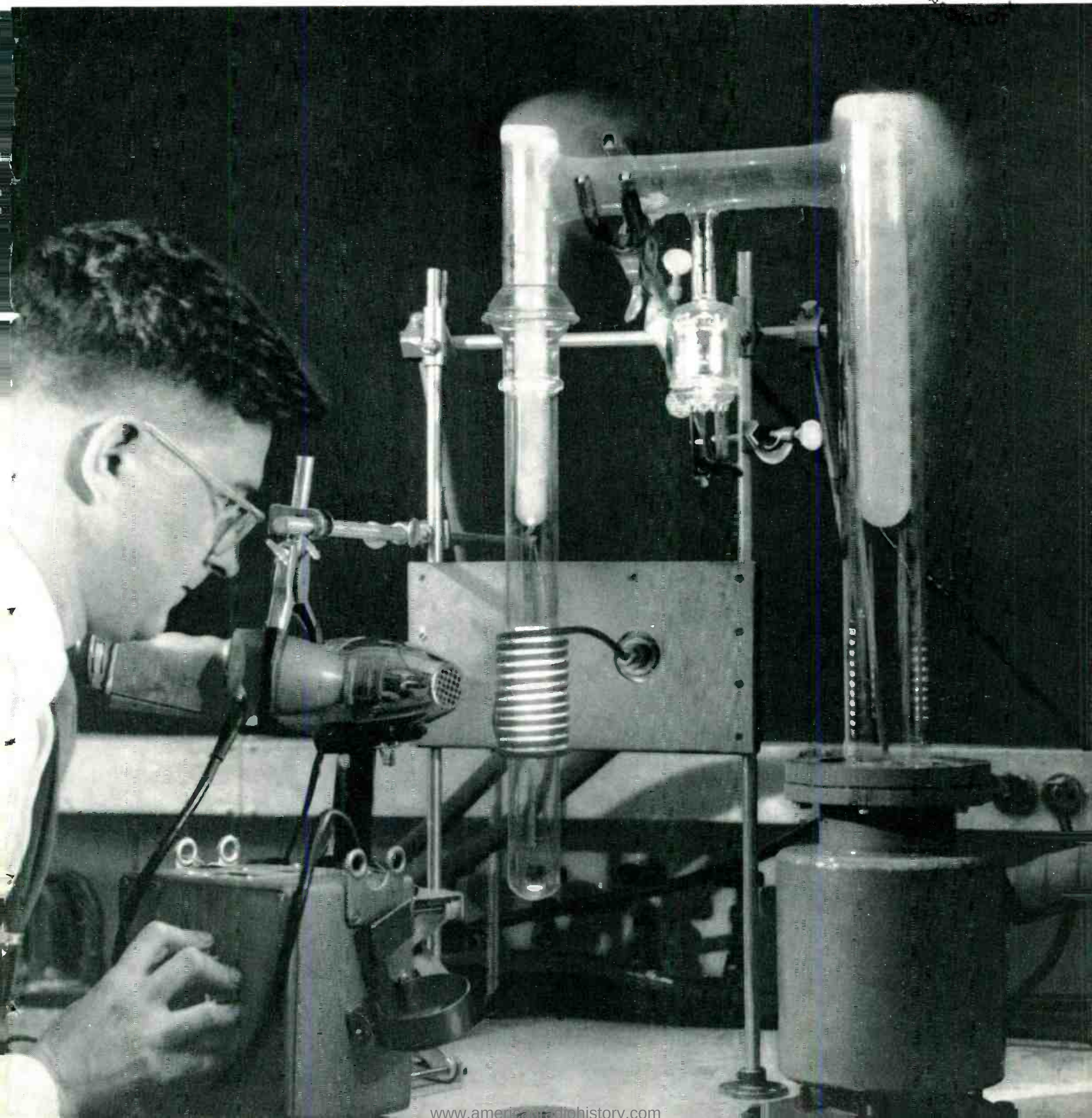
September 1959

# Bell Laboratories RECORD







THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. FISK, President; K. PRINCE, Secretary; and T. J. MONTIGEL, Treasurer. Subscription: $2.00 per year; Foreign, $2.60 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

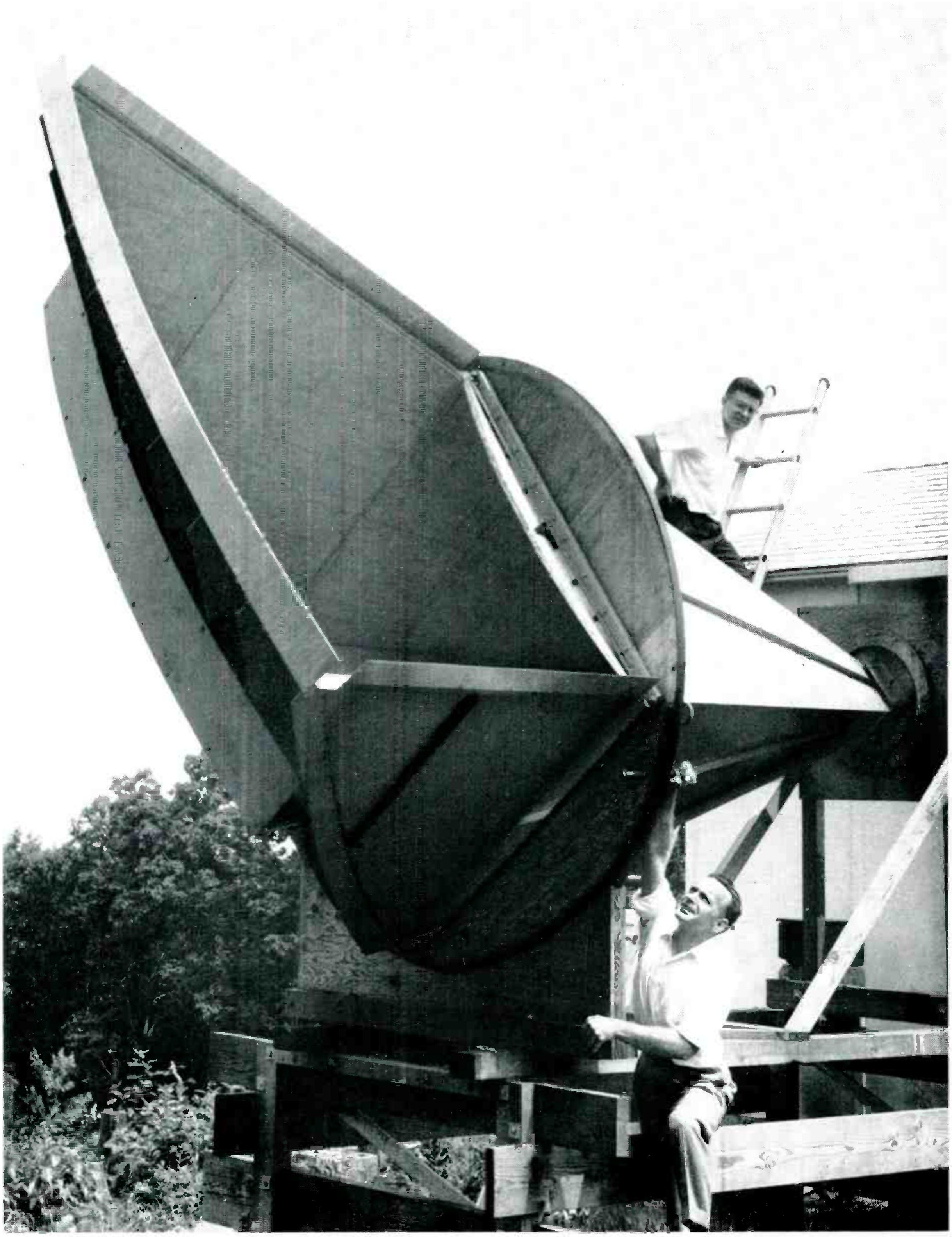
*Bell Laboratories* **RECORD**

*Volume 37 • Number 9 • September 1959*

## Contents



Cover *R. L. Batdorf observing glowing RF coil around quartz envelope which contains silicon wafers being exposed to controlled phosphorus vapors (see p. 330).*



*Horn-reflector antenna used at Holmdel, N. J., Laboratory for measuring sky temperatures. Combination of this antenna with maser permits tests needed in studying space communications.*

*For sending a broad-band radio signal across the Atlantic, earth-satellite reflectors or repeaters offer many intriguing possibilities. But even to determine whether such communication is feasible requires careful study, experimentation and measurement.*

J. R. Pierce

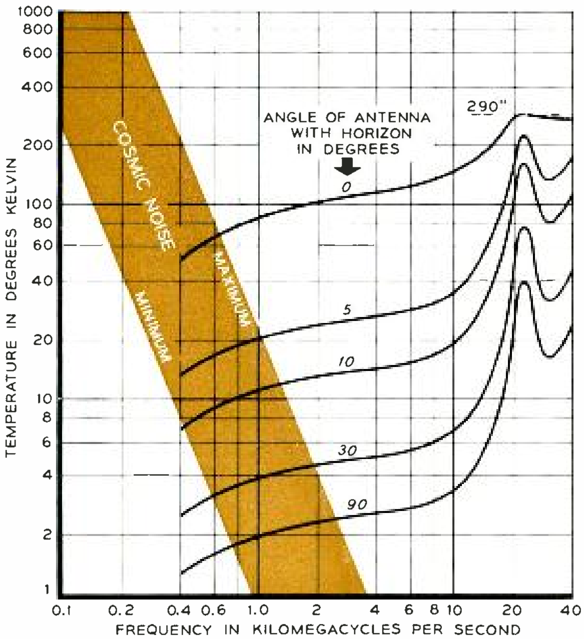
# Exotic Radio Communications

Pioneering work often seems exotic in its inception. Only a very few years ago, the idea of launching an artificial satellite seemed exotic, if not scatterbrained. But satellites have become almost commonplace. Today's exoticism is space flight by human beings, and we do not know what tomorrow's might be.

In the early part of this century, it would have taken an incorrigible visionary to foresee the present Bell System direct distance dialing network, undersea telephone cables, coaxial cable systems, and transcontinental microwave radio-relay routes. These all grew out of work which in its inception seemed far from any practical reality. It is an important part of Bell Laboratories activities to look far ahead — to study possible future communications services and thus build a fund of knowledge to draw upon if these services should become economically attractive.

In this article I shall deal primarily with some of the pioneering work at Bell Laboratories which may someday be important to the Bell System in providing broad-band transoceanic radio communication. And to introduce this subject, I shall first briefly review some of our past accomplishments. My purpose is not merely to present a list of important radio research projects. Rather, I hope to illustrate the importance of good scientific and engineering work and to show the value of the Bell System pattern of careful study, measurement and design.

Radio itself seemed exotic in an earlier day. Before the founding of Bell Laboratories in 1925, the A.T.&T. Co. and Western Electric contributed heavily to the technology of radio broadcasting. Even earlier, in 1915, A.T.&T. and Western made use of newly developed power vacuum tubes in demonstrating radio communication between Arlington, Virginia, and both Hawaii and Paris. This showed a potentiality for transoceanic communication which could not be overlooked. One result was the first use of radio for commercial telephone service, from the mainland in California to Catalina Island in 1920. The work also led directly to experiments in transatlantic telephony as early as 1923, and to the inauguration of commercial transatlantic telephone service in 1927.




*Theoretical atmospheric noise (in degrees K) versus frequency as an ideal antenna points at various angles to the horizon. The color region indicates the expected range of cosmic noise.*

In this early long-wave work, accurate measurements of field strengths were made. A form of modulation was adopted — in this case the first use on radio of the single-sideband technique — which was best suited to the nature of the medium and the needs of the system.

The value of this type of approach was again illustrated with short-wave radio, put into commercial service in 1928. A tricky sort of communication, short-wave propagation shows both long-term variations of signal strength and rapid fading. Careful measurements by Bell Laboratories workers showed that such fading has a multipath nature — that is, radio waves in bouncing different numbers of times between the earth and the ionosphere alternately add and subtract in the radio receiver. These measurements also showed a rapid variation in the direction from which signal components arrive at a receiving antenna and especially in the vertical angle of arrival.

Such extensive and accurate measurements made it clear that operating frequencies should be changed from time to time to suit the condition of the ionosphere. As a replacement for the early narrow-band antenna arrays, the simple rhombic antenna invented at Bell Laboratories permitted effective operation over the required wider band of frequencies. In following the more rapid variations in angle of arrival, the MUSA system — an array of rhombic antennas interconnected with phase-changing networks — made it possible for a receiver to track the observed changes in the vertical angle of arrival of the radio signal.

As a part of the careful studies of short-wave phenomena at Bell Laboratories from 1929 through 1931, K. G. Jansky investigated noise in the short-wave bands at the Holmdel Laboratory. In the course of these studies, he detected radio noise of extra-terrestrial origin — work which laid the basis of radio astronomy. In recognition of Mr. Jansky's discovery, the laboratory at the new National Radio Observatory at Green Bank, West Virginia, is to be named the Karl G. Jansky Laboratory.

Besides this short-wave work, higher frequencies were also explored, and much fundamental knowledge was gained. This was applied in providing a number of over-water circuits and in mobile radio. However, the next large-scale Bell System application of radio was found in the field of microwaves, which have frequencies of thousands of megacycles. G. C. Southworth started his microwave work as early as 1932, long before any use for such frequencies could be assured. H. T. Friis and his associates took up this work in 1938.

Here again we see how early scientific and exploratory work led to extensive measurements and studies, and to the development of a sound technical art. The knowledge so gained was invaluable to radar during World War II, and later made possible the experimental New York-Boston System in 1947 and the Transcontinental TD-2 Radio-Relay System in 1951.

### Reliable Microwave Service

As in previous cases, there was a lot to learn. Studies of microwave paths proved the value of using highly directive antennas. These studies set a pattern in the Bell System of using very good, narrow-beam antennas that allow the use of low power and that minimize interference. All of this work showed that microwaves could provide very reliable service indeed.

We now approach more contemporary developments, and it is time to remind ourselves again that it is largely an illusion to think of such past achievements as commonplace. They were, and certain aspects of them still are, as challenging as anything we have in mind for the future.

Current thinking in radio communications still emphasizes the use of higher and higher frequencies, but direction of propagation is another important factor. Many intriguing problems and possibilities arise when we direct antennas toward the troposphere and the ionosphere, and toward satellites. Some of these problems were foreshadowed at Bell Laboratories as early as 1934, when A. M. Skellett and W. M. Goodall, in their studies of the ionosphere, looked for reflections from ionized meteor trails. The frequencies of 2 to 6 mc used in these studies were too low to give a strong signal, but statistical analysis of the data seemed to yield evidence for such reflections.

In other studies of the ionosphere, workers outside the Laboratories proposed in 1951 to use the turbulence of the ionosphere to achieve beyond-the-horizon scatter propagation. At a frequency of 50 mc, a 776-mile circuit was established between Cedar Rapids, Iowa, and Sterling, Virginia. Bell Laboratories monitored these signals, and with carefully designed antennas was able to receive teletypewriter messages during 1951 to 1954. In the course of this work, very high signal strengths were detected for very short periods. These observations indicated strong reflections from meteor trails, a verification of Skellett's and Goodall's early ideas.

However, ionospheric scattering proved disappointing for long-distance telephone circuits. For both turbulence scatter and meteor-trail scatter, the bandwidth is too narrow and transmission is too erratic. The more important region for the scatter technique proved to be the lower-altitude troposphere.

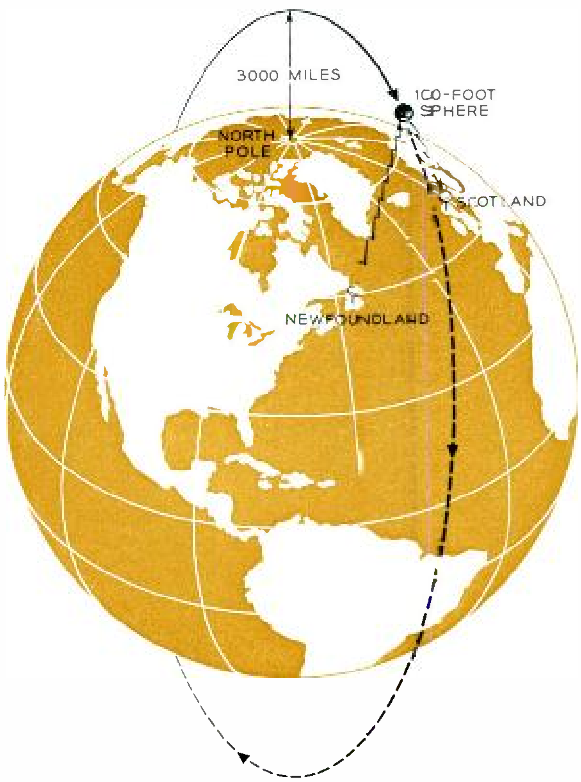
Kenneth Bullington did the pioneering work in this field. During 1950-1951, he collected data on and tested what we now know to be tropospheric scatter propagation, over paths 200 to 300 miles long. He pointed out the possibilities of this mode of transmission in historic papers published in the *Proceedings* of the I.R.E. in 1950 and 1953.

Beginning in 1955, further studies of scatter propagation were carried out over a path between a 60-foot scanning antenna at the Holmdel Laboratory and a transmitter on a farm in Pharsalia, New York, 171 miles away. The effects of antenna size, signal strength, depth and speed of fading, and angles of arrival were investigated. These data were compared with the predictions of a theory worked out by H. T. Friis, A. B. Crawford and D. C. Hogg. This theory supposes that the scattering is caused by a large number of randomly positioned but nearly horizontal discontinuities in dielectric constant in the first few miles above the earth's surface. The measurements fit the theoretical predictions very well in many respects. The knowledge acquired in these studies of tropospheric scatter is now widely used in designing scatter circuits.

### Scatter Circuits in Operation

Scatter circuits designed by Bell Laboratories and installed by Western Electric are currently in operation over the DEW line in the far north and over the "White Alice" system in Alaska. In addition, a broad-band scatter system for commercial telephone and television service was established between Florida City and Havana in 1957. This Florida-Cuba circuit handles 36 telephone channels and has the capability of hardling 120 or more.

If we now turn our attention to the problem of future broad-band radio transmission between North America and Europe, scatter circuits are an obvious suggestion. It might be possible, for example, to set up a series of relay stations via




*The geometry of a passive-reflector satellite in a polar orbit at an altitude of 3,000 miles, with terminals located in Newfoundland and Scotland.*

Greenland, various North Atlantic islands, and Scotland. Our studies indicate, however, that this type of communications would be very expensive. Large antennas and high-power transmitters would have to be built and maintained at remote arctic locations. Further, the multipath nature of scatter transmission would probably result in a poor broad-band circuit by television standards, although several dozen telephone channels might be provided.

