June 1960

Bell Laboratories

RECORD

Experimental "Short-Hop" Microwave System
The Traveling-Wave Tube Goes to Work
Automatic Number Identification
The DX Signaling System
A New Noise-Measuring Set

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 38 • Number 6 • June 1960

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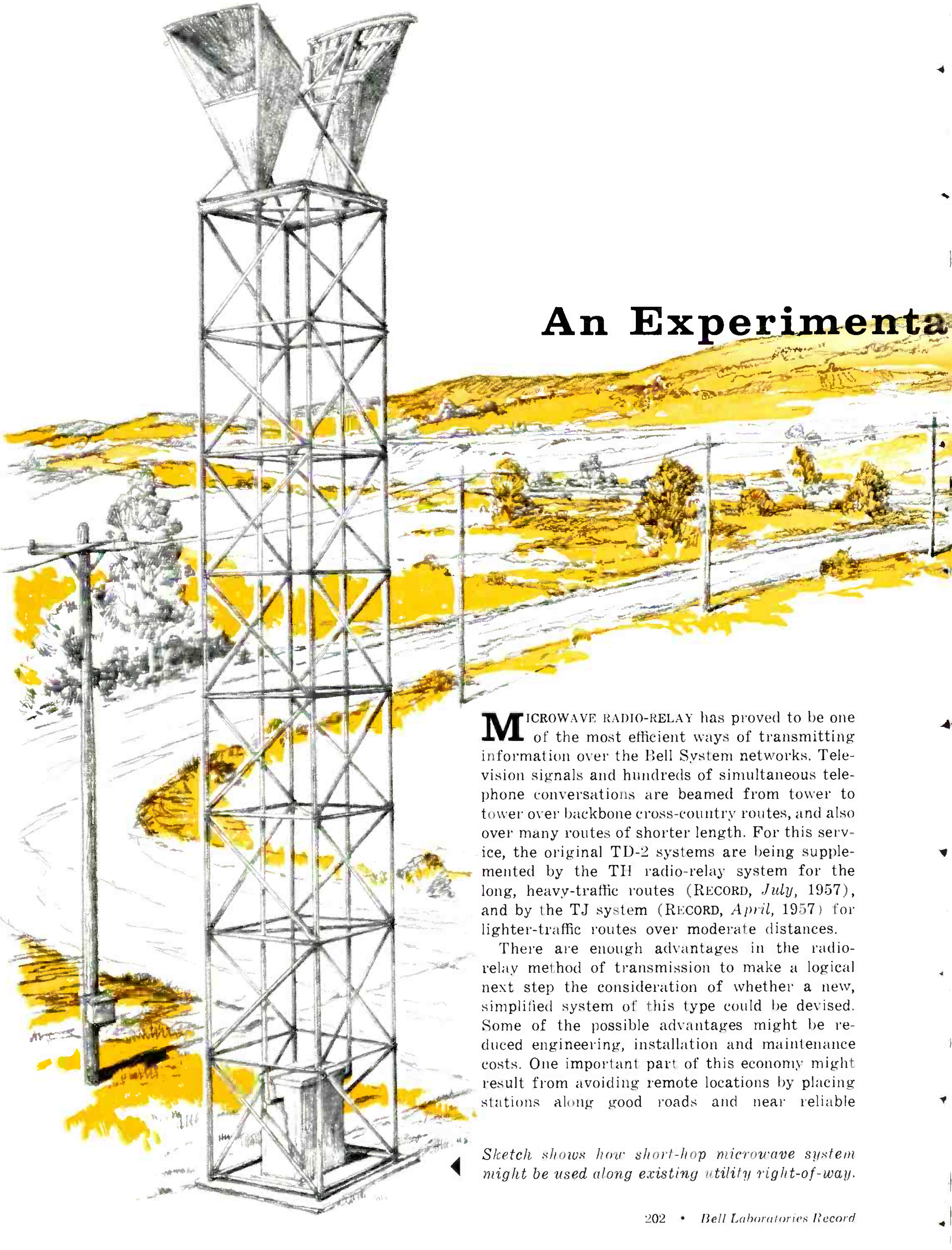
Cover *A camera, looking up from the center of the base of an experimental tower for "short-hop" microwave antennas, sees this interesting pattern (see page 202).*



An Experimenta

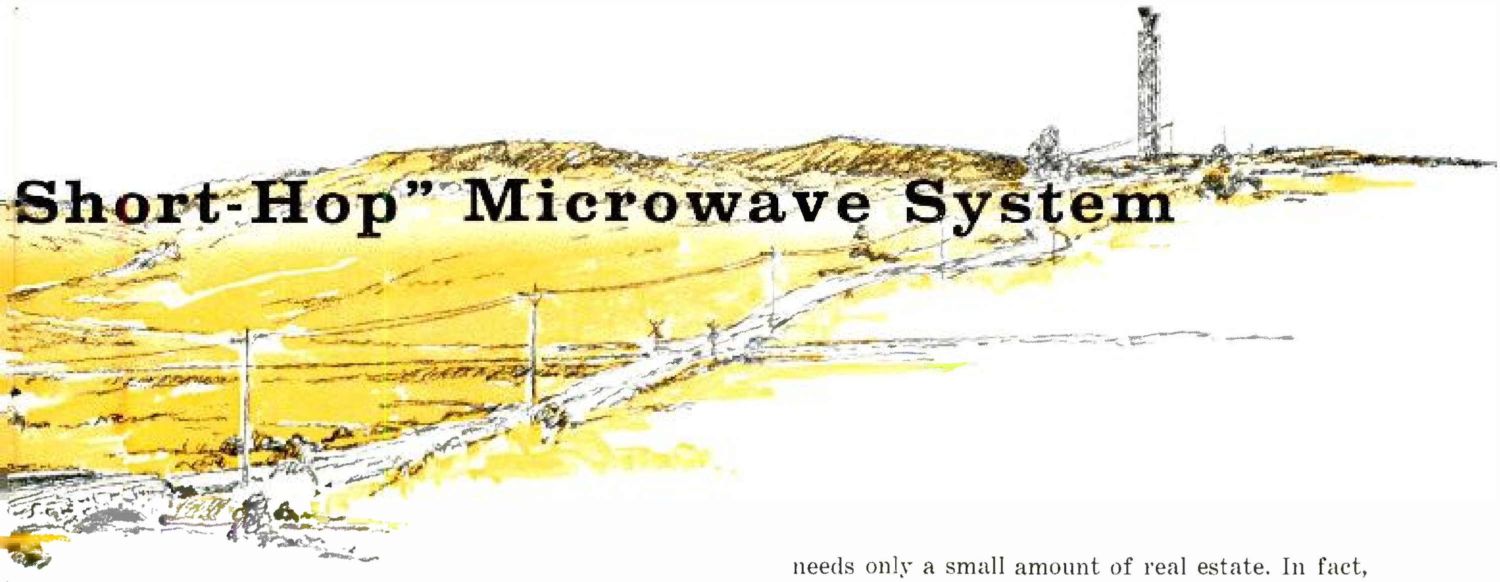
MICROWAVE RADIO-RELAY has proved to be one of the most efficient ways of transmitting information over the Bell System networks. Television signals and hundreds of simultaneous telephone conversations are beamed from tower to tower over backbone cross-country routes, and also over many routes of shorter length. For this service, the original TD-2 systems are being supplemented by the TH radio-relay system for the long, heavy-traffic routes (RECORD, *July*, 1957), and by the TJ system (RECORD, *April*, 1957) for lighter-traffic routes over moderate distances.

There are enough advantages in the radio-relay method of transmission to make a logical next step the consideration of whether a new, simplified system of this type could be devised. Some of the possible advantages might be reduced engineering, installation and maintenance costs. One important part of this economy might result from avoiding remote locations by placing stations along good roads and near reliable

Sketch shows how short-hop microwave system might be used along existing utility right-of-way.

C. L. Ruthroff and L. C. Tillotson

Short-Hop" Microwave System



sources of commercial power. The question is: Can an economical light-route, radio-relay system be built that will have the reliability and transmission performance required for standard Bell System service?

There is no definite answer to this question at the present time, because the problem is indeed a complex one. However, a new, experimental system designed at Bell Laboratories is beginning to supply some of the necessary data. A system of the light-route type has been built at the Radio Research location of the Laboratories in Holmdel, New Jersey, and has now been in continuous operation since December, 1957, with outstanding reliability and transmission performance. For research purposes, it is operating at 11,000 mc with a baseband of 2 mc, over a "two-hop" loop from the Laboratory to a tower on a hill about two miles away, and return. *(See block diagram on following page.)*

The basic concept is that of a radio-relay system with a closer spacing of repeaters (about 5 to 10 miles instead of about 30 miles for TD-2, TH, and TJ). Antennas would be mounted on poles or towers, but because of their close spacing, these need not be very tall. Tall towers, besides being expensive, require aircraft warning lights, which would use more power than the entire repeater envisaged for this type of operation. Further, and quite important, a small tower needs only a small amount of real estate. In fact, the idea is to use existing rights-of-way along telephone-pole routes wherever possible, or at most use a small amount of land, perhaps as little as 10 feet by 10 feet.

On this small area the tower is erected, and at its base is a fairly small cabinet containing the complete transmitter, receiver and power supply for the repeater or terminal. The required power should be quite small, and the power supply would have enough protection to keep the repeater functioning during an emergency period if commercial power should fail, without requiring the use of a standby generator.

The TJ system has proved that a transmitter of simplified design (RECORD, *April,* 1955) is practicable. In place of what could be a very complex circuit, the heart of the TJ transmitter is a klystron tube that supplies the microwave power to be transmitted, with the modulating signal applied directly to this tube. The availability of an efficient ferrite isolator (RECORD, *October,* 1955; *April,* 1958) was an important reason why this type of transmitter could be built. With it, reflections from the antenna do not interfere with the klystron's oscillation and modulation.

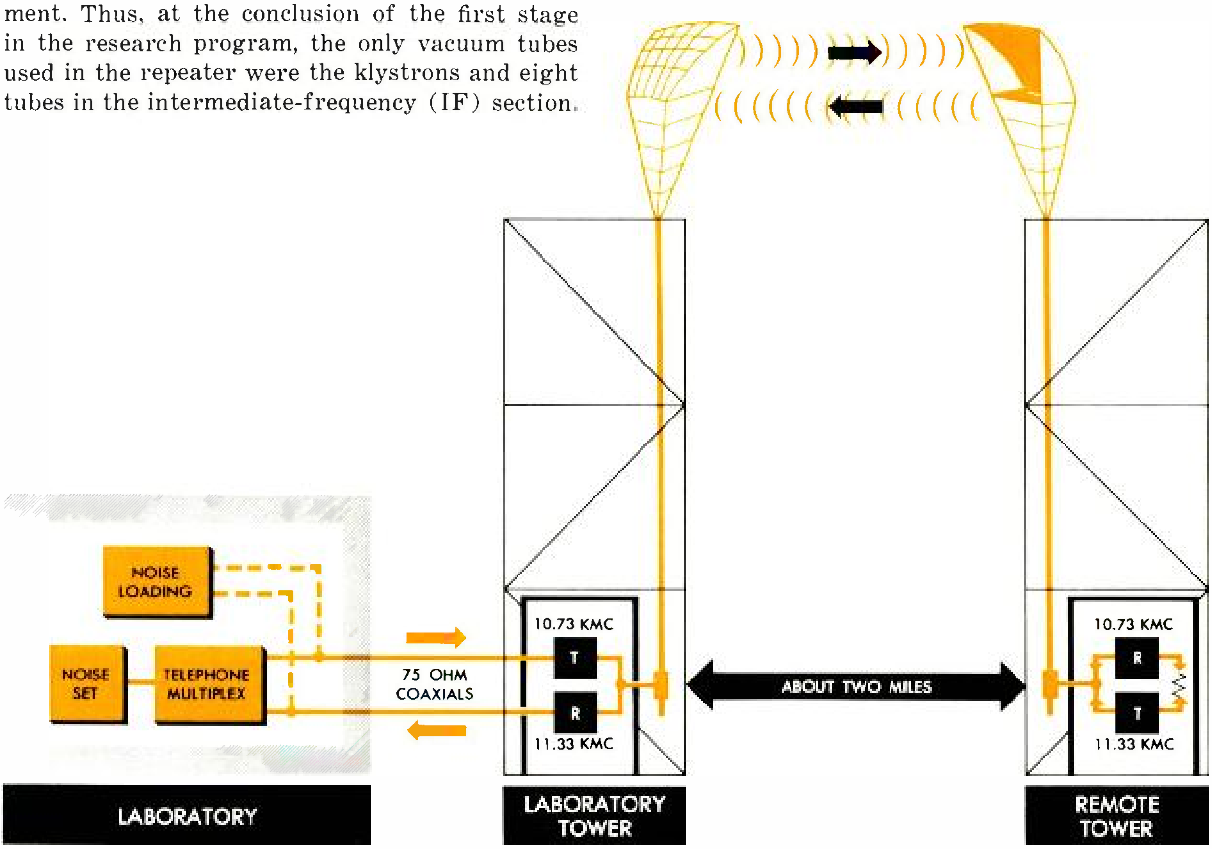
The new experimental system retains this basic type of transmitter and makes use of other new components and new techniques that point toward simplified, economical design. One such component is the "circulator," indicated at the junction of the transmitting and receiving paths in the block diagram of a terminal on page 206.

This circulator (RECORD, *August*, 1957), another ferrite device, is used to separate the incoming and outgoing signals. It has three advantages for this application: First, it provides discrimination based on direction of wave travel rather than frequency as does a filter. Thus one design is suitable for all channel allocations. Second, it provides 30 db of additional isolation for the transmitting klystron. And third, like the isolator, it requires no power.

With an efficient transmitter and circulator, another logical place to look for more economical design is in the receiver. As a first step, the designers investigated an improved discriminator for converting the FM carrier signal to the output or "baseband" signal and an improved limiter circuit for removing any amplitude modulation that may be present (BSTJ, *July*, 1958). As a result of improvements made in these two elements, no baseband amplifier is required, which means less apparatus (less cost), less transmission impairment (intermodulation distortion), better reliability and, of course, a lower power requirement. Thus, at the conclusion of the first stage in the research program, the only vacuum tubes used in the repeater were the klystrons and eight tubes in the intermediate-frequency (IF) section.

After this work was under way, however, diffused-base transistors (RECORD, *June*, 1958) became available, and transistor operation at the 70-mc intermediate frequency became a possibility. More recently, therefore, a laboratory model of the entire IF section has been built, using transistors. With this improvement, the total power required by a one-way repeater is less than 35 watts.

At present, however, minimum standard "house-current" electrical service—a single 115-volt circuit with 15-ampere capacity—is more than adequate for a two-way repeater station. The complete power supply consists of this input, a battery charger, lead-acid storage batteries (four automobile batteries), and a "transistor-core" converter. In this circuit, the storage batteries are "continuously floated" across the charger. The converter, which makes use of transistors and saturable-reactor cores, is also of the continuously operating type. It is supplied directly from the battery at all times. The result



A diagram of the experimental system at Holmdel. The tower on the left is located near the Laboratories building, and the other tower is located on a hill about two miles away. Both act as repeaters for multiplexed-telephone and test signals generated in the laboratory building.

is an extremely stable supply. With the present batteries, it will continue to operate a repeater during failure of commercial power for 23 hours at 32°F and for 12 hours at 0°F. With new low-power circuits in the transmitter and receiver, these standby times could be much longer, or one power supply could be used to operate more than one repeater. Another possibility, if the power requirement can be greatly reduced, is to use a new type of small power source; perhaps a gas-burning thermoelectric generator (RECORD, *October*, 1957), or even, in the future, solar batteries (RECORD, *July*, 1955).

The Experimental System

With power, and with the transmitters and receivers available. the next step was to assemble a number of message channels and fit them into the desired band of frequencies. In the experimental system, channels are "multiplexed," or combined, by a frequency-division scheme. Each voice-signal frequency modulates its assigned carrier frequency, and the combined multiplex signal containing all carriers modulates the klystron.

