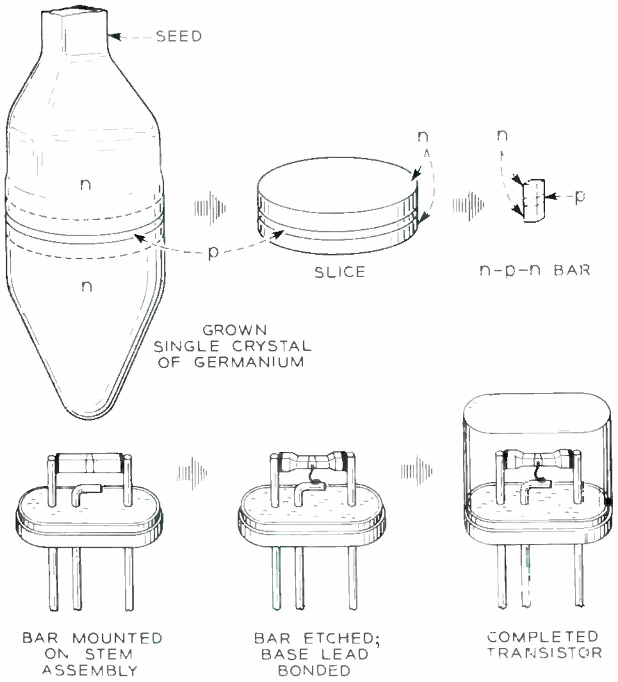

Fig. 1 — Steps in the fabrication of a germanium grown junction transistor.

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[*] Record, *June*, 1954, *page* 203.

Germanium is a brittle material, about as hard as glass, so that when it is cut or shaped with a carborundum or diamond-faced wheel, the cut surface is so damaged as to be useless as a part of the transistor. The crystal perfection is disturbed for some distance below the surface, and this damaged layer is riddled with a network of tiny cracks and disoriented crystal debris. As was discussed in a previous article,[*] such a disturbed layer is a prolific generator of unwanted minority carriers. For example, a disturbed layer will generate positive carriers in negative-conductivity germanium. The liberation of such particles in the neighborhood of active junctions can so interfere with the processes of emission and collection of signal-carrying currents as to degrade the performance of the device seriously. All of this damaged material must therefore be removed from the germanium bar in the region near the p-n junctions before the transistor can be completed. This is done by an electrolytic etch, in which the germanium bar is made the positive electrode. About three thousandths of an inch are dissolved around the perimeter of the transistor bar by this etch, and this leaves the germanium surface clean and smooth, free of cracks or chips.

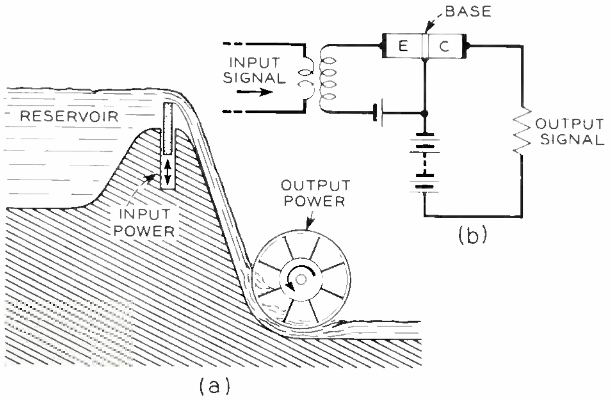

Fig. 2 — The waterfall (a) is analogous to the n-p-n junction transistor (b).

A delicate operation in fabricating the grown junction transistor is the attachment of the base lead to the p-region. The problem is to weld a gold wire, about two thousandths inch in diameter (considerably less than the diameter of an average human hair) to a particular region of the smooth germanium bar, when this region is itself thinner than the diameter of the wire. The end of the gold wire is pointed or flattened, and the wire is mounted in a micromanipulator (Figure 3) to allow accurate positioning of the contact. The point is then moved along the bar until it is known, by electrical test, that the point is in contact with the base region of the n-p-n element. The actual weld is made by passing a current of about two amperes through the gold wire to the germanium for a few milliseconds. This current heats the contact region sufficiently to form a little puddle of gold-germanium alloy; on cooling this bonds the wire to the germanium.

Even with the greatest care, this weld may be somewhat wider than the base layer. To avoid short circuiting the collector and emitter junctions at the weld, the gold wire is "doped" with a small percentage of a p-type impurity, such as gallium. This insures that the germanium-gold alloy region will be strongly p-type and will, in fact, act as part of the base region, even though it extends into what was n-type germanium before the bond was made. Figure 4 shows a section through a typical base band. The etch used to bring out the emitter and collector p-n junctions has selectively attacked the material right at the bond, producing the illusion that the wire has become detached. The local enlargement of the base layer near the bond in consequence of the doping is easily seen. In particular, the right hand or collector junction has been locally "pushed over" so that it now extends slightly into what was previously the collector n-type portion of the structure.

During the fabrication process, tests are applied to insure that the electrical performance of the fin-

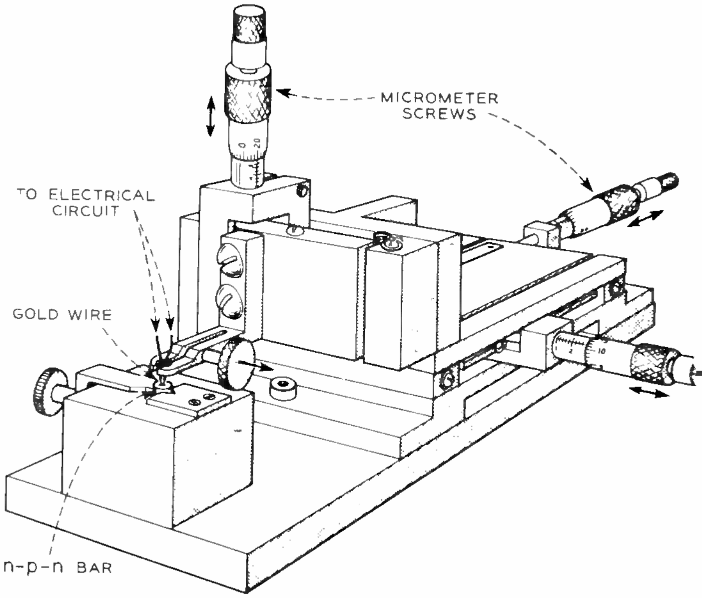

Fig. 3 — The correct position for bonding is determined by moving a gold wire over the surface of an n-p-n bar with the aid of a micromanipulator.

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[*] Record, *July*, 1955, *page* 260

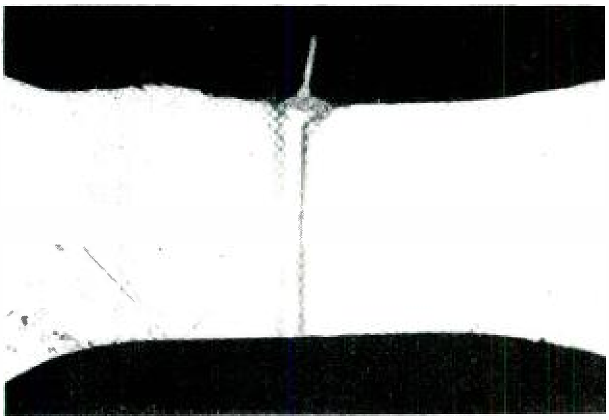

Fig. 4 — An n-p-n section of a transistor, with gold wire welded to central or base layer. Note broadening of p-layer at point of contact.

ished transistor will be as required. After the base lead is attached, the transistor is complete except for final mechanical protection. This is afforded by sealing the transistor inside a metal can. After a short aging period, the transistor is ready for final electrical tests and coding.

As mentioned earlier, the ratio of electron current collected to the total current entering the base layer (alpha) is one of the most important properties of the transistor. For junction transistors under normal operating conditions, alpha is slightly less than one, which means that there is a small loss in electron current that appears as a small current in the base lead. The ratio of collector current to this small base current is given by the expression $\alpha/1\text{-}\alpha$, a typical value of which may be about 50. Now, if we connect the transistor into a circuit like that in Figure 5, where the input signal is introduced into the *base* lead, the ratio of collector output current to signal input current is given by the same expression. That is, in such a "common emitter" circuit the output current may be 50 times the input current. The closer alpha is to unity, the higher this figure will be. As has already been pointed out, one way to push the value of alpha closer to unity is to reduce the width of the base layer, thus reducing the time in which an electron could recombine with a hole as it crosses the base layer. Another way is to grow the base layer as free as possible from imperfections and impurities which might subsequently act as recombination catalyzers in the completed transistor.

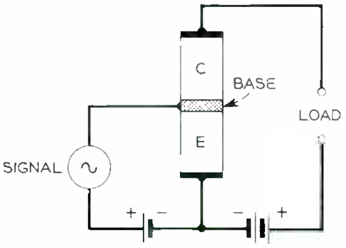

Fig. 5 — The "common emitter" circuit: signal introduced into base lead results in high current gain.

Another important performance index is the way in which the current transmission factor alpha depends on the signal frequency. For any application it is desirable that alpha be independent of frequency over the frequency band of interest. The design theory of parallel-junction structures predicts that the frequency cut-off of alpha (the frequency at which alpha has decreased to 0.707 of its low-frequency value) is inversely proportional to the square of the base thickness. Thus, for high frequency operation the base must be very thin. In an n-p-n grown junction germanium transistor, a frequency cutoff of five megacycles per second requires that the base region of the transistor be less than one one-thousandth inch in thickness.

An example of the effect of the germanium material properties on performance of the transistor is found in the minority carrier lifetime. This quantity is a measure of the length of time an electron or hole can survive in material of the opposite conductivity type before it recombines and is hence lost as a carrier of current. Typical minority carrier lifetimes in transistor germanium are a few tens of microseconds. Lifetime is sensitively dependent upon the purity and perfection of the crystal and the cleanliness of its surfaces. Long lifetime is particularly desired in

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TABLE I — COMPARISON OF DEVELOPMENT MODEL AND PRODUCTION TYPE GROWN JUNCTION TRANSISTOR

Typical values of parameters measured at $V_c = 4.5$ V., $I_e = -1.0$ Ma.

Parameter	*M-1752 Development model*	*4-C Production model*
Short circuit current transfer factor, h_{21} ($h_{21} = -\alpha$)	0.97	0.98
Short circuit input impedance, h_{11}	37	33 ohms
Open circuit feedback voltage ratio, h_{12}	4.0×10^{-4}	1.1×10^{-4}
Open circuit output admittance, h_{22}	2.0×10^{-6}	1.5×10^{-6} mho
Collector capacitance	12	8 $\mu\mu$f
Collector leakage current	7	1 μA
Frequency cutoff, fα	1.5	3 mc
Noise figure	20	17.5 db

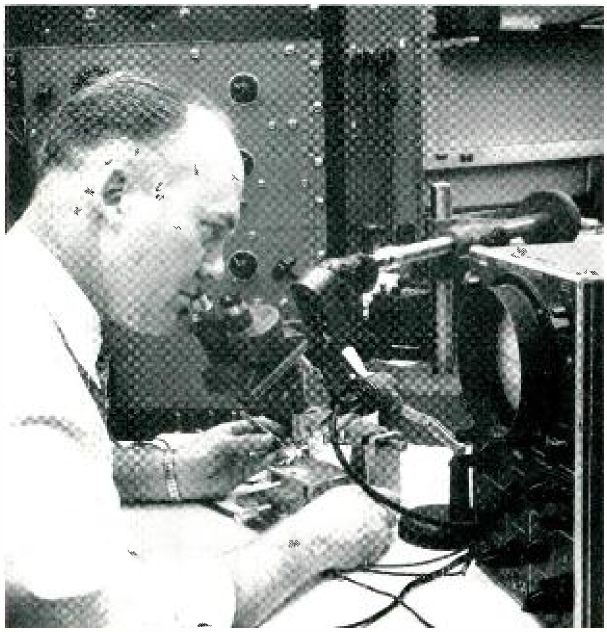

Fig. 6 — R. L. Johnston bonding lead to n-p-n junction bar in micromanipulator. Oscilloscope at right tells when correct position for bonding is found.

the base layer in order to reduce the transit loss of the electron current crossing from emitter to collector. It is desirable also in the emitter and collector regions of the transistor near the junctions because short lifetime material, like disturbed surface layers, is a copious generator of minority carriers which degrade junction performance.