What, then, is another type of possible intercontinental radio communications? As early as 1954, we considered the use of artificial earth satellites as relays, and I published a technical paper on the subject. At that time, however, problems of launching such satellites were unexplored. The first Sputnik in October 1957 changed the picture radically, and we began to look at these possibilities much more seriously.

If satellite communication ever becomes a reality, it will be no exception to past Bell System experience. That is, it will necessarily be preceded by the established pattern of meticulous study and experimental work. At the moment, we do not have enough knowledge or experience to describe in detail a practicable system or to state exactly how it might be used. We can do little more than speculate on the various possibilities.

One proposal is to place satellites 22,400 miles above the equator. At this height, a satellite would rotate in step with the earth and seem always to hang in the same position in the sky. Such satellites would be "active" relay stations — that is, they would be equipped with receivers and transmitters, and probably with accurately pointed directive antennas. This is an apparently attractive proposal, but for the present it raises at least two serious questions: the problems of accurate rocketry to launch and orient such satellites are indeed formidable, and the problems of equipment life in such relay stations are, to put it mildly, severe.

A second proposal is to place active satellites in orbit only a few thousand miles above the earth. These would not be stationary in relation to the earth, but with a sufficient number of them, signals could be relayed from each whenever it is in a usable section of its orbit. With this second proposal, rocket accuracy is somewhat eased, but equipment life in a low-altitude relay station is as serious a question as in the case of the 22,400-mile satellite.

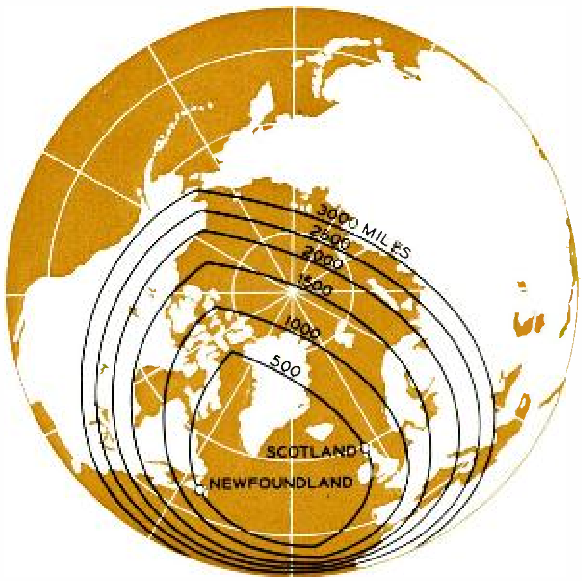
With low-altitude satellites, however, a transmitter and receiver on the satellite are not essential. Instead, one may put in orbit a group of passive reflectors. Large, high-power transmitters would then transmit to a satellite reflector, and signals would bounce from it and thus reach a distant receiver. The satellites would be aluminized plastic spheres — "balloons" perhaps 100 feet in diameter — with a high reflectivity to microwaves.

As an exercise to explore possibilities and problems, we have studied in some detail a theoretical system using passive satellites for transatlantic broad-band transmission. As shown in the illustration on page 325, the terminals were considered to be in Newfoundland and on an island in the Hebrides off Scotland. The satellites are to be imagined as traveling in polar orbits.

### *Regions of Visibility*

On the polar projection shown below, closed contour lines are drawn for various heights of orbit. These define areas in which a single satellite would be simultaneously visible to both the Newfoundland and Scotland terminals. At a height of 2,000 miles, for example, a satellite would be visible to both terminals anywhere within the 2,000-mile contour, even along the outer edges of the area.

The first of the accompanying tables *(next page)* shows calculations relating to the orbit




*Oval-shaped areas define regions in which polar-orbit satellites at various heights would be simultaneously visible to both terminals at Newfoundland and Scotland. The usable areas would be somewhat smaller, however, since transmission is difficult when satellite is near the horizon.*

**Visibility Times at Various Heights of Orbit**

| | Height of Satellite Above Surface of Earth in Miles | | | | | |
|---|---|---|---|---|---|---|
| | 500 | 1000 | 1500 | 2000 | 2500 | 3000 |
| Time of one revolution (minutes) | 100.4 | 118.0 | 136.6 | 155.0 | 175.2 | 195.2 |
| Shortest visibility (minutes) | 0 | 0 | 8.0 | 12.5 | 23.8 | 31.4 |
| Longest visibility (minutes) | 14.7 | 20.0 | 29.6 | 36.6 | 46.2 | 55.4 |
| Average visibility (per cent) | 3.5 | 6.9 | 12.9 | 17.7 | 19.6 | 22.0 |

Assumptions: Terminals in Newfoundland and Hebrides; polar orbits; refraction effects ignored; and visibility from horizon to horizon.

heights. The shortest and longest visibility times in the second and third horizontal rows are of particular interest. For the 1,000-mile height, as an example, the zero for shortest visibility time indicates that for some passes, a satellite would not be visible at all at both of the two terminals. A 3,000-mile satellite, however, would be visible at least 31.4 minutes, and as long as 55.4 minutes, for every revolution around the earth. On the average it would be visible 22 per cent of the time. Thus, even with only one satellite, one might get quite long stretches of broadband communication.

This view is somewhat optimistic, however, since we have so far ignored three sources of noise that could restrict the range of this type of communications: (1) The noise added by the receiving amplifier, (2) Cosmic noise, and (3) Atmospheric noise. Fortunately, the maser (RECORD, *July*, 1958) provides us with a microwave receiver that adds practically no noise to the received signal. Thus we can largely neglect the first of these three noise sources.

Another illustration (*page* 324) gives some pertinent data on the other two sources. In this graph, noise is described in terms of absolute temperature, ranging upward from 1° Kelvin on the ordinate, as related to frequency on the abscissa. The color region describes the range of the cosmic noise discovered by Jansky, and as we see from the graph, it becomes negligible at the higher frequencies.

The third source — atmospheric noise — is a more serious limitation. Even cold air at high altitudes is hot compared to absolute zero, so it radiates electromagnetic noise just as hot iron radiates light and heat. The radiation is small because the atmosphere is almost transparent. To evaluate the noise, we must consider how transparent the atmosphere is at a given frequency and also how much atmosphere an antenna "sees" as it follows a satellite.

In the graph, the bottom curve labelled 90 degrees illustrates that an antenna pointed straight up sees a minimum of atmosphere and therefore receives a minimum of atmospheric noise. From about 2 to 10 kilomegacycles this noise is fairly constant and corresponds to only about 2.5°K. As the antenna is rotated farther and farther toward the horizon, however, it must look through more and more atmosphere and receive correspondingly more noise. The zero curve at the top is the case where the antenna points horizontally; here it sees a very long atmospheric path, and the noise actually approaches the assumed atmospheric temperature (290°K) at very short wavelengths for which air is not very transparent to microwaves.

Note, however, that the curves for the various angles are displaced downward toward the lower noise values as the angle above the horizon is increased. Even as close as 10 degrees above the horizon, an antenna will see only about 13°K of atmospheric noise. These curves make us feel that we can realize the advantages of the maser if we use signals from a satellite reflector only when it is 7 degrees or more above the horizon. This limitation in effect contracts the contour areas in the polar-projection map, which were drawn with the assumption that signals would be received right down to the horizon.

How serious is this limitation? Suppose we consider satellites 3,000 miles high and use them only when they are at least 7 degrees above the horizon. Average visibility per rotation will thus be less than the 22 per cent listed in the first table, but if we put more and more satellites up, the result is an increase in the percentage of time that at least one satellite is visible. For 24 satellites, at least one satellite would be available to both Newfoundland and Scotland for 99 per cent of the time. The interruptions would occur at predictable intervals, and would therefore be less serious than if they were random in time. The second table *(see below)* lists some other possibilities for different minimum angles and percentages of service interruptions.

The next obvious question is whether transmitters and antennas are available for such communication. Assuming an operating frequency of 2 kilomegacycles, a 40 db signal-to-noise ratio, and 100-foot spherical reflectors at 3,000 miles, we have calculated that we would need antennas 150 feet in diameter and transmitter power of 100 kilowatts. Antennas of this size have been used, and the required power could be obtained by paralleling ten commercially available tubes. At present, however, we cannot be sure that the required type of satellite reflector would withstand the conditions of space and maintain its shape in orbit.

### Need for Knowledge

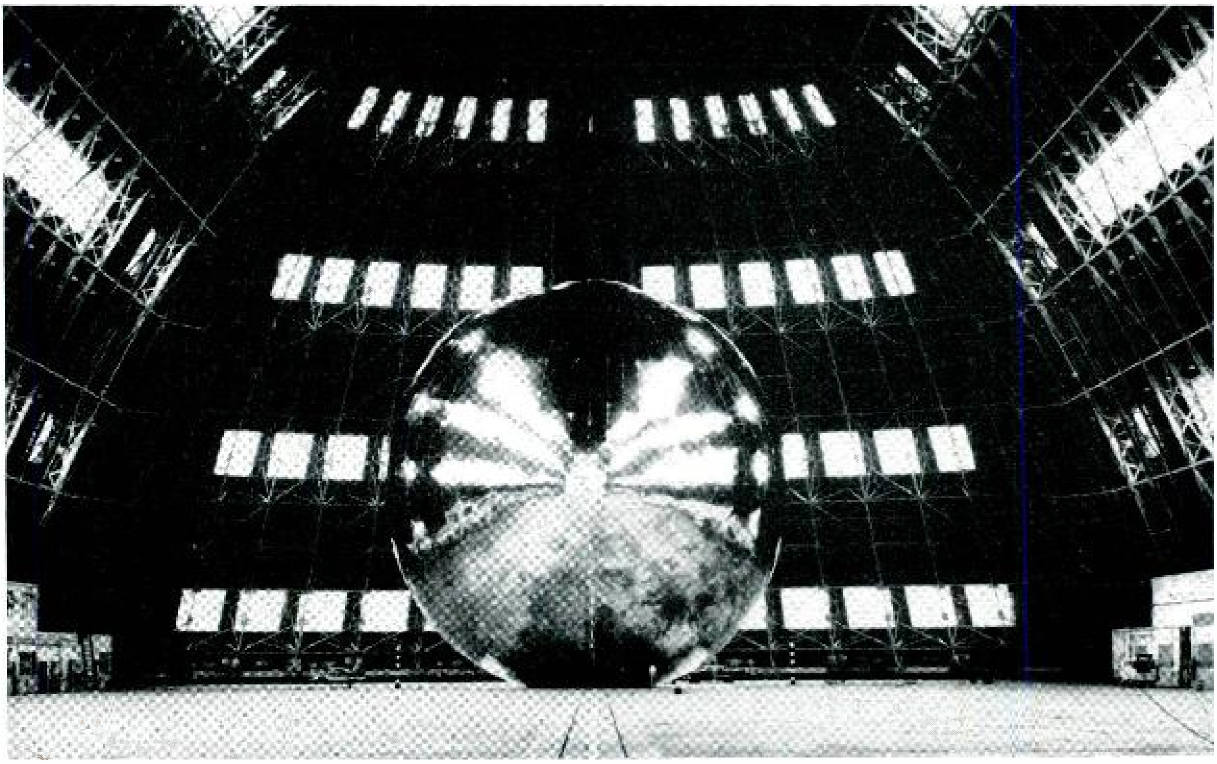
At this stage the reader may feel that this is exoticism with a vengeance. We have perhaps raised more questions than those we have tried to answer. Aside from the problem of costs, which can hardly be handled definitively at this early date, the technical problems are extensive. But herein lies the point of this discussion — we need more fundamental knowledge of the possibilities before we can begin to think realistically of actual systems. And the only way we know of to get this knowledge is to continue our traditions of careful search, study of the problems, and measurement.

On March 19, T. Keith Glennan, Administrator of the National Aeronautics and Space Administration (NASA), announced plans to launch several satellite spheres next year. These experimental spheres, fabricated from an aluminized plastic, are to be 100 feet in diameter. The announcement also mentioned the plan to establish communications between an 85-foot tracking antenna at Goldstone, California, and communications facilities on the East Coast, including

**Number of Randomly Spaced Satellites Needed for Various Minimum Elevation Angles and Percentages of Interruption**

| Minimum Elevation Angle in Degrees | Percentage of Interruption | | |
|---|---|---|---|
| | 10% | 5% | 1% |
| 0 | 9 | 12 | 19 |
| 3.25 | 11 | 14 | 21 |
| 7.25 | 12 | 15 | 24 |
| 12.60 | 17 | 22 | 33 |

Assumptions: Terminals in Newfoundland and Hebrides; Polar orbits at 3000-mile height.



*Plastic sphere, 100 feet in diameter, of type to be used in satellite transmission experiments. In orbit, thin plastic with aluminized surface will reflect microwaves.* (Photo courtesy of the NASA.)

Bell Laboratories equipment at Holmdel. The Goldstone antenna is operated by the Jet Propulsion Laboratory of Pasadena, California, which is owned by NASA and operated under contract to the NASA by the California Institute of Technology.

In connection with this type of work, then, what are some of the specific problems on which we have worked, and what are some of the problems concerning which we need additional knowledge?

While we have a very good maser in the 6,000 mc range, there is still some room for improvement, and we need masers for other frequencies. A related problem is that some types of antennas tend to pick up noise from all directions, so we are adapting the horn-reflector type antenna, which does not have this defect. With such equipment, we have already made measurements of sky temperatures which check the theoretical curves shown on page 324. We believe that these antennas may also have many uses in radio astronomy.

We have made some studies of the effect of ultraviolet light on the properties of aluminized Mylar, and for this material we have investigated absorption at various wavelengths to tell us the temperature a satellite might attain in space.

Other obvious fields for additional work are those of propagation measurements, guidance, and the many components besides masers and antennas that must go into any experimental system. A very important need is highly reliable components for experiments with active satellite repeaters. We have inaugurated work on such components.

This need for further study should emphasize that today we have no proven answers to the problem of overseas broad-band radio communications. If we ever turn on our television sets and view a European event beamed by radio across the Atlantic, it may come to us over a system no one has even thought of yet. But in the meantime, to assure the possibility we must continue to pursue a vigorous and effective research program.

*New techniques for diffusing impurities into semiconductors have led to greatly improved solid-state devices. For diffusion into silicon, Bell Telephone Laboratories has contributed toward developing various new techniques, one of which emphasizes an extreme cleanliness of the material.*

R. L. Batdorf and F. M. Smits

# The Diffusion of Impurities Into Evaporating Silicon

The use of silicon as a semiconductor material is rapidly expanding. Many diodes, solar batteries, and transistors made from silicon are now commercially available, and more refined and improved devices are under development at Bell Telephone Laboratories and in other companies.

A piece of single-crystal semiconductor material is the heart of all these devices. After extensive purifications, these materials are "doped" with special impurities in controlled amounts. Depending on our choice of impurities, we can form n-type or p-type semiconductors. In these two types, electric current is carried by different carriers — namely, electrons in n-type and "holes" (vacant electron states) in p-type material.

The fact that it is possible to form regions of electron conduction and regions of hole conduction within a piece of single-crystal semiconductor material is the basis for the operation of most semiconductor junction devices. The transition from n-type material to p-type material is called a p-n junction, and it usually has rectifying properties. Diodes and solar batteries contain just a single p-n junction, while transistors require at least two p-n junctions in a precise geometrical relationship.

The introduction of necessary impurities is therefore very important in the production of device structures. A key method by which such impurities can be introduced is the technique of solid-state diffusion (RECORD, *December, 1956*), which allows accurate control of the depth to which an impurity is introduced. Our chief concern here is a new Bell Laboratories technique for solid-state diffusion of impurities into wafers of silicon.

The process of diffusion is based on the random thermal migration of atoms. In solid materials, such migration is generally negligible at room temperature. With increasing temperature, however, this motion becomes more and more significant. An impurity brought into contact with a silicon surface will be mixed — on an atomic scale — with the solid silicon at a rate mainly determined by the thermal motion. It is this process which is called diffusion. At the surface, the impurity will have its maximum concentration and the concentration will decrease with increasing depth. As time progresses, the point at which the concentration decreases to a certain fraction of the surface concentration will move deeper into the solid. The velocity of this point decreases as the depth increases.

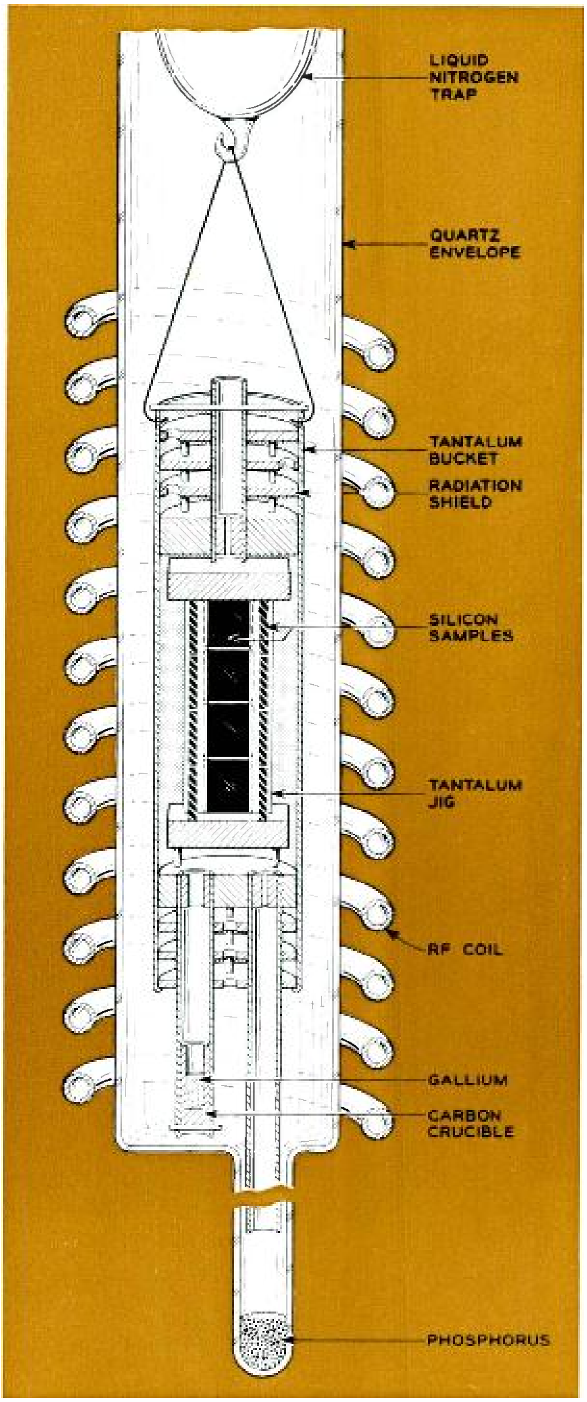
### *Diffusion and Evaporation*

In silicon, doping elements of the group boron, aluminum, gallium, indium (Group III of the periodic table) produce p-type material, whereas the group phosphorus, arsenic, antimony, bismuth (Group V of the periodic table) produce n-type material. In practice, most diffusions of these elements into silicon must be carried out at temperatures above 1000°C and certainly below the silicon melting point at 1412°C. In this temperature range, silicon is extremely reactive, making a clean surface difficult to maintain. Yet a clean surface is very important for further processing of the material.