The experimental multiplex equipment uses solid-state devices exclusively. Six two-way channels are presently available in one equipment box, and each two-way channel uses only 1½ watts. Since no equipment is used in common for all channels, failure of a component would affect only one channel. Signaling is built into each channel, and channels are easily "dropped," or branched off at any terminal or repeating station. Additional circuits are set up merely by plugging in new channel units.

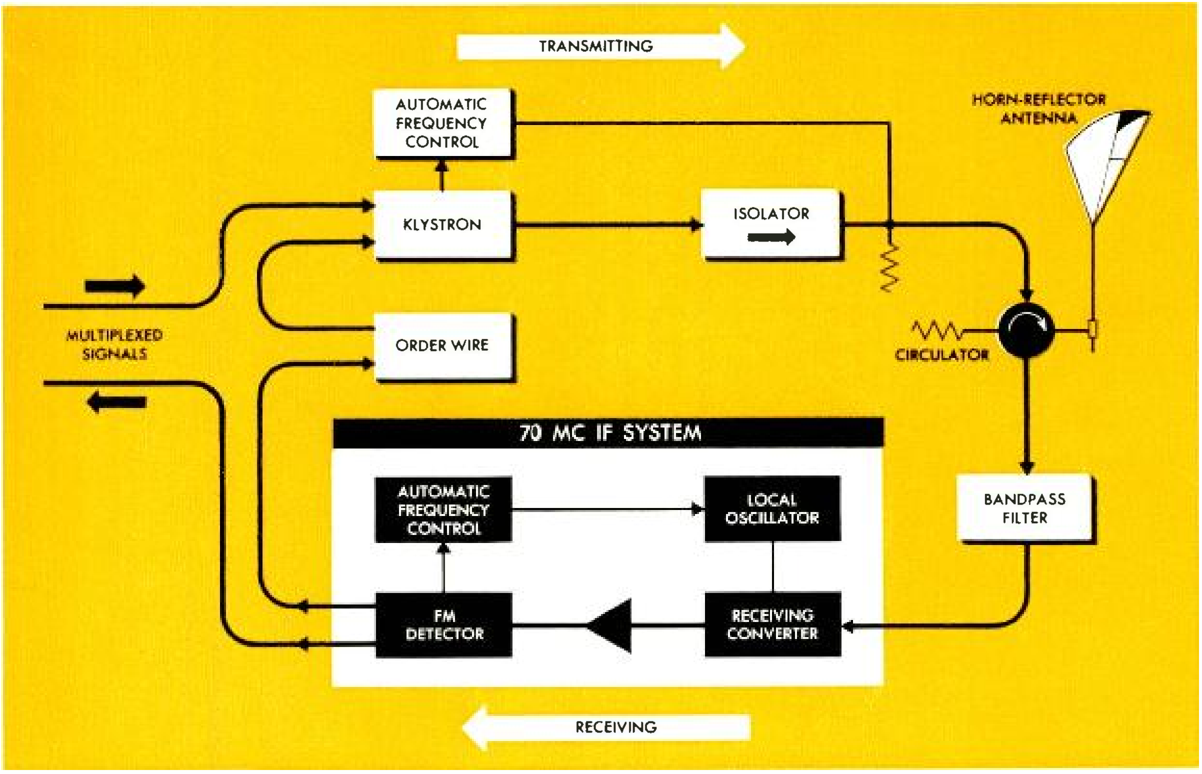
This multiplex equipment has been frequently used for sending actual telephone conversations over the experimental two-hop loop. But for more critical testing, the 2-mc baseband is "noise loaded." That is. noise power having the same electrical effect as many message channels is sent over the system. A narrow frequency range, or "slot" is kept free of noise, however, at the transmitting end. At the receiving end, the amount of noise that gets into this slot is a measure of crosstalk or interchannel interference in the system.

After 28 months of continuous field operation, the signal-to-noise performance and signal-to-crosstalk performance are within a few db of their original values. The system has required only the barest minimum of maintenance: replacement of klystrons every 16 to 18 months, addition of water to the storage batteries twice a year, and replacement of several overworked transistors in the battery chargers.

W. F. Bodtmann checking frequency of terminal equipment. Complete terminal, including power supply, is mounted in housing at base of tower.

The antennas have been erected on towers of a very simple but sturdy design (*see sketch on page 202*). Since all sections are identical, construction is simplified and work proceeds rapidly because a safe working platform can be provided at the top of each section as the structure is erected. After completion, it is very rigid—an important requirement for use with any narrow-beam signal path. The small horn-reflector antenna used with this system has a beam width of 1¼ degrees, and transmission is maintained within acceptable margins in gale winds. Over 5- to 10-mile distances, the antennas can be aimed by visual sighting in clear weather.

An important feature of the antenna system is that signals are transmitted between the antenna and the equipment on the ground via a waveguide which, being oversized, contributes very little loss. With the 2-inch aluminum pipe



Block diagram of a terminal showing the important elements in transmitting and receiving sections.

presently used, loss of 11.2 kilomegacycles is only 0.65 db per 100 feet. The system is not pressurized, but other measures have been taken to avoid the moisture problem. The waveguide is nearly straight and is smooth and clean on the inside. Also, a special waterproof "window" is used at the point where the signals couple to the waveguide, and the waveguide pipe is open for drainage at the bottom. The installation has gone through intense rainstorms, much freezing and thawing, and one violent sleet storm, but no water has accumulated in any part of the system.

What Experimental System Shows

Transmission performance has been calculated at the 11-kilomegacycle frequency, and these calculations have been checked with measurements on the experimental system. Typical path losses are 47 db over a 5-mile section and 53 db for a 10-mile section. Figures for signal-to-noise and signal-to-distortion have been well within the requirements for Bell System transmission. Operation at higher frequencies is a possibility if band allocations become available.

As in any experimental system, research is continuing to explore the many possible avenues toward efficient, low-cost operation. Work on transistorizing the IF section, for example, has already been mentioned. Another possibility is a new source of microwave power. Currently under investigation is a high-efficiency, backward-wave oscillator that promises to deliver 100 milliwatts of 11-kilomegacycle energy with a total dc input of only about 2 watts.

At the present time, however, the experimental system has demonstrated several facts that will be relevant to any future consideration of this type of service. A few dozen channels can be handled by a simplified system over a number of hops, each as short as 5 to 10 miles. Second, it appears quite practicable to use an unpressurized antenna on a low, simply-constructed tower. Third, experience to date has shown that a complete microwave radio repeater can easily be installed out of doors in unheated, tower- or pole-mounted cabinets, without field adjustments or testing. Thus, they should not require highly trained crews. Finally, the problem of supplying reliable power, one of the chief economic factors, appears to be solvable through the use of solid-state devices and by the choice of circuit and system arrangements which favor low power consumption.

The traveling-wave tube is destined to play an important role in the new TH microwave radio-relay system. In this, its first Bell System application, the tube will help make possible a substantial increase in channel capacity over that of earlier systems using comparable frequency space.

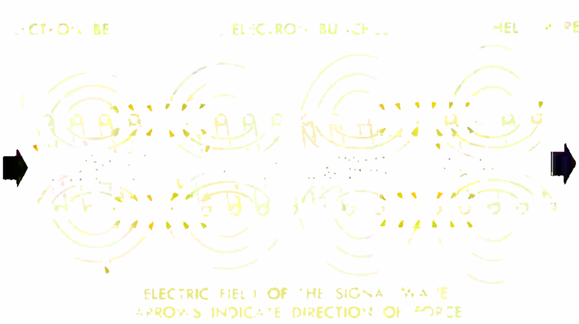
H. L. McDowell

THE TRAVELING-WAVE TUBE GOES TO WORK

When the first installation of the TH microwave radio-relay system goes into operation later this year, it will employ a traveling-wave tube amplifier as a major building block. This will be the first Bell System application of such a tube and also the first large-scale commercial application of traveling-wave tubes in the United States. In view of the exacting requirements of a heavy route, long-haul communication system such as TH, this application signifies that the traveling-wave tube has completed its evolution from an experimental device to a refined and versatile tool for the designer of heavy-duty microwave transmission systems.

About 15 years have elapsed since the traveling-wave tube was invented in England by R. Kompfner, now Director of Electronics and Radio Research at Bell Laboratories. Although at first shrouded in wartime secrecy, the exciting possibilities of this tube were revealed shortly after the war, particularly as a result of a thorough theoretical study by J. R. Pierce, Director of Research—Communications Principles, at the Laboratories. Since then, considerable effort has been devoted to the development of traveling-wave tubes. Microwave relay systems in England, France, and Japan are now using some of these tubes; others are being used in new military systems.

When the TD-2 microwave relay system was developed at the Laboratories in 1948-49, traveling-wave tubes were not sufficiently advanced for

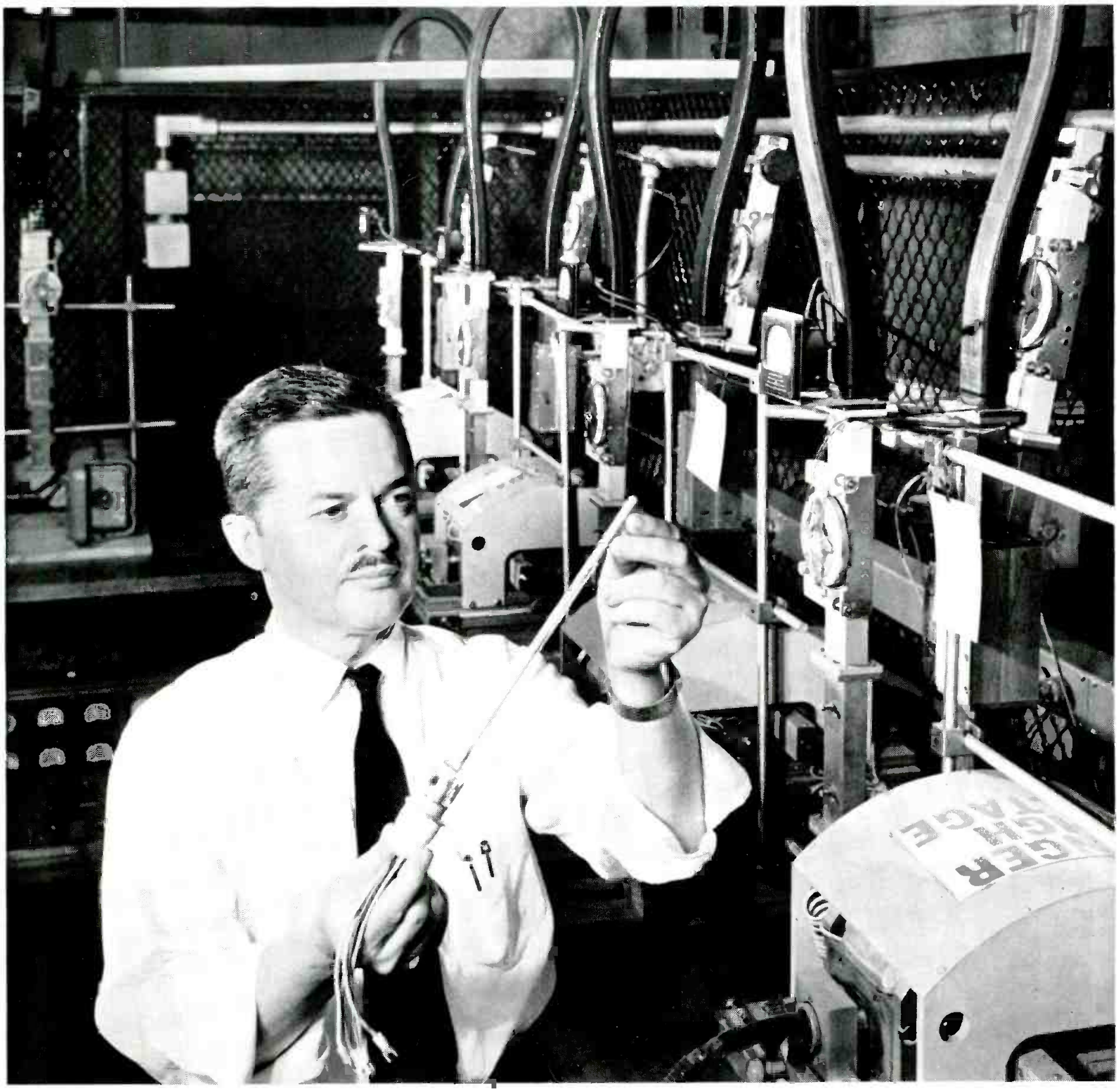


Interaction of the electromagnetic wave and electron beam is qualitatively illustrated in the diagram above. Note bunching of the electrons.

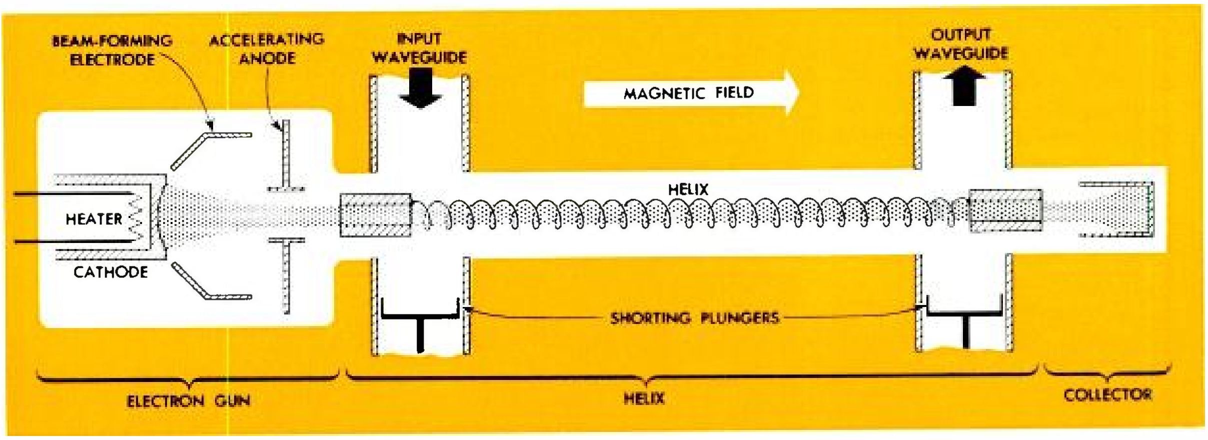
use in such an application. In the intervening time, the Laboratories has pursued an extensive program of research and development on tubes of this general class. One important fruition of this effort is the 444A traveling-wave tube, which has helped make the TH system possible.

The principle upon which a traveling-wave tube operates, and the one that accounts for its superiority over earlier microwave amplifiers, may be called "traveling-wave interaction." Briefly, this means continuous interaction, over a comparatively long distance, between a signal wave and an electron beam traveling at nearly the same velocity. By way of contrast, tubes such as microwave triodes and klystrons have an interaction region which must be short enough so that electrons can traverse it in a time much less than the period of one RF cycle. For example, a klystron amplifier may have an interaction region of the order of a hundredth of that of a traveling-wave tube designed for the same voltage and frequency.

To obtain appreciable interaction between the microwave signal energy and the electrons, the



J. P. Laico examines a 444A traveling-wave tube amplifier. A group of these tubes, operating in their magnetic circuits, right, have already undergone 30,000 hours of laboratory life testing.



In a traveling-wave tube, the signal wave clings closely to the helix wire. Therefore, it moves much more slowly in the axial direction, providing a continuous interaction over a long distance.

klystron's electric field in these short interaction regions must be very high. Such high fields can be obtained only through the use of high-Q resonant cavities, with a consequent limitation of the bandwidth to a few per cent of the center frequency.

In a traveling-wave tube, however, the electrons and the signal interact over a comparatively long distance (5½ inches in the 444A) so that there can be considerable transfer of energy from the electron stream to the signal wave without the necessity of high fields or resonant cavities. Thus the traveling-wave tube can give high gain and large bandwidth simultaneously.

The schematic diagram on this page illustrates the important elements of a traveling-wave tube amplifier. Heart of the tube is the helix, which resembles a stretched screen-door spring, but is much smaller.

A signal is launched onto the input end of the helix from a waveguide. The signal wave clings closely to the helix wire and travels around the helical path at about the velocity of light. In the axial direction, therefore, the signal wave moves at a much slower rate; the velocity reduction is about equal to the ratio of the axial length of the helix to the total length of the wire. In the 444A tube this reduces the axial velocity to about a tenth the velocity of light. Because of this inherent ability to slow down the axial propagation of waves, the helix is known as a slow-wave circuit.