Table I compares typical electrical parameter values for a production-code, grown junction n-p-n transistor with those of its development prototype. Observe that as the transistor passed from development to production, improvements were made in all the parameters cited. These improvements result from the close control of materials properties and fabrication processing which are made possible by the use of production methods. The 4C transistor is intended for voice-frequency amplifier service at low power levels. The M-1752 is a general purpose junction transistor for voice- and carrier-frequency applications. Both of these transistors have rated power dissipations of 50 milliwatts, and they are made in a similar manner. Another transistor design using n-p-n grown crystal material is the high-frequency tetrode, which was the subject of an article previously published in the RECORD.*

Another n-p-n transistor, the A-1858, developed from the M-1752 prototype, is the amplifier device used in the P carrier system, now in experimental operation at Americus, Georgia. About forty of these transistors are associated with each channel, exclusive of those used in repeater equipment, serving in amplifiers, signal generators, and in control applications. The economy of operation of these devices is strikingly illustrated by the fact that an entire transistor terminal, using about 40 A-1858 transistors, is operated with a power input only one-fourth that required by the heater of one conventional telephone repeater tube.

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* RECORD, *April*, 1954, *page* 121.

THE AUTHOR

KENNETH D. SMITH received the B.A. degree from Pomona College in 1928 and the M.A. degree from Dartmouth College in 1930. He then joined Bell Telephone Laboratories where for about ten years he assisted in the development of laboratory testing facilities at carrier and radio frequencies, and laboratory and field testing facilities for coaxial cable systems. During World War II, Mr. Smith worked on the design and development of proximity fuses, and the design of radar bombing equipment. Following the war, he engaged in development work on broadband microwave radio systems, and from 1951 to 1954 he was concerned with junction transistor development. At the present time, Mr. Smith is directing the work of a group responsible for developing large area silicon devices including the Bell Solar Battery.

Overload Control in No. 5 Crossbar

W. WHITNEY *Switching Systems Development I*

At one time or another, most people have found some difficulty in making telephone calls because of an unusual amount of telephone traffic. The additional calls through a telephone office at such times impose unusually heavy loads on the common-control equipment and delays may occur. In the No. 5 crossbar system, special circuit arrangements have been included to control possible overloads. Acting somewhat like safety-valves and gauges, the special circuits greatly reduce the effects of heavy traffic and maintain the best service possible under overload conditions.

It is a cold, snowy Friday in December, just before Christmas. Students home from college are trying to get in touch with their friends, housewives are Christmas shopping by telephone to avoid going out, high school students are visiting by telephone after school, and businessmen are making last-minute calls to clean up the week's affairs. Most of these calls are in addition to the normal traffic through the local telephone office. Under these conditions, an overload is quite possible.

One of the advantages of common-control switching systems such as No. 5 crossbar is that extra features can be provided economically in the few large control circuits — features that facilitate maintenance by testing potential trouble points on every call, and others that take into account slow-dialing customers by allowing more than ample time for them to establish their calls. However, these features all take time, and delays in the common-control circuits during overload conditions will tend to react on other circuits. One circuit delays another, that circuit delays a third, and so on down the line. This "snow-balling" effect can become serious enough that the call-carrying capacity of the office may actually be reduced unless something is done.

An office can become overloaded in many ways, and the No. 5 crossbar system provides several circuit arrangements to alleviate their effects. Some of these circuits insure that all customers get equal treatment under either normal or overload conditions, and that all equipment is used in the most efficient way. Others act automatically to change or cancel certain functions in response to detecting devices, just as safety valves let off pressure when it builds up. Still others, comparable to gauges, merely indicate that pressure is building up, and leave it to the attendant's judgment whether something should be done.

Typical of the circuits that insure efficient usage and equal treatment are the various preference chains in the connectors.* Marker connectors provide access to combined markers† for originating

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* RECORD, *February*, 1950, *page* 56. † RECORD, *November*, 1950, *page* 502.

registers, incoming registers, and line link frames. Since only one circuit can gain access to a marker at a time, it is up to the connectors to control the order in which the diverse types of competing circuits are served – the preference chains do this. Originating registers are given first preference, then incoming registers, and finally line link frames. In the typical preference chain of Figure 1, once an originating register has seized a marker, all incoming registers and line links are "locked out" from that marker, even though all demands are simultaneous. The principle of preference and lockout is used throughout the connector array in different ways. For instance, a preference circuit determines in what order markers will be seized, the preference order for each connector is different for different markers, and the connectors are alternated between two markers for first preference. The illustration at the head of this article shows the author pointing out a feature of an originating register marker connector to F. P. Cirone.

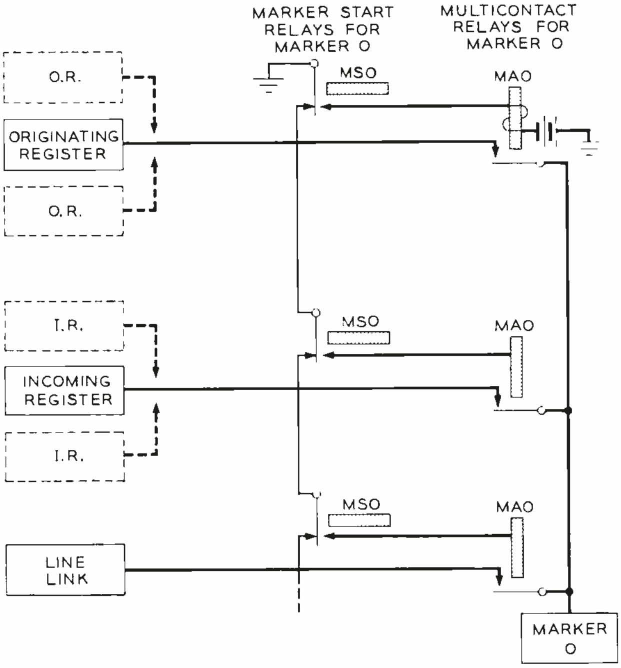


Fig. 1 — The simple preference chain used to control access to a marker.

Whenever any connectors are waiting to be served, all connectors that have been served are locked-out until the other waiting connectors are served. At that time, all connectors are freed, so that those waiting can again compete through their preference chains for available markers. This arrangement, known as "ungating," assures equitable treatment to all connectors during normal telephone traffic conditions that occur in the central office.

However, when an overload occurs, more line link marker connectors may be ungated than can be served by available originating registers, since the registers may be delayed in getting access to markers to unload calls they have registered. Here is where the safety-valve arrangement comes in – when all originating registers are busy, their connector lock-out feature is cancelled, giving the registers a better chance of reaching a marker.

Where the number of combined markers exceeds about three, it has been found expedient to split them into two new types – dial-tone and completing markers. Dial-tone markers are comparatively simple since they need only to connect calling lines to originating registers for dial tone. Line links have immediate access to a group of dial-tone markers. The preference circuits are limited to controlling the access of originating registers and incoming registers to completing markers, and the ungating feature is omitted.

Another automatic change in functions during overload conditions is the reduction of register "time-out" intervals. These are the waiting times before various circuits "time-out" and become available to other calls. Normally, the time-out interval in originating registers is 19 to 37 seconds for all delay conditions. These include permanent signals that occur when a customer takes his receiver off the hook and doesn't dial, partial-dial time-outs that result when a customer fails to dial as many digits as he should, and stuck-register time-outs that come about through no action on the customer's part but because the register cannot complete its functions due to trouble or traffic delays. When all registers are found busy by a marker attempting to connect a calling customer to a register, overload relays in all registers are operated, reducing the permanent signal time-out interval to 9 to 18 seconds and the partial-dial interval to 4.4 to 8.4 seconds. These shorter time-out intervals will prevail as long as all registers are busy and for a short interval thereafter. This reduces the waste usage of registers during overloads that results from customers dialing all or part of a called number before they receive dial tone. A similar time reduction for incoming registers goes into effect when all the incoming registers in a link group become busy at the same time.

Still another effective automatic overload feature is cancellation of the "cross and ground" test normally made by a marker to detect troubles within the central office. Since these tests are made on all calls served by a marker during normal traffic periods, the probability of a trouble occurring and not being detected during a heavy traffic period is so small that the 25 per cent reduction in marker work-time achieved by cancelling the test is decidedly worth while during heavy traffic periods. The device in the marker used to define "heavy traffic" for this purpose is quite simple and ingenious – a slow-release relay is held operated while a marker is in use and starts to release when the marker is freed. If traffic is so heavy that the marker is re-seized before the slow relay releases, the cross and ground test is cancelled for that usage. Another feature cancelled under this condition is the automatic production of a trouble record in case an associated sender becomes "stuck" – the sender will time out and dispose of the call anyway, and the prolonged marker work-time required to make a trouble record can be avoided during heavy traffic.

At the maintenance center in a No. 5 crossbar office, Figure 2, a lamp panel indicates the usage of all common-control circuits in the office, so that experienced maintenance personnel can get a fair idea of the traffic situation in the office at any instant. Lamps also indicate when all markers are busy, all registers are busy, and all senders are busy, with delayed audible alarms; these signals are comparable to gauges. Some of these signals are multipled to the operating room, in the same or a distant building, so that the traffic people can also determine when there is an overload condition. This is desirable so that they may put on more operators as needed, to handle the added switchboard traffic.

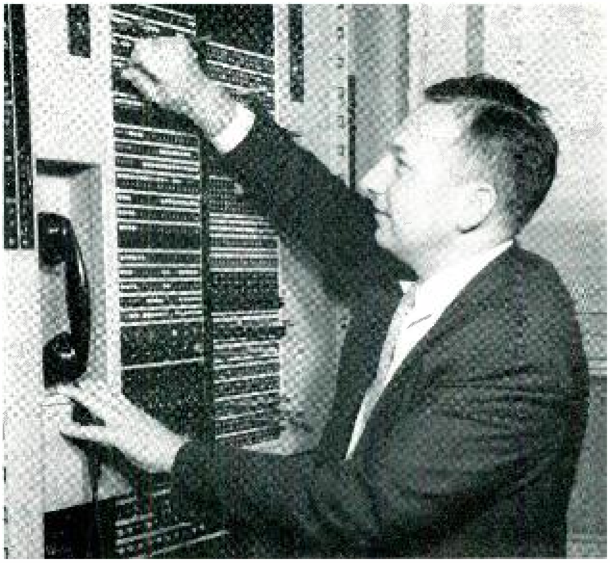
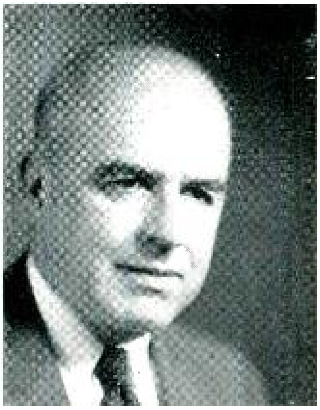


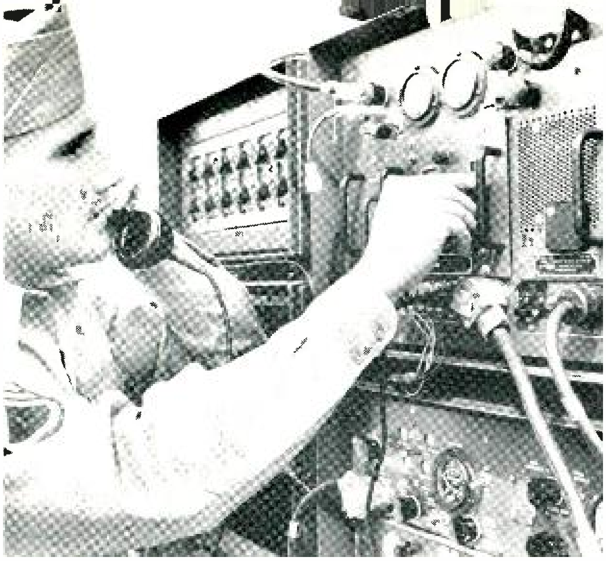
Fig. 2 — W. W. Connick makes a change in the circuits at the traffic-control lamp panel.

With all these safeguards against the effects of overloads, the performance of the No. 5 crossbar system is maintained at a high level even under abnormally heavy traffic conditions.

THE AUTHOR



Wiley Whitney entered the student training course of Western Electric in 1923, after receiving his B.S. degree from Kansas State College. Upon completion of the course he joined the Engineering Department of Western Electric, which became Bell Telephone Laboratories in 1925. Mr. Whitney was concerned with manual, panel, step-by-step, and PBX circuits until 1932 when he was assigned to A.T.&T. for design of crossbar toll facilities and toll switchboards. During World War II he was attached to the Signal Corps as a civilian in Washington, D. C., and North Africa. Since the war he has been engaged in the development of No. 5 crossbar. In March of this year, Mr. Whitney was assigned to the line concentrator development.



Military communications have for many years depended to a great extent on wire circuits, but radio is becoming an increasingly important factor in military planning and operations. To take full advantage of the best features of both wire circuits and radio, the Laboratories has developed a new VHF-UHF radio set that integrates with carrier equipment used on spiral-four cable. Up to twelve telephone channels can be handled by the system at one time, spanning distances as great as 1,000 miles with any desired combination of cable and radio links.