The new diffusion technique utilizes a vacuum system where the only vapors present are those of a diffusing impurity and of silicon. The impurity vapor is in contact with the silicon surface and thus diffuses into the silicon. Under these experimental conditions, the rate of evaporation of the silicon becomes comparable to the rate of diffusion of these elements. This evaporation affects the distribution of impurities in the solid and assures a surface of sufficient cleanliness for device application.

Because of evaporation, the surface of the silicon is constantly receding with a given velocity. Since, as we pointed out before, the penetration rate of the diffusing impurity decreases with increasing depth, there will thus be a certain depth at which the rate of diffusion is equal to the velocity at which the surface is evaporating. Therefore, only a finite penetration is possible under an evaporating surface.

If an impurity is diffused into material which is uniformly doped with an impurity of the opposite conductivity type, a p-n junction occurs where the concentration of the diffused distribution equals the concentration of the body doping. To fabricate, for example, an n-type layer on p-type material, we would use any one of the elements of Group V as the diffusing impurity. The different elements, however, diffuse with different rates, which are measured by the dif-




*The diffusion bucket and system used for the simultaneous diffusion of phosphorus and gallium into silicon. Bucket consists of a tantalum cylinder suspended from a liquid nitrogen trap in a quartz vacuum station. An RF coil around the quartz envelope heats diffusion bucket by induction. Individual silicon samples are held in jig.*

fusion coefficients. Phosphorus, for instance, has a higher diffusion coefficient (at a given temperature) than arsenic. It is clear, therefore, that a steady-state layer produced by phosphorus diffusion would be thicker than one produced by arsenic diffusion.

The rate of evaporation of silicon from the silicon sample is an additional parameter controlling the thickness of a diffused layer. This rate also increases strongly with temperature. But even at a given temperature, it can be changed. It will have a maximum value if the silicon is heated in a nearly perfect vacuum — that is, if all atoms leaving the silicon are removed without colliding with the surface. Silicon heated in an all-silicon container would have zero evaporation rate. Generally, rate of evaporation will depend on the geometry and material of the container and on amount of silicon present.

Clearly, with no evaporation taking place, we cannot achieve a steady-state layer, and the layer thickness will continue to increase for longer and longer diffusion times. On the other hand, with the highest rate of evaporation, the steady-state layer would have a minimum thickness. We see, therefore, that an increase in the rate of evaporation of silicon decreases the layer thickness, while we showed previously that an increase in the rate of diffusion of the impurity results in an increase of the layer thickness. Both rates, however, increase with increasing temperature. Thus the steady-state layer thickness would be temperature insensitive if the two

*F. M. Smits (top) and R. L. Batdorf viewing the heated diffusion bucket inside the quartz envelope, which is circled by the RF induction coil.*

effects just cancel each other. For the diffusion of Group III and Group V elements, it turns out that their rates of diffusion increase somewhat more slowly with temperature than the rate of silicon evaporation, with the result that the layer thickness decreases somewhat with increasing temperature.

The diffusion chamber must be constantly evacuated to maintain the partial pressure of undesired impurity-vapors and gases below a minimum value. At the same time, the partial pressure of the desired impurity must be maintained within this chamber. The only way this can be done is to have a constant flow of doping vapor through the chamber.

Sometimes we would prefer to diffuse two impurities simultaneously — one to produce p-type semiconductor material, and one to produce n-type semiconductor material. Under the proper conditions, we then can produce double-diffused n-p-n structures for transistors.

### Diffusion Apparatus

A diffusion system used for the simultaneous diffusion of phosphorus and gallium into silicon is shown in the drawing on the preceding page. The diffusion "bucket" consists of a tantalum cylinder suspended from a liquid nitrogen "trap" in a quartz vacuum station. Such a trap freezes certain undesirable gases and thus aids in creating a good vacuum. The vacuum line is opened with a standard taper joint located well above the lower end of the liquid nitrogen trap. This location is necessary to assure that all of the hydrocarbons from the stop-cock grease are condensed to prevent the formation of silicon carbide on the surface of the samples. An RF coil around the quartz envelope heats the diffusion bucket by induction. The photograph on this page shows the laboratory arrangement for this diffusion system.

The diffusion bucket contains radiation shields to assure a uniform temperature in the diffusion chamber. The interior of the bucket is pumped through an opening in the lid, and the base is fitted with two smaller tantalum tubes, one of which fits closely into an extension of the quartz envelope. Phosphorus vapor is supplied from a quantity of red phosphorus placed in this extension tube *(bottom of the first drawing)*, which is heated by a heating bath. The second tantalum tube contains a graphite crucible which holds metallic gallium. A temperature gradient of several hundred degrees exists along this second tube when the bucket is heated to the diffusion temperature. Consequently the temperature, and hence the vapor pressure, of the gallium may be varied by moving the crucible within this tube. The temperature of the diffusion chamber itself was measured by taking a pyrometer reading on the outside surface of the bucket.

Individual silicon samples are held in a tantalum jig so that one side of each piece of silicon is not exposed to the direct evaporation from another silicon surface.

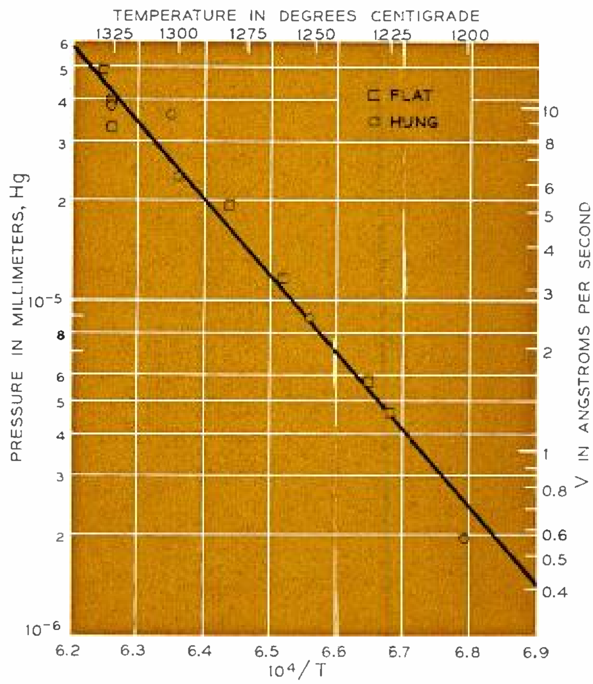
### Surface Concentration and Evaporation

As we pointed out before, the rate of evaporation depends on the particular arrangement of the silicon sample in the container and on the container itself. For this reason the rate of evaporation under actual experimental conditions has been determined by observing the loss in weight of silicon samples. The only modification necessary for these experiments was the elimination of the sample holder. In some experiments our samples were suspended from a thin tantalum wire, thus exposing essentially the entire sample surface to evaporation. In other experiments the samples rested on another silicon piece, thus exposing only one surface to evaporation. The graph shows the rates of evaporation for the two configurations are in close agreement.

Most diffusions were performed with phosphorus and gallium as the diffusants, and some experiments were also carried out with arsenic and indium. Single n-type layers on p-type material were produced with phosphorus as the diffusant. The bucket used in these experiments contained only one extension tube, and surface concentrations for the n-type diffused layers have been varied over several orders of magnitude. The upper limit of surface concentration is about $7 \times 10^{19}$ atoms per cu cm; excellent control is possible from this limit down to $5 \times 10^{15}$ and probably lower. We performed similar experiments with gallium to obtain single p-type layers on n-type material, but these were done in the bucket designed for double diffusion.

By changing the gallium temperature, the surface concentration could be varied from approximately $10^{19}$ to less than $10^{16}$ atoms per cu cm by moving the graphite holder from the top to the bottom of the extension tube.

Since the rate of diffusion of gallium is somewhat higher than that of phosphorus, n-p-n structures can be obtained on n-type material by properly choosing the surface concentrations of phosphorus and gallium respectively. The ratio of the surface concentration of the two diffused layers essentially determines the thickness of the first (emitter) layer, while the thickness of the second (base) layer can be adjusted by the impurity concentration in the parent n-type material. This method gave n-p-n structures for transistors with an alpha cutoff frequency of 70 megacycles per second.




*A graph to show the evaporation weight of silicon samples during a typical phosphorus diffusion. The evaporation data are plotted on the left ordinate as silicon vapor pressure in millimeters of mercury; on the right the evaporation rate is shown in angstroms per second.*

For device applications, the diffusion of impurities into an evaporating silicon surface is very desirable since the resulting samples possess extremely clean curfaces. The steady-state layers that form beneath this clean surface have a small temperature dependence so that reproducible results are obtained without an elaborate temperature control of the diffusion chamber. Single or double diffused structures can now be produced by these techniques, and layer thickness can be increased by restricting the evaporation of silicon.

Because the transients at the start of the process are unimportant, this process will have a natural advantage for diffusions requiring low surface concentrations. The vacuum diffusion process might conceivably be used as a first step, followed by diffusion in an oxidizing atmosphere (eliminating evaporation) to obtain thicker diffused layers with low surface concentrations.

*A new transcribed announcement machine has a longer maximum message time, and it establishes a length of cycle to match each new announcement. These features should help to introduce new transcribed message services in the Bell System.*

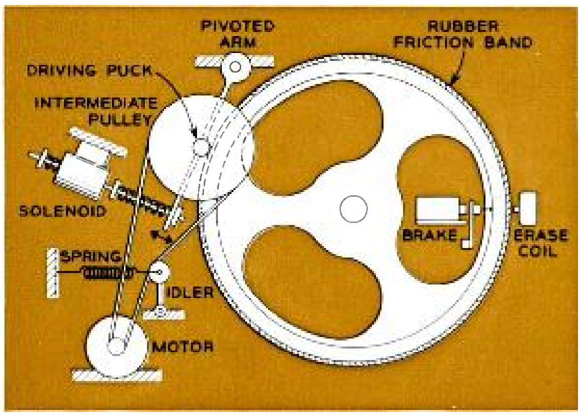
C. R. Keith

# A Variable-Cycle Announcement Machine

Magnetic recording and reproducing machines have been used for weather announcements in the Bell System for more than twenty years. In addition transcribed announcement machines have recently been used for other types of announcements, such as "intercept" ("The number you have reached is not a working number. . . ."), stock exchange, and call-delay quotation (See RECORD, *September*, 1952, and *September*, 1955). Sponsored weather reports and other recorded announcements over the telephone are also becoming increasingly important. In the course of a year, these machines may repeat announcements more than a million times.

Each of these machines uses magnetic recording, so the announcement may easily be changed at any time. But in the first machines, all announcements had to be the same length (approximately 30 seconds) unless an appreciable "silent time" was left between repetitions. In later machines, the announcement time could be changed, but only by stopping the machine and manually shifting gears or changing pulleys. In either case, the announcement must be carefully composed so that it justs fits the available time for which the machine is set.

Such "tailoring" of the announcement is eliminated in a new recorder-reproducer. This heavy-



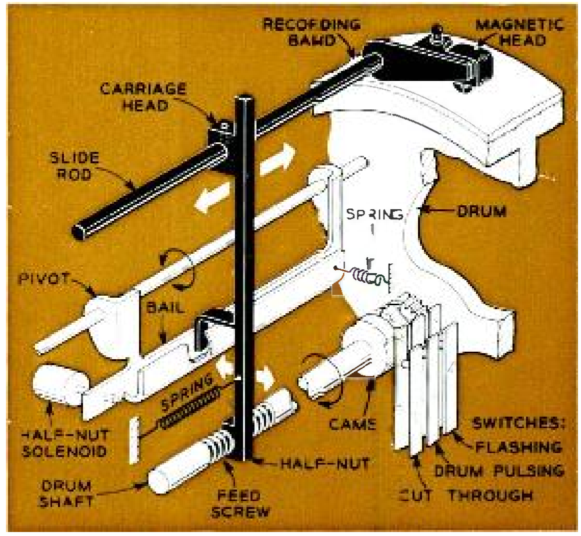

*The drive mechanisms (left), the recording drum, and (right) the brake arrangement and erase coil.*

duty announcing machine, made by Automatic Electric Co. and designed to meet Bell System requirements, automatically adjusts its playing time to the length of the particular announcement being recorded. While this variable-cycle feature has been used in telephone answering machines (RECORD, *November*, 1953), it has not previously been made available in heavy-duty central office equipment. Other valuable features incorporated in the new machine are a longer maximum announcement time (4 minutes), improved gearless drive, and start-stop operation.

As in the case of the intercept and delay quotation machines, the announcement is recorded on a cylindrical magnetic band which field experience has shown to be substantially free of maintenance troubles over extended periods of time. This band (BELL SYSTEM TECHNICAL JOURNAL, *May*, 1953) has magnetic properties quite similar to the tape used in home tape recorders. In addition, it provides an elastic surface conforming to the magnetic head, making the adjustment of the head much less critical than would be the case if the head rested on a hard magnetic surface. It is mounted on a heavy drum approximately 9 inches in diameter and $3\frac{1}{2}$ inches wide. A maximum recording time of four minutes is obtained by using a comparatively narrow sound track and a low drum speed (10 rpm). The recording head is mounted on a slide rod which carries it over the width of the drum in about 40 revolutions. This makes a continuous track 0.055 inch wide and over 100 feet long on the drum surface.

Accurate retracing of the magnetic sound track is important in order to allow close spacing of the tracks without permitting the magnetic head to trace more than one track at a time. The required tracing accuracy is obtained by moving the magnetic head across the band by means of a feed screw. Motion is transmitted to the magnetic head by means of a half-nut *(see drawing on this page)* which may be engaged with or disengaged from the feed screw by the operation of a solenoid. In this drawing, the view is from the rear of the machine, looking forward to the magnetic head and recording band *(upper right in the drawing)*.

The magnetic head moves across the band through the action of the head carriage running vertically through the center of the drawing. To set this arm in motion, the half-nut solenoid *(lower left)* is operated, and this operation pulls the bail and the lower part of the carriage arm. The half-nut at the bottom of the arm thus engages a feed screw on the drum shaft, and the entire arm, carriage, slide rod, and magnetic head move as a unit so that the magnetic head travels across the recording band.



*Basic motion of the magnetic head: the bail pulls the half-nut against the feed screw, which moves the magnetic head across the recording band.*

Also shown, in the lower right part of this drawing, are three cams on the drum shaft and their corresponding switches. One of these flashes a signal lamp when the available recording time is nearly used up. Another causes a "cut through" pulse that connects a customer to the machine at the beginning of the message. The middle cam of the three operates a switch that energizes the half-nut solenoid to ensure that the half-nut engages the feed screw only when the drum and feed screw are in the proper angular position.

The illustration on the next page shows how the variable cycle feature is obtained. This drawing can be viewed as an upward extension of the previous illustration — that is, it shows elements above the head carriage and carriage slide rod, which are repeated here. The basic purpose of this mechanism is to place a stop at the end of the announcement.

Establishing the variable cycle consists of the following actions, beginning when a new recording is to be placed on the drum. The first step is the erasure of the old announcement. At the start of this erasure, a clamp operated by the limit-switch solenoid *(left in drawing)* releases. A spring *(upper left)* now is free to pull back the bar, across the upper center of the drawing, containing a "variable-limit" switch. This assembly is pulled back until it comes to rest at its starting position against the upper part of the magnetic-head carriage. Later, as the new announcement is recorded — that is, as the magnetic head moves across the recording band — the magnetic-head carriage pushes the switch assembly forward so that its position always has an exact correspondence to the position of the magnetic head. Then, at the end of the dictation, the clamp solenoid is de-energized, allowing the variable-limit switch assembly to be clamped in that position. Now, when the magnetic head tracks the recorded announcement in a subsequent playback, the switch is operated within a few seconds after the last word is spoken, and another cycle begins. In this way, each new announcement establishes its own length of cycle within the limit agreed upon by the customer. This outer limit, or maximum length of announcement, is established by another limit switch, indicated in the upper right of the drawing, whose position is adjusted manually.

### *Drive Mechanism*

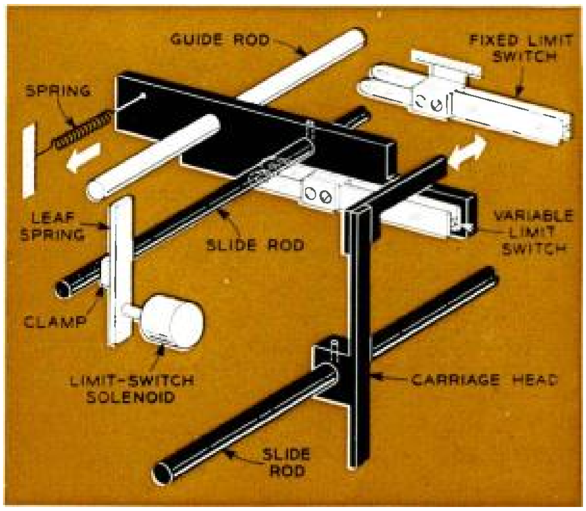
The more important details of the drive mechanism can be seen in the illustration shown on page 334, and again it will be helpful to consider a standard series of operations. Imagine, therefore, that a calling telephone user has just listened to the recorded announcement, and that for the moment there are no further requests for service. At the right in this drawing, a solenoid operates to release a spring that presses a brake against the inside rim of the drum. This brake is set, however, only when the drum is in the correct angular position — that is, when the magnetic head is at the beginning of the announcement, ready for the next call.

An erase coil is also indicated in the right part of the drawing. This coil extends the full width of the recording band, so that the entire message, regardless of length, is erased during one turn of the drum. The coil is energized with 60-cycle current, which is controlled by cam-operated switches. At the end of one revolution of the drum, the alternating current is caused to decay for half a second before it is cut off. This prevents formation of a "noise bar" that would result from a rapid decrease in magnetic flux.

The drum is driven by the combination "puck" and belt drive indicated in the left part of the drawing. Power is supplied by an 875 rpm motor especially designed for driving audio recording equipment. The first reduction in speed is due to a flat, impregnated fabric belt from the motor shaft to an intermediate pulley. A spring-pressed idler keeps the belt tight. The intermediate pulley is mounted on a pivoted arm to which is attached a spring and the plunger of a solenoid. When the solenoid is energized, a roller on the pulley shaft is engaged with a rubber friction band (not the magnetic band) on the drum. In this drive the roller or puck is pressed radially against the driven drum to prevent any build-up of pressure between the roller and the drum due to a change in bearing friction. This is in contrast to the usual puck drive in home phonographs where the intermediate drive wheel is wedged between the drive shaft and the driven turntable. When the solenoid is not energized, the puck is out of contact with the drum, preventing deformation of the rubber friction band.