Such a circuit makes it possible, using only moderate voltages, to accelerate electrons to the point where they can keep up with the wave. This is the purpose of the electron gun. It shoots an electron beam, which in the case of the 444A has been accelerated to 2400 volts, through the center of the helix to a collector at the far end of the tube. A magnetic field in the helix region overcomes mutual repulsion of the electrons and "focuses" the beam through the helix.

The interaction between a wave and a beam of electrons traveling at about the same velocity is illustrated qualitatively on page 207. The electric field on the signal wave acts to slow down some electrons and to accelerate others, until gradually electrons become bunched in regions in which they "see" a decelerating electric field caused by the signal wave. As the bunched electrons are slowed down, the energy they lose is gained by the RF fields of the wave. Thus the wave gains energy at the expense of the electron beam and we have amplification. In other words, both the density of the electron bunches and the amplitude of the signal wave progressively increase as they travel together down the tube. At the collector end of the helix, the amplified signal is transferred to an output waveguide.

Great Inherent Bandwidth

Because of the nonresonant nature of the helix, traveling-wave tubes have very great bandwidths. Actually, the bandwidth of the input and output coupling networks often sets a practical limit to the useful bandwidth. To meet the strict requirements of the TH system, a special helix-to-waveguide coupling was developed which reflects less than one per cent of the signal over the TH band (5925-6425 mc). However, the inherent electronic bandwidth of the tube is much greater than that of the coupling system. This bandwidth characteristic was obtained using a special coupling section tuned for "best coupling" at certain individual frequencies.

Many difficult problems were encountered and solved in the process of developing the traveling-wave tube from an experimental device to a usable tube. In the early days of its development, for example, a tendency of the tubes to oscillate was a serious problem. The solution was to introduce loss in the center region of the helix to absorb reflected waves traveling backward along the helix. Also, machines had to be developed for winding helices without errors in pitch exceeding 0.5 per cent. Accuracy of this degree assured stability under conditions of poor "match"—that is, when the tube is working into a filter.

Another problem—supporting the helix so as to maintain its precision and cool it effectively—was solved by developing a process for glazing it to the three ceramic support rods. (Glazing is a technique for rigidly bonding a metal to a ceramic using a glassy substance as an intermediate layer.) At the same time, electron guns capable of producing high-density beams had to be devised and mechanical techniques for making electron guns and helix structures to high precision had to be worked out. Because the electromagnets used for focusing early tubes required considerable power, permanent magnets that require no power were developed (RECORD, *May*, 1958).

It was also necessary to minimize distortions caused by noise and nonlinearities in the gain and phase characteristics. Further, much work had to be done to obtain high reproducibility of performance. Finally, life test studies had to be conducted. These studies have indicated that the life expectancy of early production tubes should be greater than 10,000 hours (*see page 208*).

444A TRAVELING-WAVE TUBE

Characteristic	Value
Frequency Range	5925 to 6425 mc
Helix Voltage	2400 volts
Collector Voltage	1200 volts
Beam Current	40 ma
Magnetic Flux Density	600 gausses
Maximum Efficiency (11 watts/40 ma x 1200 v)	23 per cent
Power Output as Used in TH (Reduced for improved performance)	5 watts
Gain at 5 watts	30 db minimum
Noise Figure	28.5 db

The 444A is now in production at the Allentown, Pennsylvania, Works of the Western Electric Company. Some of the important characteristics of this tube are shown in the table in the lower left-hand corner of this page.

It will help make possible a substantial increase in the channel-carrying capacity of the TH system over that of the TD-2 system. This increase is possible because the 444A has a power output ten times as great as that of the 416B microwave triode—this in spite of an increase in the operating frequency from 4000 to 6000 mc. As a further advantage, the great bandwidth of the traveling-wave tube will result in a considerable simplification in the setup and maintenance procedure for the microwave amplifier as compared with that used in TD-2. This results because the traveling-wave tube will provide an essentially flat 30-db block of gain over the 500-mc wide TH frequency range. Thus a 444A amplifier will work interchangeably in any of the 16 channels of the TH system without the necessity of cavity tuning or complex adjustments.

In the TH system, the 444A tube will find its major use as the final amplifier stage in the transmitter of each of the 16 channels. Ideally, one might think of using a single traveling-wave tube to amplify all the channels at once, since its bandwidth is great enough to do this. However, intermodulation between the channels would be excessive in such an arrangement. Also, reliability considerations dictate that a single tube failure should not be responsible for taking more than one channel out of service.

Another 444A tube will be used in each TH channel to amplify the local oscillator signal before it is fed to the transmitting modulator. Together with some additional traveling-wave tubes used in the microwave generator, there will be a total of 36 traveling-wave tubes in each fully-loaded repeater station. Although these tubes operate at many different frequencies and power levels, a single type of amplifier package will satisfy all of these requirements. With 130 repeaters required for a single one-way transcontinental broadband channel, there will be many thousands of these traveling-wave tubes in the field before long.

Because traveling-wave tubes have become indispensable building blocks in modern microwave systems, it is likely that the 444A will be followed by many other such tubes. There are already many applications of such devices in military systems. Toward this end, strong development effort on traveling-wave tubes is continuing at the Laboratories.

To be useful over a long period of time, a telephone system must be adaptable. Thus new devices always must fit into existing equipment. A recent example of this adaptability in the Bell System is Automatic Number Identification — an adaptation of older switching systems to centralized automatic message accounting without operator intervention.

H. A. Miloche

Automatic Number Identification

Each month, from about 58 million telephones, the Bell System processes over 5 billion calls. The more spectacular aspects of this fact are the vastness of the physical plant and the complexity of the operation. Less glamorous, but not a whit less important, is the problem of charging for this service the right amount of money to the right customer.

During the early part of this century the Bell System found that, to operate efficiently, it must mechanize its switching procedures. And while mechanized adjuncts to the charging problem have been in use since then, it is only during the last decade that efforts have been made to develop a system of mechanized billing.

Around 1900, engineers introduced the service meter — now known as the message register. This device kept a running count of local calls originated by customers of the metered service. All other charged calls, however, were timed and ticketed by operators. The message register was incorporated in the panel dial system, introduced in the early 1920's. Register use was expanded in the panel system in the early 1930's for what was then called "extended-area" dialing. A new principle here was the multiple operation of the registers depending on the destination and duration of extended-area calls. Each increment of time and distance was considered and billed as a "message unit."

In the early 1940's, the step-by-step switching system was arranged for automatic ticketing (RECORD, *July*, 1944). This equipment, without human aid, produced for extended-area calls, printed tickets containing all pertinent charging information. The calling-number entry on the ticket was obtained through the first use of automatic number identification in the Bell System. However, manually or photographically recorded register readings and automatically printed tickets still had to be processed manually for billing purposes.

It was not until the late 1940's, and the advent of AMA (Automatic Message Accounting) (RECORD, *January*, 1949), that even partially mechanized billing became possible. It became so then because *automatic* message accounting produced billing information for the first time in a form—perforated paper tape—that permitted the use of machines rather than people for its reading and interpretation.

AMA, however, is not universally applicable and central offices installed without provision for it are costly to convert. This category includes panel, step-by-step, and the earlier No. 1 crossbar offices. In these offices, many extra-charge calls that the customer might otherwise dial are handled by operators for billing purposes.

This situation was relieved by the adaption of crossbar tandem, about 1950, for CAMA (Centralized Automatic Message Accounting) (RECORD, *July*, 1954). These facilities permit use of tandem routing on dialed extra-charge calls. Here, centralized equipment provides billing information similar to that of AMA.

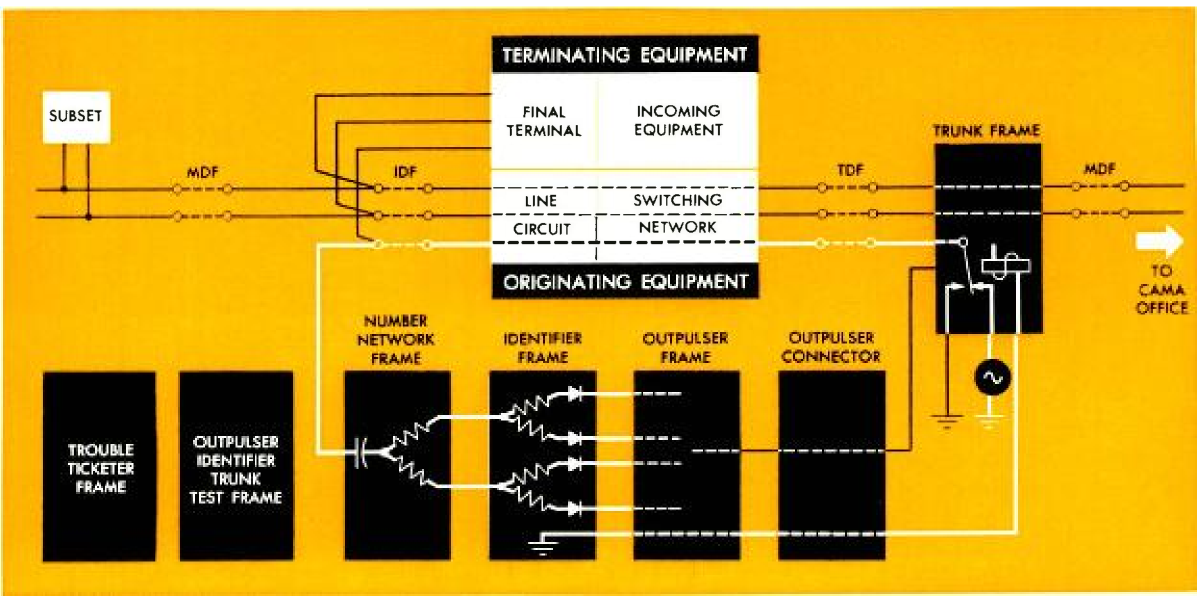
The System Aspects of ANI

In CAMA tandem, the directory number of the calling customer is incorporated in the billing information by an operator who requests this number of the customer and keys it into the equipment at the tandem office. At the time the Bell System adopted this method of calling-number identification for CAMA, automatic methods were under consideration. However, the inclusion of automatic number identification, ANI, would have caused considerable delay in the introduction of CAMA. Therefore CAMA was developed on the basis of operator identification, leaving ANI for future development. That "future" is here.

ANI will be used in existing panel, step-by-step, and No. 1 crossbar offices for extended-area or direct distance dialing. Present designs of these types of central-office equipment therefore influence ANI strongly. In general, they all employ separate paths for originating and terminating calls, branching near the point of entry of the customer's line. The originating path does not have directory-number significance, but the terminating path obviously must. And although ANI is concerned with originating traffic, it exploits the fact that there is attached to the originating path this "branch" identified with the calling customer's directory number. To understand how this works, we will explore the panel-office arrangement.

It should be made clear at the outset that the most suitable way to identify a customer is by his directory number. Accuracy and efficiency in the processing of billing data require this identification to be both concise and unique. While billing requires identification to be translated ultimately into terms of name and address, such terms are certainly not concise. Neither, as in the case of two John Smiths living in the same apartment house, are they unique. Thus directory-number identification is a good way to solve the problem.

In terms of switching, each directory number is a specific mechanical destination, or reference point. In the panel system, a number's significance is permanently attached to the final terminal and to the associated cable terminations



For number identification, ANI uses a lead in the switching path to send a signal from the trunk circuit to the calling line. Signal returns to identifier frame, where its location identifies it.

H. A. Miloche holds a ten-circuit network package. Panel at left is front of bus-bar frame. Network card installed on other side of frame permits pins to protrude and be strapped to bus-bar terminals.

at two specific frames in the switching office — the IDF (intermediate distributing frame) and the MDF (main distributing frame). A number is assigned to a customer by cross connection at the MDF to the outside cable pair serving that customer. Should the customer move to another location served by the same central-office, a corresponding change in the cross connection to his new cable pair permits him to keep the same number and obviates directory change.

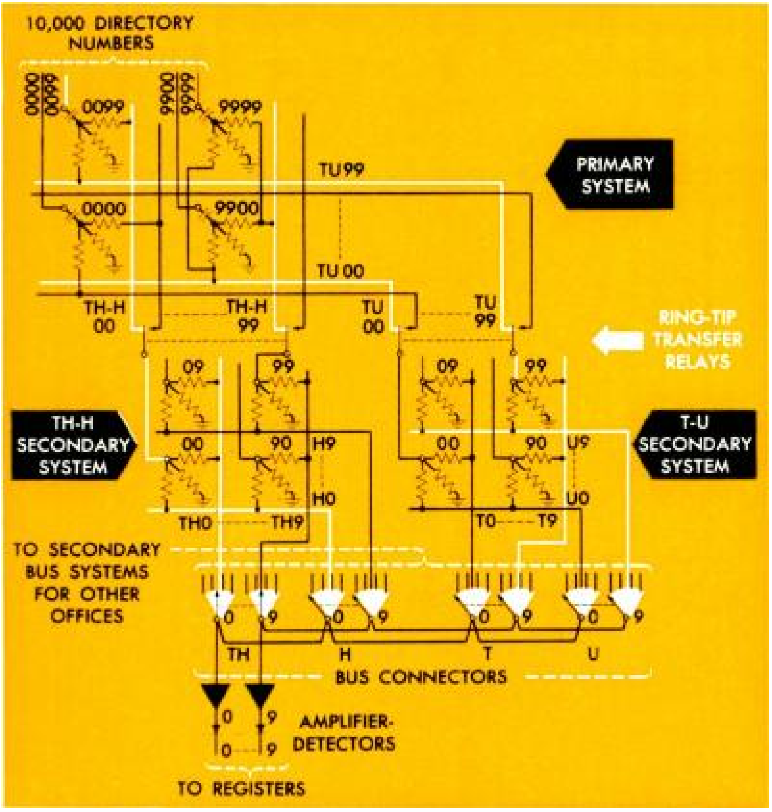
The customer receives originating service through a line circuit. Since directory numbers are not permanently associated with this equipment, the customer is assigned his line circuit through cross connection at the IDF. This equipment is part of a line group he shares with other customers. If traffic loads on the line group become objectionably unbalanced, the IDF cross connection permits regrouping customers without affecting directory numbers. Directory numbers, when vacated, are not immediately reassigned. But line circuits, representing the greater investment, can be, thus permitting efficient use of line equipment.

The switching network in a local central office contains a large number of paths that might be used for a call. Therefore, the specific switching path and trunk employed are quite unpredictable. Regardless of the point of origin and the trunk selected, however, a path is established for the duration of the call between the trunk and the point at the IDF which identifies the directory number of the calling customer. ANI uses an existing lead in this path to transmit a signal to the identification equipment.

Obviously, ANI must not be permitted to interfere with the operation of signaling, talking, supervision and control. However, during a call the control lead is grounded. ANI, therefore, makes use of the fact that an ac signal may be superimposed on the ground connection to this lead at the trunk. The presence of this signal at the IDF is used for identification.

Basically, ANI has two functions — identification of the calling customer's directory number and transmission of this identity to a CAMA office. The identification is a high-speed, one-at-a-time operation. This means the operating unit must be able to service all CAMA calls occurring during busy hours, individually and within tolerable delay. One ANI system can serve six central offices, of 10,000 customer numbers each, in the same building. As a result, the identification signal could signify any one of 60,000 numbers. To be of practical use, however, this signal must be translated into digital information. The translation into five digits each having "1-in-10" significance, employs an elaborate network.

ANI employs a new type of outgoing-trunk circuit at the local central office in the path of extra-charge calls that go through CAMA of-



Identification signal appears first at number network where it is divided into the first two and last two digits of directory number. In secondary network number is divided into four separate digits.

fices. When the calling customer's number is to be identified, the trunk equipment initiates a connection to an "outpulser" which seizes an "identifier." At the same time, a 5800-cycle signal connects to the control conductor of the trunk. This signal goes back through the switching path to the calling-line circuit and the IDF cross connection to an associated number network having directory-number significance.