New Military VHF-UHF Radio Set

A. L. DURKEE *Systems Engineering*

Adequate communication facilities are indispensable to our military services, in peacetime as well as in war. The extensive arrangements now being provided for national defense depend for their effectiveness on the availability of a well-integrated network of wire and radio communication circuits, capable of handling telephone, telegraph, facsimile, and other types of signals with the greatest possible speed and a high degree of reliability.

Although wire circuits are the backbone of this network, radio is playing an ever greater role. Aircraft, ships at sea, and other mobile units must naturally depend on radio for communication. Radio is also advantageous for many fixed installations where wire line construction would be difficult, as in mountainous country or places where large bodies of water must be crossed. In addition, radio has a further advantage in that circuits can be installed and system arrangements altered as rapidly as the situation demands. This advantage is becoming more and more important in military planning.

During World War II, a new type of general-purpose cable, called "spiral four,"* was made available for military use, together with a four-channel carrier system† to operate over the cable. Improved carrier systems‡ have recently been developed for use on spiral four, capable of transmitting either four or twelve channels. To serve as an alternate for various wire and cable facilities, a transportable, multi-channel radio relay system was needed; as one of the specifications, the Signal Corps required that such a system be usable directly with the new spiral-four carrier equipment. As a result, Radio Set AN/TRC-24 uses either the four-channel (AN/TCC-3) or twelve-channel (AN/TCC-7) terminal equipment of the cable carrier system, permitting radio and wire links to be integrated into communication lines up to 1,000 miles long.

A complete AN/TRC-24 radio set consists of a transmitter, a receiver, a transmitter power-supply, transmitting and receiving antennas with reflectors and transmission lines, a 45-foot sectional mast to support the antennas, and an assortment of spare parts and accessories. All this equipment is packaged in a number of rugged, compact units designed for portability, and any package can be easily handled by two men. The equipment can withstand rough handling and will operate satisfactorily under any climatic conditions. It is designed to operate on 105-125 or 210-250 volts at 50 to 60 cycles. Power may be supplied from commercial lines or from a mobile engine-driven alternator.

Since the radio relay system integrates with spiral-four equipment, the radio terminals use the carrier terminal units already available. The four-channel terminal "stacks" the voice channels frequency-wise in the range from 4 to 20 kc, with a narrow-band order or service channel from 0.3 to 3.0 kc. The twelve-channel terminal "stacks" twelve channels in the range from 12 to 60 kc, and limits the service

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* Record, *April,* 1943, *page* 251. † *December,* 1943, *page* 168. ‡ *July,* 1955, *page* 274, *and August,* 1955, *page* 290.

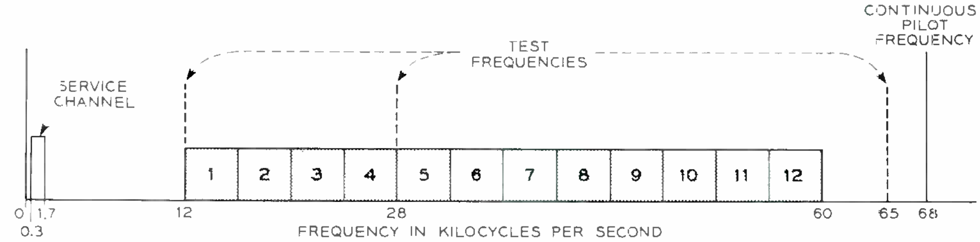
channel to 0.3-1.7 kc. The output of a twelve-channel AN/TCC-7 terminal is shown in Figure 1. A continuous pilot frequency at 68 kc is used for regulation, and test frequencies at 12, 28, and 65 kc are also used when they are needed for adjustment and test purposes.

The radio relay system finally evolved operates in the frequency range from 100 to 400 mc, and uses frequency modulation (FM). It is intended primarily for use on line-of-sight transmission paths up to about 30 miles in length. Two radio sets "back-to-back" are used as a radio-frequency repeater to cover longer distances, and as many as eight repeater sections can be used in tandem to form trunks about 200 miles long. A number of these trunks can also be connected together or with other facilities to form longer, more complex networks.

For line-of-sight distances the frequency range from 100 to 400 mc offers several advantages. These frequencies are not normally reflected from the ionosphere, and the 100 watts delivered by the AN/TRC-24 transmitter will not send them very far beyond the horizon. Interference, either natural or man-made, is thus minimized. Fading is comparatively mild on line-of-sight paths at these frequencies, and there is little or no atmospheric noise (static) to contend with.

Between 100 and 225 mc, 250 radio channels are available, spaced 0.5 mc center-to-center, and between 225 and 400 mc, 175 channels with 1 mc center-to-center spacing. Channel selection and frequency control are accomplished with plug-in radio-frequency tuning units and a crystal circuit built into the radio transmitter. Harmonics of a 0.5 mc or 1.0 mc crystal oscillator are used to "lock" the transmitted carrier at the proper frequency. The receiver is kept tuned to the incoming signal by an automatic frequency control circuit.

Fig. 1 — The carrier terminal "stacks" twelve telephone channels between 12 and 60 kilocycles.



The availability of many channels and the ease with which channels can be changed permits considerable freedom in laying out a network so as to avoid interference. Of course, some restrictions must still be placed on the allocation of channels for each link in a relay system. For example, Figure 2, two repeater sections require four different channel allocations to prevent interference. If, however, the system is extended, the same frequency allocations may be used in subsequent sections provided those sections working on the same frequency are far enough apart to avoid over-reach interference. Frequency assignments ordinarily can be repeated at intervals of about 100 miles.

AN/TRC-24 circuits 1,000 miles long may involve as many as 40 radio repeaters; consequently, transmission characteristics of the radio sets must be good enough so that satisfactory operation is obtained when 40 are connected in tandem. Distortion in repeaters must be minimized, and noise contributed by the individual repeaters must be low enough so that the total noise in a 1,000-mile circuit will not be excessive. In designing the system, the objective was to provide performance comparable in quality to that obtained with Bell System long-distance circuits.

Noise in a radio system arises from a number of sources. The principal contributions are: noise generated in the carrier terminal equipment, fluctuation noise produced in the radio receivers, external radio-frequency noise and interference, and intermodulation noise resulting from cross-modulation of various components in the transmitted signal. Limits on the permissible levels of these several types of noise, consistent with the desired over-all noise performance, became the basis for determining such system parameters as transmitter power, antenna gain, carrier-frequency deviation, and radio-frequency bandwidth.

Intelligence transmitted by the radio system consists of either four or twelve telephone channels "stacked" to form a wideband signal. The use of amplitude modulation (AM) would require that the input amplitude versus output amplitude characteristic of radio repeaters be strictly linear, since amplitude variations of the AM wave must be faithfully preserved. With FM, the intelligence is determined by the frequency rather than the amplitude of the transmitted wave. The critical characteristics of an FM radio repeater are linearity of the phase versus frequency characteristic and flatness of the amplitude versus frequency characteristic over the transmitted band. Frequency modulation was selected as the most advantageous method, and the use of FM in the AN/TRC-24 system has made it possible to utilize up to 40 repeaters in tandem without serious degradation of the signal.

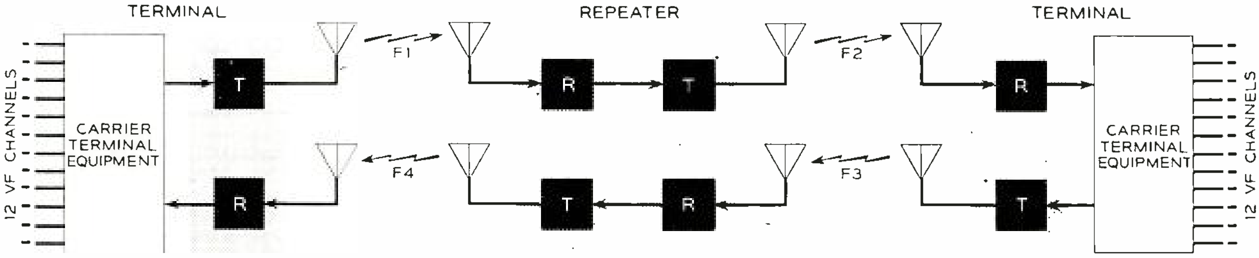


Fig. 2 — Two repeater sections require four different radio channel assignments.

One advantage of FM over AM is the possibility of obtaining lower noise in the voice channels for a given amount of transmitter power. With FM, the noise is reduced as the peak deviation of the carrier frequency is increased, the top modulating frequency remaining fixed. By making the carrier deviation serveral times the highest modulating frequency, a substantial noise reduction is obtained, although this improvement is gained at the expense of increased radio-frequency bandwidth. For a typical voice channel in the AN/TRC-24 system, the noise reduction over a similar AM system amounts to about 11 db in the 100-225 mc range, and about 15 db in the 225-400 mc range.

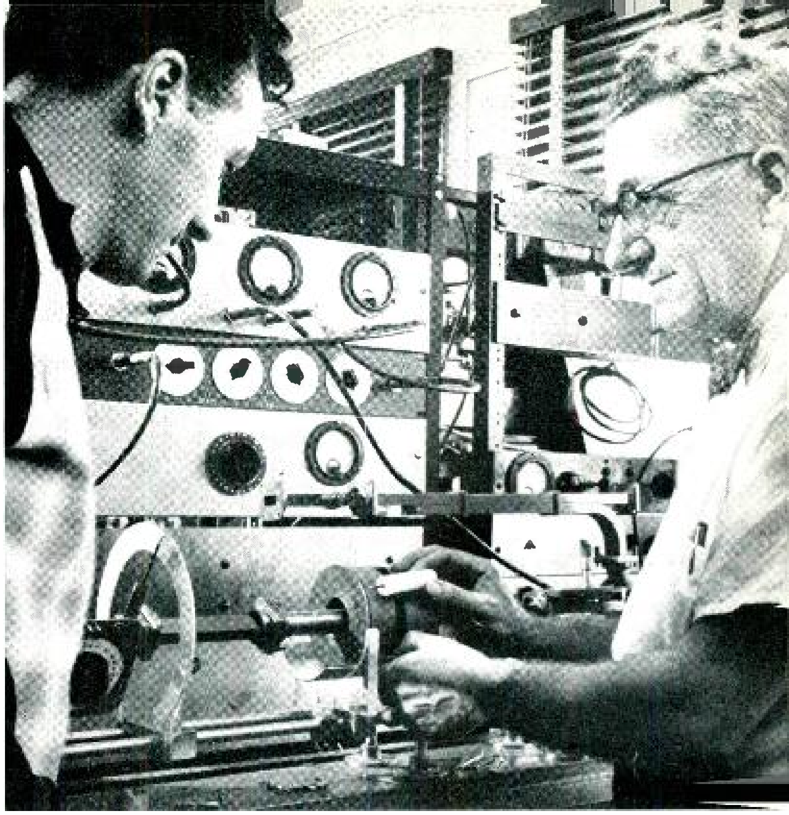
In most military installations, the radio relay stations will be attended for security or other reasons even though the equipment is suitable for unattended operation. When required, attendants can communicate with each other via the service channel, which is arranged as a party line so that each attendant can talk and listen to all others on the circuit. A 1600-cycle signaling tone lights a lamp and energizes a buzzer at each station to alert the attendant. Audible and visible alarms are also provided at each station in the event of trouble; one operates whenever the transmitter power output drops below a preset level, and another indicates low-signal conditions in the receiver.

Radio Set AN/TRC-24 is intended mainly for use in primary communications between Army headquarters, down to Division level. However, because of its versatility, and because it can be integrated with spiral-four cable circuits, it is expected that this new system will find wide application in all branches of the military services.

THE AUTHOR

A. L. Durkee received the degree of B.S. in Engineering from Harvard University in 1930 and joined the Department of Development and Research of the American Telephone and Telegraph Company in July of that year. There, and later as a member of the Laboratories following the consolidation in 1934, his work has been largely on radio transmission problems associated with the development of transoceanic and other radio-telephone circuits. Recently he has been engaged in radio propagation studies associated with the development of communications systems for military applications.

Ferrite Isolators at 11,000 Megacycles



J. P. SCHAFER *Radio Research*

When power is fed to microwave antennas through long waveguides, reflections due to bends, surface irregularities, or other discontinuities in the path cause distortion of the signals and may result in "ghosts" on television screens. The higher the frequency, the greater is the effect of these reflections. An isolation circuit recently developed at the Holmdel Laboratory uses ferrites to pass 11,000-megacycle energy in one direction only and to attenuate greatly the reflected signals. Such ferrite isolators are expected to simplify circuits involved in radio repeater and other microwave components.

The ceramic-like ferromagnetic materials called "ferrites" have been responsible for a number of new and interesting research projects in the field of high frequency radio and waveguide applications. Under the influence of a magnetic field, a ferrite has the property of rotating the plane of polarization of microwaves that are transmitted through it. This phenomenon is analogous to the so-called "Faraday effect," by which the plane of polarized light waves is rotated when these waves pass through a transparent medium in a magnetic field.