Previous heavy-duty announcing machines have been made to operate continuously whether or not any customers' lines are connected to the machine. However, the new machine operates on a start-stop basis, so that when there are no calls, the drum is stationary, the motor is turned off, and the magnetic head is at the beginning of the message. This system not only reduces wear on mechanical parts but also increases the probability that the calling party will hear the beginning of the message when first connected to the machine.

Various control circuits may be used with this announcing machine to provide remote control from another central office or from the customer's premises. For maintenance, complete control of the recorder-reproducer is also possible at the equipment location.




*The variable-limit switch (center) establishes a time cycle for a particular announcement; the fixed-limit switch (upper right) is set manually to establish maximum announcement length.*

*To be successful, a business must keep its records in order. This often means a sorting job of great magnitude — the Telephone Companies, for example, must sort millions of toll-message slips each year. To cut down the time required for such operations, Laboratories engineers have joined the search for ways of sorting business data on electronic computers.*

J. F. Chesterman

# Sorting Methods in Large Business Operations

Sorting pieces of paper into some desired order, based on a number or other criterion recorded on the paper itself, is a difficult and time-consuming operation. Most of us are unaware of this because we rarely encounter a sorting problem more involved than arranging the 13 cards of a bridge hand, or sorting the cancelled checks we receive from the bank at the end of the month. We must imagine sorting hundreds or even thousands of paper items (such as an entire library catalog file), before we can appreciate how large and complex sorting operations can be.

Large business must sort thousands of bills, receipts or other records every day. Their problem is so great that they must devise special, highly efficient sorting methods. For example, the Operating Companies in the Bell System must process two billion toll messages annually. And despite postwar advances in direct distance dialing, operators currently write about 80 per cent of these messages on toll "tickets" measuring $2\frac{1}{2}$ by 5 inches. A typical billing office will receive about 75,000 tickets each business day; their daily sorting is a substantial undertaking, as will be evident from a specific example.

A relatively small central office serving 3,000 customers will "generate" about 15,000 toll tickets each month. These toll tickets must be sorted into order according to the four digits of each customer's line number; this number is called the "sorting key." Other data on the ticket — for example, the date of the call — might be used as the key in other sorting operations. But for purposes of illustration, the calling customer's line number is a convenient sorting key.

Because 15,000 toll tickets make a stack of paper a little over eight feet high, the "sorter" evidently needs special equipment. For this purpose, Bell System Companies have found a ticket-sorting rack to be highly efficient.

This device has one hundred pockets, numbered from 00 through 99. In the first of two sorting stages, a clerk places each of the 15,000 tickets into one of the pockets, according to the value of the two right-hand (units and tens) digits of the line number. She then removes the tickets and stacks them in a manner that pre-

*Clerks at an Automatic Message Accounting center of the Southern New England Telephone Company operate electro-mechanical card sorter. This machine can sort 15,000 cards in two hours.*

serves this initial ordering. They are then redistributed among the 100 pockets based on the two left-hand (hundreds and thousands) digits of the line number.

The clerk removes the tickets after this second sorting stage, starting with those in the "00" pocket and placing those from each successive pocket underneath. When she has completed this, all of the tickets are in ascending order. It takes about 13 hours to sort 15,000 toll tickets in this manner, or the equivalent of two sorting clerks working almost a full day. And this is only a part of the total processing required for one relatively small central office.

Obviously, we are constantly looking for less time-consuming methods of sorting toll tickets. But a major stumbling block has been the impossibility of replacing the human operator who reads the numbers constituting the sorting key. One solution is to record the toll message data in the form of holes in punched cards, and this has been done as a by-product of Automatic Message Accounting. More recently, engineers have designed special cards to be "mark-sensed" by the operator at the time the call is made.

Machine sorting of punched cards is based on the same method of using pockets, or slots, for distributing the cards in stages. But for practical and economic reasons, ten slots are used instead of 100. This requires twice as many sorting stages — one for each digit in the key number instead of one for each pair of digits. The punched cards would be processed by an electro-mechanical sorter like the one pictured on this page.

This sorter works in the following way. For the first of four stages, it distributes the cards among one of ten slots based on the 0 to 9 value of the units digit of the line number. A clerk then removes the cards and stacks them to preserve this initial order. The machine then distributes the cards a second time based on the 0 to 9 value of the tens digit. Two similar sorting stages, using the hundreds and thousands digits, respectively, complete the operation.

Punched card sorting is far superior to the manual method because it takes a little less than 2 hours, or about one-seventh of the manual time, to sort 15,000 toll tickets. Associated costs reduce the economic advantage of punched-card sorting somewhat; however, other billing operations, such as toll-message rating and printing, can also be performed by electro-mechanical machines. Therefore, accounting departments in the Operating Companies are trying to increase the percentage of toll messages recorded on punched cards to take advantage of the combined savings from sorting, rating and printing.

In large accounting centers the cost of processing toll tickets, and that of the many other facets of telephone-billing, have become so great that it would be practical to perform this work with large scale, electronic data processing systems. These systems use magnetic tape as their input and output media, permitting data to be read in or written out roughly 100 times faster than with punched-card machinery.

Information can be readily transferred from punched cards or other machine-language sources to magnetic tape, but at this point, a significant difference is introduced in the method of data handling. Instead of recording the information pertaining to each toll call on a separate card which can be moved physically from one place to another, the electronic system distributes information for all calls as a continuous flow of items along several thousand feet of magnetic tape.

Any rearrangement of these items requires them to be rewritten, or copied, onto another magnetic tape. But since large electronic computers are quite expensive, we want to minimize the number of rewritings required to sort data into proper order. Also, because nearly one-half of the processing of information contained on magnetic tape consists of putting in some desired order the individual items to be processed, designers must devise highly efficient methods for this sorting function.

One approach to the sorting of data on magnetic tape is based on the method already described for manual-ticket or punched-card sorting. This is called "digital" sorting because it distributes the items according to the value of each digit of the sorting key. One sorting "pass" is required for each digit in the key. For example, if the key is telephone line numbers (such as 3427), then four passes must be made.

One output tape (corresponding to a pocket or slot) is required for each possible value the digit may assume. In the decimal system, this requires ten magnetic tape outputs and, to avoid recopying the output passes on the input tapes, the equipment must have ten additional tapes for the return passes.

A large number of input and output tape machines (or an equally undesirable increase in sorting time if only a few tape machines are used) constitutes a serious disadvantage of digital sorting applied to magnetic tape systems. Another disadvantage arises from the fact that a separate pass is required for each digit of the key on which the sort is to be made. Businesses frequently need to sort items with sorting keys of 10 to 15 digits. The disadvantage here is particularly evident when there are only a few items to be sorted. Items with 10-digit keys, for example, require ten sorting passes and ten output tapes, whether there are 200 or 200,000 items to be sorted.

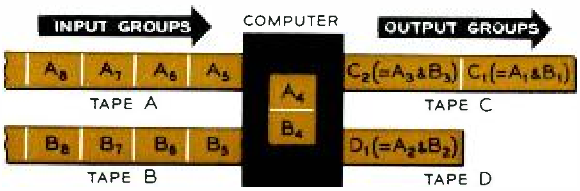
At Bell Laboratories, a widely used but fundamentally different method, called "collative" sorting, has proven to be very effective for most sorting of data contained on magnetic tape. This consists of collating, or merging, items into successively longer groups or sequences of ordered items in successive passes until the items are completely sorted.

The method is most easily visualized by considering a simple case in which the items to be sorted are read from two input tapes, merged within a computer, and then written onto two output tapes. This arrangement is illustrated conceptually by the sketch below. Input tapes A and B feed successive sequences, designated by A's and B's in the figure, of ordered items into the computer. The computer merges each pair of sequences, one from tape A and one from tape B, into double-sized sequences, and writes them on alternate output tapes, first C, then D, then back to C, and so forth.

For the next pass, all tapes are rewound, and pairs of sequences are read from tapes C and D. They are then merged to achieve another doubling in sequence size, and the combined sequences are written alternately onto tapes A and B.

The computer performs a numerical, not a random, merge based on the values of the sorting keys found in the items in the sequences. This merging method may be more easily understood by reference to the table at the top of the next page. This shows the two-digit keys for each of six items on each of two input tapes, A and B, and the same keys as they would appear on output tapes, C and D, after numerical merging. On all four tapes the last key in a sequence is indicated by underlining.

Note that there are half as many sequences on Tapes C and D after the sorting pass as there were on tapes A and B beforehand, and that the new sequences are twice as long. Successive passes continue this "halving" and "doubling" of the groups until the last pass, which results in merging the two long sequences into a single




*Conceptual diagram of how items can be sorted in a computer. Reader should picture tapes as moving left to right and note letters' subscripts.*

**TABLE 1**

**Two-Digit Sorting Keys of Items Being Ordered by a Collative Sort**

| Input Tapes | | Output Tapes | |
|---|---|---|---|
| A | B | C | D |
| 12 | 06 | 06 | 11 |
| 57 | 31 | 12 | 23 |
| 89 | 45 | 31 | 46 |
| 11 | 23 | 45 | 72 |
| 72 | 46 | 57 | 83 |
| 93 | 83 | 89 | 93 |

Merging method using two input and two output tapes with a two-digit sorting key. Output tape C accepts items from first half of either of the two input tapes according to ascending numerical value. Output tape D accepts items in a similar manner from the last half of both lists.

sequence on one of the output tapes. In the simple example cited in the table, the next pass will be the last pass because it will combine the two six-item sequences on tapes C and D into a single sequence of twelve items on tape A.

Further increases in the number of pairs of input-output tapes would result in corresponding increases in the multiplying factor. For example, if three pairs of input-output tapes are used, each successive pass would triple the number of items in a sequence. However, each added pair of tapes produces a smaller increase in the multiplying factor — a change from two pairs of tapes to three gives a gain of 3/2 or 1.5, but a change from four to five gives a gain of only 5/4, or 1.2. Because of this diminishing rate of return, and the relative expense of the equipment required, the number of pairs of tapes most frequently used lies in the range from two to four, and two pairs of tapes are most efficient for certain high-speed computers.

The advantage of magnetic-tape sorting is evident from the fact that the collative method, using three pairs of input-output tapes, can "order" the 15,000 toll calls of our earlier example in about 3½ minutes. This is thirty times as fast as punched-card sorting with electro-mechanical equipment, and it therefore represents a substantial breakthrough in data processing's battle against time.

Obviously, the electronic systems required for this high-speed sorting are many times more expensive than electro-mechanical equipment. Thus, the advantage of high speed with electronic equipment is somewhat offset by the greater expense of that equipment. But to keep this advantage as large as possible, the Laboratories has made intensive studies of techniques to further reduce the time consumed by magnetic-tape sorting. Most of these have centered around ways to get the maximum amount of "ordering" in the first pass of the items through the computer. To understand this, we need to explain the operation of the first pass.

With collative sorting and three pairs of input-output tapes, the average number of items in sequence after any given pass will be three times the average sequence length existing before that pass. For example, if the average sequence length is 300 items at some intermediate stage of sorting, the average sequence will be 900 items after the next pass, 2,700 items after the next, etc.

How large an average sequence can be achieved as the result of the first pass? This question is significant because the larger the average sequence is after the first pass, the fewer will be the number of subsequent passes required. Unfortunately, unless special measures are employed, the average sequence length after the first pass will probably be two.

The first pass of the sorting operation normally is unproductive because items to be sorted are usually made available to the computer on a single input tape. Thus the first pass merely distributes the items equally over three output tapes. Only after this is done can the equipment

*Clerical personnel at the Teaneck office of the New Jersey Bell Telephone Company use this ticket sorting rack to put toll-message slips into order.*

start merging individual items from three input tapes into ordered groups of three items each, distributed among three output tapes.

The examples shown in the table on this page show how to adjust the first pass to achieve order sequences. Case A illustrates the result obtained when the first pass merely takes advantage of the initial ordering of the input items. Not all sequences are the same length but their average length is two items — which may be expected from an originally random order.

Case B illustrates an operation for the first pass modified to achieve longer sequences. This is called a "three-live-tape" pass because any one of the three output tapes can always receive any key read from the input tape. The particular tape selected in any instance depends on the relationship between the last three output keys and the next key read from the input.

Note that the three-live-tape procedure distributes the 24 input items in a total of only six sequences on the three output tapes, resulting in an average sequence length of four items instead of the average of two achieved in Case A. This may appear to be a small advantage, but in certain circumstances it will reduce the number of sorting passes by one.

Similar techniques can achieve a high average sequence length after the first pass. For example, a computer can read groups of 10 items at a time from an input tape and order them completely within itself before writing them onto output tapes. Of course there is a limit beyond which long first-pass sequencing is not economical. First-pass sequencing requires the computer to perform a number of logical operations, and these logic steps take time. A point is ultimately reached, therefore, where the logical processing in the first pass takes more time than is saved by reducing the number of subsequent passes. Another limiting factor exists in the size of the entries to be sorted. If these are large, only a few of them can be contained within the computer during the first-pass ordering procedure.

We can see then that the number of collative sorting passes can be reduced in several ways. The particular techniques a computer uses depend upon the nature of the data — the size of the entries and the degree of the initial ordering. It therefore appears that an electronic computer can use several procedures especially adapted to the data in each case.

The speed of decision making within a computer relative to its speed of reading items from input tapes is an important factor in improving the sorting operation. For this reason, Laboratories engineers are studying the kinds of data encountered in data processing in the Bell System. From these studies, design engineers can determine the proper balance between internal and external computer speeds, and ultimately furnish accounting departments of the Operating Companies with a speedy sorting system.

**TABLE 2**

**Results of First Sorting Pass**

| Sorting Keys of Items on Input Tape | | Output Tapes 1 | 2 | 3 |
|---|---|---|---|---|
| 60 | Case A: Items are distributed to only one output tape at a time. | 60 | 45 | 17 |
| 78 | | 78 | 92 | 56 |
| 45 | | 34 | 39 | 13 |
| 92 | | 61 | 22 | 55 |
| 17 | | 83 | 46 | 98 |
| 56 | | 67 | 14 | 07 |
| 34 | | 57 | 77 | 31 |
| 61 | | | | 73 |
| 83 | | | | 36 |
| 39 | | | | 62 |
| 13 | | | | |
| 55 | | | | |
| 98 | | | | |
| 67 | Case B: Items are distributed on a "3-live-tape" basis. | 60 | 45 | 17 |
| 22 | | 78 | 56 | 34 |
| 46 | | 92 | 61 | 39 |
| 07 | | 13 | 83 | 55 |
| 31 | | 22 | 98 | 67 |
| 73 | | 46 | 07 | 73 |
| 57 | | 57 | 31 | 14 |
| 14 | | 77 | 36 | |
| 77 | | | 62 | |
| 36 | | | | |
| 62 | | | | |

List at left to be placed in order. In Case A, keys read from input tape follow each other on same output tape when they are in ascending order. Thus, 60 goes to first output tape; 78 follows it. On next key read, shift is made to second tape because key is less than 78. Thus, 45 starts new sequence on Tape Two. In this manner all 24 keys on input tape become 12 sequences of three output tapes. Case B shows modified operation to make longer sequences. Each new key will follow the largest key on one of the three output tapes smaller than itself. But if the new key is smaller than all of the last three output keys, it will go on the output tape having the largest key and will thus start a new sequence of ordered entries. For example, 60 goes on Tape One as does 78. Next key, 45, starts new sequence on Tape Two, but following key, 92, goes back to Tape One to follow largest key, 78. Key 17, of course, starts the third tape. Key 56 goes to Tape Two because this tape has the largest key (45) equal to or smaller than its last key.

*When people are away from home, it is sometimes difficult to reach them by telephone. Now, however, hotels and motels may install an efficient "message-waiting" service — the guest returns to his room, sees a lamp flashing on his telephone, and calls an attendant to receive his messages.*

M. L. Benson

# Message-Waiting Service

Nowadays, a guest expects a hotel or motel to give him much more than lodging for the night. He expects many auxiliary services such as parking garages, room service, and other arrangements designed to prolong his stay and make it more comfortable. For this reason, hotel proprietors are increasingly turning to the telephone for new service features. In many hotels, a guest now has rapid access to the various "extras" with his telephone dial. Valet, room service, the bell captain and others are available with minimum effort and delay. In addition, very often, a guest may dial his own calls in the local telephone system.

### Light Indicates Message

The most recent of these new telephone services is the "message-waiting" light. This light is installed in the room telephone, and when it flashes it indicates to the guest that the hotel has a message to deliver. A message-waiting telephone set is shown in the photograph on the next page. This set is available in several colors with a red plastic cap over the message lamp.

The requirements for message-waiting service were as follows: (1) The lamp was to be visible and reliable under all normal lighting conditions; (2) The message indication was to be entirely under the control of the attendant at the hotel message center or wherever the hotel keeps messages for guests. That is, the indication was to be established, maintained, and removed with no action required of the guest except his receiving the message; (3) The service was not to interfere in any way with the normal PBX system, and vice versa; (4) It was to require no additional wiring in the hotel room; and (5) It was to be comparatively inexpensive. The Bell System Message-Waiting Service was designed to meet these requirements.

A message can come to a hotel message center in several ways. It might be a teletypewriter or Telautograph message from the hotel's PBX operator. It could be a verbal message or a written message such as a telegram, letter or note left at the desk. In any case, the attendant at the

*The new message-waiting telephone set. When a guest returns to his room and sees the lamp flashing on the room telephone, he calls the hotel or motel message center to receive his messages.*

message center ends up with a piece of paper containing the message, and must associate this message with a particular room telephone.

The attendant has in front of her a "message-waiting" console *(next page)* containing a number of pull-type keys. Once she determines which telephone is to be signaled, she pulls the appropriate key and files the message. When the key is pulled, it remains operated, and the message-waiting light on the telephone flashes at 60 impulses per minute. If this guest should receive additional messages before the first is delivered, the attendant merely notes that the key has already been operated, and files the other messages with the first.