The 5800-cycle signal then filters through a primary network on the number-network frames and secondary networks in the identifier and presents itself to amplifier-detectors in the identifier. These detectors "find" the signal at unique points in the secondary network and thus identify the directory number. This identity is registered in the outpulser which transmits information through the trunk to the CAMA office. This information consists of numerical digits that will be placed on the CAMA tape.

Each directory number has its own number network. The particular number network at which the identification signal appears is one of a maximum of 6 groups of 10,000, and its identity is established as a 5-digit number. The first is an arbitrary digit representing the office code, for example "CH3." The other four represent the thousands, hundreds, tens, and units digits (TH, H, T, and U) of the listed directory number.

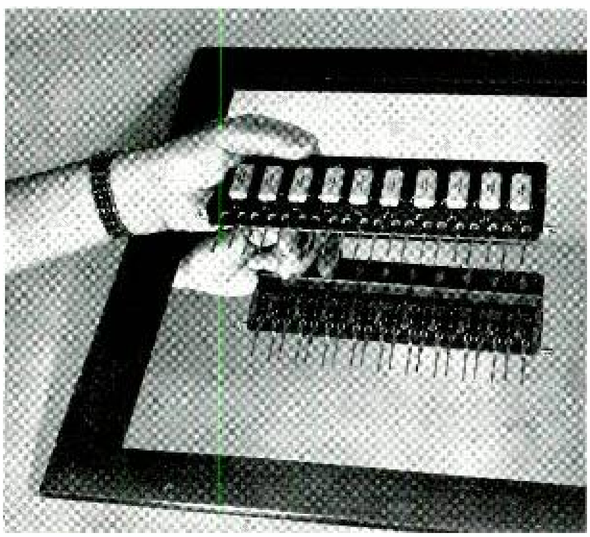
The group of 10,000 number networks in which the signal is found identifies the office. To derive the remaining four digits the signal coming into the number network is divided two ways. In the interest of simplified explanation, let us consider that one branch handles the TH and H digits and the other the T and U digits. Each of these branches becomes an input into a secondary network, which, in our example, separates respectively, TH and H, and T and U. The entire network is such that an input signal on any one of 10,000 number networks appears on the appropriate secondary output leads of 10 TH leads, 10 H leads, 10 T leads, and 10 U leads — each numbered 0 to 9. The identifier attaches its 10 amplifier-detectors successively to these four sets of leads and thus reads out the directory number.

Consider a primary network as a square array of 10,000 number networks — 100 by 100 (*see diagram above*). The networks in each vertical row have the same TH and H digit combination. One branch from each of these networks is connected to a common vertical bus, to give that branch specific TH and H significance. The 10,000 networks employ 100 such buses, to permit all possible TH and H digit combinations 00 to 99. Similarly, each horizontal row of networks has the same T and U digit combination. Thus the second branch of each network employs 100 horizontal buses, to permit all possible T and U combinations 00 to 99.

In this network, an input signal at any one number network is connected to one vertical bus and to one horizontal bus. In addition, a multitude of "sneak" paths exist connecting each bus, vertical or horizontal, to every other horizontal or vertical bus. Consequently, all buses have unwanted signals. These are attenuated to a tolerable level by a grounded resistor connected to the midpoint of each number network.

After the identifier has applied a signal to a trunk sleeve, it looks at the secondary buses for the return of this signal. Assume the network is to identify line number "0099" of directory number "CH 3-0099." The signal will enter the network system at number network 0099 and will appear on vertical bus 00 and horizontal bus 99. These buses connect respectively to TH-H secondary network 00 and T-U secondary network 99. In the secondary systems, the signal will appear on vertical bus TH 0, horizontal bus H 0, vertical bus T 9, and horizontal bus U 9. Amplifier-detectors are then connected to TH buses 0 to 9 for the first office and in turn, to the TH buses for other offices.

This sequence continues until the signal has been found on one of the leads tested, determining both office and TH digit. Further search, confined successively to the H, T, and U buses of the identified office, results in complete identification of the calling directory number, 0099.



Ten-circuit network package of the primary network. Capacitor (top)—resistor (mirror) devices connect to pins strapped to contact bus-bar projections on front of primary network panel.

The foregoing is concerned with identification on single-party lines. Two-party lines require a second set of vertical and horizontal buses for identification. While two customers may share an outside cable pair and a line circuit, each customer has his own directory number. For this reason, a second final terminal is associated with the line circuit through a second set of cross connections at the IDF. The two stations may be rung independently by grounding the ringers at the stations and connecting one ringer to the "ring" and the other to the "tip" of the line. Thus these stations are called ring and tip stations.

Party-Line Identifications

An identification signal applied to a trunk selected on a call from either customer reaches the number networks of both. If the number networks for both directory numbers were connected into the same primary bus system, no unique identification would be possible. Therefore, the first set of buses is used for individual lines and ring stations of two-party lines; the second set is used for tip stations of two-party lines.

The two sets of primary buses constitute ring and tip fields. On calls from two-party lines, identification signals exist in both fields. Through a party test, made elsewhere, the identifier knows which field to examine and controls this by connecting the secondary network system to the proper set of primary buses.

The number networks for the parties of a line serving more than two parties are connected through a separate channel to a single amplifier-detector. From detection of the identification signal on this channel, an operator in the CAMA office is called upon to perform the identification.

Private branch exchanges employ a number of lines under one directory-number listing. Calls from all of these lines are chargeable to the same account and are therefore identified by the same number. This means the network for the listed number must be connected into the ring field and the networks for associated lines must be multiplied to it.

ANI is one more illustration of the adaptability of the telephone switching plant to the ever expanding needs of the system. It represents an ingenious solution of one of the problems posed by the Bell System's long term objective — nationwide dialing — and brings us another step closer to the attainment of this goal.

Signaling, the silent partner of switching, is the way telephones, switching centers and trunks "converse" when setting up and taking down connections. To suit the wide range of conditions in exchange and short-haul-toll trunks, engineers at Bell Laboratories have developed DX—a uniform and economical system of dc signaling.

N. A. Newell

DX SIGNALING

A Modern Aid to Telephone Switching

As soon as a customer lifts the handset of his telephone, the communication process starts. No word has been spoken and only a small portion of the vast switching network at his command has been called upon, but signaling—a vital part of telephone switching, be it local or transcontinental—is already at work. Ever-present in telephone lines and trunks, signaling alerts the central office to a customer's desire to call and prepares the way for additional information to establish and later release the voice connection.

The Bell System has more than two million trunks available to act as the intermediate links in connections between customers' lines. These trunks terminate at both ends in the switching equipment of local, tandem or toll central offices. To complete a connection, one or more trunks may be used for the particular path that the call will follow. On dial calls, each trunk in this series path is automatically selected by information signaled from the customer's telephone and by conditions encountered in the switching equipment.

To accommodate these connections between two customers' individual telephone lines, a trunk must provide for voice transmission and signaling in two directions. At present, most trunks have wire, or "physical," lines (as opposed to carrier channels) for voice transmission, and these furnish readily available paths for direct-current signaling. For many years, various forms of dc signaling have been relied upon for these trunks.

The Duplex, or DX, signaling system is an improved dc signaling system for such wire-line trunks. Basically, DX is a simplified version of differential duplex telegraph circuitry. With identical equipment at both ends, it uses the trunk wires and ground to provide two equal signaling paths, one in each direction. In this way, a single signaling circuit is made suitable for either terminal of a variety of trunks. The new signaling system has three other advantages:

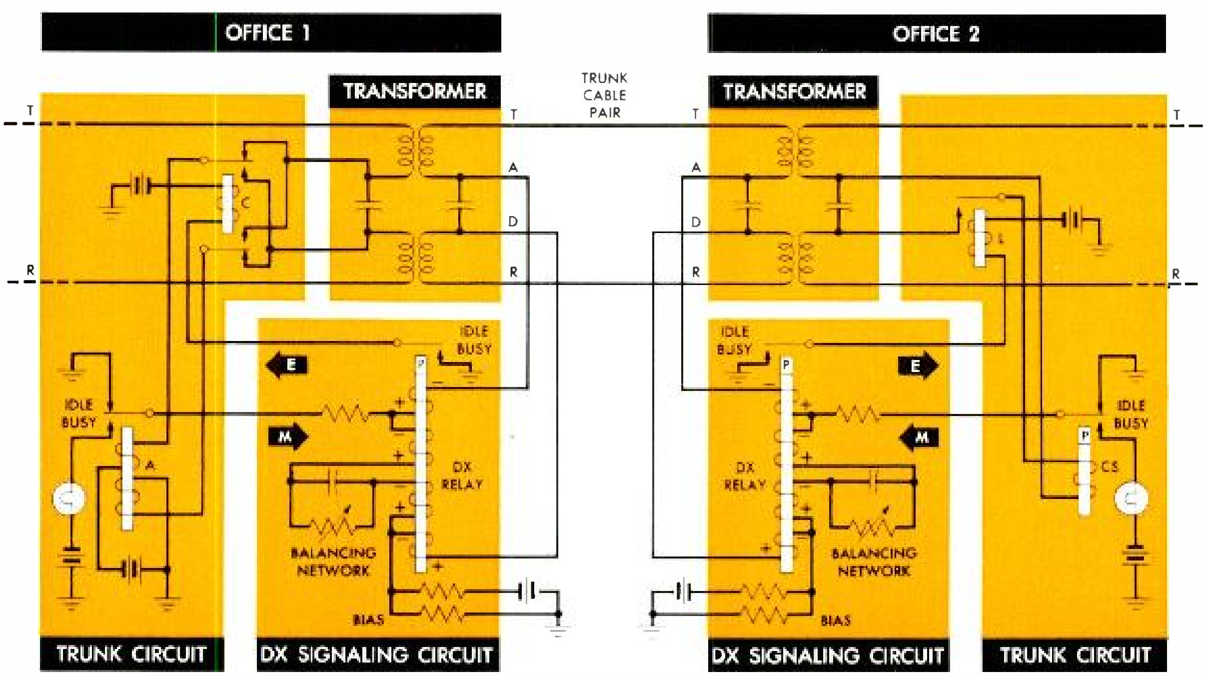
(1) it is self-compensating against differences in ground potential along the route of the trunk; (2) it partially compensates for differences that might exist in the voltage of the battery supplies at the two terminals; and (3) it is "balanced" against the effects of alternating currents that might otherwise alter the accuracy of the dc signals. These advantages will be explained in more detail later.

The DX system cannot be used on trunks that have carrier-derived line facilities. Carrier trunks are used principally in the toll network, though the carrier principle is being applied to exchange trunks in some areas. For such trunks, the single-frequency (SF) signaling system is available (RECORD, *February*, 1954; *July*, 1959). This system passes signals in the form of alternating current at a selected frequency directly through the voice-frequency channels of the carrier trunks.

Before describing the design requirements for the DX system, let us consider some of the fundamental concepts involved in signaling over telephone trunks. The basic accomplishment of signaling is the transfer, usually over some distance, of two different conditions. As the conditions change from one to the other, information is passed, and both the direction and the duration of each condition has significance.

Generally, one condition is the opposite of the other and their meanings have this same relation. For example, a signal sent forward (from calling to called office) might mean "connect" or "disconnect," and for return supervision, "off-hook" or "on-hook." Dial pulses are generated by shifting from "connect" to "disconnect" states at a speed determined by the mechanical dial on the telephone or relay sender equipment in the switching center. Most trunks permit the origination of calls at one end only; these are called "one-way" and do not need the symmetrical signaling terminals that are generally necessary for two-way trunks. Changes in line facilities, types of apparatus and operating limits are other reasons for the existing multiplicity of signaling circuits.

Trunk-signaling systems that use dc, both functionally and historically fall into two groups —"loop-supervision" and "E- and M-lead signaling." The earliest group, loop supervision, is named for the metallic loop formed by the conductors in the trunk and the equipment at the trunk terminals (RECORD, *July*, 1951). Loop signals are generally transmitted in one direction by opening and closing the dc path through the loop. In the opposite direction, one of three methods may be used: (1) connecting and disconnecting the battery supply; (2) altering the values of the

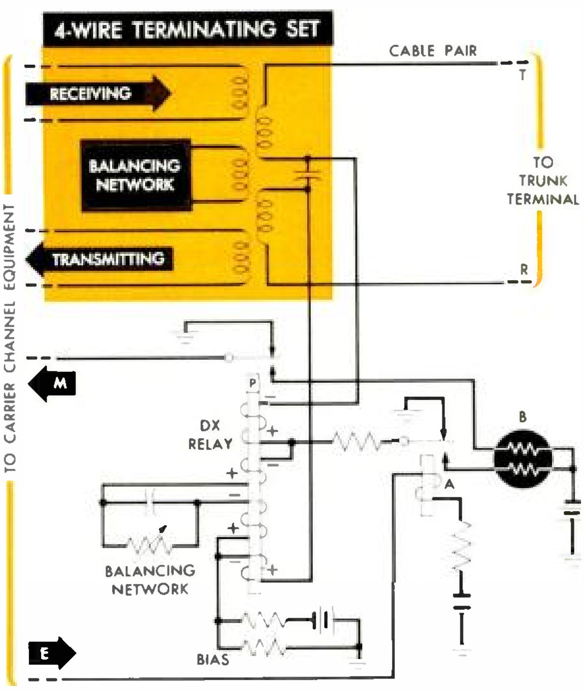


DX signaling circuits for two ends of a one-way trunk for calls going from Office 1 to Office 2. Trunk could be only link between two customers' lines or one of several connected in tandem.

potential on the "M" lead at a rate determined by the dial speed, and the DX relay at Office 2 follows these pulses. The number of pulses equals the transmitted digit. For the duration of the call, the signal condition for "connect" is maintained at Office 2. This office also changes from "idle" to "busy" on the M lead as soon as the called customer answers (off-hook signal). At Office 1, receipt of the answer signal by the DX relay signifies the start of conversation.

When the call is over, the trunk is first released from the calling end, Office 1. There, relay A releases, ground is restored to the M lead, the signal conditions in the line are reversed, and the DX relay in Office 2 releases. This action gives a "disconnect" signal to the called-end trunk circuit, and switches at that end are released. Either at this time or just before, Office 2 also sends back to the calling end the "idle," or on-hook, signal by an identical process.

As signaling occurs, the M leads at each end of the transmitting facility generally have the same potential on them, during both the idle and busy conditions. This matching of potentials gives DX an advantage over loop-signaling circuits in that no signaling current is flowing through the line most of the time.



The DX intermediate-signaling circuit. This conversion circuit is used at the junction between different types of line facilities in a trunk.

Because there is very little distortion in the signals sent over DX, the circuits can be used in tandem with another signaling circuit (of the E- and M-lead type) on one trunk. As presently designed, DX is restricted to line facilities composed of cable pairs equipped at both ends with repeating coils.

The efficiency of the DX system is not hampered when E-type voice repeaters are inserted in the line conductors, nor is it affected by the signal-by-pass circuits used with V-type voice repeaters. It passes nominal ten- or twenty-per-second dial pulses with little signal distortion and accomplishes this task with only the usual mechanical and electrical relay-adjustment requirements. By contrast, many of the present dc signaling circuits require special, supplementary adjustments on the pulse-repeating relays and "pulse correctors" in the trunk circuits.

Applications of DX Signaling

Although the signaling range of DX is less than that of CX or SX, the signal distortion is so small that two DX circuits can be used in tandem for one trunk. The new system is particularly suitable for (1) short intertoll trunks; (2) two-way, exchange and toll-connecting trunks; and (3) local and tandem trunks using the high conductor resistance now possible with E-type voice repeaters. Standard trunk circuits, equipped with E and M leads for the DX circuits, are available for most of these applications.

Some trunks have different types of line facilities, such as carrier channels or phantomed circuits connected in tandem with cable pairs. At junction points, where one section has E- and M-lead signaling, the DX system is an economical way to extend signaling to the end of the trunk. This extension circuit, called the "DX intermediate-signaling circuit" is shown at the left. Basically, the intermediate arrangement has the signaling circuit of the first diagram, plus a mercury-contact, 276-type relay. This converts signals from E-lead conditions to M-lead conditions so that the intermediate circuit can work into another line-signaling circuit.