Before describing the microwave application, let us first consider how light waves are rotated. Michael Faraday discovered that the plane of polarization of light waves could be rotated when traveling through a transparent medium in a direction parallel to the direction of a magnetic field. This rotation is non-reciprocal – that is, the sense or direction of the rotation is the same for both directions of propagation – and this fact distinguishes it from rotations that occur in optically "active" substances such as quartz and many sugars, in which the rotation of a reflected wave cancels the original.

Lord Rayleigh in 1901 described a one-way transmission system in optics using two polarizing Nicol prisms oriented at an angle of 45° with each other. Placed between them was a material such as plate glass, which caused the Faraday rotation. A Nicol prism is a selective optical device that permits full intensity of transmission only when the direction of the plane of polarization coincides with a given axis of the prism. It completely cuts off the light when the plane of polarization is at right angles to the axis. Light, after passing through the first prism, had its plane of polarization rotated 45° by the transparent material with its associated magnetic field. This rotated wave passed through the second prism without hindrance. In the reverse direction, however, the wave was rotated another 45° and was unable to pass through the first prism. It was further shown by certain other investigators that ferromagnetic materials produced the Faraday rotation effect more easily than ordinary transparent materials.

In 1950, C. L. Hogan of Bell Telephone Laboratories demonstrated that magnetized ferrites also exhibit such a non-reversible Faraday effect at microwave frequencies, and that these ferrites are essentially transparent to microwave energy. With ferrites, passive devices called "isolators" can therefore be built to permit microwave energy to be passed freely in one direction, and substantially suppressed in the other. This contrasts with most other passive transmission devices such as those using wires, resistors, and capacitors. Such components have no inherent "sense of direction," so that a transmission system using them can ordinarily transmit equally well in either direction.

An isolator, as the name implies, is used to prevent or reduce interaction between circuit elements. A particular need for such a device was at hand in an experimental repeater system operating at 11,000 megacycles.* In radio systems generally, and particularly in cases where an oscillator delivers power directly to an antenna at the end of a long transmission line, distortions can be produced by the wave reflected from the antenna. Thus, the antenna impedance seen by the oscillator may be a rapidly varying function of frequency. The frequency will be "pulled" up or down depending on the phase of the reflection. If frequency modulation is used, the distortion resulting from "frequency pulling" would make systems using long waveguides impracticable.

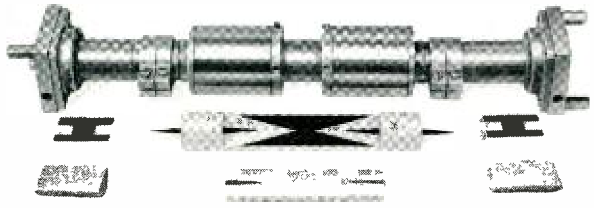


Fig. 1 — Above: the completely assembled isolator. Ferrites and absorbers in polyfoam supports are seen below.

The desired performance of the isolator was that it should have a forward loss of not more than a fraction of a decibel and a reverse loss of 50 decibels or greater. Since it has been difficult to obtain consistently more than about 35 decibels isolation when using a single ferrite rod isolator, it was decided to provide a double or two-section device (Figure 1). A double isolator has other advantages, such as widening the range of operating temperature and frequency.

The function of this isolator can be followed with the aid of Figures 2 and 3. Figure 2 is an exploded view photo of the individual parts, and Figure 3 is a simplified drawing that illustrates the operation of the more important elements. The illustration at the head of this article shows the author (right) discussing a ferrite problem with W. F. Bodtmann at Holmdel Laboratory. The ferrite is held alongside an electromagnet used for rotation studies.

In Figure 2, A1 and A2 are transformer plates to convert from 0.4 inch x 0.9 inch rectangular waveguide to a 0.75 inch inside diameter round waveguide. The first of these transforms the wave in the rectangular guide, which is called TE_{10}, to a TE_{11} wave in the circular guide, which contains the fer-

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* Record, *April*, 1955, *page* 131.

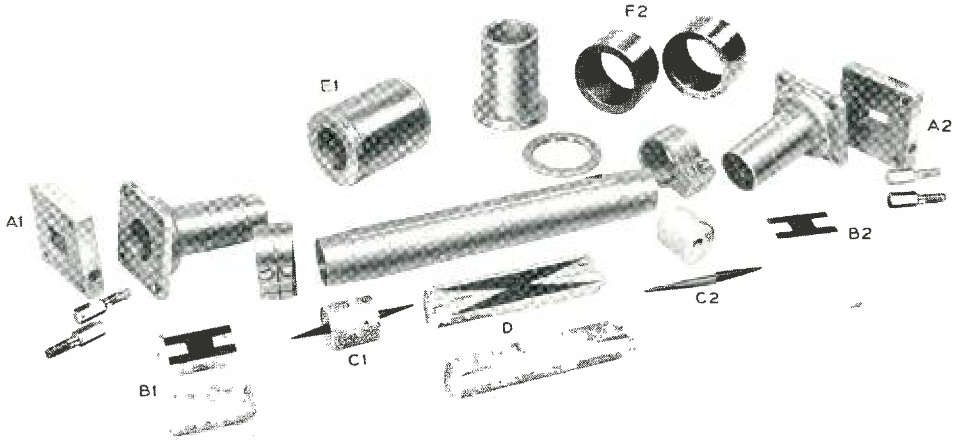


Fig. 2 — Exploded view of parts of double-ferrite isolator.

rite. The configurations of the electric lines of force in the two guides are shown in Figure 4. Faraday rotation can occur only in a waveguide capable of supporting waves of all polarizations—vertical, horizontal, or any intermediate orientation. The rectangular guide of Figure 4 can transmit only the vertical polarization as shown. The symmetry of the circular guide, however, is such that it has no preference of polarization, and when Faraday rotation is produced by the ferrites, the wave is propagated without distortion or attenuation.

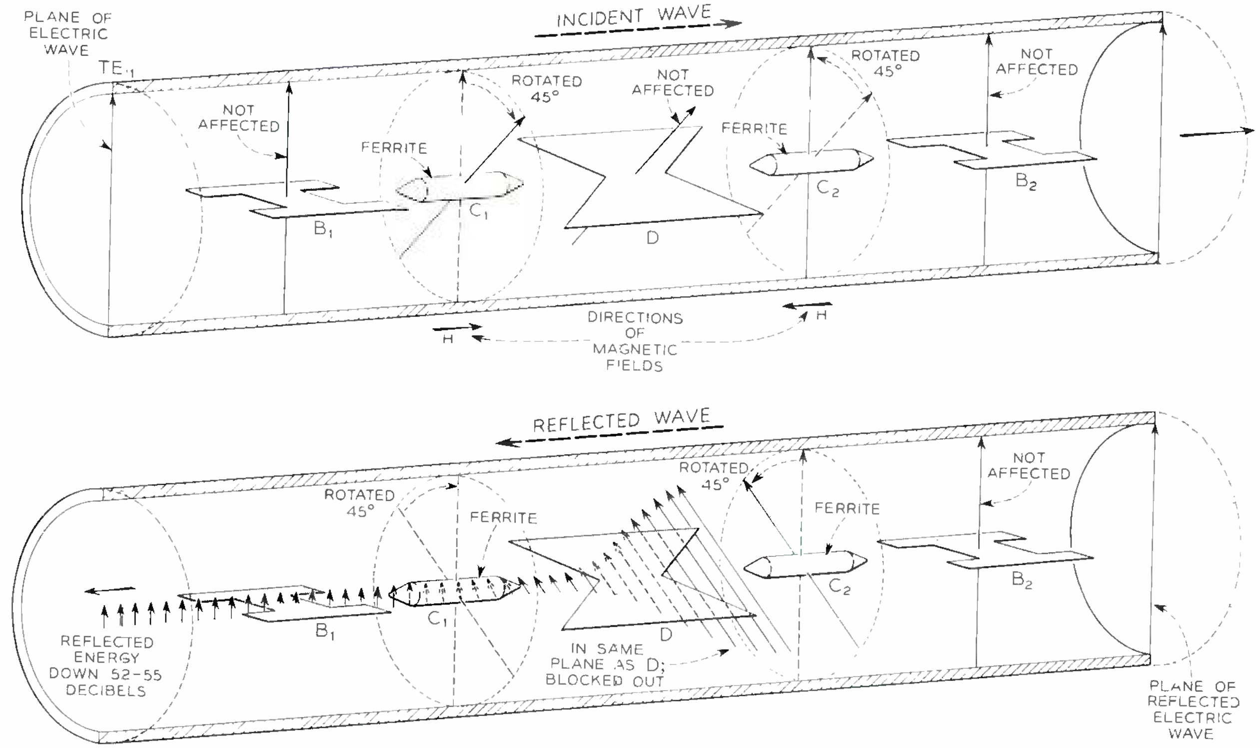


Fig. 3 — Simplified drawing showing rotation effects inside cylindrical section of isolator.

The units labeled B1 and B2 on Figures 2 and 3 are cross-component absorbers made of 3 mil thick carbon-loaded polyvinyl resistance sheets of a size to produce about 35-40 decibels attenuation to any cross-component waves that may be present due to irregularities in the round guide or that may be generated in the ferrite rods. These units absorb energy when they are parallel to the lines of electric force. The TE_{11} wave entering the round guide is not affected by the first absorber B1, since it is in the horizontal plane at right angles to the lines of electric force. The plane of polarization of this wave is rotated 45° by the first ferrite C1. The ferrite rods were cut to a size that produces the desired rotation with the necessary magnetic field. The rods are about 0.150 inch in diameter and 2.5 inches long, with tapered ends to reduce the mismatch that is involved.

The center cross-component absorber D is of the same material as B1 and B2 and has 45-50 decibels attenuation. The 45° rotated wave is not affected by this absorber since it is mounted in the guide 90° from the electric plane of the rotated advancing wave. The second ferrite C2 also rotates the plane of the wave 45°, but the horizontal field of the magnet E2 associated with this ferrite has been purposely reversed from that of E1 and thus causes a rotation in the opposite direction. This reversal in field places the plane of the wave exactly in the same (vertical) direction as the input. The wave passes absorber B2 and into the output rectangular guide without any attenuation.

Any wave returned toward the generator by reflections from output circuit mismatching should then be attenuated by the isolating action of the device. Tracing the wave on its return journey will demonstrate how this takes place. The absorber B2 again has no effect on the return wave. Since the Faraday rotation effect is non-reciprocal, the ferrite C2 rotates the wave another 45° in the same direction that the wave was rotated for the forward transmission. This brings the electric plane of the wave in the same plane as the absorber D, which is there-

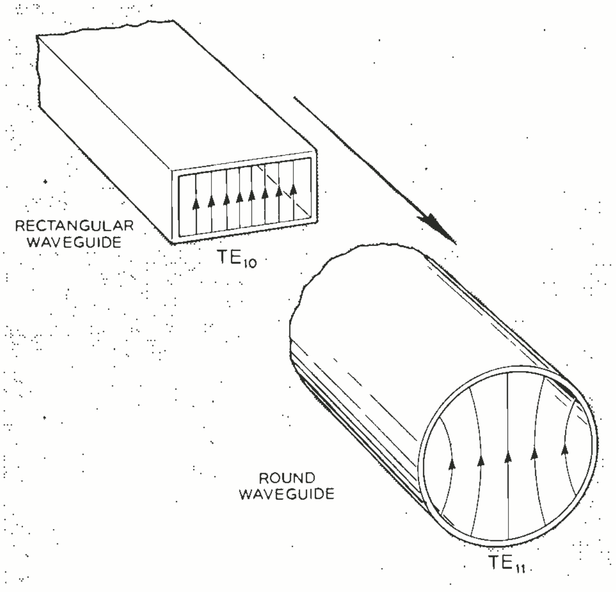


Fig. 4 — Left: configuration of electric lines of force of TE_{10} wave in rectangular guide; right: lines of force of TE_{11} wave in round guide.

fore able to produce its maximum attenuation. The residual wave passing this absorber in the return direction encounters the first ferrite C1 and is again rotated 45° and appears at the input end of the isolator in the vertical plane. It is able to pass into the generator waveguide since it is not attenuated by B1. The amount of the isolating action of the device therefore depends almost entirely on the center absorber D, since B1 and B2 merely absorb extraneous cross-components and prevent their reflection.

Alnico-5 permanent magnets E1 and E2 produce the longitudinal magnetic field along the axis of the ferrite rods, which in turn produces the rotation of the plane of polarization of the TE_{11} wave. The effective field in the ferrites may be adjusted by sliding the magnet along the round waveguide tubing. This produces the correct field in each ferrite to give the exact 45° rotation required.