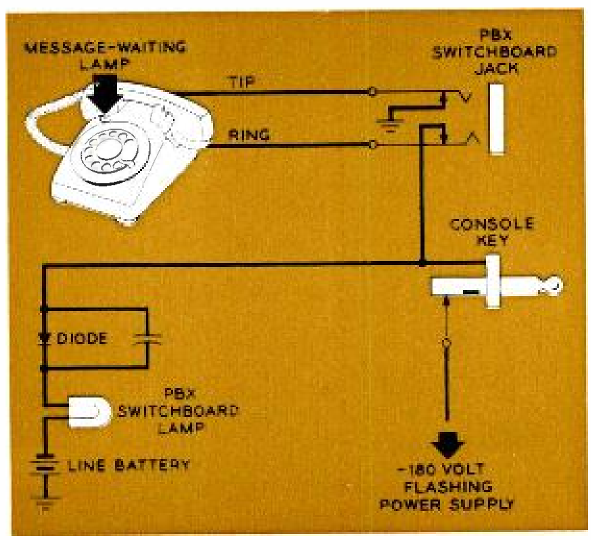
In the normal course of events, the guest will return to his room, see the flashing light, call the message center, and have the message or messages read to him. The attendant will then restore the key, and the lamp will stop flashing. However, the guest may choose to make one or more telephone calls before he asks for his messages. When he picks up the handset, the lamp is extinguished, but it starts flashing again as soon as the handset is restored. The only way to retire the signal permanently is for the attendant to return the key to the unoperated position at the message center.

The diagram on this page indicates the main features of the circuit. Shown here are the message-waiting telephone set *(upper left)*, a corresponding jack on a PBX switchboard *(upper right)*, a PBX switchboard lamp *(lower left)*, and the message-waiting key *(right)*. With automatic dial equipment, of course, the circuit arrangement is different, but the electrical effect is the same, and this circuit can therefore be used to illustrate the basic principles of the message-waiting service.

The message-waiting key is here shown in the operated position (pulled to the right) to place an interrupted or flashing -180-volt supply on the ring side of the PBX line. This voltage goes out on the line through the message-waiting lamp and back on the tip side of the line to ground. Note that if a plug is inserted into the jack, the flashing voltage is removed. This corresponds to the situation referred to earlier, wherein a guest places or receives a call prior to asking for his messages. For the duration of the call, the lamp does not flash, and the possibility of noise from the message-waiting circuit is thereby minimized. When the call is completed, the signal reappears.

It can also be seen on this diagram that without additional circuit elements, the -180-volt supply would operate the PBX switchboard lamp (or with dial equipment, the line relay) in the reverse direction through the line battery to ground. The diode in the circuit prevents this type of false operation.

The console with the message-waiting keys may be located at any convenient place in the hotel. In a large commercial type of hotel, it




*Simplified electrical circuitry for the message-waiting service. Actual circuit for automatic dial operation is different, but electrical effect is identical to manual switchboard arrangement.*

*Kenneth Borden, Southern Bell PBX Equipment Engineer, points out features of message-waiting console to operator at installation of message service at the Fontainebleau Hotel, Miami Beach.*

would probably be located somewhere close to the desk where the majority of messages are delivered and a sizable portion of the messages are received. In a resort hotel, where guests stay for longer periods, most messages are delivered over the telephone, and the message-waiting console would be most convenient to use in the switchboard room. In smaller establishments — motels for instance — the switchboard operator is the only one on duty for considerable periods of time. For this application it might be desirable to mount the message-waiting keys directly in the face of the switchboard.

### Variety of Installations

The arrangements for the message-waiting keys were made as universal as possible to meet the great variation in local conditions. Standard consoles include desk-mounted arrangements for 120 and 260 keys, as well as standard apparatus cabinets having a capacity of 300 keys. These latter units may grow both horizontally and vertically. The consoles have both front and rear access and therefore can be either flush or surface mounted. Equipment is furnished with either a gray-green finish similar to that used on teletypewriters, or unpainted so that it can be finished to match the local decor. In addition, the basic framework and gate used to support the keys in the cabinet can be ordered separately for locations where it is desirable to have a built-in type of installation that will harmonize with its surroundings better than a console or cabinet. An example of this might be in a location visible to the public, like a hotel desk. Lastly, adapters are available to mount the key units in standard openings in switchboards.

In the standard arrangement, one power supply and an interrupter are provided per 300 lines. The basic unit includes a power supply, interrupter, and networks for 120 lines. Additional networks are available in units of 20.

The power supply is a commercial semiconductor-type unit. For maximum use of the available power, half the lamps will light on one half cycle of the interrupter and half on the other.

Maintenance equipment is provided on the basis of one set per power supply and interrupter. There is a test panel, containing four keys and a test lamp, for each 300 keys or fewer. As mentioned above, each output of the interrupter flashes half the total number of lamps and must be tested separately. Two buttons are provided for each output. Operation of the "FL" (flash) button causes the lamp to flash if the power output from that interrupter contact is satisfactory. The operation of a particular message-waiting lamp can be tested when the corresponding key is the only one operated in that interrupter output circuit. At this time, operation of an "STA" (station) key places the test lamp in series with the station lamp, and the flashing of the former indicates that the latter is lighting properly. It is expected that the station lamps will be tested during periods of very light traffic when one key at a time may be operated for the test. Two emergency keys are used to by-pass the interrupter should it fail for any reason.

While it is true that the message-waiting service was designed essentially for hotel application, it is available to all PBX customers. There is an increasing number of motels equipped with full telephone service for commercial rather than recreational travelers. Inasmuch as a motel ordinarily does not have bellboys, the message-waiting service seems particularly applicable to this type of arrangement. In addition, the message-waiting lamp can be used to permit someone at a central control point to signal the user of a PBX extension over the regular PBX line. This could be a prearranged message — the beginning of a conference, the arrival of visitors, or a summons to a superior's office. Another application might be the transmission of one of several prearranged messages by varying the flashing rate of the signal.

*Automatic billing equipment is a key item in the fast growing Direct Distance Dialing (DDD) program. With the Centralized Automatic Message Accounting (CAMA) equipment added to 4A - 4M toll switching systems, DDD now can be economically applied in many new metropolitan areas.*

R. J. Jaeger, Jr., and M. E. Maloney

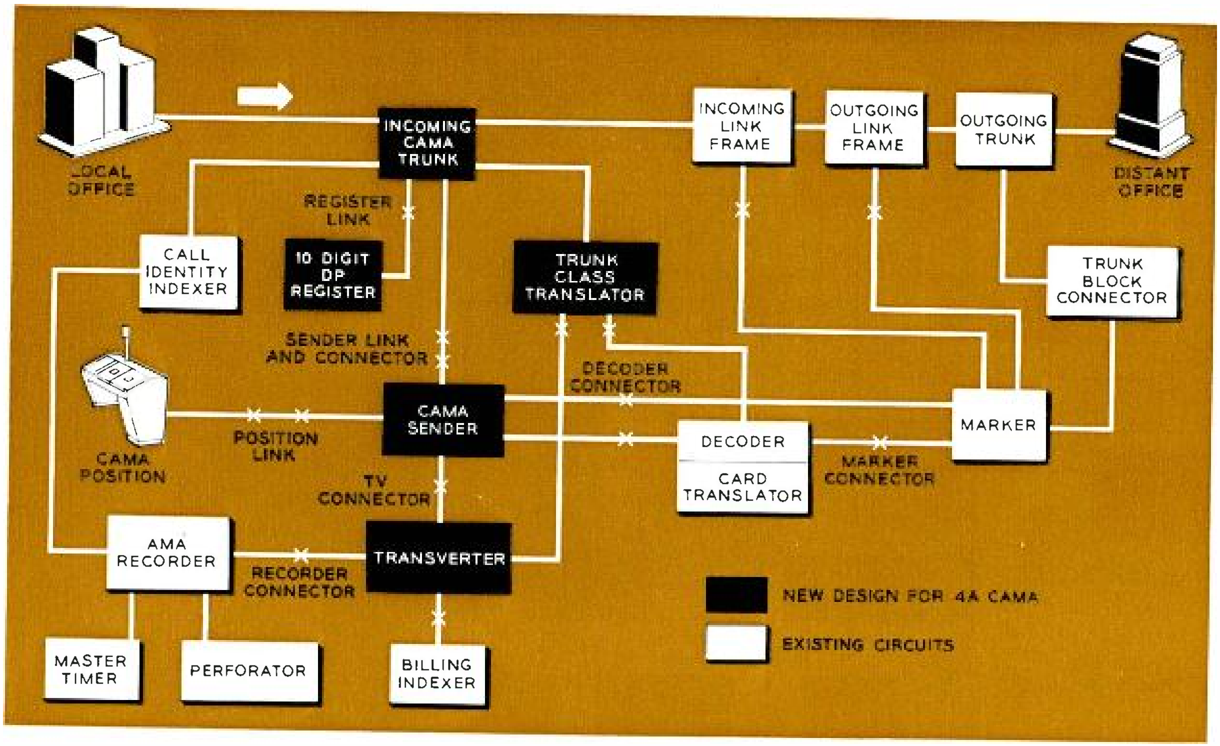
# 4A and 4M Toll Crossbar With CAMA Equipment

The Bell System is often able to offer improved telephone services, such as Direct Distance Dialing (DDD), by modifying and adding to existing telephone equipment. The application of Centralized Automatic Message Accounting (CAMA) techniques is a good example. Since it is not economical to provide complex automatic charging equipment in many local offices with low volumes of toll traffic, the AMA equipment is centralized in offices that already handle concentrated toll traffic. CAMA was first placed in service in 1953 in Washington, D. C., using crossbar tandem as a switching medium (RECORD, *July*, 1954). The success of this new service was immediate, and other switching systems, including the No. 4 type toll crossbar systems, came under consideration as candidates for use with it.

Studies soon indicated that there were several areas of application for 4A CAMA that could not suitably be met by crossbar tandem CAMA. These were (1) "single building" cities where there was no need for local tandem, but where 4A toll offices were in service or being planned; (2) larger cities which might have local tandem, but in which, because of local conditions, it was found economical to place CAMA on a 4A system; and (3) cities where well established step-by-step intertoll systems were in service. Moreover, certain existing 4A toll crossbar offices, engineered to handle the backbone traffic of nationwide toll dialing, possess a large call-carrying capacity that is not always fully used; CAMA traffic could be added to these offices.

The development of 4A and 4M CAMA, which is now completed, used much of the existing crossbar tandem CAMA circuitry, since in many respects the application of CAMA to these systems is similar to crossbar tandem CAMA. This is to be expected because the basic switching plans are the same. There are, however, interesting differences which this and several succeeding articles will describe.

The block schematic on the next page shows the major elements of 4A CAMA and their interconnections. The 4M units are almost identical to




*Block schematic of the new design for 4A CAMA. Main sender functions are to receive and store the incoming digits, call the decoder-marker circuits, and outpulse required digits to the next office.*

4A CAMA, since the 4M system is the No. 4 system modified to have 4A features.

A key circuit in crossbar switching systems of the tandem and No. 4 types is the incoming sender. Normally, this circuit is connected to a call as long as the call is being processed in the crossbar office. The primary sender functions are (1) to receive and store the incoming digits, (2) to call in the decoder and marker circuits at the appropriate time for establishing connection to a trunk to the desired destination, and (3) to outpulse the required digits to the next office in the proper form. A sender with CAMA features must also register the calling number from a CAMA operator or from the Automatic Number Identifier (ANI) (RECORD, *May*, 1958) and then make connection to a transverter for recording the call details on the AMA tape. Because both the physical size and the holding time per call of the various circuits affect the cost of a system, the application of CAMA to the 4A system was planned to make as efficient use as possible of the larger circuits.

The holding time of the new CAMA sender has been kept to a minimum by relieving it of the burden of receiving the slowly dialed digits from the customer. The digits dialed by a customer served by a step-by-step local office, following the directing code, will be received and stored in a small separate register circuit. When the customer finishes dialing, the register circuit will rapidly retransmit the digits in multifrequency form to the sender. Incoming multifrequency trunks from senderized local offices, (that is, from offices that can retain and retransmit digital information, in contrast to step-by-step offices which do not have this ability) will connect directly to the sender. Thus, the sender's holding time per call is kept to a minimum because the called number will always be received rapidly in multifrequency form from another circuit. The use of a single type of sender in a common group also contributes to more efficient use of the senders.

### Size and Class Marks

The actual size of the CAMA sender is physically less than the regular 4A senders, which are similar in function but have no CAMA features. Size is reduced by using wire-spring and dry-reed relays, and by avoiding the temporary storage of incoming trunk-class marks that are used by other circuits. It has generally been the practice for the sender to receive and store class marks from the incoming trunk at seizure. As the call progressed, the class marks would be given as needed to the decoder and transverter. These class marks, which are quite numerous in a CAMA office, are needed to give the common-control circuits such information as which one of twenty AMA recorders serves the incoming trunk. For reasons of economy, these marks are not stored in the CAMA sender. They are furnished to the decoder and transverter by a new circuit called the trunk-class translator.

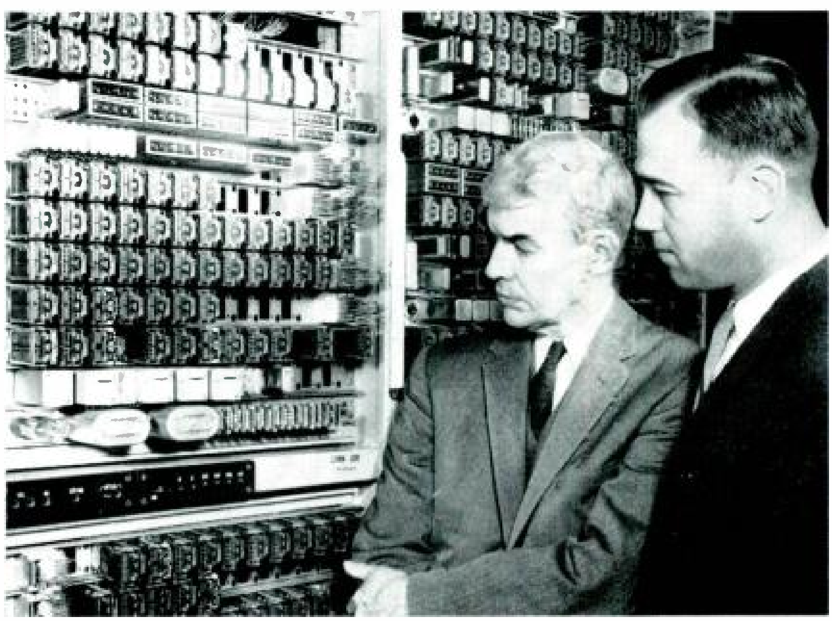
### *Example Call*

To illustrate how these and other new features are employed in the 4A CAMA system, the progress of a call from a customer in a local SXS office will be described. A diagram of this functional sequence is shown on the next page.

The customer dials a three-digit directing code which is used in the local office to set up the connection to an idle CAMA trunk. Seizure of the trunk circuit causes an immediate connection to a dial-pulse register at the CAMA office so that the customer can continue dialing without interruption. The customer follows the directing code with the called number, which may consist of seven or ten digits. The register can anticipate exactly seven or ten digits by checking the second digit for the "zero" or "one" found in area codes. Then the trunk circuit is signaled to connect to a sender when the customer has about completed his dialing. When the sender is connected, the digits are multifrequency pulsed to the sender, and the register releases to serve another call.

Then the sender, having been notified by the trunk circuit at seizure that the operator must identify the calling number, establishes a connection to the CAMA switchboard when the called number has been received. The operator now requests the calling customer's number and starts multifrequency key-pulsing it to the sender. Receipt of the first digit of the calling number causes the sender to seize a decoder, which in turn seizes a marker to establish the connection to an outgoing trunk. The first digit was selected as the decoder seizure-point because it follows the variable time the operator needs to identify the number. If the connection to the distant office were established prior to this point, and if the operator required extra time for identification, the distant receiving equipment would be seized unnecessarily early.

As soon as the decoder is seized, it connects to the trunk-class translator. The particular class relay operates in the translator that gives the desired class marks for the trunk, and the decoder records the trunk class. Less than 1/25 second is required for this function. The decoder, using the trunk-class marks and the called-number code from the sender, makes a translation to provide routing instructions for the marker, which it then seizes. The marker records the routing instructions, selects an idle outgoing trunk, releases the decoder and connects the CAMA trunk to the outgoing trunk. While the marker is setting up the connection through the link frames, it gives the sender the information for pulsing to the next office. Marker release allows sender to outpulse called number.



*The authors (M. E. Maloney, left) inspecting the new 4A equipment with CAMA units in the background. Full trouble-detecting features are found in 4A and 4M CAMA for all the common-control circuits.*

The decoder-marker functions take place so quickly that the operator is still pulsing the calling number as these circuits release. When the last digit of the calling number is received, the sender is ready to seize a transverter.

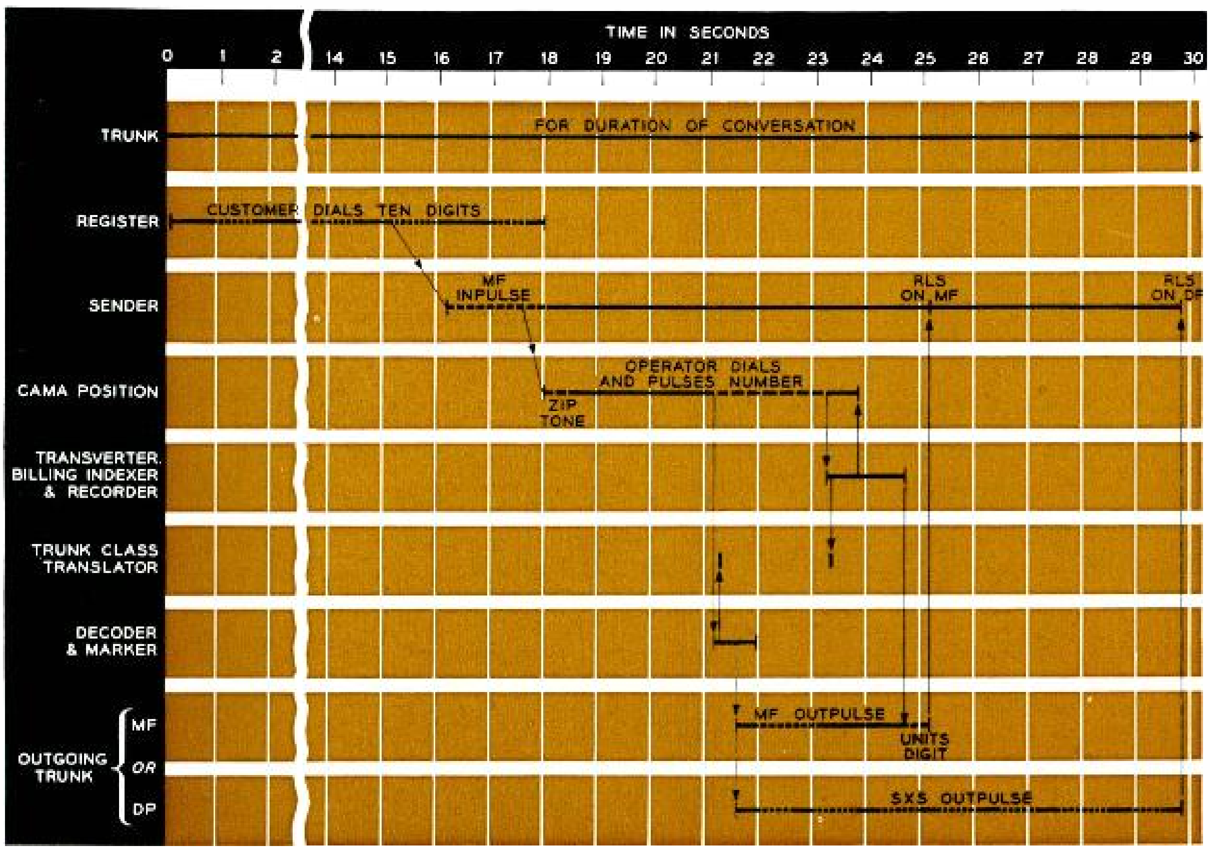
Upon seizure, the transverter, in the same manner as the decoder, immediately connects to the trunk-class translator to obtain the number of the AMA recorder serving the trunk. It also calls in a billing indexer and passes to it the required digits to obtain billing information for the initial entry on the AMA tape.