The new DX signaling circuits consist of relatively few components, occupy a small amount of space, and require little power. They should offer more reliable and more uniform signaling for the Bell System's exchange and short-haul-toll plant, and at the same time they are compatible with the E and M version of single-frequency signaling used on carrier-derived speech channels.

Changes have been introduced into the 4A and 4M toll switching systems to furnish them with Centralized Automatic Message Accounting (CAMA) features. Part of this change lies in the introduction of a new "translator" for giving information peculiar to certain trunks.

D. A. James

4A and 4M CAMA: Trunk Class Translator

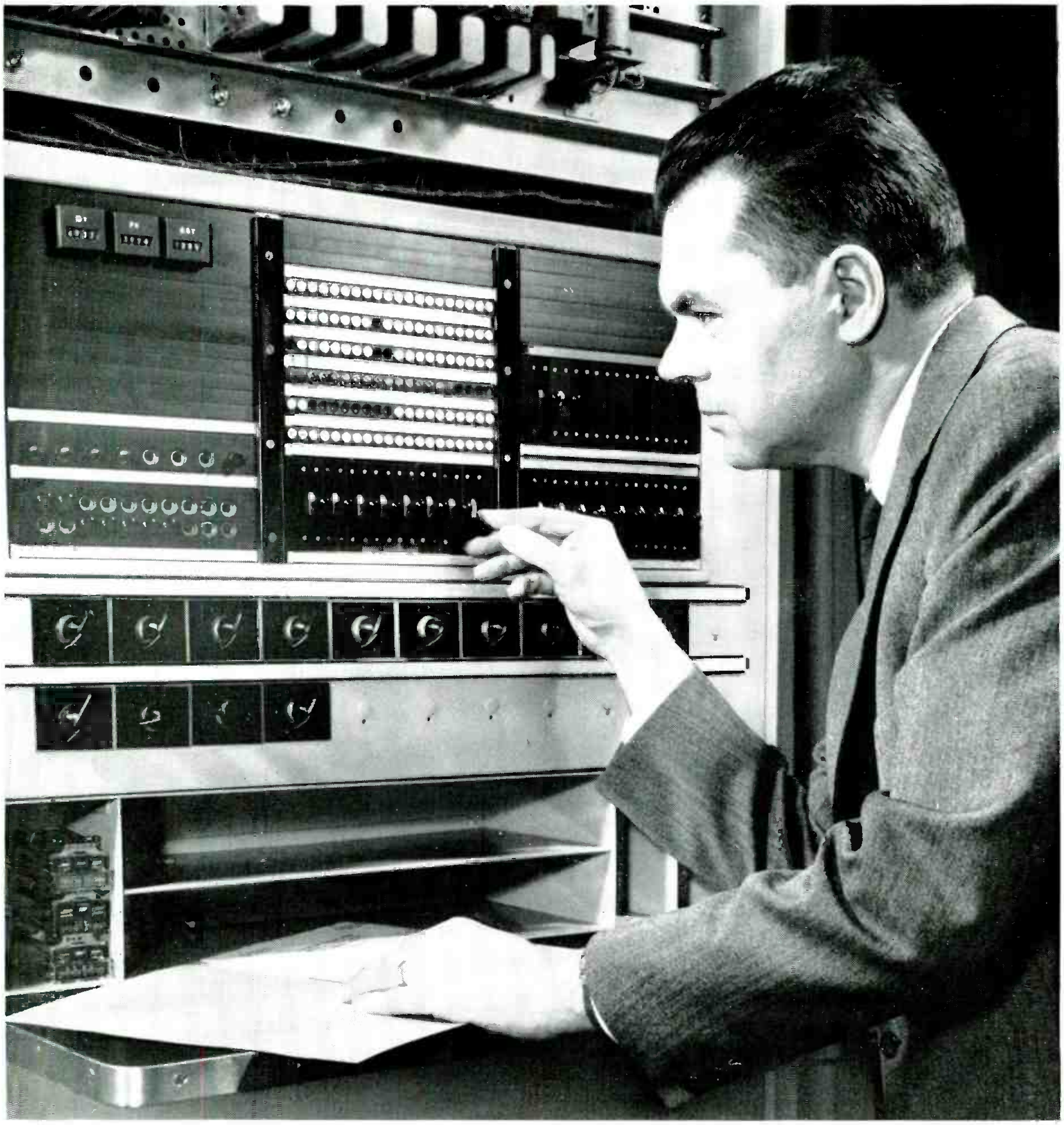
Automatic message accounting facilities at a centralized point are needed where toll traffic originating at the local offices is not heavy enough to justify local message accounting facilities; or, where the nature of the local office equipment makes such arrangements impractical.

Centralized Automatic Message Accounting (CAMA) techniques may therefore be imposed on certain switching systems to broaden their application and give greater over-all system efficiency. The application of CAMA to the 4A and 4M systems required increased capacity for trunk class information. This information provides a starting point for determining charges and other factors to be used with a particular trunk.

In 4A CAMA this presented a problem, principally because of the great flexibility incorporated in the system. For example, each trunk circuit may have its own "class" information, independent of all others. In non-CAMA 4A toll crossbar switching arrangements, trunk class information is passed from an incoming trunk circuit to a sender by a dc signaling method and stored there — to be "doled" out to other circuits as it is needed. In 4A CAMA, however, the amount of trunk class information is such that this conventional signaling method would have required an unreasonable number of leads from a trunk circuit to a sender.

It was therefore decided that only information required by the sender or required very early in decoder usage would be passed to the sender in this way. All other class information needed by the decoder and transverter would be obtained directly by these two circuits from a new trunk class translator, which must provide answers to the following questions:

- Who owns the facilities being used? (Needed for proper division of revenue)
- In what numbering area did the call originate? (Used in charging and routing)
- What rate class should be used to establish charges?
- Which one of a maximum of twenty recorders should be used in recording charges on this call?

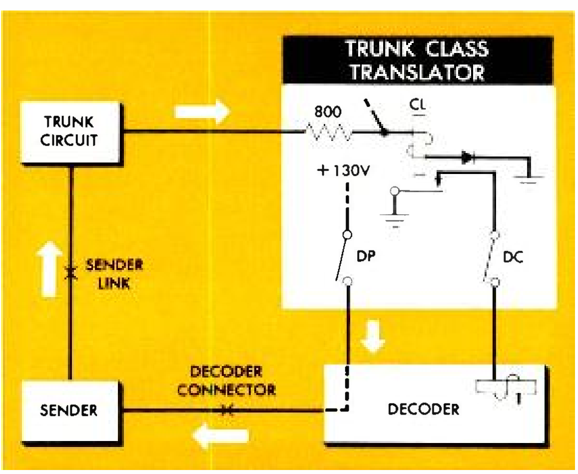


Author with the trunk test frame. This unit is used for testing the new trunk class translator, which can perform a translation—including seizure time without delay—in about 35 milliseconds.

The trunk class translator designed for this purpose is shown in simplified form in the schematic on page 223. When a CAMA sender seizes the decoder, the decoder immediately requests a trunk class translator, and operates its DP and DC relays. The +130-volt signal is then connected through the DP relay contact, through the decoder connector and sender link and trunk circuit to operate the desired class (CL) relay in the translator; the output of the class relay is then passed through the DC relay and registered in the decoder. Only a portion of the class information is passed to the decoder, because this circuit is principally concerned with routing of the call. Traffic separation data (for revenue breakdown) and the area of call origin are thus transmitted to the decoder. On the other hand, the transverter is concerned with charging and must recognize area of origin, rate class, and the proper recorder to use on this call. Therefore, this information will be passed to the transverter when required in the manner previously described.

The speed of operation of such a translator has been shown by observation to be in the order of 35 milliseconds — including seizure time without delay. On a decoder or transverter usage, by seizing the class translator early, this time falls almost entirely within the normal holding times of these circuits. With the normal two usages per call, one translator, in an emergency, could thus handle the traffic of a 4A or 4M office with only minor delays. However, two circuits are normally provided.

Perhaps the most important consideration in designing a translator of this type is to insure that trouble conditions cannot fully disable it. Because only two translators are provided, any trunk trouble that could, for example, blow a translator fuse or cause apparatus damage could also quickly disable the entire CAMA portion of the office. In this regard it should be noted that the class relay windings terminate on ground through a diode (*see diagram*). This arrangement reduces the vulnerability of the numerous paths through the sender link that are associated with the trunks using this particular class relay. For example, all trunks associated with a particular class relay have sender link appearances, all of which are a potential source of false battery or ground. Without special arrangements, a false condition at any of these points could hold a class relay "operated" and completely disable



A block schematic of the trunk class translator. When a CAMA sender seizes the decoder, it immediately requests a trunk class translator.

a translator to all traffic. These leads are further guarded by the 800-ohm resistance, also shown in the diagram, which prevents a false signal on any lead from disabling more than the one trunk.

This design, therefore, is such that trouble on a lead associated with a trunk will not put a translator out of service. Furthermore, the translator is self-checking to the extent that any false inclusion or omission of output information would be immediately recognized.

Sufficient flexibility has been assured so that a new class combination could be established at any time with minimum effort, or changes in single trunks or trunk groups made. In many cases this requires only one cross-connection change.

Normally, two trunk-class translators will be furnished per transverter group, with all transverters, decoders and CAMA trunks having an appearance on both circuits.

The Basic Translator Frame

The basic translator frame has capacity for a maximum of 18 decoders, 12 transverters, 100 class relays and 1200 trunks. For growth beyond 1200 trunks, a supplementary frame may be furnished for an additional 600 trunks.

Half of the decoders and transverters have first-choice access on each translator. This choice will be shifted to the mate if the preferred translator is busy. It is also possible to make a translator busy to all odd or all even decoders and transverters, automatically diverting the traffic to the other translator.

To be certain that half of the office is not disabled, an interlock is present so that service is always available to every decoder and transverter. For example, both translators cannot be made busy to odd decoders.

Critical parts of the circuit are scanned constantly in an effort to head off call failures. Thus, standing checks are provided where necessary; these can make the translator busy or cause a trouble record to be made. For example, the preference relays, which indicate the decoder being served at a particular time, must agree within a very short time with the decoder busy relays. Any discrepancies between these two circuits will sound an alarm and make the translator busy.

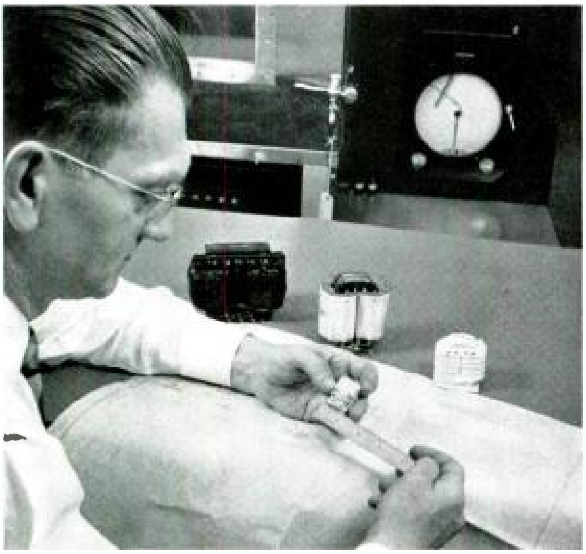
In summary then, this translator has a speed compatible with the remainder of the 4A switching system, is reliable by virtue of its simplicity, and should also, through its simplicity, result in low maintenance cost.

Miniaturized Power Transformers

Both physically and electrically, transformers appear to be among the simplest devices used by electronic engineers. Yet, in many cases, the transformer is the basic component that establishes the electrical characteristics, controls the power requirements, and links together the important circuits of an entire system.

In many military systems, particularly those designed for airborne applications, power transformers account for a significant portion of both the size and weight of the necessary equipment. Because of this close relationship of transformer size and weight to the over-all size and weight of airborne electronic equipment, there is considerable current interest in miniaturizing these important components.

Miniaturization implies a lot more than merely shrinking in size. With most electronic components, and especially with transformers, heat dissipation is an important consideration. When the size of a transformer is radically reduced, without changing its volt-ampere or power rating, the decreased area available for heat transfer results in an increase in internal temperature. This, in turn, can seriously effect its operating characteristics.



From left: World War II transformer; miniaturized version of same; and newest, smallest version of it. Author holds experimental miniaturized unit.

Concurrent with reduction in size and weight is another requirement: operation at extremely high ambient temperatures. For example, the transformers used in jet aircraft must sometimes operate in environments as hot as 200°C. This means that the transformer must be designed to minimize temperature rise within the component and to withstand an adverse environment. Taken together, the size and temperature considerations generally require the development of new designs and manufacturing methods. To cope with a specific application, designers treat each miniaturization effort as an individual development problem, to take advantage of new materials that can operate reliably at the given temperatures.

As part of a program to uncover some of the important problems involved in miniaturizing transformers for use in high-temperature environments, the Air Force requested Bell Laboratories to undertake the development of miniature power transformers with certain electrical characteristics. Specifically, the Laboratories was asked to develop experimental, miniature power transformers capable of satisfactory operation over a range of ambient temperatures from −55°C to 200°C. The units were to be no larger or heavier than units designed under an earlier contract for −55°C to 85°C ambient temperatures. These earlier units were already extremely miniaturized.

This article describes briefly the reductions in transformer size achieved in these miniaturization experiments. The table opposite summarizes the weight and volume characteristics of the designs developed under the two contracts.

Electrically, the prototype transformers (the two columns at right) were required to have substantially the same characteristics as their larger counterparts, over the new temperature ranges. To establish a suitable criterion for the

MINIATURE POWER TRANSFORMERS—WEIGHT AND VOLUME CHARACTERISTICS						
Type	World War II		Redesigned for −55°C to 85°C		Redesigned for −55°C to 200°C	
	Weight in pounds	Volume in inches³	Weight in pounds	Volume in inches³	Weight in pounds	Volume in inches³
I	0.44	8.3	0.2	4.1	0.2	2.7
II	1.0	18.9	0.3	6.0	0.29	3.3
III	1.0	20.0	0.32	6.0	0.29	3.3
IV	5.1	71.5	2.2	22.3	1.6	16.7
V	7.0	74.2	1.4	21.6	1.1	11.2
VI	1.5	17.9	0.9	6.0	0.24	4.3

results of the work, the Air Force chose for redesign six typical transformers from a specific airborne radar system used in World War II.

During the latter part of World War II and the years immediately following, the basic materials used in the construction of transformers were improved to such an extent that considerable progress was made in miniaturization. In a typical instance, a transformer of World War II vintage, having a volume of 74.2 cubic inches and weighing 7 pounds, was redesigned to a unit with a volume of 21.6 cubic inches and a weight of 1.4 pounds.

More recently, through improved design techniques and materials developments, the same transformer was further reduced in an experimental redesign to a volume of only 11.2 cubic inches and a weight of only 1.1 pounds. This series of miniaturizations is illustrated by the three units shown on the table in the accompanying photograph. All of these units are 400-cycle, plate transformers with the same volt-ampere rating. They are made of different materials, however.

The larger unit, on the left, is constructed with enameled wire, cloth, paper and insulating varnish. The middle transformer is made of ceramic-insulated wire, mica and Fiberglas insulations, and silicone-resin coating. The newest and smallest of these transformers uses nickel-plated wire insulated with a combination of ceramic and the plastic Teflon, mica and Fiberglas insulations and an impregnating and coating compound made of silicone rubber. In addition to being smaller and lighter than earlier designs, this newest transformer can operate within its rated range in the desired ambient temperature range of from −55°C to 200°C.

Evaluation tests were recently completed on miniaturized transformers of the rectifier, plate-supply type with these electrical characteristics: 1600 volts, 700 volt-amperes, 400 cycles. They were operated in an ambient temperature of 200°C at an altitude of 70,000 feet. The test units were operated under rated load conditions for 1000 hours, and then had the line voltage raised to 125 per cent for 24 hours. They suffered no adverse effects. These miniaturized models were also subjected to extreme water immersion and high-humidity exposures following the 1000-hour life tests. Again, there was no degradation of dielectric-strength characteristics.

These remarkable reductions in the size and weight of power transformers have been made possible principally by the advent of new materials. From these new materials have come miniature transformers that perform well under present operational environments.