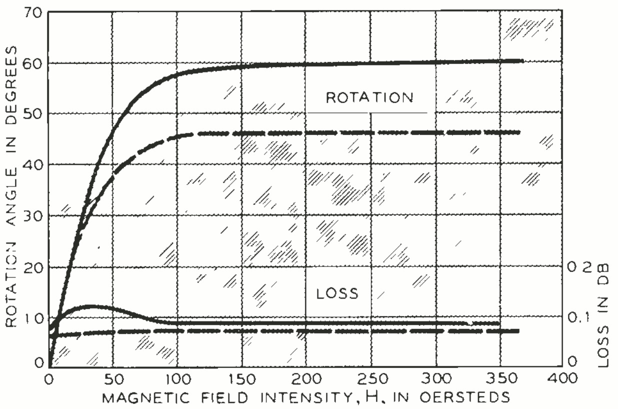


Fig. 5 — Loss and rotation characteristics of two ferrite rods used in isolator; the magnetic field is adjusted to give 45° rotation for both ferrites.

The absorbing elements and ferrite rods are mounted in polyfoam supports, which are cemented in place in their proper positions in the finished device. These polyfoam pieces introduce negligible loss in the system.

The ferrite material used in these isolators was chosen as a result of a development program of our Metallurgical Research Department. Ferrites are ferromagnetic oxides that are structurally the same as magnetite or lodestone. Mixtures of the oxides of nickel, zinc, magnesium, manganese and iron in various combinations are pressed into desired shapes and then heated to temperatures of the order of 1,000 degrees Centigrade. Many factors enter into the choice of a ferrite for a particular application, such as insertion loss and rotation as a function of size, shape, and d-c field; frequency and temperature sensitivity; reproducibility; and the ease with which they may be ground into shape.

The ferrite chosen in this case, a nickel-zinc-iron oxide mixture, has favorable characteristics with respect to most of these factors, the least favorable being frequency and temperature sensitivity. The insertion loss for each of the individual rods is less than 0.1 decibel. Figure 5 shows the loss and rotation characteristics as a function of applied dc field for the two sizes of rods used.

The over-all forward loss of the complete device is measured by noting the difference in power output when the isolator is removed and replaced with a straight section of waveguide of similar length. The over-all forward insertion loss was about 0.25 decibel at the operating frequency.

The reverse loss or isolation was measured by reversing the isolator so that transmission is in the opposite direction from normal. If all the adjustments had been made as outlined, the isolation should be equal to the loss in the center absorber or 45-50 decibels. It has been found, however, that slight readjustments of the position of either or both magnets, and perhaps an adjustment of the angle of the center absorber, materially improve the isolation. It has been possible to make corrections so that the final values of isolation at a given operating frequency are about 52 to 55 decibels.

The requirement for the initial use of these isolators was that they have over 50 decibels isolation at a particular frequency in the 10.7 to 11.7 kilomegacycles operating band. Figure 6 shows the frequency characteristic of one of these units, which was adjusted to have maximum isolation and minimum forward loss at 11.03 kilomegacycles. It will be seen that it provides a value of isolation of 53 decibels and a forward loss of 0.25 decibels at the specified frequency.

After having been adjusted at a given frequency, the isolators show a variation in isolation as a function of temperature. Starting at 55 decibels for a particular isolator at room temperature, the isolation decreases for both higher and lower temperatures, decreasing to about 40 decibels at 140 degrees and at 0 degrees Fahrenheit. This falling off in isolation is due to the fact that the rotation caused by the ferrite rods changes with temperature, becoming less as the temperature increases. This change in rotation becomes more rapid as the Curie Temperature point is approached. The Curie point is that temperature at which a given material loses its magnetic effects, and for the ferrites used, it is about 300 degrees Fahrenheit. Ferrites having much higher Curie points would be a remedy for this temperature variation, and such ferrites are now available having similar rotation and loss characteristics as the lower Curie point materials.

At a given temperature, as shown in Figure 6, the isolation also varies considerably as a function of frequency. This is due to the increase in rotation of the individual ferrites with frequency and depends upon many factors, such as the diameter of the rod, density of the ferrite, and closeness of operating frequency to the guide cut-off. Various schemes for compensation of this rotation-frequency sensitivity have been suggested.

The double isolator itself is one form of such compensation. For some applications where the requirements call for operation over a wide band rather than at a single frequency, it is desirable to adjust one of the ferrites to give 45° rotation at a value above the operating frequency, and the other, below it. Measurements have been made of the characteristics of isolators adjusted to operate over the 10.7 to 11.7 kilomegacycle band without the requirement of extreme isolation at any particular frequency. One such unit gave 30 to 35 decibels isolation at the edges of the band but did not exceed 45 decibels at any frequency between.

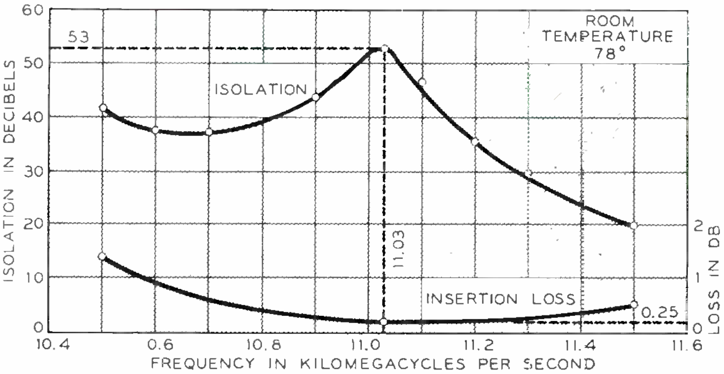
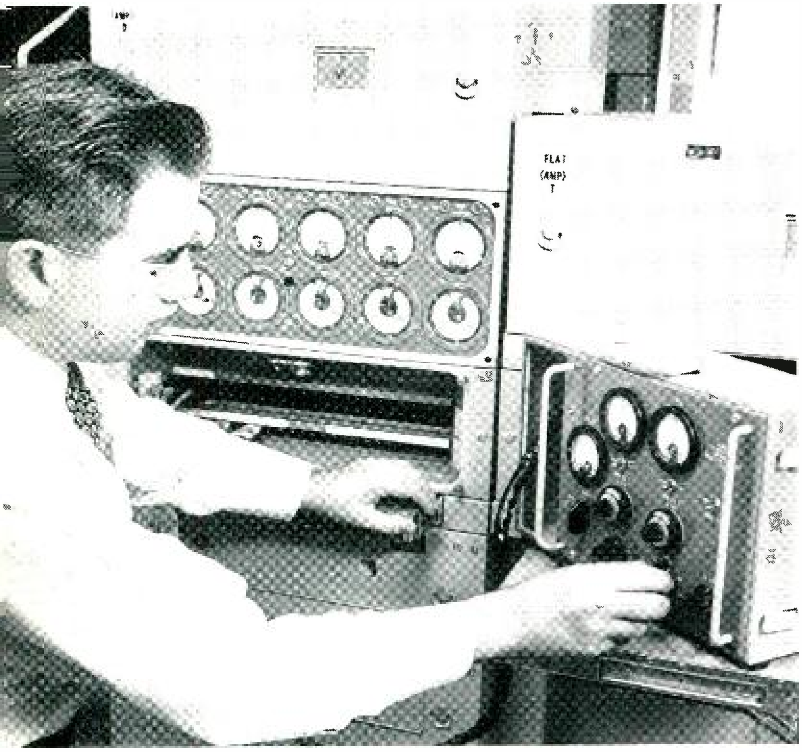


Fig. 6 — Frequency characteristic of double isolator circuit. Note forward loss of only 0.25 decibel and reverse loss of 53 decibels at 11.03 kilomegacycles.

The isolators described in this article are not production models but were built on an experimental basis for research projects. Investigation is continuing on ferrite properties and configurations of isolators, and these investigations should result in improved devices for this and other microwave frequency bands.

THE AUTHOR

J. P. Schafer joined the Engineering Department of the Western Electric Company in 1915 and later received a B.S. degree in Electrical Engineering in 1921 and his E.E. degree in 1925 from Cooper Union. He was early engaged in fundamental studies of radio circuits and in the development of long and short wave high-power radio transmitters. After joining the Laboratories group at Deal, New Jersey in 1928, he studied the propagation of radio waves through the upper atmosphere, including the effects of sunspots and magnetic storms. During World War II, he was concerned with the development of radar and countermeasure military equipment. For the past ten years, he has done research principally on microwave radio relay systems including studies of the use of ferrite materials. He has been at the Holmdel Laboratories since 1953.



Equalization in the L3 System

E. G. MORTON
Transmission Systems Development II

Prior to the development of the L3 system, high-quality equalization in long-distance carrier systems was provided by extensive studies after the systems were put in the field. In the L3 system, engineering studies at the Laboratories made it possible for the first time to provide automatically controlled equalizers that could be installed at the same time as the system itself. Not only does this advanced technique make for greater economy and higher efficiency in the present system, but its flexibility promises still greater improvements in long-haul telephone and television transmission.

When telephone or television signals are transmitted over long distances, the relative amplitudes of various signal frequencies in the transmission system must be maintained essentially the same at all times. Large deviations from uniformity may cause intolerable distortions in telephone conversations, introduce echoes or "ghosts" in television pictures, or affect the performance of long distance dial switching systems. The problem of correcting deviations from uniform or "flat" transmission is that of system equalization.

In the L3 system, the largest deviation from flat transmission is caused by the loss in the cable – a loss which rises with frequency. To compensate for this, the gain-frequency characteristic of the line repeaters is designed to match the loss characteristic of four miles of cable.* Although the line repeater may therefore be considered as providing the first coarse step of equalization, its gain is not a perfect match for the cable loss because of the finite number of its elements and because of the difficulty of measuring accurately the gain of a single repeater. Consequently, there is a residual gain distortion for each auxiliary repeater section (approximately four miles of cable and a single line repeater). Since this residual distortion is small, it is permitted to accumulate through a number of repeaters before it is equalized or corrected.

There are many other causes of deviation from flat frequency transmission, some fixed, and some variable with time. Among these are variations from nominal in the values of the electrical elements in the repeaters, temperature variations in the cable and repeaters, and such changes in element values

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* Record, *April*, 1954, *page* 139.

in time as the change in transconductance or gain in the electron tubes. Of these, only the variation of the cable's loss-frequency characteristic with temperature is large enough to necessitate correction at each line repeater. The other deviations are smaller and are allowed to accumulate for correction at the equalizing repeaters located at approximately 125-mile intervals along the line.

In the L3 system the frequency of adjustment necessary to meet transmission requirements determines the type of equalizer used, and the frequency with which the equalizer needs to be adjusted is dependent on the rapidity of the system gain changes due to the various sources of deviation. Fixed deviations, such as the mismatch between the gain characteristic of the line repeater and the loss characteristic of four miles of cable, are corrected by fixed equalizers. Other deviations, such as those caused by the replacement of amplifiers, are slowly variable and are best corrected by equalizers which are manually adjusted after a given number of amplifier changes. In the illustration at the head of this article, C. H. Dykeman is shown controlling thermistor currents preparatory to adjusting the manual equalizers. Relatively rapid variations, like the transconductance change of electron tubes, introduce deviations from flatness of as much as 1 db per week for every 1,000 miles of cable. Another rapid variation of equal severity is caused by changes in the temperature of the huts housing the line repeaters. Deviations such as these accumulate continuously and are best corrected by automatic equalizers.

Figure 1 illustrates the fixed gain deviation in one auxiliary repeater section in the L3 system. For reasons of economy, only two designs of fixed equalizer are provided, despite the fact that the lengths of equalized sections are quite variable.

Where the accumulated gain deviations are slowly varying, unpredictable, or both, manually adjustable equalizers with a high degree of flexibility are employed. In the case of the replacement of amplifiers due to element failure, a gain deviation results because of the differences in the element values in the new and old amplifiers. The characteristic of this gain deviation cannot be predicted because of the many elements involved. Another gain deviation occurs when the fixed equalizer does not exactly compensate for the number of auxiliary repeater sections between main or terminal repeaters.[*] The compensation introduced by the fixed equalizer can represent either a gain or a loss depending on whether it undercompensates or overcompensates for the number of sections included. Some minor gain deviations resulting from imperfections in the characteristics of the automatic equalizers are unpredictable and dependent on the initial settings of the automatic equalizers.

Although earlier coaxial systems required extensive measurements for the design of their automatically controlled equalizers, in the L3 system some of the sources of gain deviation were anticipated, and automatic equalizers were designed concurrently with the development of the system. The automatic equalizers designed to compensate for such known and predictable changes were appropriately called "cause-associated" networks.

Data on the effects of temperature variations in the cable were based on theoretical computations and later verified by careful measurements. The derived variation in cable loss is very nearly proportional to the square root of frequency and directly proportional to temperature change.

Data were computed for the design of the equalizing network that corrects for variations in repeater gain with tube aging, and the results were substan-

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[*] Record, *May*, 1955, *page* 182.