Release of the billing indexer causes a position-release signal to be given to the sender, which then disconnects from the position to free the operator to serve another call. The transverter, continuing its functions, connects to the AMA recorder and perforator for the initial entry. This entry gives the data that the accounting center will need in making up the bill for the call. The subsequent separate answer and disconnect entries, which give the duration of the conversation, are related to the initial entry by means of a trunk index number. This number, which is provided for each entry by the call-identity indexer, identifies a trunk as one out of the hundred associated with the AMA recorder. When the transverter has completed its functions, it finally signals the sender and is now ready to be released.

If the sender had been directed by the marker to multifrequency outpulse, it is likely that it would be awaiting the release of the transverter to send the last digit. The last digit is always held up until the transverter is released; this is to prevent ringing the called customer's telephone until the call has been fully processed by the AMA equipment. When the outgoing trunk requires dial pulsing, the transverter will normally be finished before outpulsing is completed.

When a call encounters trouble, or when for other reasons it cannot be completed, it is routed to a reorder signal or an appropriate recorded announcement. When this occurs, all charging functions are cancelled.

After the completion of outpulsing, the sender releases and the call is left under control of the incoming trunk circuit. This circuit is then ready




*Path of a typical customer-dialed CAMA call as it progresses through a 4A office. The customer's number (in code form) is passed on to the CAMA operator, who pulses it to the CAMA sender unit.*

to initiate — as they occur — the answer and disconnect entries on the AMA tape through the call-identity indexer.

If the local office from which the call comes has automatic number-identification equipment (ANI), the sender is so informed by the trunk circuit on seizure, and no attempt is made to seize a CAMA position. When the called number has been received, the sender signals the local office and waits for a special signal called an information digit. This digit tells the sender whether the calling number is automatically identified, or whether the sender should seize a CAMA position for number-identification. The ANI equipment calls for operator-identification when the calling customer is on a four-party line or when the identifier fails to function. After the number is automatically identified, it is multifrequency pulsed to the sender immediately following the information digit.

Progress of the call in the CAMA office is essentially the same whether the calling number is automatically or operator identified. The decoder is always seized when the first digit of the calling number is received, and the transverter is always seized when the complete calling number is registered.

Complete trouble-detecting features are provided in 4A and 4M CAMA for all the common-control circuits. Both sides of the trouble record card will be used in the CAMA offices to provide recording space for the new circuits. The reverse side of the card, previously unused, will be used for recording troubles in the transverter, position-link controller, AMA recorder, master timer, and register link.

New testing arrangements include an incoming-trunk automatic test frame and a sender test circuit. In addition to testing the non-CAMA 4A or 4M incoming senders, the sender-test circuit tests CAMA senders, dial-pulse registers, CAMA positions, transverters and billing indexers. The automatic trunk-test frame checks the operation of the call identity indexer and trunk-class translator as well as the operating features of the trunk itself.

Although the decision to add CAMA features to the 4A and 4M systems was made primarily to meet the needs of step-by-step areas that did not have access to other CAMA facilities, the large call capacity and growth capabilities of the 4A and 4M systems make them candidates for CAMA service in metropolitan areas not using step-by-step equipment. This development contributes significantly to the extension of Direct Distance Dialing to all parts of the Bell System.

# "Communications To Come"

In an article written for the 50th Anniversary issue of *Telephone Engineer & Management*, Frederick R. Kappel, president of the A.T.&T. Company, outlined some of the opportunities for progress in communications in the years ahead.

He started by pointing out the scope of the industry's job: an expected U. S. population of more than 235 million and a total number of households that may reach 67 million by 1975—almost 30 per cent more than today. The proportion of these households with telephone service will continue to grow.

To develop this market, telephone people will have to get much closer to it. This means market research, product planning, and sales forces will be increasingly important. In the near future, telephone men will mix advancing technology and intensive marketing to bring more, better and new services to millions more people.

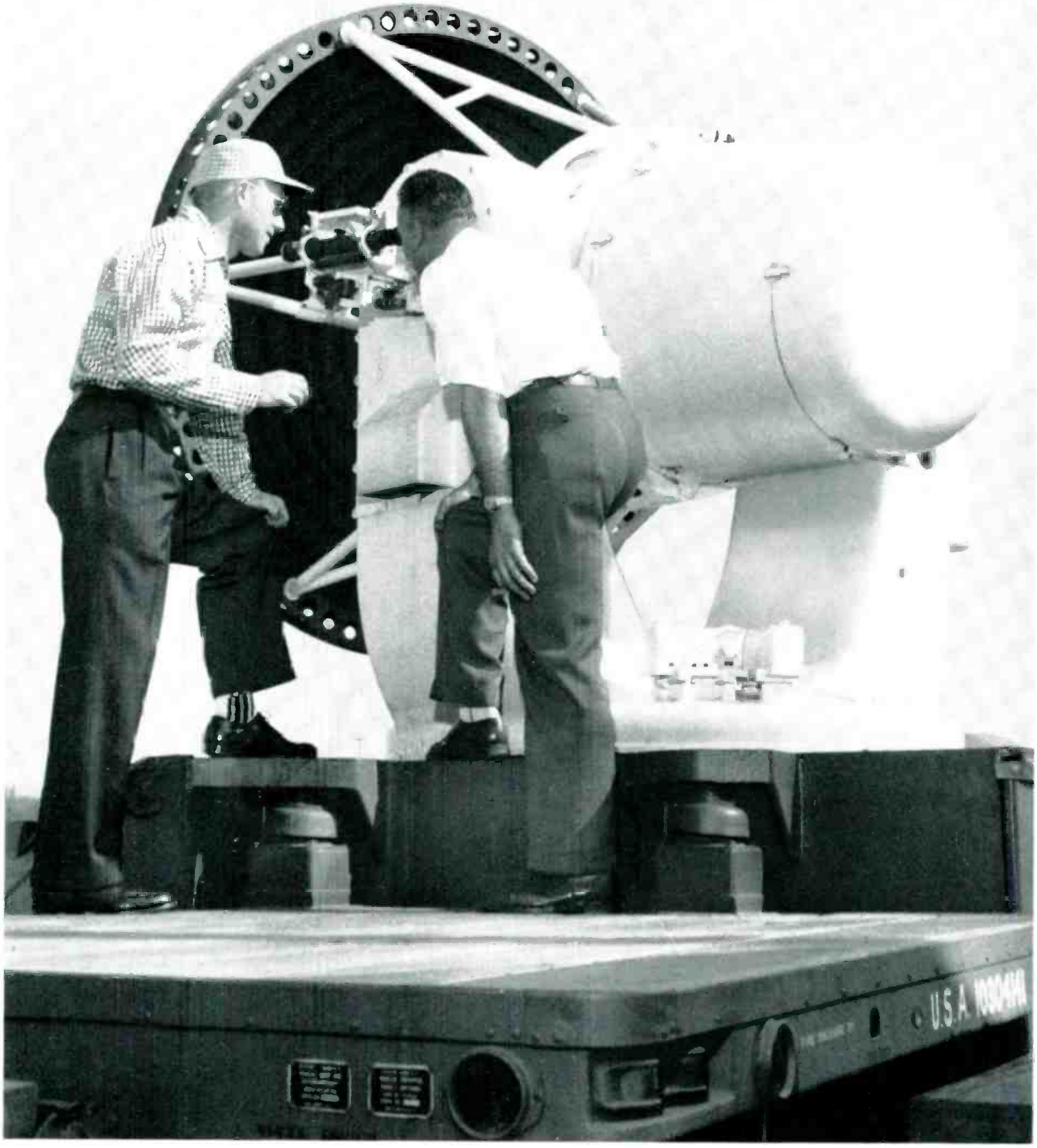
Many of the services Mr. Kappel foresees in his article are already in experimental or developmental stages at Bell Laboratories. Among these are automatic dialers, pushbutton calling, and pushbutton selection of particular telephones, along with smaller instruments, built-in instruments and hands-free instruments of high quality — perhaps concealed and stereophonic.

Data transmission between business machines and computers could become the future's most widely used service. Communication and data-handling equipment will combine to control business and production processes in many locations, and will also aid management in its job.

Operator dialing across the oceans is imminent, and world-wide direct dialing is an attainable goal. Space communication by radio will develop; it has already started. Space vehicles will use radio for communication and guidance. Also, use of satellites to relay information to and from different parts of the world will become a fact (*see page* 323).

The obligations of the telephone industry to military and defense needs will grow more and more extensive and important because its services are vital to the task of defending and maintaining national security.

In his conclusion, Mr. Kappel pointed out that the communication industry's best progress in service will come only if it realizes good earnings today and tomorrow.




*K. W. Bauereiss, left, and C. E. Priefer check aligning telescope on target-tracking radar mount. The radar's mechanical axis is aligned to the electrical axis by collimating techniques.*

*As part of the air defense of the United States for the past five years, Nike-Ajax batteries have been protecting many of our cities and critical areas. Much of this protection is due to Nike's powerful radars—the result of intensive engineering effort at Bell Laboratories.*

P. L. Hammann

# The Radars of Nike-Ajax

The guided missile system known to the world as Nike-Ajax has been protecting the United States from air attack for some time (RECORD, *February*, 1959). Designed and manufactured by the Bell System and Douglas Aircraft Company, this system was the first of its type to be operational. A major contribution to the rapid availability of this defensive weapon was the design and development by Bell Laboratories engineers.

The Nike-Ajax system guides its missiles to an enemy aircraft, destroying it when they detonate. The missile itself is a highly maneuverable, highly destructive device (RECORD, *April* 1959). But its ultimate value depends on the ability of the system — the radars, the computer, the guidance technique — to put the missile in position. One of the most challenging jobs on this project was the design of the radars for Nike-Ajax.

Actually, Nike-Ajax uses three completely separate radar systems to do its job. One, called the acquisition radar, continuously surveys the entire area surrounding a defended area for hostile aircraft targets. Two other radar systems, similar to but independent of each other, furnish precision tracking data to a computer so that the missile can be launched and guided to the enemy.

### Tracking Radars

One of these tracks the target aircraft from the time it is detected until the time it is destroyed. The other system tracks the missile from just before it is launched until it intercepts the target. The second system also furnishes steering signals to electronic apparatus in the missile so that each maneuver of the enemy aircraft can be countered almost instantly by the missile. These two radar systems comprise the target-tracking radar and the missile-tracking radar.

Laboratories engineers designed the acquisition radar for a high peak power output, one sufficient to detect high-flying jet bombers at the maximum range of the Nike-Ajax system. The antenna, protected by a glass fiber radome, rotates continuously at various speeds under control of the acquisition radar operator. The transmitter of the acquisition radar is located in a cylindrical enclosure immediately below the antenna assembly. All necessary controls are at a console position of the radar inside a trailer. No one need attend the equipment which must of necessity operate in an open air environment.

An additional cabinet inside another trailer contains the electronic apparatus needed to complete the acquisition radar system. It includes power supplies, voltage regulators, equipment to indicate moving targets, amplifiers, and switching apparatus.

The equipment associated with the cathode-ray display oscilloscopes is housed in the operating console. It consists of a plan position indicator (PPI) and a precision indicator (PI). A range unit that indicates on a dial the range of the target in yards is also located in the console.

In case of an enemy attack, the officer in charge of a Nike battery will probably have had prior knowledge of the general direction of the attack from "early warning" information plotted on an early-warning plotting board. Thus, when he first detects a target on the PPI oscilloscope, he can immediately designate it to the operator of this equipment. This operator will then promptly center the target signal on the PI oscilloscope.

The PI oscilloscope gives a much clearer picture of the situation than does the PPI oscilloscope. The former contains an expanded view of only that small part of the PPI display centered around the azimuth and range mark intersection of the target. This greater detail permits accurate coordinate information for subsequent use by the target-tracking radar in acquiring the target.

*P. L. Hammann observes Army operator at the console of the missile tracking radar. Because much of the operation of this radar is programmed automatically, only one operator is needed here.*

Before designating the target to the target-tracking radar, the acquisition radar operator "challenges" the aircraft by an identification system known as IFF (Identification, Friend or Foe). If the target is deemed "hostile," it is "designated" to the operators of the target-tracking radar.

### *Target-Tracking Operation*

Upon receiving the target-designation signal, these operators automatically "slew" their target-tracking radar to the coordinates received from the acquisition radar. They also send a simultaneous response to the battery commander that they have received the designated command and have initiated action. These commands and replies are transmitted as signal lights at all three console positions. A two-light system prevents errors due to malfunctions of lights or circuits.

The three operators at the console of the target tracking radar each handle one coordinate: range, azimuth, or elevation. When all three coordinates coincide with the enemy target, data from this radar goes to the computer. A "target tracked" signal then appears and the computer starts the predicting process.

As mentioned previously, the missile-tracking radar is similar to the target-tracking radar. The physical appearances of the two antenna assemblies are identical. However, the function of the second radar is to precision track the missile and also to transmit steering signals to it. To do this, a transponder in the missile generates a signal that is tracked by the missile-tracking radar. A transmitter in the radar that sends the steering and burst commands also triggers the transponder so that a signal is sent back for tracking purposes.

Prior to engagement of the enemy, an appropriate missile will have been selected for firing. The missile-tracking radar automatically slews to this missile and locks onto it. It will continue to track this missile without further attention until intercept.

In the radar-control trailer, two cabinets and a single operator-console house the rest of the electronic apparatus for the missile-tracking radar. Only one operator is needed here because a large portion of the operation is automatically programmed for the missile-tracking radar. However, the operator monitors each step of the engagement and can over-ride automatic operation whenever a decision seems in doubt.

The coordinate information generated by the two tracking radars comprise the input data to the computer. For this reason, the antenna mounts of both radars must be accurately leveled and oriented. An error existing in either will result in an error at intercept. But an identical error existing in both systems is cancelled out in the computation and thus does not affect the intercept solution.

Maintenance personnel align these two systems with high quality leveling devices and telescopes installed on each antenna mount. The mechanical axes of these systems are initially aligned by techniques used in surveying. The electrical axis of the radar is aligned to the mechanical axis by a collimating means which uses a "boresight mast" installed some distance from the radars.

Laboratories engineers found a way to set and maintain the two antenna mounts to high accuracies as a matter of routine in all possible climatic conditions. Their specifications call for over-all system performance to be maintained throughout the temperature range of −40 to +140 degrees F. That this has been accomplished is attested to by the continued operation of the system in the hot deserts of New Mexico and by the results of two winters of cold weather testing at Ft. Churchill on Hudson Bay in Canada.

The antenna mounts demonstrate their ruggedness by their ability to stay aligned in high wind conditions and their continuous use as a working platform by personnel during maintenance and alignment. This is somewhat less than the care usually required with surveying instruments of similar precision.

When the computer goes into action, automatic plotting boards start to plot (1) the position of the target, and (2) the predicted position of the target and the missile at intercept based on firing at any given moment. Then, when the target is within range, the computer automatically turns on a "ready to fire" light. By evaluating the plotting board data, the battery commander can now fire the missile at any time he deems appropriate for the tactical situation at hand. Unless all prior operations have been performed correctly, however, the "ready to fire" signal will not appear and the firing operation cannot be carried out.

*The author, left, examines transmitter panel of acquisition radar while C. E. Priefer checks inside glass fiber radome housing the antenna. This radar is controlled by operators in nearby van.*

After the missile takes off, the plotting boards also plot its coordinates. The five radar operators — one acquisition, three target-tracking and one missile-tracking — monitor and continue the tracking operations throughout the flight of the missile to the target.

When the missile intercepts the target, the "burst" command generated in the computer is sent to the missile through its tracking radar. This command is calculated to produce a detonation at the best point for that particular trajectory to ensure destruction of the enemy aircraft. Immediately after intercept, the missile-tracking radar automatically slews to the next missile to be fired. The system follows the same automatic procedure again and the next missile is "ready to fire."

During the flight of the missile, the battery commander has decided, from observing his PPI indicator, which target is to be engaged next. This target can be made ready for "designation" prior to intercept of the first one if he desires or the tactical situation warrants. Or he also can fire an additional missile at the first target. Furthermore, at any point in the firing procedure the commander can terminate the operation, detonate the missile, and start a new cycle.

The three radar systems used in Nike-Ajax are made up of electronic circuits that require many hundreds of vacuum tubes and a large number of varistors or diodes. Engineers paid considerable attention to the design of the apparatus for proper maintenance and routine testing procedures. Their basic philosophy was to subdivide the circuits into small sections containing from five to ten vacuum tubes and associated apparatus. These "chassis" are of the plug-in variety, easily removed in a matter of seconds. A spare chassis for each plug-in device is contained in the equipment for spares and maintenance. This is a series of cabinets either in a third trailer or in a separate enclosure adjacent to the radar equipment.

Suitable test equipment, in most cases an integral part of the radar circuits, is available so that relatively inexperienced personnel can quickly localize any difficulty to an individual plug-in chassis. The unit is then replaced by the available spare, permitting operations to proceed. Defective chassis are normally sent to a maintenance and repair section of the Army Ordnance Department (RECORD, *December*, 1956).

### Maintenance Items

Also contained in the spares and maintenance equipment is a complete set of tools and associated routine maintenance items, such as greases. These are all the items Army personnel need to keep the entire system operational at all times. In addition, a complete set of operating and maintenance notes is shipped with each system so that it is available when personnel need to refer to the proper maintenance procedure.

An important factor in the design of the entire Nike-Ajax guided missile system was the Army's requirement of a new and complex weapon. But this weapon was to be manned and operated by personnel who had to be trained quickly and easily, to perform a wide variety of tasks. Thus, most of the operations of Nike-Ajax are not highly technical or extremely detailed.