L. W. Kirkwood

Military Component Development

The Shape Recognizer

The "Shape Recognizer," an early experimental step toward machines that "read," was described recently by Leon Harmon of the Visual and Acoustics Research Department. In the picture above, the machine displays a lighted square showing that it has "recognized" a line drawing of a square. The device also identifies triangles, pentagons, hexagons and circles.

Mr. Harmon designed the shape recognizer to demonstrate a principle that makes possible recognition of these drawings, whether they are large or small, and no matter which way they are turned. Such principles are important to an understanding of ways to design versatile machines that identify a variety of characters. Machines of this sort would be valuable to the Bell System and many other businesses.

In the picture, the light at the top illuminates the shape, which is "seen" by a scanner below the clear plastic table. Photo-cells are mounted, pointing up, on the ends of 32 metal rods. When an "Identify" button is pressed, the rods unfold simultaneously, like the ribs of an umbrella, so that each photo-cell is given a radial motion and crosses one boundary of the drawing. These crossings occur at different times for each photo-cell, and the different times are used in a special "logic" circuit to determine the shape.

A new noise-measuring set for telephone circuits has been developed at the Laboratories. Using recent advances in devices, this compact and easy to use set takes into account the characteristics of the human ear and the modern telephone.

W. T. Cochran

A New Noise-Measuring Set

People in the communications business have been measuring unwanted noise in one way or another for over 30 years. Originally, the noise on a telephone line was measured — or approximated — by comparison. An observer would listen to noise on the line, and switch his telephone set to an adjustable "noise standard." He would then adjust the output of the noise standard until he thought the interfering effect equaled that of the noise on the telephone line. In other words, he adjusted the standard until there was some sort of audio equivalence between the two sources. The observer then read the dial on the noise standard that gave a reading in "noise units."

This arrangement had many drawbacks. Something was needed in which objective evaluation of the noise could be substituted for the subjective judgment being used. For this reason, Bell Laboratories developed, about 1935, the "2A" noise-measuring set to measure electrically noise heard by an observer in the comparison method.

Three things directly affect how this electrical noise, which is measured, corresponds to the acoustic noise, which is heard. Therefore, the noise-measuring set was built to take into account: (1) the frequency content of the noise; (2) the duration of its bursts; and (3) its amplitude.

The telephone line, the telephone set, and the human ear each have a frequency characteristic — they do not respond equally to all frequencies. For instance, the ear is not nearly as sensitive to acoustic energy at 60 cycles as it is to the same energy at 1000 cycles. To obtain some sort of equivalence between the measured electrical noise and the noise that is heard, a combined frequency characteristic must be built into the noise-measuring set. The set's frequency characteristic is determined, then, by the characteristics of the telephone plant and the human ear.

Since the development of the first electronic noise measuring set, the 2A, there have been two major innovations in telephone set design. Both of these altered the "combined frequency characteristics" mentioned above. The response of the 2A set was determined by a frequency char-

The author, left, and Andrew Tittle of the New Jersey Bell Telephone Company discuss advantages to the user of the new 3A noise-measuring set.

acteristic called "144" (*see illustration on page 230*). With the advent of the 302-type telephone set, however, this weighting was no longer applicable. At this point, the 2A set was modified to meet the new frequency response characteristic called "FIA," and was renamed the 2B.

The change in weighting characteristics introduced a bothersome difficulty into the noise-measuring set. The change caused a reduction in the gain of the set, and for this reason, a correction had to be added to every measurement made with the 2B. More recently, the vacuum tubes and some of the elements have become obsolete. Furthermore, noise studies conducted at Bell Laboratories on the 500-type telephone, now in general use, resulted in a new frequency characteristic called "C-message." The solution to this growing problem became obvious — a new noise-measuring set.

Calling on their many years of experience and knowledge of Telephone Company needs, Bell Laboratories engineers built a new set, called the "3A noise-measuring set." This set is completely transistorized and is very much smaller and lighter than the 2B set. The 3A set weighs only 14 pounds and is quite compact (7 inches by 11 inches by 8 inches). Contrasted to this is the bulky (10 inches by 17 inches by 19 inches) 2B, weighing 50 pounds. This weight difference, of course, is a delight to any Telephone Company craftsman who may have carried the 2B over hill and dale.

But size and weight are not the only things to consider in the design of a portable test set. Simplicity of operation, versatility, physical appearance, and cost must also affect the design. The question is: Who decides what is simple, versatile, and good looking? Probably the best and most qualified "who" is the potential user.

Therefore, during the development of the 3A set, engineers constructed two models of the new set and placed them on field trial. Helpful comments were made by engineers and craftsmen in several of the Bell Telephone Companies. These helped form another version of the 3A set.

But there was still another stumbling block — the cost objective had not yet been met. A little redesign, substitution of parts, mechanical ingenuity, and lots of cooperation between the Western Electric Company and Bell Laboratories eventually resulted in a product combining the improved physical qualities with reasonable manufacturing cost.

The 3A noise-measuring set performs its job basically as follows. On the face of the set are two rotary switches. One, called the function switch, performs an important set of jobs. When the operator turns on the set, he must turn the switch "through" the first position, checking the battery (by the meter indication), and the second position, checking the calibration of the set. This happens *every* time he turns on the set, lessening the chances of error due to a weak battery or faulty circuits. The operator then turns the switch to select one of four input impedances. Which one depends upon the measurement to be made.

The other rotary switch controls the amplitude of the signal that reaches the meter. The positions of this switch are calibrated so that the "noise reading" is given by the sum of the switch indication and the reading on the meter. Unlike the 3A's predecessor, there are no corrections to be added or subtracted from this noise reading.

Sometimes a noise reading is difficult to obtain because the type of noise makes the meter indication too jumpy. It is something like trying to read a page of fine print while riding a bus over a bumpy road. The type of noise causing this comes from such factors as relays operating in the telephone central office, or lightning near the telephone line. By throwing a damping switch on the 3A set, the operator can obtain a meter indication that will be "smoothed" and easily read.

The frequency response of the 3A is determined by a network which plugs into the front of the set. The characteristics used in the 3A set for modern telephone equipment are different from those used in previous years, generally because of the most recent advances in telephone-set design. When the 2B set replaced the 2A, the FIA frequency characteristic replaced the 144. The measurements were called "dbrn" (db above a reference noise). Because of the different "shape" of the FIA weighting, the 2B set could not be expected to give the same answers. For this reason, the "reference noise" (which is arbitrary) was adjusted until the 2B set gave the same answers, for many types of noise, as the 2A. The units of the 2B set were called "dba" (db adjusted).

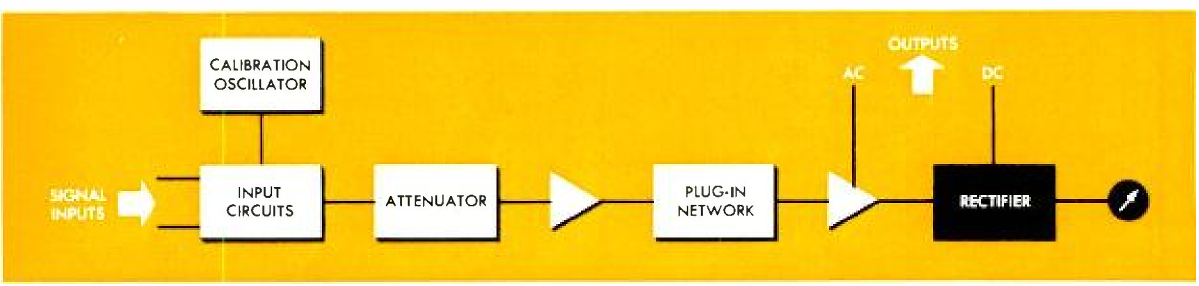
Since the C-message weighting is different still, another change in the reference noise might be expected. However, if the same procedure was followed as with the FIA weighting, the reference would have to be shifted in such a way that low-noise circuits would have less noise than the reference, giving negative db readings. To avoid this, engineers decided to return to the original reference, and to the original name of "dbrn." However, the new weighting gives different answers from the original, and it is therefore important to designate the new readings as "dbrn-C message."

At present, there are two packages intended for use with the set, and each of the two contains two networks. The extra network is necessary because the set may measure noise on other than ordinary telephone circuits. Such a circuit may be one used by commercial radio broadcasters from their studio to their transmitter. Since their programs are heard not on the telephone but on a radio receiver, another "frequency characteristic," or network, must be used in the 3A set to measure the noise.

Internal Design

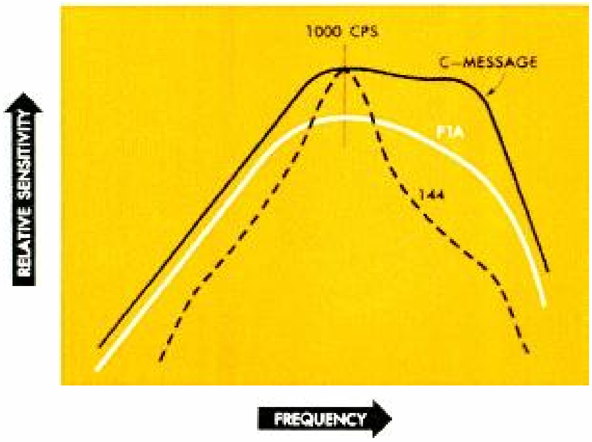
Not all of the design problems were on the outside of the set. For example, there appeared a basic problem in building the amplifiers, which took designers inside the set. These have to boost a very small signal into a measurable quantity and do it accurately. The noise-measuring set is subjected to temperatures varying from the ice and snow of winter to the mid-day sun of summer, and the amplifiers should maintain their characteristics over this temperature range (about 32 to 120 degrees F).

The rectifier and the meter are very important internal items too. The rectifier determines how the components in a given noise voltage combine to give a meter reading. Since the noise-measuring set must assign a number to the noise an observer would hear, the rectifier must combine noises just as the ear does. To make this possible, engineers devoted almost as much development time to the rectifier as they did to the two much more complicated amplifiers.



Noise measurement on 3A set is obtained from sum of values read on attenuator and on meter. Set also can serve as general-purpose amplifier for performing various service work in the field.

The rectifier and meter combination determine the "response time" of the noise set. Experiments show that the human ear appreciates nearly the full loudness of sounds of the constant amplitude lasting more than 1/5 of a second. For shorter times, however, the ear does not respond as well. That is, the sounds do not seem to be as loud as those with 1/5 of a second or longer duration. Thus, we say the ear has a "response time" of 1/5 of a second.



Frequency characteristics used over the years in noise-measuring sets reflect the response of the human ear and changes in telephone-set design.

The rectifier and meter make the noise set behave just about like the human ear. For noises lasting 1/5 of a second or longer, the set will indicate the full amplitude of the noise. But for noises lasting progressively less than 1/5 of a second, the noise set will indicate progressively less than this full amplitude, a "behavior" similar to that of the ear.

Ac and dc output signals may be used to extend the use of the 3A noise-measuring set. For instance, the set may be used as an ordinary general-purpose amplifier. The signal to be amplified is fed into the input of the 3A set and the amplified signal is taken from the ac output. The dc output may be used to drive a large variety of pen recorders. This is a very convenient way to obtain a continuous record of the noise disturbance at the input of the set.

The 3A set also finds other uses in various electrical measurements encountered in a telephone central office. This noise-measuring set is a good example of cooperation among the Bell System Companies — especially in Bell Laboratories design and Western Electric manufacture to obtain a dependable and versatile instrument.

Transparent Gallium Phosphide Prepared as Aid to Semiconductor Research

Scientists at Bell Laboratories are developing methods of growing and studying the properties of single crystals of a transparent semiconductor, gallium phosphide. The studies will help in the basic understanding of semiconductors with a high energy-gap—those with a relatively large difference in energy between conduction and valence bands. High energy-gap materials are part of a field of semiconductor research that has interested Bell Laboratories since well before its invention of the transistor in 1948. Because gallium phosphide is transparent, it is possible to observe visually the differences taking place under varying conditions of carrier density.

News of Semiconductor Research

Gallium phosphide belongs to the family of semiconductors referred to as "III-V" compounds, which are composed of elements taken from the third and fifth groups of the periodic table. Knowledge gained from studying gallium phosphide should be applicable to other members of this group, some of which are already known to exhibit interesting semiconductor properties. These include gallium arsenide and indium antimonide, which have shown promise in devices such as point-contact and Esaki diodes.

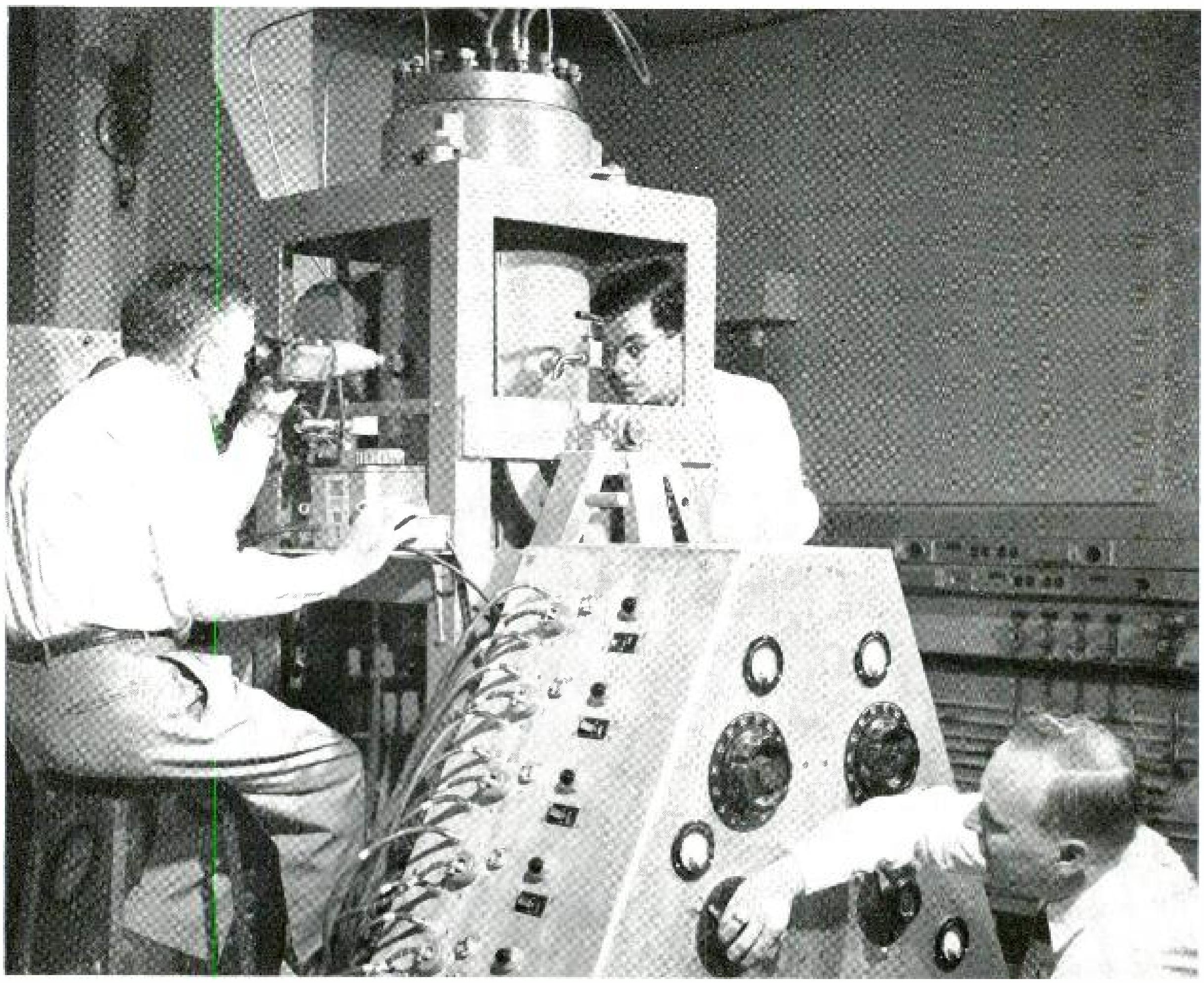
Although the semiconductor properties of gallium phosphide were first reported in 1954 by O. G. Folberth and F. Oswald in Germany, large single crystals with reproducible properties still have not been made because of processing difficulties. One of the main problems is that the compound decomposes at temperatures near its melting point unless held in gaseous phosphorus under high pressures. The work at the Laboratories has been aimed at producing large single crystals of gallium phosphide by the floating-zone melting technique. Special equipment was built to withstand the high-pressure phosphorus atmosphere.

