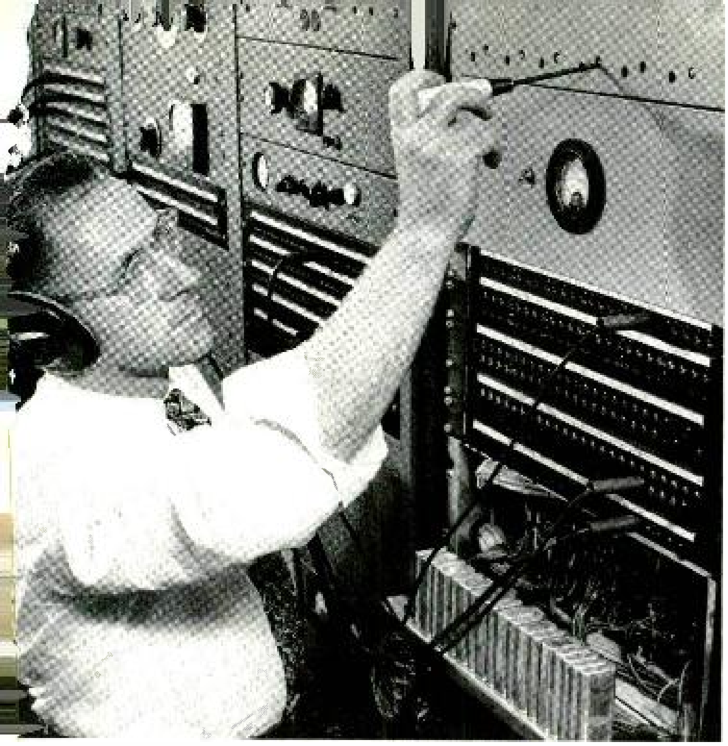


Speech Bandwidth Compression

W. E. KOCK

Audio and Video Systems Research

It is a continuing objective of the Bell System to make more efficient use of its transmission media — to place more telephone conversations or television programs on the same pair of wires, cable, or microwave radio system. One method of increasing channel capacity is to compress speech frequencies into a very narrow range, so that each telephone conversation occupies only a very small part of the "room" in a frequency spectrum. "Vocoder", "Audrey", and "Vobanc" are names given to devices developed at Bell Laboratories for studying such problems of speech bandwidth compression.

It has been suggested that the recent advance in communication engineering known as information theory "bears some of the same hallmarks of greatness that characterize two other important scientific milestones, namely relativity and quantum theory."* Unquestionably the impact of this theory is being felt in many fields of electronics. It provides among other things a means for defining "how much" information is contained in telephone speech or in symphonic music or in a television picture.

This aspect of information theory is significant in the field of speech communication because speech is a relatively simple form of signal compared to the music of a symphony orchestra. A vocal sound is more like the tone of a single string of one violin in that it contains but one fundamental and but one series of harmonically related overtones. Because of this, information theory asserts that speech does not really need the full telephone bandwidth that is now employed.

If a way were to be found which would successfully concentrate the speech information into a narrower band, more telephone conversations could be sent over existing transmission facilities. The savings in channel capacity accruing from this process are of economic importance since the outside plant investment in telephone transmission lines constitutes a major portion of the total telephone investment.

Consideration of the simple "frequency" structure of speech mentioned above has led to three promising methods of bandwidth reduction. They are discussed in turn. It should be noted that speech is also a special signal in the "time" dimension. It is not continuously flowing, but rather has gaps in the form of pauses, and methods for exploiting this aspect of speech have also been explored for telephone transmission economies. Some of these have been successful in permitting a large number of conversations to be "sandwiched" into a smaller number of telephone channels without objectionable degradation. However, since these methods

* The Information Theory, Francis Bello, *Fortune*, Dec., 1953.

constitute a time compression rather than a frequency compression, they are not discussed here.

The concept of bandwidth reduction for speech transmission is not new. During the middle and late Thirties, Homer Dudley of the Laboratories developed and demonstrated the Vocoder, a bandwidth compression system which permitted ten speech conversations to be sent over one standard telephone channel. This system might be likened to two high-speed electronic computers, one at the sending end and one at the receiving end. At the sending end, the computer ascertains what frequencies are present in the incoming speech signal, decides whether the sound being uttered by the talker is voiced (as a vowel) or unvoiced (as a sibilant), and measures the pitch of the signal, if voiced. Since, in normal speech, transitions from one sound to another occur slowly (less than ten per second) the information acquired by the computer can be sent as slowly varying electrical signals over channels which are only 15 cycles wide. At the receiving end, the second computer rebuilds the original speech from the information it receives by causing the frequency content and pitch of an electrical oscillator to vary in accordance with the variations of the original speech. A diagram of the operation is shown in Figure 1.