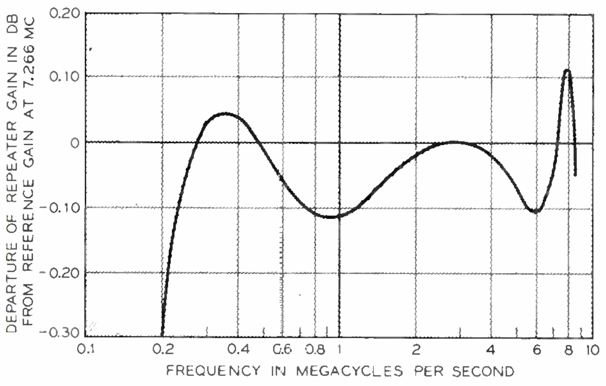

Fig. 1 — Fixed gain deviation in one auxiliary repeater section.

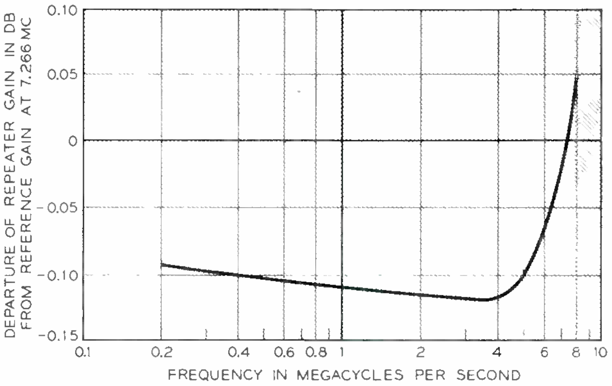

Fig. 2 — Gain deviation in one repeater for a one db reduction in electron tube transconductance.

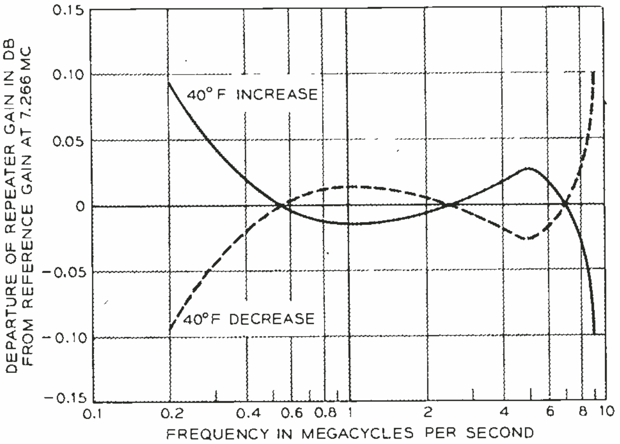

Fig. 3 — Gain deviation in one repeater for plus or minus 40°F variations in ambient temperature.

tiated by laboratory and field measurements. The equalizer loss-frequency characteristic which compensates for such gain changes is shown in Figure 2. The curve illustrates the change in gain at one repeater that ocurs when the transconductance of each tube in the repeater is reduced 1 db.

Computation of a third cause-associated network, used in the L3 system to compensate for variations of repeater element values with temperature, was complicated by uncertainties in the temperature coefficients of many of the repeater elements. For this reason, the effect of variations with temperature was determined by laboratory measurements under simulated operating conditions. The combined effect of temperature changes on all elements is shown in Figure 3 for plus or minus 40 F variations in the ambient temperature of the repeater.

The cause-associated networks provide automatic equalization through the use of variable resistors, called thermistors, as network elements. These thermistors respond to variations in the amplitude of single frequency pilot signals transmitted over the system. As the amplitudes of the pilot frequencies change because of temperature or aging effects in the system, regulators[*] sense the change, and automatic equalizers introduce compensating effects.

Although the regulator controlling the line amplifier operates in response to changes in the 7,266 kc pilot frequency only, no single pilot may be used as a measure of transmission change over the entire frequency band of the L3 system. For example, the operation of the three automatic equalizers in main or terminal repeaters is dependent on pilot frequencies at 308, 2,064, and 7,266 kc, but the thermistors in these equalizers receive their control currents from computers rather than directly from the regulators involved.[†]

Pilot frequencies are supplied to the input of an equalizing section by two methods. In some cases oscillators supply the pilots directly, but in the majority of cases the pilots are supplied from the preceding equalizing section. In the first case, the rigid requirements placed on the amplitudes of transmitted pilots are met by the design of the oscillators, but when the preceding equalizing section supplies the pilots, an additional amplitude control is needed at 308 kc because equalization of the preceding section is not perfect at this frequency. This need is filled by a narrow-band, manually adjustable equalizer. The frequency characteristic of this equalizer for the two extreme settings of the control dial from mid-position are shown by the solid and dashed line curves of Figure 5.

Further planning for equalization of the L3 system includes the provision for long-distance television service. In these long-haul systems, involving over 1,000 miles of cable, many complex effects become troublesome that were previously of minor importance. Repeater gain variations which are not strictly linear with temperature must now be equalized over the range of temperatures encountered in service; the fact that all electron tubes in a repeater do not age at the same rate must be

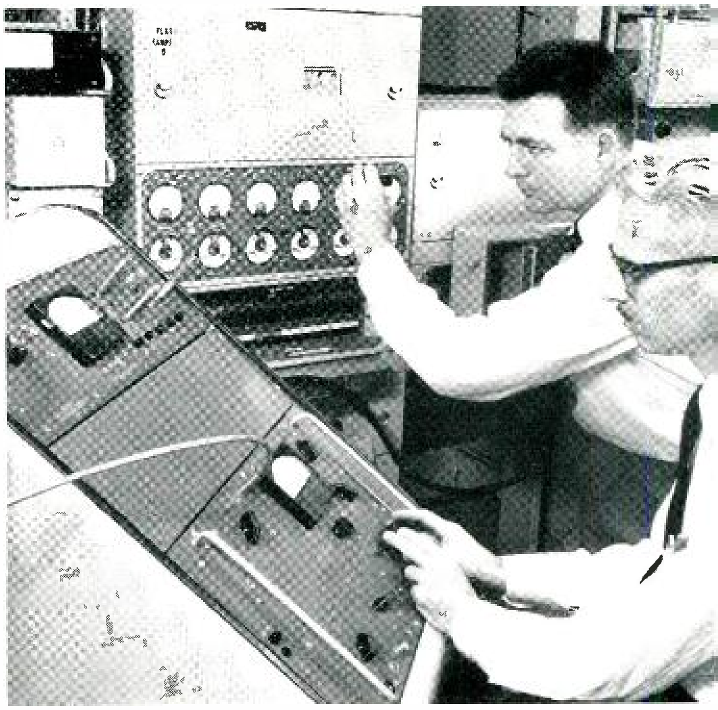

Fig. 4 — W. Freeman (front) of the A.T.&T. Company and the author calibrating the pilot indicators.

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[*] Record, *October*, 1954, *page* 385. [†] Loc. cit.

taken into account; and increased importance is given the variations in the response of the regulating network of the line repeaters at the extremities of its operating range.

On the basis of computations now being made to evaluate these more complex effects, three additional automatic equalizers will be designed. Interpretation of the data will be facilitated by the results of stability measurements now being taken on an existing L3 system. When the new automatic equalizers are installed, additional manually adjustable equalizers will be used to control more closely the amplitudes of the received pilot.

In practice, the equalization structure of the L3 system has proved to be extremely flexible. For example, manually adjustable equalizers have now been developed to improve transmission in the television band of the system. These equalizers, independent of those mentioned earlier, will be located in the television branch of the receiving terminal. System modifications can therefore be made without extensive changes in the basic equalization plan, even in those instances where new equalization techniques may be required. This flexibility should simplify complex equalization problems and improve long-haul telephone and television transmission.

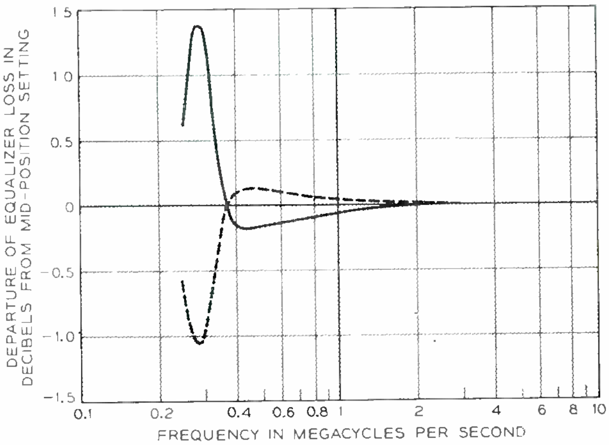


Fig. 5 — Loss characteristic in the 308 kilocycle pilot correction equalizer.

THE AUTHOR

E. G. MORTON joined the Laboratories in 1935. As a Technical Assistant, he helped with the development of test equipment for the L1 coaxial system and engaged in field work on System measurements. During World War II he worked on the design of test equipment for measuring characteristics of waveguides and coaxial cables. In 1944 he became a Member of Technical Staff, and since the war he has been engaged in the design of test equipment for the L3 system and in various other phases of its development. Mr. Morton received a B.S. degree in Electrical Engineering from Polytechnic Institute of Brooklyn.

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

Dunlap, K. S. — *Repetitive Telephone Calling System Employing Power Supplied Over the Subscriber's Loop* — 2,713,617.

Field, L. M. — *Oscillation Generator* — 2,712,605.

Hewitt, W. H., Jr. — *Hall Effect Devices* — 2,714,182.

Kannenberg, W. F. — *Orifice Coupling to Resonant Cavities* — 2,713,153.

Malthaner, W. A., and Vaughan, H. E., — *Arrangement for Supplying Alternating Current Power for Actuating Telephone Subscriber's Station Equipment Over the Subscriber's Loop Circuit* — 2,713,613.

O'Connor, T. J., and Williams, C. H., — *Spring Return Mechanism* — 2,714,000.

Raisbeck, G., and Wallace, R. L., Jr., — *Transistor Modulator Circuits* — 2,713,665.

Sears, R. W. — *Electron Discharge Devices* — 2,713,650.

Vaughan, H. E., see Malthaner, W. A.

Wallace, R. L., Jr., see Raisbeck, G.

Williams, C. H., see O'Connor, T. J.

Winslow, F. H. — *Production of Polymer Spheres* —2,712,536.

"Two-Train" Switching in Toll Crossbar Offices

J. J. COZINE *Switching Engineering*

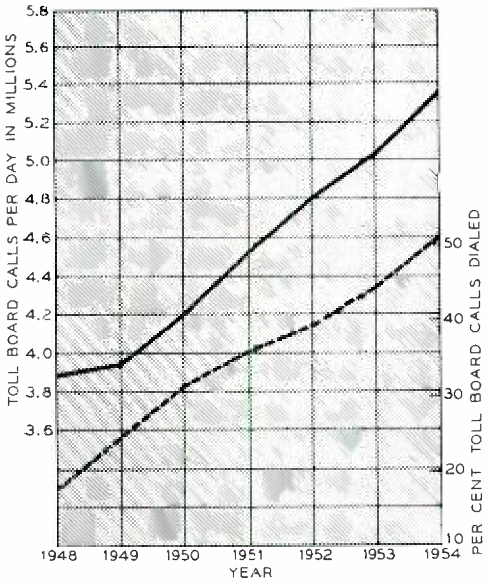
One of the less publicized but important features of the 4A toll crossbar system is the "combined" operation of two switching trains. In the "separate-train" arrangement of the earlier No. 4 and A4A systems, one group of crossbar switches, called a "train", is used for outward and through toll traffic, and a separate train is used for inward traffic. The 4A system also uses two trains, but so combined as to give increased traffic-handling capacity and greater efficiency of associated common-control equipment.

A substantial increase in toll traffic during the past few years has caused the maximum capacity of several No. 4 and A4A toll crossbar systems to be reached or closely approached. Between 1948 and 1954, the number of toll calls per day handled by the Bell System increased approximately 1½ million, Figure 1. In 1954, over fifty per cent of these calls were dialed to completion – that is, without the services of any operator other than the one originating the customer's call. During these same years the number of dial-type intertoll trunks increased from ten thousand to seventy thousand, Figure 2. Toll traffic is still increasing and estimates of future growth indicate that two toll crossbar systems will eventually be required in some cities.

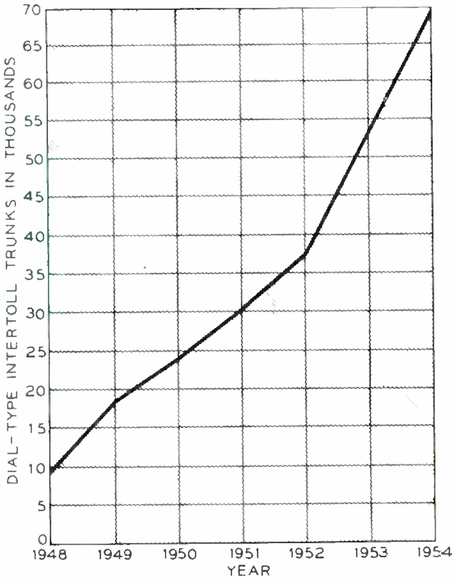
One objective in the development of the 4A system was increased traffic-handling capacity over the earlier No. 4 and A4A systems, to extend the time before a second system is required in heavy traffic areas. The 4A design serves up to 2,500 more intertoll trunks than the older systems, and permits more efficient use of common-control equipment. Figure 4 shows the relationship between the number of intertoll trunks and frames in both the old and new designs for two hypothetical traffic situations.