The experimental pressure equipment was designed by C. J. Frosch and L. Derick of the Solid State Electronics Research Department, and E. Buehler of the Metallurgical Research Department. With this equipment, large multicrystalline ingots of gallium phosphide are produced by reacting the components in an evacuated quartz tube at temperatures above 1500 degrees C and at pressures of 10 to 30 atmospheres. Laboratories scientists use bars cut from these ingots to investigate the feasibility of the floating-zone technique for growing large single crystals. Messrs. Frosch and Derick have grown single crystals as large as about ¾-inch long and ¼-inch in cross-section.

Small single crystals have also been grown by vapor-reaction methods by Mr. Gershenzon and R. M. Mikulyak of the same department. Their method involves a reaction of gallium suboxide and phosphorus in the vapor phase. These crystals tend to form "whiskers." Usually n-type semiconductors, they exhibit free carrier concentrations of 10^{11} to 10^{14} per cc, as calculated from resistivity measurements.

From such crystals of gallium phosphide, Messrs. Gershenzon and Mikulyak have produced diffused- and alloyed-type diodes. Samples of these have shown breakdown voltages as high as 35 volts and rectification ratios up to 3×10^6. They are still usable at temperatures up to 500 degrees C. The diodes exhibit two interesting anomalies: first, they have a compensated, or non-conducting, layer which gives rise to a series resistance that limits current. Second, they possess "recombination-generation" centers within the junction transition region. These centers produce variations in the forward- and reverse-current characteristics, and they also cause time lags in the establishment of steady-state conditions.

Messrs. Frosch and Gershenzon reported the preparation and properties of gallium phosphide at a meeting of the Electrochemical Society held May 1 at Chicago. This paper was followed by one by Messrs. Gershenzon and Mikulyak on the preparation and characterization of p-n junctions in gallium phosphide.



Carl Frosch, left, and Murray Gershenzon, center, watch molten zone in an ingot of gallium phosphide. Robert Mikulyak, right, adjusts current through radio-frequency coils used to heat ingot.

Record Construction Program Announced At A.T.&T. Annual Meeting

The business of the Bell System continues to grow, Frederick R. Kappel, A.T.&T. president, told 11,200 shareowners attending the Company's annual meeting at the Kingsbridge Armory in the Bronx. Reporting that the gain in telephones and long-distance conversations is ahead of last year, Mr. Kappel commented that, "we do not anticipate any radical change in these trends."

News of the Bell System

Construction of new and improved communication facilities will total a record $2.6 billion during 1960. These facilities help to increase operating efficiency further, he said. The Bell System is also putting new telephone and communication systems on the market. Vigorous advertising and selling effort is aimed at increasing telephone usage. All these activities will contribute to good results in service and earnings in 1960.

The record construction program for 1960 is necessary to enable the System to serve more customers and handle the increasing volume of business; to introduce and extend new forms of service; to replace outworn or obsolescent equipment; and to put the business in the best position to anticipate the ever-growing communication needs of this big and growing nation.

Since the stock split last year the number of A.T.&T. shareowners has increased by about 125,000 to a total of more than 1,754,000. "We have never favored an up-and-down dividend policy," Mr. Kappel said. "Our responsibility . . . is to do the best long-run job we can for every shareowner. We do not believe dividends should be paid according to any formula that would relate current pay-out to current earnings—for in such case, up-and-down variations in earnings call for corresponding up-and-down change in the dividend. None of us wants to think of lowering a dividend rate once it has been established. This is basic in the character of the business," he pointed out.

A.T.&T. science exhibit at Annual Meeting was one of many showing various Bell System activities.

"We shall continue to need large amounts of new capital to finance our construction," he continued. "New capital requirements have averaged about a billion dollars a year. We cannot forecast what form our future financing may take."

Pointing out that the Bell System is a growing business, Mr. Kappel stated that the *manner* in which it grows is even more important. He said it must grow as a progressive business that (1) can constantly do more for more people; (2) is regarded as alert, efficient and always up to date; (3) knows how to make improvements in service pay; (4) can meet competition wherever it may develop; and (5) is a business in which ideals of service and marketing talent and zest for discovery all meet and mingle and strengthen each other. This concept of business energizes research and development, he said. It calls for continual introduction of new instruments and services on a profitable basis, and requires vigorous promotional effort.

Ever since the telephone was invented, Bell System research has led the way in making possible fast, convenient, dependable, low-cost communication services, he told the shareowners. "We have kept out in front—we are determined to stay out in front—and we are just as determined to lead the field in space communications." Currently the Laboratories is working with the National Aeronautics and Space Administration (NASA) on a series of experiments to test the possibilities for world-wide communication via one form of space satellite. The Command Guidance System, developed and designed by Bell Laboratories and produced by Western Electric, was used to guide Tiros I into the most nearly

President Kappel answers question asked by young shareowner, right, below flag. Mr. Kappel explained the Company's policies and programs in answer to many such questions. For the second consecutive year, the Annual Meeting was held in the large Kingsbridge Armory, in the Bronx.

circular orbit ever achieved (RECORD, *May*, 1960). It has been successful in guiding the Titan ICBM and will be used in the future to guide numerous space vehicles, he said.

"The Bell System is right now at the forefront of knowledge in space communications, and that is where we intend to stay."

Mr. Kappel expressed confidence that the Company will meet competition wherever it may develop. "We have technical know-how, a nationwide network that is absolutely unmatched, and we are constantly learning how to use it in new ways that offer great advantages to present and future customers.

"We have an organization of people who have abilities and spirit second to none," Mr. Kappel said. "With all these we need freedom to manage. Good earnings, good profits are fundamental to our ability to make the investments in the future that produce progress. Regulation, necessary as it may be, must still leave room for adequate incentives and adequate rewards. Government attitude must be such as will encourage effort," he stated further.

Referring to the federal excise tax on telephone service, Mr. Kappel said, "it is unjust and discriminatory. This tax was passed during World War II as an emergency measure to reduce telephone usage and save scarce materials, as well as to increase tax revenues. But it has endured 'temporarily' ever since. Last year Congress voted to end the tax on local service at the end of June 1960. It did nothing to eliminate the equally discriminatory tax on long-distance calls. And it could still vote to continue the local tax, as the administration has requested.

Our opportunities have never been greater. The need for communications of all kinds is bound to increase. We have a wonderful organization of people at work. We have a sound, strong financial structure. We are continually gaining new knowledge and skills. The new products and systems we are introducing make our service more attractive and strengthen our earnings."

Gallium-Arsenide Diodes Show Improved High-Frequency Performance

Point-contact diodes, made of gallium arsenide, when suitably processed and fabricated, are extremely useful in many high-frequency applications. W. M. Sharpless, of the Electronics and Radio Research Department reported research on this subject in a paper recently presented to the IRE Professional Group on Microwave Theory and Techniques at San Diego. One of the III-V semiconductor compounds, gallium arsenide possesses properties that make it superior to either silicon or germanium for high-frequency diodes.

News of Device Research

One of the factors contributing to this improved performance is the high energy-gap, or wide "forbidden region," which improves the possibility of high-temperature operation. Also contributing are the high mobility of electrons and low dielectric constant, both of which enhance the high-frequency performance. In addition to using the diodes as varactors, Laboratories investigators have successfully used point-contact rectifiers prepared from gallium arsenide in such applications as first detectors operating in the millimeter-wave range (55 kmc.) They have also used the point-contact devices as high-speed switching diodes.

Mr. Sharpless also discussed the processing techniques involved in producing gallium-arsenide point-contact diodes. For example, he mentioned the special precautions J. M. Whelan took in preparing all the high-mobility, single-crystal materials used in the experimental diodes. He also noted the particular care required in obtaining a good ohmic contact. Here, a thin tin-and-nickel coating is deposited on the back surface of the crystal and heated in a vacuum furnace. The tin then starts to diffuse into the gallium arsenide, leaving a tough nickel surface for subsequent soldering operations.

The method of formation of the point-contact area also affects the characteristics of the diodes. In this method, the surface is first given a mirror polish, is lightly etched, and then a sharply pointed phosphor-bronze "S" spring is brought into contact with the surface.

To form the contact area, a series of 60-cycle pulses are applied to the rectifier terminals. During this process, a high current density is produced which heats the small point-contact area of the spring wire. The designers believe this diffuses a small amount of copper into the "vacancies" which result from polishing damage on the surface of the semiconductor. This diffusion forms the tiny, extremely abrupt, junction area desired for efficient high-frequency operation.

B. C. DeLoach, of the Guided Wave Research Department, has designed parametric amplifiers using gallium-arsenide point-contact diodes operating in the X-band. Employing approximately 100 mw of pumping power, these diodes have produced gains in excess of 10 db with approximately 50-mc bandwidths. The pump frequency in this case was near 23 kmc. The double-sideband noise figure was 3.2 db. Indications are that circuit refinements could lead to lower noise figures and higher gain-bandwidth products.

Significant improvement in the noise figure results when the diodes are cooled. For instance, M. Uenohara, of the Electron Tube Development Department, studied a typical diode with a parametric amplifier he designed. The diode was used as a variable-reactance element in the parametric amplifier operating at 6 kmc. Under those conditions, Mr. Uenohara found a gain of 16 db and a bandwidth of about 25 mc. And he found the noise temperature in double-sideband operation to decrease from 68 degrees K with the diode at room temperature to 21 degrees K with the diode cooled to 90 degrees K. About 10 degrees of this noise temperature is believed to be contributed by the circuit. The excess noise temperature of the cooled parametric amplifier is of the order of that obtainable with the latest masers operating at this frequency. Because of its simplicity, such a parametric amplifier may become a reasonable competitor of the maser in some high-frequency system applications.

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Hartman, C. D., see Germer, L. H.

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Scheibner, E. J., see Germer, L. H.
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Walsh, D. J., see Batdorf, R. L.
Wannier, G. H., *Wave Functions and Effective Hamiltonian for Bloch Electrons in an Electric Field,* Phys. Rev., 117, pp. 432-439, Jan. 15, 1960.
Wertheim, G. K., *Measurement of Local Fields of Impurity Fe^{57} Atoms Using the Mössbauer Effect,* Phys. Rev. Letters, 4, pp. 403-405, April 15, 1960.
Zetterstrom, R. B., see Howard, W.

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.—*Monostable Trigger Circuit*—2,934,659.
Baker, P. A. and Sumner, E. E.—*Transistor Monostable Circuit*—2,931,920.
Bogert, B. P.—*Time Reversal Delay Distortion Corrector*—2,933,702.
Caroselli, F.—*Microwave Impedance Branch*—2,931,992.
Chislow, J. H.—*Heat Abstracting and Shielding Means for Electron Discharge Devices*—2,933,-292.
Doherty, W. H.—*Electrical Conductor Having Transposed Conducting Elements*—2,932,805.
Elmer, L. A.—*High Speed Time Sharing Rotary Switch*—2,932,-700.
Felker, J. H. — *Square Root Computer*—2,934,268.
Hawks, V. J., Van Tassel, E. K. and Weller, D. C.—*Rural Carrier Telephone Transmission System*—2,932,694.
Hewitt, W. H., Jr.—*Attenuator*—2,934,723.
Hohmann, L. A., Jr.—*Signal Translating Circuit*—2,933,563.
Kinariwala, B. K.—*Active Impedance Branch*—2,933,703.
Kompfner, R.—*Pulse Coincidence Detecting Tube*—2,933,640.
Lewis, W. D.—*Microwave Switching Circuits*—2,934,658.
Loosme, O.—*Chemical Lapping Method*—2,933,437.
Matson, U. A.—*Transformer System*—2,932,804.
Meyers, S. T.—*Transistor Switching and Regenerative Pulse Amplifier Circuit*—2,933,692.
Pfann, W. G.—*Zone-Melting with Joule Heat*—2,932,562.
Pierce, N. J.—*Electroforming Millimeter Wave Components*—2,-932,609.
Rack, A. J.—*Transistor Trigger Network*—2,934,657.
Ronci, V. L.—*Semiconductor Housing Structure*—2,934,588.
Smith, T. A.—*Control Apparatus for Stereo Projectors*—2,927,504.
Strnad, A. R.—*Vacuum Tight Window for High Frequency Devices*—2,931,942.
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Van Tassel, E. K., see Hawks, V. J.
Weller, D. C., see Hawks, V. J.
Wittwer, N. C., Jr.—*Electrode Support and Spacing Structure for Electron Discharge Devices*—2,933,636.

TALKS

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

AMERICAN PHYSICAL SOCIETY MEETING, Detroit, Mich.

Baruch, P., *Mobility of Radiation Induced Defects in Germanium.*
Batterman, B. W., *Measurement of the X-Ray Atomic Scattering Factors of Iron and Copper.*
Bemski, G., and Szymanski, B., *Oscillatory Magneto-Resistance in InAs.*
Blumberg, W. E., and Feher, G., *Electron-Nuclear Double Resonance in Irradiated KC1.*
Ditzenberger, J. A., Struthers, J. D., and Whelan, J. M., *Effects of Si in GaAs.*
Feher, G., see Blumberg, W. E.
Geballe, T. H., and Pollak, M., *Incipient Impurity Conduction in Silicon.*
Glarum, S. H., *Dielectric Relaxation Functions.*
Hebel, L. C., *Nuclear Relaxation by Impurities in Metals.*
Hopfield, J. J., Power, M., and Thomas, D. G., *Excitons and the Absorption Edge of CdS.*

Huyett, M. J., Lundberg, J. L., and Wilk, M. B., *The Diffusivities and Solubilities of Gases in Polymers.*

King, J. C., *Acoustic Absorption in Silica at Low Temperatures.*

Lax, M., *Noise in Driven Quantum-Mechanical Systems.*

Lee, C. A., *Determination of Forward and Reverse Tunneling Currents in Esaki Diodes by Noise Measurements.*

Ligenza, J. R., *Mechanism for the Isotopic Oxygen Exchange Between Silica and High Pressure Steam.*

Link, G. L., *A New Effect Observed in $BATiO_3$.*

Logan, R. A., *The Temperature Dependence of Current in Esaki Diodes.*

Lundberg, J. L., see Huyett, M. J.

Matsuoka, S., *Properties of Polyethylene Crystallized at High Pressure.*

Pollak, M., see Geballe, T. H.

Power, M., see Hopfield, J. J.

Schawlow, A. L., see Peter, M.

Struthers, J. D., see Ditzenberger, J. A.

Szymanski, B., see Bemski, G.

Thomas, D. G., see Hopfield, J. J.

Whelan, J. M., see Ditzenberger, J. A.

Wilk, M. B., see Huyett, M. J.

1960 I.R.E. INTERNATIONAL CONVENTION, N.Y.C.

Aaronson, D. A., *Magnetostrictive Ultrasonic Delay Lines for a PCM Communication System.*

Blackman, R. B., *Smoothing and Predicting of Time Series by Cascaded Simple Averages.*

Blecher, F. H., *Application of Synthesis Techniques to Electronic Circuit Design.*

Manley, J. M., *Some Properties of Time Varying Networks.*

McAfee, K. B., *Determination of Randomness in Silica Glass by Gaseous Diffusion.*

Meiboom, S., *Nuclear Spin Relaxation in Water.*

Peter, M., and Schawlow, A. L., *Optical and Paramagnetic Resonance Spectra of Cr+++ in Ga_2O_3.*

Slichter, W. P., *Defects in Polyethylene Spherulities.*

Spitzer, W. G., *Infrared Measurements of Isotopic Oxygen Exchange Between Vitreous Silica and High Pressure Steam.*

Suhl, H., *On Inhomogeneous Broadening of Nuclear Resonance in Magnetic Domain Walls.*

Suhl, H., *The Problem of Reconciliation of Ferromagnetism and Superconductivity.*

Van Roosbroeck, W., *Transport with Space Charge of a Pulse of Current Carriers Injected in a Semiconductor.*

White, D. L., *Piezoelectric and Magnetostrictive Properties of Single Crystal Gallium Iron Oxide Resonators.*

Wolfe, R., *Anomalous Hall Effect in $AgSbTe_2$.*

OTHER TALKS

Ahearn, A. J., *Mass Spectrographic Studies of Impurities in Solids and Liquids*, United States Naval Ordnance Laboratory, Silver Spring, Md.