In those cases where designers had to employ new technology for the first time, they made sure that the apparatus was as foolproof and as easy to operate as possible. As an example, the tracking system used in the target and missile-tracking radars contains many complicated waveguide parts. The very nature of the improved capability of this method of tracking increases the number of elements that make up the waveguide system. This, coupled with the need for broad frequency coverage, presented a formidable design task.

The development, however, was carried to the point where no adjustments or operating techniques are required other than those normally associated with waveguide systems in the simplest of radar equipment. No additional burden was therefore placed on the operating personnel by this significant advance — a waveguide system of much higher performance than had previously existed.

Another example of how designers improved capability without adding operational complexity can be seen in the servo system of both tracking radars. These servos are of very high performance since the extreme accelerations of the missile just after it fires must be followed by the missile-tracking radar. But at the same time, the servo system must produce high quality tracking on the missile and on the target aircraft at long range when the accelerations are low. The engineers designed the antenna mount in such a way that the servo components used are quite similar to those that served earlier, simpler radars.

In some cases, performance has increased over that in the early development period. As problems were more clearly defined in the prototype testing and actual tactical operation, designers were able to improve, and at the same time simplify, operation in many areas. As this program has continued over the years, field engineers from the Bell System have installed modifications to keep all the Nike-Ajax components at the highest level of performance at all times.

*Inside a radar van, three operators — for range, azimuth, elevation — bring the three coordinates into coincidence with data from acquisition radar.*

# NEWS

## K. G. McKay Elected Vice President of Laboratories

K. G. McKay

K. G. McKay, Director of Development of Components and Solid-State Devices, was elected Vice President in charge of Systems Engineering at a meeting of the Laboratories Board of Directors held last month. Morgan Sparks, Director of Transistor Development, succeeded Mr. McKay. Both appointments were effective September 1.

A research physicist, Mr. McKay has been associated with electronic, semiconductor and solid-state research and development programs at the Laboratories since 1946. In 1952 he was named to head a group concerned with physical electronics research and in 1954 was placed in charge of the Solid-State Research Group. He was named Director of Development of Solid-State Devices in 1957, and named to his most recent position last September.

Mr. McKay is a native of Montreal, Canada, and a graduate of McGill University, where he received the bachelor of science and master of science degrees in 1938 and 1939, respectively. He was awarded the Sc.D. degree by Massachusetts Institute of Technology in 1941 and worked with the National Research Council in Canada for the next five years.

## Atlantic Cable to Europe Completed

The first transatlantic telephone cable system to link North America with the mainland of Europe was completed last month when the cable-laying ship *Monarch* finished laying cable across Cabot Strait between Sydney Mines, Nova Scotia and Terrenceville, Newfoundland.

The Cabot Strait section is a single cable designed to carry voices in both directions. It is linked at Terrenceville to a similar cable which extends to Clarenville, Newfoundland. Two deep-sea cables—one for each direction—already have been laid between Clarenville and Penmarch, France.

The new cable will provide 36 circuits to Europe. The new TASI system (RECORD, *March*, 1959) is expected to approximately double this capacity in the future.

## Branch Laboratory Opens at Columbus

Bell Laboratories facilities in Western Electric's new plant in Columbus, Ohio, opened in June with a 137-member work force headed by F. A. Korn. This 18th branch laboratory established by the Laboratories is located at 6200 East Broad Street, in a rural area about a half hour from downtown Columbus.

The Columbus organization includes 93 technical people, but is expected to grow to over a hundred by the end of the year. The group is divided into three technical subdepartments headed by J. W. Brubaker, M. F. Fitzpatrick and H. M. Knapp.

The Laboratory takes up part of three floors in the Western's office building, and additional laboratory space in the production building. Laboratories people will work on development programs and do liaison work with Western Electric on No. 1 and No. 5 crossbar switching systems and on related apparatus components. Fundamental studies on electronic switching systems are also a part of the Columbus program.

## New Artificial Larynx From Solid-State Devices

A new artificial larynx has been developed at Bell Telephone Laboratories for people who have lost their voices through laryngectomy (surgical removal) or paralysis of the vocal cords. The new unit was recently described by H. L. Barney in a talk before the medical electronics session of the Western Electronic Show and Convention meeting in San Francisco. Mr. Barney directs research in an interdisciplinary field of science known as psychoacoustics, and he supervised the development of the new artificial larynx.

The unit is being designed for production at the Indianapolis location of Bell Laboratories, and is to be manufactured by the Western Electric Co. Plans are to make it available for nationwide distribution by the Operating Companies in 1960.

With a minimum of difficulty and training, laryngectomees can use the new electronic larynx to speak conversationally. It is especially effective when conversing over the telephone.

By means of a finger-operated switch, which when pushed permits at once talking and inflection control, the user can easily control the pitch of his artificial voice. This gives his speech a natural sounding quality previously unobtainable.

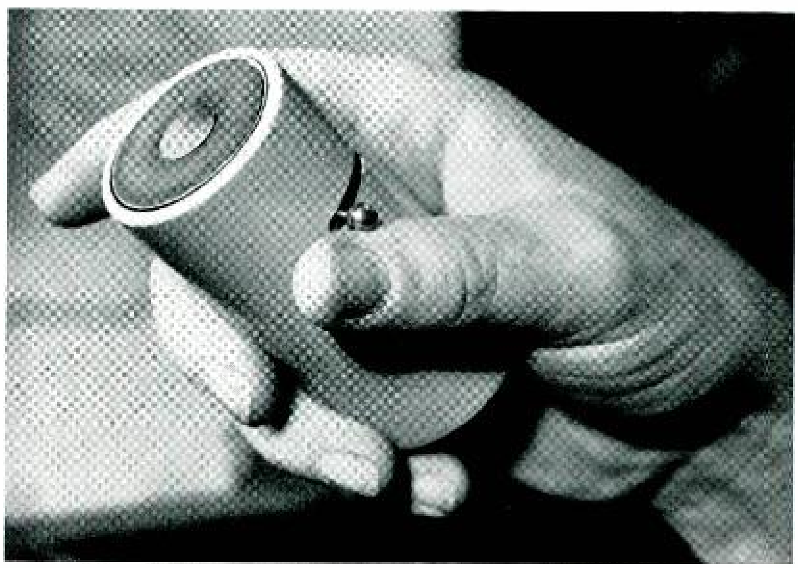
The underlying principle of the new artificial larynx lies in a vibrating driver (transducer) held against the throat. Completely self-contained and cylindrically shaped, it measures only 1¾ inches in diameter by 3¼ inches long. Included in this one small package is a modified telephone receiver serving as the throat vibrator, a highly-efficient transistorized pulse generator with pitch control, and a battery power supply. To miniaturize the new artificial larynx, Laboratories engineers built experimental units using modular techniques. And they anticipate that an even more compact unit can be built with printed circuit techniques.

To use the unit, the laryngectomized person presses the vibrator against his throat. Switching on the pulse generator with his finger, he transforms vibrations transmitted into his throat cavities into speech sounds by normal use of his articulatory mechanisms — throat cavity, tongue, mouth, teeth, and lips — in his vocal tract.

The volume of the output speech obtained with the artificial larynx is equal to that of a person speaking at a normal conversational level, though the sound is a bit buzzy and mechanical. Nevertheless, the frequency spectra of vowel sounds show that the frequency range transmitted into the person's throat is sufficient for satisfactory production of such sounds. And while intelligibility tests give results lower than those of normal speech, they are superior to those of any other artificial larynx. Depending on their experience, users of the new artificial larynx can make at least 97 per cent of their sentences intelligible in normal conversation.

Because the artificial larynx requires an economical, self-contained power source, circuit parameters had to be adjusted to yield maximum acoustic output from a small amount of current. Accordingly, two transistors are used in a "relaxation" oscillator whose frequency is controlled by a variable resistance, and whose pulse width is determined by a feedback network.

The output of the relaxation oscillator is a series of negative pulses occurring at a frequency of about 100 cycles per second. The user may vary this repetition frequency from about 100 to about 200 cps with a rheostat which he operates by the push-to-talk switch, thus changing the pitch



*The new Bell Laboratories designed artificial larynx uses a modified telephone receiver unit to transmit sound through the user's throat.*


*H. K. Dunn, left, and H. L. Barney testing new artificial larynx. Mr. Barney is pressing the transistorized unit to his throat in manner employed by user to generate sound energy in vocal tract.*

of his voice to obtain the desired inflection. For women talkers, the frequency range is adjusted to 200 to 400 cycles, corresponding to the normal range of pitch of a woman's voice.

A third transistor acts as a power output stage that amplifies the pulses applied to it from the relaxation oscillator. For stable operation, a diode isolates the multivibrator from the input impedance of the power amplifier during the period between pulses.

Two 5.2-volt mercury cells in series provide the power necessary to operate the artificial larynx continuously for a period of approximately 12 hours. These batteries are rated at 250 milliampere-hours with a maximum permissible current drain of 25 milliamperes. With push-to-talk operation, 12 hours of continuous operation should be equivalent to several days or even weeks of normal talking.

An alternative to the self-contained mercury cells for powering the artificial larynx is a small a-c power supply which can be fed from a normal wall outlet at home or in the office. When the artificial larynx is plugged into the power supply, its batteries are disconnected from the circuit.

Great impetus to the development of the experimental device was given by some of the nation's foremost surgeons, connected with the National Hospital for Speech Disorders in New York City. They had felt that, with the great advances in electronics brought about by the transistor, specialists in acoustics research could devise a far better artificial larynx than any presently available.

## New Laboratories Field Office At Vandenberg

Bell Laboratories has opened a Field Office at Vandenberg Air Force Base in California where a radio-inertial guidance system for Titan, the new intercontinental ballistic missile, will be tested. M. M. Bower, of the Military Systems Development Department, will be resident technical director at the new Field Office.

The Bell Laboratories-Western Electric guidance equipment will be employed in operational tests of the Titan weapon system. These tests, involving all the associate contractors, will be conducted under the general supervision of the Air Force Ballistic Missile Division and the Space Technology Laboratories.

Mr. Bower, who moved to Vandenberg in July, will be joined soon by A. H. Falk and E. C. Snyder, Jr., also of Military Systems Development. The buildup of personnel is expected to reach its peak by the end of the year. The majority will be members of the Western Electric Field Engineering Force.

Vandenberg is 170 miles north of Los Angeles and 300 miles south of San Francisco. The Air Force Base is on part of the land that was occupied by the former Camp Cooke, where Army armored units trained during World War II and the Korean conflict.

## Bell System Offers New Laboratories Science Films

Five new films and a record album on scientific subjects are being offered for schools and organizations through Bell System telephone companies. They will be loaned without charge.

The motion pictures, filmstrips, and the records were prepared by Bell Laboratories scientists and engineers, all of whom are recognized authorities in their fields. These audio-visual aids are appropriate for showing to university science and engineering students, meetings of technical societies, and to groups with a scientific interest.

The movies are: "Crystals — An Introduction" (16mm, color, sound), "Submarine Cable System Development" (16mm, color, sound), and "Brattain on Semiconductor Physics" (16mm, black and white, sound). The two filmstrips are: "Zone Melting," and "The Formation of Ferromagnetic Domains." The record album, "The Science of Sound," consists of two 33⅓ rpm records that describe and demonstrate acoustical phenomena.

# FEEDBACK PROBLEM SOLVED FOR PUBLIC-ADDRESS SYSTEMS

A new electronic method developed at Bell Laboratories minimizes howling, or "singing" of indoor public address systems caused by acoustic feedback of room reverberations. It permits a two-fold increase in the loudness of a conventional public-address system while maintaining the stability.

Moreover, for the same loudness, the new method offers a three to four-fold safety margin against accidental variations in amplification. These unpredictable variations in amplification — caused by heating of amplifiers, different positions of the speaker or entertainer, and changes in the size and position of the audience — are responsible for instability in public address systems. Acoustic feedback limits the degree of loudness in other applications, besides public-address systems, in which microphones and loudspeakers must operate in close proximity.

This new method of countering distracting and exaggerated room reverberations is the work of M. R. Schroeder, of the Visual and Acoustic Research Department. In 1954, from studies in acoustics, he formulated a theory of response fluctuations inside a room. This theory forms the basis of his invention.

Key to the present development is a constant frequency-shift device, called a "frequency-shift modulator." It is inserted into the circuit between the microphone and loudspeaker. The frequency shift of the input signal is made equal to the mean distance between the major peaks and adjacent valleys of the room's gain - response characteristic as represented on an oscilloscope. Sound energy generated at the gain peaks is quickly absorbed in the valleys of the response characteristic. The actual frequency shift required is five cycles per second, an amount undetectable for speech and most types of music.

The Bell System does not manufacture public-address systems, nor does it plan to manufacture the feedback control equipment. The method, however, may be of value to the Bell System in intercommunication systems and hands-free telephones.

*M. R. Schroeder switches on frequency-shift modulator, watches reverberations of his voice on oscilloscope. The reverberations shifted in frequency permit a two-fold increase in the loudness.*

*D. A. McLean compares reduced size of a printed circuit using the new sputtered thin-film resistors (in his left hand) with the comparable conventional printed-circuit board (in his right hand).*

## Sputtered Resistors Make High Component Density Possible

Sputtered thin-film resistors, formed from refractory, or heat-resistant, metals such as tantalum and titanium, may be one of the more important developments in microminiature electronics. D. A. McLean, of the Component Development Department, presented a paper on the subject to the Western Electronics Conference in San Francisco on August 19. He reported that such resistors can be produced on glass or ceramic bases in lines as narrow as 1 mil (0.001 inch), spaced 1 mil apart, thus producing extremely high resistance in a small area.

Research in sputtering has been conducted at Bell Laboratories for several years. In the technique, ionized gas molecules bombard a cathode, dislodging atoms of metal which then redeposit on nearby surfaces. Last year, R. W. Berry, of the Component Development Department, announced the development of sputtered tantalum capacitors with capacitances up to 100,000 micromicrofarads per square centimeter for 50-volt operation. H. Basseches, also of that department at that time, announced the feasibility of thin-film sputtered resistors.

The newly announced miniature resistors owe their success to a highly precise masking process, which makes it possible to produce the thin films in specifically restricted locations. An expendable copper mask is used for this operation.

In producing a resistor, an over-all thin film of copper is first deposited onto the ceramic or glass base, for example, by sputtering. Then, the desired pattern is etched into the copper surface by standard photoetching techniques, leaving the bare substrate (the rest of the base) exposed.

Tantalum, other refractory metals, or alloys with appropriate electrical characteristics are then deposited onto the etched copper pattern, and the whole unit is placed in an etching bath. The copper with its overlay of tantalum is removed, leaving behind only the tantalum that was in direct contact with the bare surface. The masks are extremely thin, permitting fine detail. Also, since the sputtered materials adhere to the substrate itself, mechanical support is no problem and thus complex patterns can be produced.

In one experiment, the technique permitted a three-stage flip-flop circuit, which normally occupies a standard printed circuit card about 3½" by 7", to be reduced to a ceramic substrate only 2" by 2". The experiment did not attempt to achieve the maximum reduction possible, but the board still contained 24 resistors, in values up to 121,000 ohms; nine capacitors of 1,000 micromicrofarads, and plug-in arrangements for six transistors and nine diodes. In this arrangement, the density of passive components is about 275,000 per cu. ft., including the 50-mil thick substrate. Use of both sides of the board would approximately double this figure.

According to Mr. McLean, one of the most important aspects of the new development is the production of high quality capacitors and resistors from a single metal, cutting down the number of required operations. Also, interconnections can be made simultaneously with the components, thus eliminating faulty interconnections and removing one of the greatest reliability hazards in miniaturized circuitry.

# TALKS

Following is a list of speakers, titles, and places of presentation for recent talks presented by members of Bell Laboratories.

### A.I.E.E. SUMMER AND PACIFIC GENERAL MEETING, Seattle, Washington.

Aruck, M., and Cronburg, C. I. L., Jr., *96 Channel Multiplex System for ON Carrier on Radio.*

Cronburg, C. I. L., Jr., see Aruck, M.

DeMonte, R. W., *Synthesis of Cable Simulation Networks.*

Froehlich, F. E., *Synchronous Serial Data Transmission With Asychronous Inputs.*

Gammie, J., and Hathaway, S. D., *The TJ Microwave Radio-Relay System.*

Gross, F. J., *Simulation of Data Switching Systems on a Digital Computer.*

Hathaway, S. D., see Gammie, J.

Priebe, H. F., Jr., see Toy, W. N.

Schwenzfeger, E. E., *A High-Volume, High-Speed Weather Information Distribution System.*

Shafer, W. L., see Toy, W. M.

Singer, F. J., *Research Areas in the Field of Communications Are Still Inadequately Covered.*

Toy, W. N., Shafer, W. L., and Priebe, H. F., Jr., *A Small High-Speed Transistor and Ferrite Core Memory System.*

Windeler, A. S., *Design of Polyethylene Insulated Multipair Telephone Cable.*

### ANNUAL CONFERENCE ON ELECTRON TUBE RESEARCH, La Ciudad Universitaria, Mexico City, Mexico.

Ashkin, A., Cook, J. S., and Louisell, W. H., *Modification of the Space Charge Wave Dispersion for Parametric Amplification.*

Ashkin, A., and Bridges, T. J., *Parametric Amplification of the Fast Cyclotron Wave.*

Bridges, T. J., see Ashkin, A.

Cook, J. S., see Ashkin, A.

Kluver, J. W., *M-Type Parametric Amplification of the Fast Cyclotron Wave.*

Louisell, W. H., see Ashkin, A.

### AMERICAN CRYSTALLOGRAPHIC ASSOCIATION, Cornell University, Ithaca N. Y.

Abrahams, S. C., *The Crystal and Magnetic Structure of the Antiferromagnetic Phase of Cupric Fluoride Dihydrate.*

Dworkin, S., see Wood, Mrs. E. A.

Geller, S., Miller, C. E., and Treuting, R. G., *New Synthetic Garnets.*

Germer, L. H., *Diffraction of Low Energy Electrons.*

Knox, K., *The Structures of Some Perovskite Fluorides.*

Miller, C. E., see Geller, S.

Pearson, G. L., *Current and Potential Uses of Solar Energy.*

Treuting, R. G., see Geller, S.

Wood, Mrs. E. A., and Dworkin, S., *Crystals—An Introduction.*

### OTHER TALKS

Anderson, P. W., *Theory of Dirty Superconductors*, Cambridge, England.

Arlt, H. G., *Standardization of Raw Material at the Company Level*, Southern Tier Section of the Standards Engineers Society, Binghamton, New York and N. Y. C.

Chapin, D. M., *Making a Silicon Solar Cell* and *Using the Sun's Energy*, Oklahoma State University, Stillwater, Okla.

Courtney-Pratt, J. S., *Image Dissection Cameras*, Society of Photographic Instrumentation Engineers, Long Island City, N. Y.