Early Vocoder speech was often lacking in naturalness and suffered somewhat in intelligibility. Improvements led to a successful Vocoder application in a specialized military project during the war. Still more recently, the Vocoder has been refined to such a state that it is at present often difficult to detect the difference between the original and the re-created speech. G. W. Blake is shown in the headpiece tuning a modulator in the Vocoder.

Comparison of two speech sounds by means of visible speech spectrograms is often more revealing than comparison by listening only. Figure 2 shows the marked similarity between the original and the Vocoder imitation.

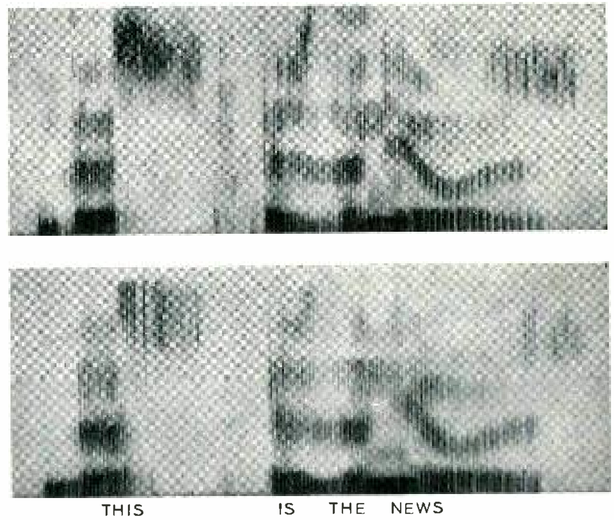


Fig. 2 — Visible speech spectrograms of the sentence, "This is the news," show little difference between the original radio broadcast (top) and the synthetic Vocoder version (bottom). The analysis is limited to 3,000 cycles.

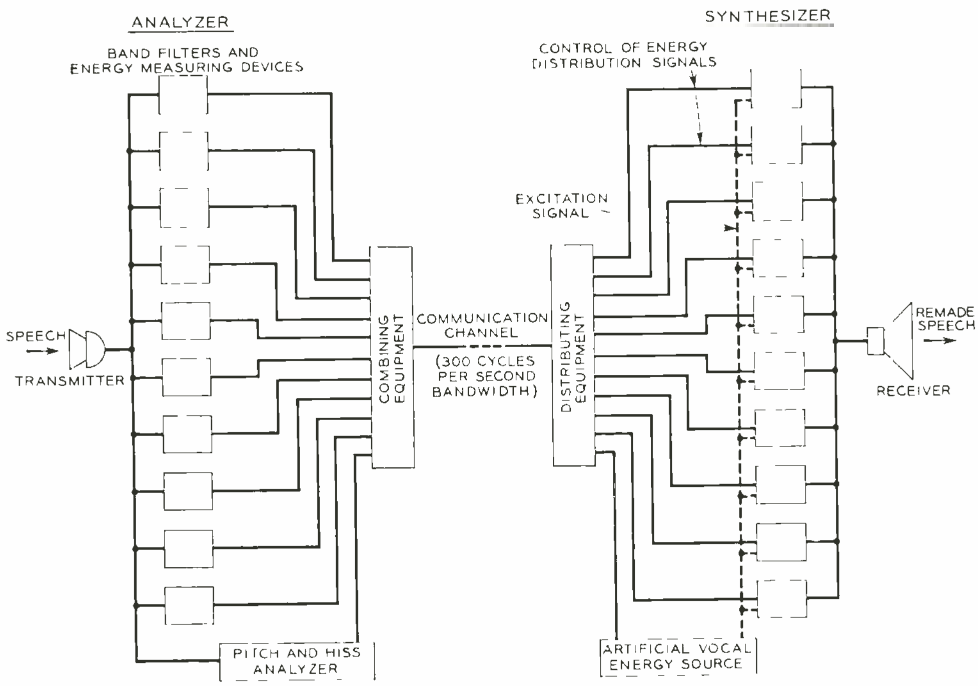
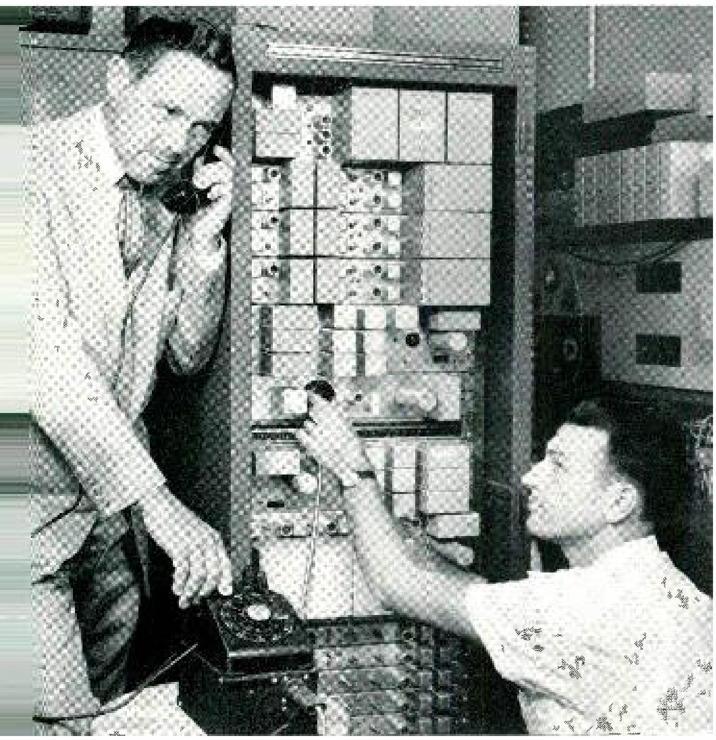