Amory, R. W., *The Solution of Complex Cable Network Problems by Computer Techniques*, A.I.E.E.-I.R.E., Newark College of Engineering, Newark, N. J.

Anderson, W. W., *Principles and Applications of Esaki Diodes*, I.R.E., Fort Monmouth, N. J.

Badal, M. J., *Characteristics of Diazo Films*, National Microfilm Association Conv., N.Y.C.

Barney, H. L., *Some Acoustic Characteristics of Vowels Produced by Esophageal and Artificial Larynx Speakers*, I.R.E. Prof. Gp. on Medical Electronics, Houston, Tex.

Bartholomew, C. Y., *Preparation of Clean Silicon Surfaces*, Lehigh University Physics Colloquium, Bethlehem, Pa.

Benes, V. E., *Martingales on Metric Spaces*, A.M.S., Chicago, Ill.

Benes, V. W., *Transition Probabilities for Telephone Traffic*, Institute of Mathematical Statistics, N. Y. C.

Bennett, W. R., *Amplification in Nonlinear Reactive Networks*, Polytechnic Institute of Brooklyn Symposium on Active Networks and Feedback Systems, Brooklyn, N. Y.

Bode, H. W., *Feedback—The History of An Idea*, Polytechnic Institute of Brooklyn Symposium on Active Networks and Feedback Systems, Brooklyn, N. Y. C.

Bode, H. W., *Our Never Ending Job*. Western Electric Co. Training Center, Winston-Salem, N. C.

Bomberger, D. C., *How We Use Technicians at Bell Telephone Laboratories*, N. Y. State Soc. of Prof. Engineers Conference on Utilization of Scientists and Engineers, Garden City, L. I., N. Y.

Bozorth, R. M., *Magnetic Properties of Some Semiconductors*, Bryn Mawr College, Bryn Mawr, Pa.

Brady, G. W., *Structure in Solutions*, MIT-Harvard Biophysics Colloquium, Cambridge, Mass.

Bulloch, W. D., *Communications of Tomorrow*, Western Michigan Center of Industrial Management Soc., Sixth Annual Industrial Conf., Grand Rapids, Mich.

Chisholm, D. A., *Millimeter Wave Tubes*, Columbia University Colloquium at Pupin Physics Laboratories, N. Y. C.

Cutler, C. C., *Radio Communication by Means of Satellites*, I.R.E., Lancaster, Pa.

Dacey, G. C., *Esaki (Tunnel) Diodes*, Engineering Societies Bldg., N. Y. C.

Dalrymple, E. G., *Nike-Hercules Guided Missile System*, Diehl Engr. Soc., Park Hotel, Plainfield, N. J.

D'Altroy, F. A., *The Role Bell Telephone Laboratories Plays in the Bell System*, M.O.R.A. Club, Y.M.C.A., Allentown. Pa.

Denton, R. T., *A Ferromagnetic Amplifier Using Longitudinal Pumping*, Prof. Gp. on Microwave Theory and Techniques Annual Meeting, San Diego, Calif.

Donovan, P. F., *Nuclear Radiation Spectrometry Using Semiconductor Detectors*, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dougherty, H. J., *Control Systems and Switching Logic*, City College of New York Branch of A.I.E.E.-I.R.E., N. Y. C.

Geller, S., *On the Relation of Structure and Properties of Some Sulfides, Selenides and Tellurides*, A.C.S., Cleveland, Ohio.

Goldey, J. M., *Integrated Circuits and Functional Devices*, I.R.E. Microelectronics Symposium of Elmira-Corning Section, Corning, N. Y.

Goldstein, H. L., *The Twistor—A New Memory Element for Digital Computers*, North Carolina Mid-Section of A.I.E.E. Meeting, Winston-Salem, N. C.

Gupta, S. S., *Order Statistics from Gamma Distribution and Their Applications to Reliability and Life Test Problems*, New York University Office of Special Services to Industry, New York University, N. Y.

Guttman, N., *Recent Research in Speech*, Southern Speech Conv., Winston-Salem, N. C.

Hammann, P. L., *The Nike Missile Family*, A.I.E.E. Meeting, Kansas City, Mo.

Hamming, R. W., *The Association for Computing Machinery*, Fourth Annual Symposium on Recent Advances in Programming Methods, Ohio State University, Columbus, Ohio.

Hebel, L. C., *Physics as a Career*, Livingston High School, Livingston, N. J., 3/14; Millburn High School, Millburn, N. J., 4/6.

Herring, C., *Some Current Problems of Semiconductor Transport Theory*, Brown University Physics Colloquium, Providence, R. I.

Herslow, H. E., *The Business Woman's Role in Safety*, Greater New York Safety Council Conv., Hotel Statler, N. Y. C.

Higgins, W. H. C., *Engineering in the Space Age*, I.R.E. American Rocket Soc. Spring Technical Conf., Cincinnati, Ohio.

Hight, S. C., *Man in Space*, Chatham Adult School, Chatham High School, Chatham, N. J.

Jackson, H. M. II, *The Nike Guided Missile Family*, First Methodist Church of Plainfield Men's Club, Plainfield, N. J.

Jenkins, H. M., and Shepard, R. N., *Stimulus Generalization and Abstraction in Classification Learning*, Eastern Psychological Association, N. Y. C.

Jenkins, H. M., and Shepard, R. N., *Structural Factors in the Learning of Classifications*, Eastern Psychological Association, N. Y. C.

Karlin, J. E., *Human Factors in Electronics—A Progress Report from Industry*, Bell Telephone Laboratories, N. Y. C.

Key, R. S., and Kirkwood, L. W., *Alumina Powder as a Potting Material for Electronic Power Transformers*, Second National Conf. on Application of Electrical Insulation, Washington, D. C., 12/8/59; A.I.E.E. Winter General Meeting, N. Y. C., 2/2.

Kirkwood, L. W., see Key, R. S.

Laue, R. V., *An Example of Estimation from Doubly Truncated Samples*, American Statistical Association Physical Science Section Meeting, Purdue University, Lafayette, Ind.

Law, J. T., *p-Layers on Vacuum Heated Silicon*, Electrochemical Soc. Conf., Columbus, Ohio.

Levidow, W., *Bistable Magnetic Amplifier Switches for Signal Detection and Comparison*, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.

Levinson, J., *Retinal Photoreceptors and Flicker Fusion*, Optical Soc. of America, Washington, D. C.

Liehr, A. D., *The Coupling of Vibrational and Electronic Motions in Degenerate Electronic States of Inorganic Complexes*, University of California, Berkeley, Calif., 4/4/; California Institute of Technology, Pasadena, Calif., 4/8/; University of British Columbia, Vancouver, B. C., 4/12.

Liehr, A. D., *Ionic Radii, Spin-Orbit Coupling, and the Geometrical Stability of Inorganic Complexes*, 137 Meeting of A.C.S., Cleveland, Ohio.

Liehr, A. D., *Spectra of Inorganic Complexes*, University of California, Los Angeles, Calif.

Liehr, A. D., *Theory of Ionic Radii in Transition Metal Complexes*, University of Washington, Seattle, Wash.

Matthias, B. T., *Role of Valence Electrons in Superconductivity*, A.C.S. Meeting, Princeton University, Princeton, N. J.

McCabe, B., *Nike-Hercules Guided Missile System*, American Soc. of Swedish Engineers, N. Y. C., 3/18; Naval Reserve Officers' School, Clifton, N. J., 3/23.

McMillan, B., *Control in Linear Systems*, Symposium on Hydrodynamic Instability and Its Statistical Analysis, Hotel New Yorker, N. Y. C.

Miller, R. C., *Some Studies of Domain Dynamics in Barium Titanate*, Solid-State Physics Colloquium, U. S. Naval Ordnance Laboratory, Silver Spring, Md.

Moore, E. F., *Machine Models of Self-Reproduction*, Bell Telephone Laboratories, Holmdel.

Murphy, R. B., *Parametric Confidence Limits on Percentage Points to Life Distribution Censored from Above*, New York University, N. Y. C.

Paterson, E. G. D., *The Role of Quality Assurance in Product Reliability*, Symposium on Reliability of Service Equipment, London, England.

Pierce, J. R., *Problems in Communication*, Conf. on Electrical Engineering in Space Technology, Dallas, Tex.

Pierce, J. R., *Satellite Systems for Commercial Communications*, Dallas Advertising League, Dallas, Tex.

Pierce, J. R., *Transoceanic Communication by Means of Satellites*, University of Michigan, Ann Arbor, Mich.

Pierce, J. R., *Types of Signal Modulation and Space Communication*, University of Michigan, Ann Arbor, Mich.

Pollak, H. O., *Applied Mathematics for Academic Year Insti-*

tutes, University of Illinois, Urbana, Ill.
Riney, T. D., *Stress-Temperature Hysteresis as Related to Plastic Deformation in a Copper Glass Seal*, North Carolina State College, Raleigh, N. C.
Robertson, G. I., *Machines with Intelligence*, Rotary Club of Old Saybrook, Conn.
Rosenberg, S., *Reinforcement Parameters in a Two-Person System*, University of Delaware, Newark, Del.
Schawlow, A. L., *Fine-Line Optical Spectra in Solids*, Brookhaven National Laboratory, Upton, N. Y.
Shepard, R. N., see Jenkins, H. M.
Skrabal, R. J., *Mechanical Engineering in the Bell Telephone Laboratories*, Student Branch Meeting, A.S.M.E., University of Missouri, Columbia, Mo.
Suozzi, J. J., *Some Theoretical Consideration on Bistable Magnetic Amplifiers*, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.
Tischendorf, J. A., *Efficiencies of Estimators of Scale and Location Parameters Constructed from Order Statistics of Censored Samples*, Central Region Meeting of Institute of Mathematical Statistics, Purdue University, Lafayette, Ind.
Tischendorf, J. A., *Sequential Life Testing to Establish Reliability*, Symposium on Modern Techniques in Quality Control Engineering, Boston, Mass.
Traube, M. J., *The Nike-Hercules Guided Missile System*, Morristown Armory, Morristown.
Troe, J. L., *The Nike-Hercules Guided Missile System*, Boy Scout Troop 173 Father-Son Dinner, Parsippany, N. J.
Vacca, G. N., *Weathering of Rubbers*, Rubber and Plastics Gp. of Montreal Section of Chemical Institute of Canada, Montreal, Canada.
Walsh, W. M., *Pressure and Temperature Effects on Electron Spin Resonance*, Raytheon Manufacturing Company, Waltham, Mass.
Watson, H. A., *Amplification of Microwave Frequencies*, Lehigh University, Bethlehem, Pa.
Wolfe, R., *Thermoelectric Power Generation and Refrigeration*, A.I.E.E., Lynn, Mass.

THE AUTHORS

Clyde L. Ruthroff, co-author of "An Experimental 'Short-Hop' Microwave System" in this issue, began his Bell System career as a central-office craftsman with the Long Lines department of the A.T.&T. Company in Lincoln, Nebraska in 1946. In 1950 he received the B.Sc. in E.E. from the University of Nebraska, and in 1952, received an M.A. in mathematics from the same university. Since transferring to Bell Laboratories in 1952, Mr. Ruthroff has been engaged in radio research at Holmdel, N. J. His work in this area has been principally concerned with frequency-modulation problems.

C. L. Ruthroff

L. C. Tillotson received the B.S. degree in electrical engineering in 1938 from the University of Idaho and the M.S. degree in electrical engineering from the University of Missouri in 1940. After joining Bell Laboratories in 1941, he worked for five years on the design and development of filters and networks. In 1946 he transferred to radio research at Holmdel, N. J., where he has been primarily concerned with microwave filters and radio-relay systems. He is in charge of a group studying microwave applications —the subject of, "An Experimental 'Short-Hop' Microwave System," in this issue. At present he is concerned with communications satellite programs and is planning an active satellite repeater experiment. From June, 1958 to July, 1959, Mr. Tillotson served with the Department of Defense as a member of the technical staff of the Advanced Research Projects Agency division of the Institute for Defense Analyses. In this capacity he worked on technical problems of ballistic-missile defense and military space communication systems. He is a member of the Institute of Radio Engineers and Sigma Xi.

L. C. Tillotson

H. L. McDowell, a native of Washington, D. C., received his B.S.E.E. degree from Cornell University in 1948. In that same year

H. L. McDowell

he joined Bell Laboratories. While here, his principal field of activity was the development of electron tubes, with his special sphere of interest being traveling-wave amplifiers. In August 1959, Mr. McDowell resigned from the Laboratories. He is the author of the article, "The Traveling-Wave Tube Goes to Work," in this issue.

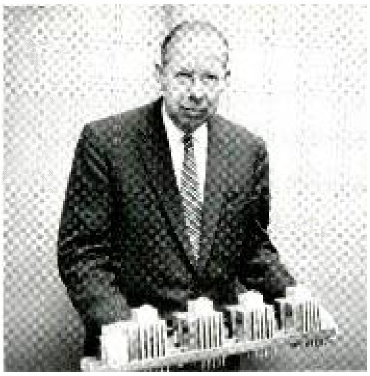
H. A. Miloche is a product of New York City. He joined the Laboratories upon receipt of his B.S. in M.E. degree from Cooper Union in 1923. His field is switching systems equipment design, which has presented opportunities for contributions to such developments as No. 1 crossbar and crossbar tandem. In the same capacity, he is currently concerned with projects such as ANI —better fitting No. 1 crossbar and panel switching systems to the needs of nation-wide dialing. The story on ANI in this issue is by him.

H. A. Miloche

N. A. Newell, author of "DX Signaling: A Modern Aid to Telephone Switching" in this issue, was born in Addison, N. Y. He received the E. E. degree from Lehigh University in 1920, and joined the Development and Research Department of the A.T.&T. Company in the same year. Here, he was concerned with advances in local and toll telephone switching and with the signaling equipment and arrangements for such systems; activities he subsequently continued after his transfer to the Laboratories in 1934. His work in this field has included the preparation of design objectives and engineering data for system developments. Mr. Newell is a member of the A.I.E.E. and Tau Beta Pi.

D. A. James

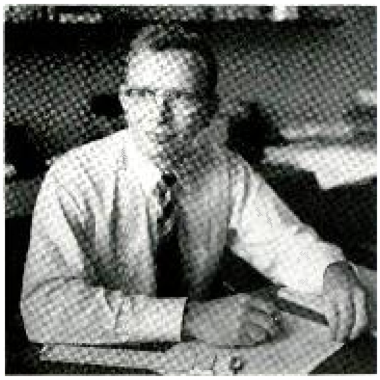
D. A. James ("4A and 4M CAMA: Trunk Class Translator") received an S.B. degree in electrical engineering from the Massachusetts Institute of Technology in 1942. For the succeeding two years he held a position with the Western Electric Co. He then spent two years in the U.S. Navy where he worked on infrared signaling devices. In 1946 he returned to the Western Electric Co. to work on the design of test equipment for toll crossbar circuits. In 1948, he joined the Bell Laboratories technical staff, where he has been concerned with testing 4A crossbar senders and decoders, the design of a card translator test circuit and a 4A CAMA automatic trunk-



N. A. Newell

test circuit. Presently, Mr. James is in charge of a group responsible for common-control circuit design in toll crossbar.

W. T. Cochran, a native of Indianapolis, Indiana, received his B.S. E.E. degree from Purdue University in 1956 and is presently enrolled in the graduate division of N.Y.U. Since joining the Laboratories and completing the Communications Development Training Program, he has worked in the design of audio frequency test equipment. Emphasis has been on the use of modern solid-state devices in sets that are intended to add ease, convenience, and accuracy to the problem of voice frequency measurement in the Bell System. Mr. Cochran is a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Pi Sigma. He wrote the article "A New Noise-Measuring Set," in this issue.



W. T. Cochran