The larger No. 4 and A4A toll crossbar offices are provided with two separate "trains" of switching equipment. A "train" consists primarily of incoming and outgoing link frames, through which connections between trunks are established by markers associated with that train. In these earlier systems, the two trains were designed to handle different types of traffic. The intertoll IT train was designed to serve only outward and through traffic, and the toll-completing TC train to serve only inward traffic. This arrangement is economical for installations not requiring the additional traffic-handling capacity of the 4A.

g. 1 (left) — The recent in-
ease in toll calls handled
·r day is about 1 1/2 million.
ightly more than half of
ese calls were dialed to com-
etion by operators.



g. 2 (right) — Dial intertoll
inks in service.



In some cities, the capacity of the earlier systems has been reached because of the limitations of the IT trains. Although inward traffic to the TC trains has also increased, some of it has been transferred to crossbar tandem offices. This provides relief for the TC trains and, in most cases, spare capacity. It is therefore possible in some instances to transfer a limited amount of outward traffic from the IT to the "de-loaded" TC trains. However, because of some differences between IT and TC operation in the No. 4 and A4A systems, this transfer entails certain penalties.

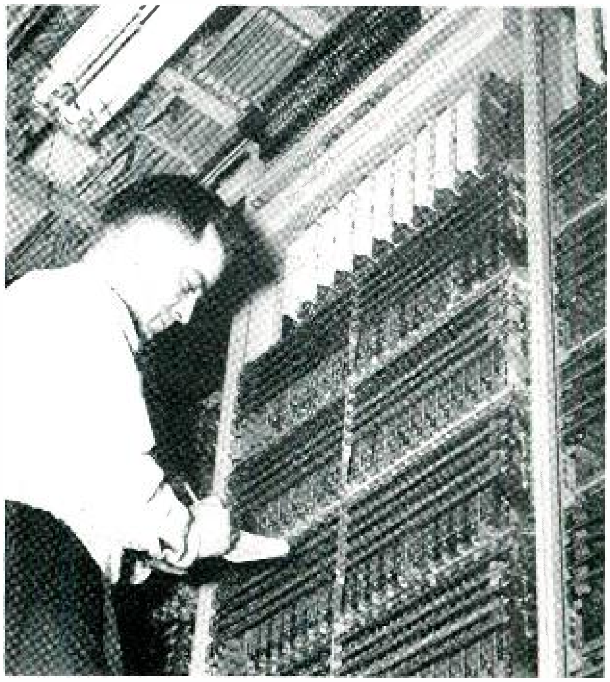


Fig. 3 — R. L. Ilsley of Long Lines traces a circuit through the crossbar switches.

Separate-train IT-TC operation in No. 4 and A4A offices is illustrated in Figure 5. Incoming intertoll trunks that carry only inward traffic (a) appear only on the TC train; those that carry both inward and through traffic (b) appear on both trains. From the outward toll switchboard, two groups of toll tandem trunks (c) are provided, one to each train. A single group of toll tandem trunks from decentralized toll switchboards (d) appears on both trains. All these different types of trunks must be connected through the office to the proper type of outgoing trunk. Normally, outgoing intertoll trunks appear only on the IT train, and toll-type codes — those with a 0 or 1 as either of the first two digits, such as 402 or 124 — are assigned to these trunks. Toll-completing trunks appear on the TC train, and local office codes such as CH3 are assigned to them. When an incoming (a) or (c) trunk appears on only one train, the outgoing trunk will also be on that train and the proper type of marker — IT or TC — is dictated by the incoming trunk itself. However, when the incoming trunk appears on both trains, the type of code received — toll or local office — determines on which train the outgoing trunk is located and which type of marker is necessary.

Because of the difference in code requirements for the two trains, difficulties arise when outgoing intertoll trunks are assigned to a de-loaded TC train. Toll-type codes might be assigned to these trunks, and they could then be reached by incoming trunks that appear only on the TC train. They could not, however, be reached by incoming trunks that appear

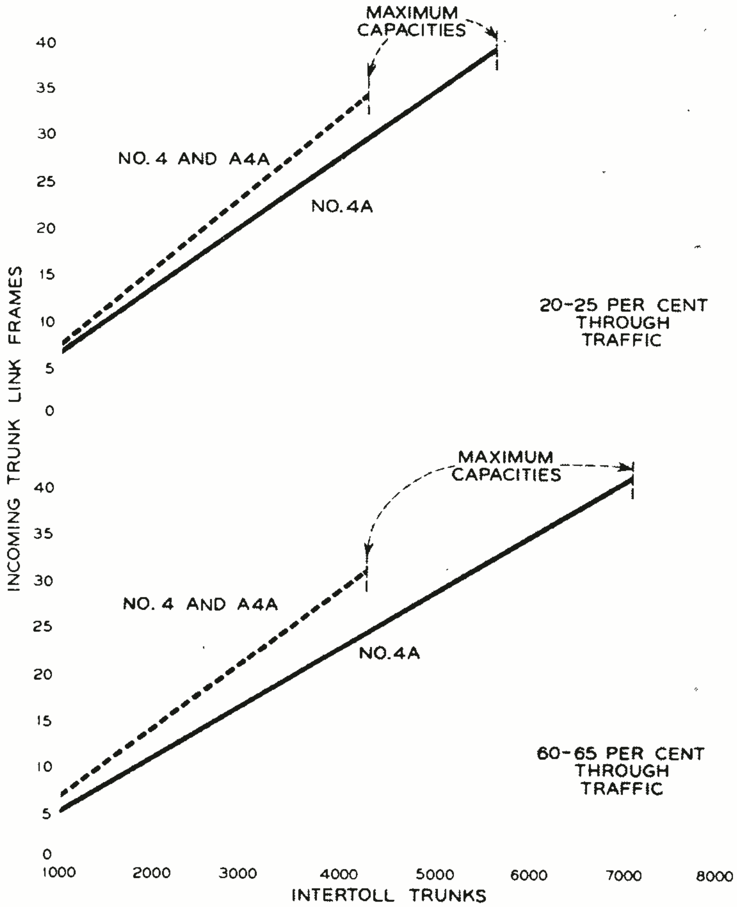


Fig. 4 — Comparison of traffic-handling capacities of the No. 4 and 4A systems for two hypothetical traffic situations.

on both trains, since the received toll code will always choose a marker associated with the IT train. If local office codes can be assigned to these trunks, they can be reached by all incoming trunks appearing on the TC or both trains.

However, assigning such codes is not always possible since in large metropolitan areas where this transfer may be necessary there are a great many local offices and, in general, most of the usable codes are already assigned. In addition, when IT trunks are moved to a TC train and new codes assigned, traffic routing bulletins must be changed at all outward and decentralized toll switchboards having access to those trunks.

In the No. 4 and A4A systems, the IT train has twice as many paths between incoming and outgoing frames as the TC train. With this design, the probability of a marker finding an idle path through the IT train on first trial is about the same as that for the TC train with two trials. The extra paths in the IT train are necessary since intertoll trunks use expensive facilities and seldom are provided as liberally as the less expensive toll-completing trunks. During the busy hours, frequently only one intertoll trunk in a group is free; the large number of paths practically insures that an IT marker will find an idle path to a free trunk on first trial.

On the other hand, when a TC marker cannot find a path to a selected toll-completing trunk on the first trial, the trunks are tested in the reverse direction on second trial. With moderate traffic on toll-completing trunks, a different idle trunk is usually selected and a new set of paths is tested. But, because of heavier traffic on intertoll trunks, second trial is usually of no benefit on those trunks transferred to the TC train. In busy periods, a TC marker will frequently choose the same idle trunk on second trial, test the same busy paths, and the call will be delayed, even though an idle trunk is available.

Two trains are also used in the new 4A switching system, Figure 6, but operation is on a "combined" basis, each train being designed to serve all three types of traffic. All future two-train toll switching offices will be of this type; earlier two-train offices may or may not be modified for combined operation when other 4A features are added, since individual requirements will vary.

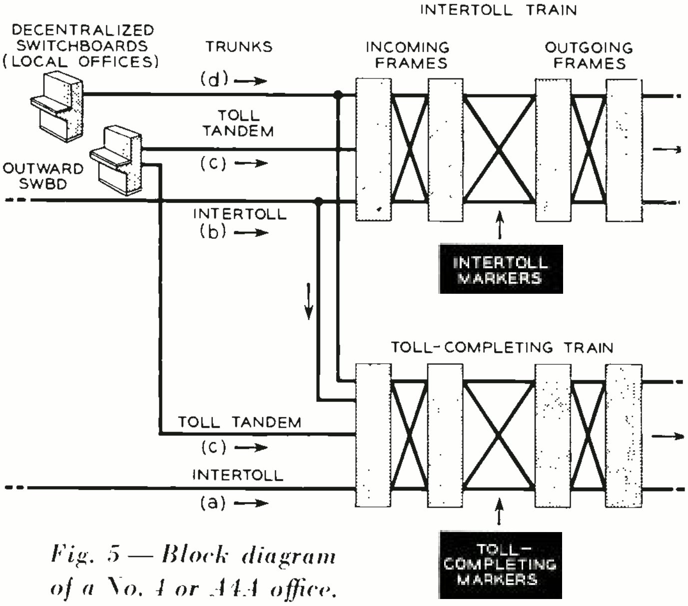


Fig. 5 — Block diagram of a No. 4 or A4A office.

In "combined" operation, both trains are provided with the same liberal number of paths, and all incoming trunks, both intertoll and toll tandem, are multipled to both trains. Outgoing intertoll and toll-completing trunks are no longer restricted to specific trains but may be assigned to either train. This can be done without the code restrictions of the No. 4 and A4A systems.

A decoder and card translator are used to select a marker, and the selection is not dependent upon particular code types or the location of an incoming trunk, as it was in the earlier systems. In the 4A system, the received code is the controlling factor; any code can be used to select a marker in either train. A decoder can predetermine the availability of an outgoing trunk and its train and then select the proper marker; or a decoder can select a marker in one train, have it test for idle trunks, and, if none are available, select a marker in the other train and have this marker test for idle trunks in its train. Such versatility is made possible by the multipling of all incoming trunks to both trains, so that a marker can set up a connection from any incoming trunk to the outgoing trunk it selects. This arrangement also permits full flexibility in routing since outgoing direct-route trunks and associated alternate-route trunks may be assigned to the outgoing frames of either train. However, it is preferable to assign all associated trunks to one train or the other, since shifting between trains results in increased decoder holding time.

The two trains are functionally identical, and this permits taking advantage of the non-coincidence of the "busy hours" of inward, outward, and through traffic. By so doing, the markers are used more efficiently. In the earlier systems, enough markers had to be provided to take care of the peak loads in each train. This meant that at some peak periods, while markers in one train were being used at capacity, those in the other train were being used at less than capacity. Outgoing trunk assignments in the 4A system can be made so as to distribute inward, outward, and through traffic over both trains and use all markers more efficiently.

With all incoming trunks multipled to both trains, and outgoing trunks – both intertoll and toll completing – appearing on either train, inter-train load balancing is done at the outgoing link frames. To permit a straight transfer of one or more trunk groups without disturbing other trunk assignments, and thus avoid the costly process of exchanging and rearranging trunk groups on both trains, spare terminal capacity is provided. Trunks may be reassigned without the reassignment of codes, and therefore without changes in bulletins and route guides at switchboards having access to these trunks, as was previously necessary.