Darlington, S., *Nonstationary Smoothing and Prediction Using Network Theory Concepts*, Symposium of Professional Groups on Circuit Theory and Information Theory of I.R.E., U.C.L.A., Los Angeles, Calif.

Higgins, W. H. C., *Missiles and Astronautics*, Rotary Club, LaPorte, Indiana.

Javan, A., *Description of Some Experiments Using Gas Discharges*, U. of Michigan, Ann Arbor, Mich.

Kunzler, J. E., *Oscillatory Dependence of Temperature with Magnetic Field*, U. of Washington, Seattle, Wash.; and Pennsylvania State University, University Park, Pa.

Leihr, A. D., *Semi-Empirical Theory of Vibronic Interactions in Some Simple Conjugated Hydrocarbons*, International Conf. on Quantum Chemistry, Boulder, Colo.

Louisell, W. H., *Effects of Higher Idler Frequencies on Parametric Amplification in Electron Beams*, Plasma Oscillation Conf., Indianapolis, Indiana.

McAfee, K. B., Jr., *Atomic Interactions in Barrier Separations*, Gordon Research Conf. on Separations and Purifications, New London, N. H.

McCluskey, E. J., Jr., *Error Correcting Codes—A Linear Programming Approach*, International Conference on Information Processing, U.N.E.S.C.O. House, Paris, France.

Moore, E. F., *Machine Models of Self-Reproduction*, Summer Institute on Combinatorial Problems, I.B.M. Research Center, Ossining, N. Y.

Och, H. G., *The NIKE Missile Family*, Michigan Aeronautics and Space Association, Detroit, Mich.

Ralston, A., *The Design of a Real Time Digital Computer for a Military System*, 3rd National Convention on Military Electronics, Washington, D. C.

Raspanti, M., *SPUD, A Stored Program Universal Demonstrator for Computer Training*, A.I.E.E. District Meeting, Baltimore, Md.

Saltus, G. E., *Logic and Circuitry*, U. of Michigan, Ann Arbor, Mich.

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

Burbank, R. D., see Heidenreich, R. D.

Clogston, A. M., see Spencer, E. G.

David, E. E., Jr., Guttman, N., and Van Bergeijk, W. A., *Binaural Interaction of High-Frequency Complex Stimuli*, J. Acous. Soc. Am., 31, pp. 774-782, June, 1959.

Dillon, J. F., and Nielsen, J. W., *Effects of Rare Earth Impurities on Ferrimagnetic Resonance in Yttrium Iron Garnet*, Phys. Rev. Letters, 3, pp. 30-31, July 1, 1959.

Dworkin, S., and Holden, A. N., *An Experimental Evaluation of Sound Filmstrips vs. Classroom Lectures*, J.S.M.P.T.E., 68, pp. 383-385, June, 1959.

Edson, J. O., Froehlich, F. E., and Townley, R. K., *Measurements of Narrow Band Noise on Telephone Facilities in Connection with Analog Data*, Comm. and Electronics, 42, pp. 83-86, May, 1959.

Evans, D. H., *Design by Algorithm: A Mathematical Method of Designing Standard Assemblies for Minimum Manufacturing Cost*, Trans. I.R.E., Production Techniques, 4, pp. 4-10, June, 1959.

Foote, H. L., Shair, R. C., and Smith, D. H., *Electrical Storage of Solar Energy*, Mech. Engg., 81, pp. 41-43, July, 1959.

Frisch, H. L., and Lundberg, J. L., *A Viscosimetric Criterion of Polymer Polydispersity*, J. Polymer Science, 37, pp. 123-129, May, 1959.

Frisch, H. L., see Pollak, H. O.

Froehlich, F. E., see Edson, J. O.

Geller, S. and Miller, C. E., *Substitution of $Fe^{3+}$ for $Al^{3+}$ in Synthetic Spessartite*, Am. Min., Letter to Editor, 44, No. 5&6, pp. 665-667, May-June, 1959.

Guttman, N., see David, E. E., Jr.

Heidenreich, R. D., Nesbitt, E. A., and Burbank, D. R., *Magnetic Annealing in Perminvar—Part I: Structural Origin*, J. Appl. Phys., 30, pp. 995-1000, July, 1959.

Heidenreich, R. D., see Nesbitt, E. A.

Holden, A. N., see Dworkin, S.

Howard, J. B., *Engineering Thermo-Plastics for Ocean Telephone Cable*, Plastics Technology, 5, pp. 57-61 & 68, May, 1959.

Jaccarino, V., *Effects of the $Co^{59}$ hfs on the $F^{19}$ High-Frequency NMR in Antiferromagnetic $CoF_2$*, J. Chem. Phys., 30, No. 6, pp. 1627-1628, June, 1959.

Laudise, R. A., and Sullivan, R. A. (W.E.) *Pilot Plant Production of Synthetic Quartz*, J. Am. Institute of Chem. Engrs., 55, pp. 250-255, May, 1959.

LeCraw, R. C., see Spencer, E. G.

Lundberg, J. L., and Nelson L. S., *Initiation of Thermal Reactions by the Flash Illumination of Absorbing Bodies*, Nature, 183, pp. 1560-1562, June 6, 1959.

Lundberg, J. L., see Frisch, H. L.

Miller, C. E., see Geller, S.

Moore, G. E., *Dissociation of Solid SrO by Impact of Slow Electrons*, J. Appl. Phys., 30, pp. 1086-1100, July, 1959.

Morin, F. J., *Oxides which Show a Metal-to-Insulator Transition*, Phys. Rev. Letters, 3, pp. 34-36, July 1, 1959.

Nelson, C. E., and Rubin, H. E., *Spectral Transmission of Microfilms as Related to Quality of Enlarged Electrostatic Prints*, Nat'l. Microfilm Assoc. Proc., pp. 127-154, 1959.

Nelson, L. S., see Lundberg, J. L.

Nesbitt, E. A., and Heidenreich, R. D., *Magnetic Annealing in Periminvar—Part II: Mechanism*, J. Appl. Phys., 30, pp. 1000-1003, July, 1959.

Nesbitt, E. A., see Heidenreich, R. D.

Nielsen, J. W., see Dillon, J. F.

Pollak, H. O., and Frisch, H. L., *The Time Lag in Diffusion III*, J. Phys. Chem., 63, p. 1022, June, 1959.

Rider, D. K., see Schlabach, T. D.

Ross, I. M., *Switching Transistors*, Proc. Western Joint Computer Conf., pp. 93-95, March, 1959.

Rubin, H. E., see Nelson, C. E.

Sanders, T. M., see Weinreich, G.

Schlabach, T. D., and Rider, D. K., *Thermal Degradation of Printed Wiring Adhesives*, Adhesives Age, 2, No. 7, pp. 18-22, July, 1959.

Shair, R. C., see Foote, H. L.

Smith, D. H., see Foote, H. L.

Spencer, E. G., LeCraw, R. C., and Clogston, A. M., *Low Temperature Line-Width Maximum in Yttrium Iron Garnet*, Phys. Rev. Letters, 3, pp. 32-33, July 1, 1959.

Spitzer, W. G., and Whelan, J. M., *Infrared Absorption and Electron Effective Mass in N-Type Gallium Arsenide*, Phys. Rev., 114, pp. 59-62, April 1, 1959.

Thomas, C. O., Smith, H. A., (U. of Tenn.), and Posey, J. C., (Union Carbide Nuclear Co.), *The Separation of Hydrogen and Deuterium by the Reaction of Iron with Water*, J. Electrochem. Soc., 106, pp. 516-519, 1959.

Townley, R. K., see Edson, J. O.

Van Bergeijk, W. A., see David, E. E., Jr.

Waltz, M. C., *A Microwave Resistor for Calibration Purposes*, Microwave J., 2, No. 5, pp. 23-27, May, 1959.

Warner, A. W., *Ultra-Precise Quartz Crystal Frequency Standards*, Trans. I.R.E., Professional Gr. on Instr. I7, No. 3&4, pp. 185-188, Dec., 1958.

Weinreich, G., Sanders, T. M., and White, H. G., *Acoustoelectric Effect in N-Type Germanium*, Phys. Rev., 114, pp. 33-44, April 1, 1959.

Whelan, J. M., see Spitzer, W. G.

White, H. G., see Weinreich, G.

# PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, G. F., Jr., Krom, M. E., Mehring, A. C. and Whitney, W.—*Centralized Memory Line Concentrator System* — 2,894,072.

Anderson, J. R. and Remeika, J. P. — *Barium Titanate as a Ferroelectric Material* — 2,893,107.

Bachelet, A. E., Dorff, L. A. and Mitchell, D. — *Mobile Radio Telephone System* — 2,896,072.

Bacon, W. M. and Ostendorf, B., Jr. — *Cipher Telegraph System* — 2,897,268.

Bellows, B. C. — *Distortion Corrector* — 2,896,176.

Blount, F. E. and Krom, M. E. — *Line Concentrator Checking Arrangement* — 2,894,073.

Bowers, F. K. — *Delta Modulation Compander* — 2,897,275.

Cesareo, O. — *Number Matching Circuit* — 2,894,071.

Crowe, W. J. — *Nonreciprocal Wave Transmission*—2,894,216.

DeMotte, F. E., Denton, E. C. and Hoffman, T. R. — *Circuits for Improving the Stability of Ultrasonic Delay Lines* — 2,897,489.

Denton, E. C., see DeMotte, F. E.

Dorff, L. A., see Bachelet, A. E.

Dreyfus, H. and Hose, R. H. — *Design for a Telephone Mounting* — D-185,742.

Feder, H. S. — *Magnetic Frequency Generator* — 2,896,090.

Fox, A. G. — *Nonreciprocal Wave Transmission* — 2,896,174.

Fuller, C. S. and Pearson, G. L. — *Lightning Surge Protecting Apparatus* — 2,896,128.

Hoffman, T. R., see DeMotte, F. E.

Hose, R. H., see Dreyfus, H.

Howland, F. L. and West, J. W. — *Semiconductor Diode* — 2,897,419.

Ketchledge, R. W. — *Radiation Sensitive Scanning System* — 2,897,369.

Kock, W. E. and Miller, R. L. — *Two-Way Television Over Telephone Lines* — 2,895,005.

Koenig, W., Jr. — *Relay Chain Circuit* — 2,895,088.

Kohman, G. T. — *Growing of Quartz Crystals* — 2,895,812.

Kompfner, R. — *Traveling Wave Tube* — 2,895,071.

Krom, M. E., see Abbott, G. F., Jr.

Krom, M. E., see Blount, F. E.

Kronacher, G. — *Dual Phase Shift Conversion Circuits* — 2,894,256.

Kronacher, G. — *Time Interval Encoder* — 2,896,160.

Linvill, J. G. — *Computing Circuits* — 2,894,217.

Mehring, A. C., see Abbott, G. F., Jr.

Miller, R. L., see Kock, W. E.

Mitchell, D., see Bachelet. A. E.

Murphy, R. P. — *Two-Way Photoelectric Translator* — 2,894,255.

Ostendorf, B., Jr., see Bacon, W. M.

Pearson, G. L., see Fuller, C. S.

Potter, R. K. — *Magnetic Printer* — 2,894,798.

Raisbeck, G. — *Wave Transmission System* — 2,896,178.

Raisbeck, G. — *Circuit for Measuring Alpha of Transistors* — 2,897,448.

Remeika, J. P., see Anderson, J. R.

Rowen, J. H.—*Nonreciprocal Circuit Element* — 2,895,114.

Southworth, G. C. — *Nonlinear Transmission Media* — 2,897,452.

Thomas, D. E. — *Transistor Characteristic Curve Tracers* — 2,896,168.

Toy, W. N. — *Linear Voltage-to-Frequency Converter* — 2,894,215.

Weinreich, G. — *Negative Resistance Semiconductive Element* — 2,895,109.

West, J. W., see Howland, F. L.

Whitney, W., see Abbott, G. F., Jr.

# THE AUTHORS

*J. R. Pierce* ("Exotic Radio Communications") is Director of Research in Communications Principles at Bell Laboratories. A native of Des Moines, Iowa, Dr. Pierce joined the Laboratories in 1936 after receiving the Ph.D degree from California Institute of Technology. He has specialized in the development of electron tubes and in microwave research, and during World War II he concentrated on the development of electronic devices for military applications. He was voted the "Outstanding Young Electrical Engineer of 1942" by Eta Kappa Nu, and in 1947 he was awarded the Morris Liebmann Memorial Prize of the I.R.E. for his research leading to the development of the beam traveling wave tube. In addition to his many technical articles, Dr. Pierce is the author of three books—"Theory and Design of Electron Beams" (1949), "Traveling Wave Tubes" (1950), and "Electrons, Waves and Messages" (1956)—and is co-author with E. E. David of the Laboratories of "Man's World of Sound" (1958). He is a member of the National Academy of Sciences, and is a Fellow of the American Physical Society and of the I.R.E. He served as Editor of the "Proceedings of the I.R.E." in 1954-55. He is also a member of the British Interplanetary Society, Sigma Xi, Tau Beta Pi and Eta Kappa Nu.

J. R. Pierce

R. L. Batdorf

*R. L. Batdorf*, born in Reading, Pa. received a B.S. in chemistry from Albright College in 1950 and a Ph.D. in physical chemistry from the University of Minnesota in 1955. Later that year he joined the Semiconductor Research Department of the Laboratories. At present he is investigating the feasibility of new semiconductor devices as a member of the Solid-State Electronics Research Department. Mr. Batdorf is a member of the American Chemical Society. He is co-author of the article on the diffusion of impurities into evaporating silicon appearing in this issue.

F. M. Smits

*F. M. Smits*, born in Stuttgart, Germany, received a Ph.D. in physics from the University Freiburg i. Br., Germany in 1940. After working for four years as a research associate at the same university, he joined Bell Telephone Laboratories in 1954, where he first studied solid-state diffusion in germanium and silicon. At present he supervises a group concerned with device feasibility and process studies. In this issue he is co-author of the article on diffusion of impurities into evaporating silicon. Mr. Smits is a member of the American Physical Society.

*P. L. Hammann*, a native of Kansas, joined the Laboratories in 1940 after receiving a B.S. degree in Electrical Engineering from Kansas State University in 1939. His initial work was concerned with high-frequency radio receivers used in instrument landing systems. Since 1941 he has been engaged in the development of radar systems for the Navy, Air Force and the Army. In 1951 he became responsible for the development of the radar equipment in the Nike-Ajax guided missile system and continued this activity in the Nike-Hercules system. Currently, he is associated with project planning and evaluation in the Hercules program. He is a member of Eta Kappa Nu and a senior member of the I.R.E. Mr. Hammann is the author of "The Radars of Nike-Ajax" in this issue.

P. L. Hammann

*J. F. Chesterman* received an A.B. degree in Economics from Dartmouth in 1932 and a B.S. degree in E.E. from M.I.T. in 1934. Originally from Montclair, New Jersey, he joined the Commercial Department of the New Jersey Bell Telephone Company in 1934 where he worked on business office methods, rate engineering, and station and revenue forecasting. Transferring to the Engineering Department in 1946, he engaged in planning for central office dial conversion and AMA installations. In 1952 he joined the Systems Engineering Department of Bell Laboratories to work on switching, AMA, and related projects. Since 1954, he has been engaged primarily in the data processing projects for electronic mechanization of the customer billing operation performed by the Operating Companies.

J. F. Chesterman

*M. L. Benson*, a native of Brooklyn, N. Y., received the B.S. degree from New York University in 1932 and the M.S. degree from M.I.T. in 1935. This was followed by graduate work at Johns Hopkins University. He joined the Chesapeake and Potomac Telephone Companies in 1937 as a lineman, with successive assignments in construction, plant maintenance and engineering. From 1942 to 1946 he served as communications officer for the Air Force, the Corps of Engineers, and the Military Police. In 1953, he joined the Laboratories. At the Laboratories, Mr. Benson has been concerned with tandem

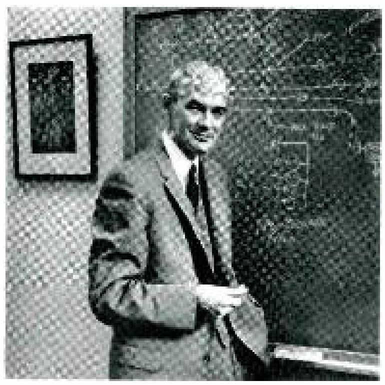
## AUTHORS (CONTINUED)

M. L. Benson

switching, Bell System Data Processing, facsimile, and PBX marketing studies. Later, he worked on the expansion of the 756-type PBX, and recently transferred to the A.T.&T. Co., where he is presently concerned with customer telephone products planning. In this issue, Mr. Benson is the author of the article on the message-waiting service.

*R. J. Jaeger, Jr.*, a lifelong resident of the New York area, joined the Switching Development Department of the Laboratories in 1951. His Bell System career started in 1941 with the Long Lines Department of A.T.&T., where his work was initially concerned with toll switchboard maintenance. From 1943 to 1945, he saw active military duty as a Naval Aviator. Soon after his return to the Long Lines Department, he started working on the installation and cut-over of the New York No. 4 toll crossbar office. Since coming to the Laboratories, Mr. Jaeger has been primarily concerned with the planning and development of new features for No. 4-type toll switching systems. Most recently he has been associated with development of the TASI system. Mr. Jaeger received a B.A. degree in mathematics from Hofstra College in 1951. He is co-author of the article "4A and 4M Toll Crossbar with CAMA."

R. J. Jaeger, Jr.



M. E. Maloney

*Martin E. Maloney* was born in Waterloo, N. Y. He graduated from Georgetown University (B.S., 1923) and Cornell University (E.E., 1927). In switching development, he worked on dial PBX's, crossbar, and automatic ticketing systems until he transferred to switching engineering in 1940. Since then, except for three years of the war working on air force communications, he has spent all of his time on toll dialing systems, DDD, adaptation of crossbar tandem to long haul use, and centralized AMA. At present he is engaged in planning work for future toll systems. He is co-author of the 4A and 4M toll crossbar article in this issue.

C. R. Keith

*C. R. Keith* is a native of Kansas but spent most of his school years in California, and he received the B.S. degree from California Institute of Technology in 1922. After six years at the Laboratories in carrier research, Mr. Keith left the Laboratories to work for Western Electric, Ltd., in London, England, on sound recording for talking motion pictures. In 1935 he returned to New York, where he continued in sound recording activities for Electrical Research Products, Inc., and later for the E.R.P. Division of Western Electric. After returning to the Laboratories in 1951, Mr. Keith has worked mainly on telephone answering sets and central-office announcing machines, and in this issue is author of the article on the variable-cycle announcement machine. He is a Fellow of the Society of Motion Picture and Television Engineers, a Senior Member of the I.R.E., and a member of the Board of Governors of the Audio Engineering Society.