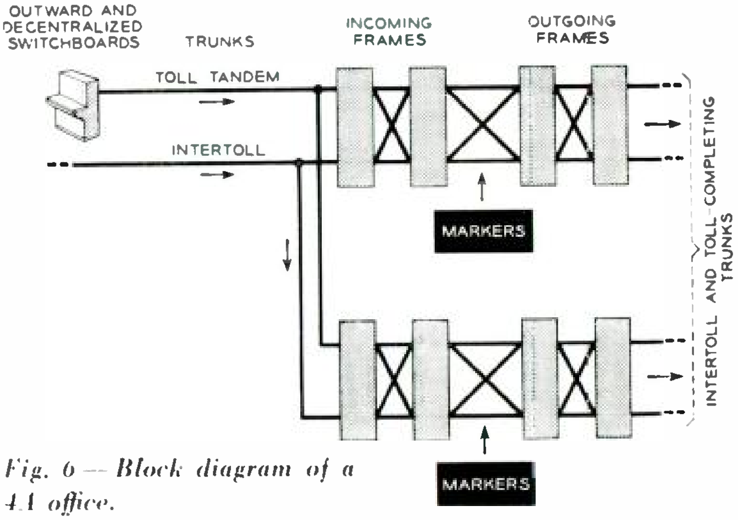
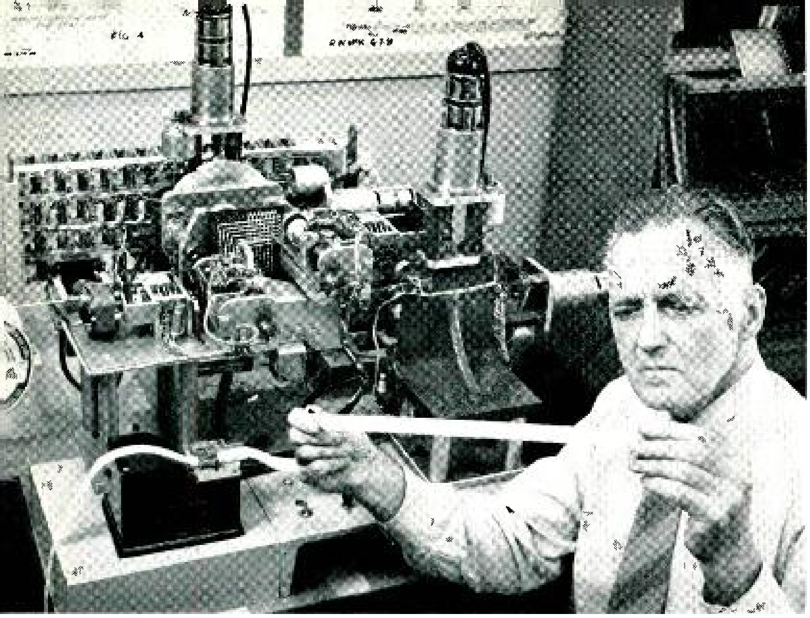


Fig. 6 — Block diagram of a 4A office.

THE AUTHOR

J. J. Cozine joined the Laboratories in 1936, while attending the Polytechnic Institute of Brooklyn. His activities included work on mobile, aircraft, and fixed radio transmitters and receivers. During 1944 and 1945 he served in the Signal Corps, becoming wire chief at General Headquarters in the Philipines. Rejoining the Laboratories in 1946, he was concerned for two years with transmission filters and networks, and then with texts and simplified schematics for plant training material. Since 1951, Mr. Cozine has been engaged in the engineering study and planning for local and toll crossbar systems and CAMA.

Automatic Wiring Machine Announced



Instructions are fed to the M-4 from a punched tape, like that held here by R. F. Mallina who designed the machine.

An ambidextrous machine that can automatically wire complex electrical apparatus was recently announced by the Laboratories. The experimental machine, called the "M-4," was developed to study apparatus and equipment designs best suited for automation.

Designed by R. F. Mallina, the M-4 can neither see nor hear, but it can "feel" and thus follow instructions with great accuracy. Instructions are fed to the machine from a punched tape. A series of relays, acting as the machine's "brain," translate this information into electrical signals. The signals then control the cams and gears of the machine. It uses a process for making solderless wrapped connections, also started at the Laboratories. This process, applied by hand controlled tools, is now used for important production work by the Western Electric Company. Connections are made by automatically wrapping six turns of solid-conductor wire around a rectangular terminal. The high wrapping tension provides an airtight, corrosion-resistant contact between the wire and terminal at numerous points. Bell Laboratories tests indicate that the solderless wrapped connection could be expected to provide a satisfactory connection for at least the life of associated apparatus. Solderless wrapping eliminates the danger of burns from hot soldering irons. It does away with disagreeable solder fumes and the chance of short-circuits from solder splashes or wire clippings.

The experimental machine uses two rotating spindles. The wire is fed directly from a large spool. One spindle pulls the wire, in an inverted L-shaped movement, to a connecting terminal. At the same time the wire is cut to the correct length at the second spindle. The spindles remove a bit of insulation from each end of the wire as they whip the bare wire ends around the terminals. This produces a pressure of about 15,000 pounds per square inch at each contacting area. Following their punched tape instructions, the spindles then pick up the supply wire from the spool and move to the next electrical connection where the process is repeated. Machine wiring eliminates the need for preparing, storing and handling many short pieces of wire.

The M-4 can be used in conjunction with plastic panels, all alike, on which are mounted different groups of electrical parts such as electron tubes, or transistors, resistors, and capacitors. The terminals of the parts protrude through holes in the panels spaced at regular (modular) intervals.

It can be visualized that when suitable apparatus and equipment designs are ready for manufacture, several machines developed along the lines of the M-4 might be used at once, all receiving instructions from a common "brain."

Bell Solar Battery in Service

The Bell Solar Battery will be placed in service in an experiment near Americus, Ga., on October 4 to furnish electrical power to a rural telephone line. This will be the first time the sun's energy has ever been used in such a manner.

This development is a part of the Bell System's continuing research to help bring more and better telephone service to rural areas. The solar battery will feed power to a new rural telephone system using transistors instead of electron tubes.

The experiments are being conducted jointly by Bell Telephone Laboratories and Southern Bell Telephone and Telegraph Company.

Dial System for Ford Motor Co.

The second largest industrial dial telephone system in the United States was cut into service recently by the Michigan Bell Telephone Company for the Ford Motor Company at its 1,200-acre Rouge manufacturing area in Dearborn, Michigan. Over $1,000,000 and 75,000 man-hours were spent on the installation of the system, which will serve 6,000 telephones and handle as many calls annually as Michigan municipalities like Battle Creek or Bay City. The new system can handle over 1,000 simultaneous calls.

Dr. Kelly Gives Talk

"Factors Promoting Productivity in Research and Development at Bell Telephone Laboratories" was the subject of a talk given by Dr. M. J. Kelly on September 13 before the 128th national meeting of the American Chemical Society in Minneapolis. The meeting which Dr. Kelly addressed was sponsored by the Society's Division of Industrial and Engineering Chemistry.

W. H. Martin Named Director of Army Research and Development

The Secretary of the Army last month announced the appointment of William H. Martin, retired Vice President of the Laboratories, as Director of Research and Development for the Army. The appointment became effective September 1.

William H. Martin

Mr. Martin, who has been Deputy Assistant Secretary of Defense for Applications Engineering, retired from the Laboratories in January 1954, after more than 42 years of Bell System service. He received the B.A. degree from Johns Hopkins in 1909 and the B.S. degree from Massachusetts Institute of Technology in 1911. He then joined A.T.&T., transferring to the Laboratories in 1934. He served as Switching Research Director, Director of Station Apparatus Development and Director of Apparatus Development before being named Vice President in 1949. He joined the Defense Department upon his retirement from the Laboratories in 1954. In his new post, Mr. Martin will be in charge of all plans, implementation and financing of research and development projects for the Army.

H. P. Moulton Elected A. T. & T. Vice President

Horace P. Moulton was recently elected Vice President and appointed General Counsel of American Telephone and Telegraph Company, succeeding T. Brooke Price, who retired September 1.

Horace P. Moulton

Mr. Moulton has been Associate General Counsel for A.T.&T. since last April. A graduate of Dartmouth and Harvard Law School, Moulton has been with the company since 1951. Previously he was counsel for the New England Telephone and Telegraph Company, and before that, was associated with a Boston law firm.

Kenneth Bullington Honored by I.R.E.

Kenneth Bullington of the Laboratories has been named by the Institute of Radio Engineers as recipient of its Morris Liebmann Memorial Prize, awarded annually in recognition of important contributions to the radio engineering art.

The prize, to be presented during the I.R.E. national convention in New York City next March, was given "for his contributions to the knowledge of tropospheric transmission beyond the horizon, and to the application of the principles of such transmission to practical communications systems."

Mr. Bullington joined the Laboratories in 1937 and since that time has been engaged almost entirely in studies relating to the propagation of radio waves. His work on scatter propagation during the last three years has been a major factor in extending the range of military communications systems. These systems can transmit television pictures 200 miles, as recently announced by the Laboratories.

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

Arnold, W. O., and Hoefle, R. R., A System Plan for Air Traffic Control Embodying the Cussor-Coordinated Display, Proc. I.R.E., P.G.A.N.E. **2**, pp. 14-22. June, 1955.

Boorse, H. A., see Smith, B.

Brattain, W. H., see Garrett, C. G.

Garrett, C. G., and Brattain, W. H., Physical Theory of Semiconductor Surfaces, Phys. Rev., **99**, pp. 376-388, July 15, 1955.

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

Guldner, W. G., see Wooten, L. A.

Haus, H. A. (M.I.T.), and Robinson, F. N. H., The Minimum Noise Figure of Microwave Beam Amplifiers, Proc. I.R.E., **43**, pp. 981-991, Aug. 1955.

Heidenreich, R. D., and Storks, K. H., Note on Electron Diffraction Patterns of CuO, J. Appl. Phys., Letter to the Editor, **26**, p. 1056, Aug., 1955.

Hoefle, R. R., see Arnold, W. O.

Kircher, R. J., Properties of Junction Transistors, Trans. I.R.E., **AU-3**, pp. 107-124, July-Aug., 1955.

Koliss, P. P., Mechanical Splice Closures for Telephone Cables, Telephony, **149**, pp. 23-24, Aug. 13, 1955.

Meyer, F. T., Improved Detached-Contact Circuit Drawing, Elec. Engg., **74**, p. 645, Aug., 1955.

Moore, G. E., Wooten, L. A., and Morrison, J., Excess Ba Content of Practical Oxide Coated Cathodes and Thermionic Emission, J. Appl. Phys., **26**, pp. 943-948, Aug., 1955.

Moore, G. E., see Wooten, L. A.

Morin, F. J., and Geballe, T. H., Electrical Conductivity and Seebeck Effect in $Ni_{0.80}Fe_{2.20}O_4$, Phys. Rev., **99**, pp. 467-468, July 15, 1955.

Morrison, J., see Moore, G. E.

Pederson, D. O., The Regeneration Analysis of Junction Transistor Multivibrators, Trans. I.R.E., P.G.C.T., **CT2**, pp. 171-178, June, 1955.

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

Smith, B., and Boorse, H. A. (Columbia University), Helium II Film Transport. III. The Role of Film Height, Phys. Rev., **99**, pp. 358-367, July 15, 1955.

Storks, K. H., see Heidenreich, R. D.

Treuting, R. G., Some Aspects of Slip in Germanium, J. of Metals, Sect. 2, **7**, pp. 1027-1031, Sept., 1955.

Walker, L. R., Power Flow in Electron Beams, J. Appl. Phys., **26**, pp. 1031-1033, Aug., 1955.

Wooten, L. A., Moore, G. E., and Guldner, W. G., Measurement of Excess Ba in Practical Oxide Coated Cathodes, J. Appl. Phys., **26**, pp. 937-942, Aug., 1955.

Wooten, L. A., See Moore, G. E.

Talks by Members of the Laboratories

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

West Coast A.I.E.E. – I.R.E. Convention, San Francisco

Beck, A. C., Waveguides for Long Distance Communication.

Baldwin, M. W. Jr., The Subjective Sharpness of Simulated Color Television Pictures.

Bowers, F. K., The Design of Blocking Oscillators as Fast Pulse Regenerators.

Linvill, J. G., and Mattson, R. H., Junction Transistor Blocking Oscillators.

Mattson, R. H., see Linvill, J. G.

Morton, J. A., Transistors Today.

Schelkunoff, S. A., Conversion of Maxwell's Equations into Generalized Telegraphists Equations.

Other Talks

Anderson, O. L., Reversible Density Changes in Glass Under Pressure, Gordon Conference on Glass Structure, Meriden, N. H.

Davis, P. (National Bureau of Standards), and Pollak, H. O., On the Analytic Continuation of Mapping Functions, American Mathematical Society Summer Meeting, Ann Arbor, Mich.

Felker, J. H., Transistor Applications in Digital Computers, University of Michigan Summer School, Ann Arbor.

Fry, T. C., Mathematics as a Profession Today – In Industry, Mathematical Association of America, University of Michigan, Ann Arbor.

McMillan, B., Probability and Statistics in Communication, Institute of Mathematical Statistics, Ann Arbor, Mich.

Pearson, G. L., The Silicon Solar Battery, American Physical Society, Mexico City.

Pollak, H. O., see Davis, P.

Schaefer, J. W., Some Characteristics of Guided Missiles, Kiwanis Club, Plainfield, N. J.

Schawlow, A. L., The Structure of the Intermediate State in Superconductors, International Conference on Low Temperature Physics, Paris.

Slepian, D., The Coding Problem in Information Theory, Institute of Mathematical Statistics, Ann Arbor, Mich.

Sparks, M., Transistor Chemistry, New England Association of Chemistry Teachers, Tufts College, Medford, Mass.

Vogel, F. L., Dislocations in Plastically Bent Germanium Crystals, Physics of Metals Conference, Royal Military College, Kingston, Ontario.

Weinreich, G., The Diffusion Delay Diode, University of Cambridge; Radar Research Establishment; University of Bristol, England.