Fig. 1 — The transmitting analyzer and the receiving synthesizer of the Vocoder can be considered as two portions of an electronic computer. The analyzing computer transmits low frequency signals over a narrow band line to instruct the synthesizing computer on how to reconstruct the speech correctly.

One problem which has presented difficulties in the Vocoder is that of correctly ascertaining the pitch of the original speech wave. If the speech whose bandwidth is to be compressed has arrived at the Vocoder over certain kinds of telephone lines, the frequencies below 300 cycles may be missing. Since the fundamental pitch frequency of speech lies below 300 cycles, some means of acquiring this fundamental pitch is needed. Several methods for doing this are under investigation, and the results appear promising.

The second speech compression method under investigation is even more ambitious than the Vocoder in the amount of bandwidth saving to be expected. It makes use of Audrey* (Figure 4), a device developed at the Laboratories by S. Balashek and the late K. H. Davis for automatically recognizing spoken digits. The name Audrey was coined from the first letters of the words "automatic digit recognizer." This machine, which Dr. Ralph Bown once named an "electronic brain with ears," analyzes the sound it hears and makes up its mind as

* Record, *February*, 1953, *page* 52.



g. 3 — The author (left) and F. A. Russo make final adstments on an experimental Vobanc terminal. Recently nducted tests show the intelligibility of Vobanc speech be superior to that of speech sent over existing halfnd systems.

Fig. 4 — S. Balashek (foreground) and J. Berrang with Audrey. The sound analyzer of Audrey can be used in a narrow band speech transmission system.

to which sound in its memory category it is most like. For a complete word such as "seven," it compares the series of sounds that it has heard with the series it has been told constitutes one of the digits. It then makes the final decision as to which of the ten digits in its memory pattern the word most resembles. Although Audrey is quite able to recognize the digits as spoken by certain voices, it so far cannot perform well on all voices.

It was observed that Audrey was failing mostly in the second step, that of recognizing the complete word. This is because the series of sounds in a given digit vary from person to person according to his or her accent, and correct answers were obtained only for those individuals who matched the master series which had been built into Audrey. However, its success in the first step, that of recognizing the individual sounds, suggested that Audrey was in fact acquiring information which could be used for a new speech transmission device.

This device employs the sound recognition capabilities of Audrey at the transmitting end, and a Vocoder-like sound generator at the receiving end to artificially produce the series of individual sounds as recognized by Audrey in the original speech. The sound generator thus recreates the individual sounds or "phonemes" whenever the transmitting end signals that these particular sounds are being uttered. Figure 5 is a diagram of the operation.

The first such system to be built utilized a category of only ten phonemes, yet fairly understandable speech was produced, especially when well-known sayings were spoken. Since successive phonetic sounds in speech normally occur at rates of less than 10 per second, this speech could have been transmitted over extremely narrow bandwidth channels. Figure 6 shows the similarity between visible speech spectrograms of a word spoken by a talker and recreated by Audrey.


NURSE

Fig. 6 — A comparison of visible speech spectrograms of the word "nurse" as spoken directly (shown above) and as recreated by Audrey (below) shows only small differences.

A third promising method of speech compression is one which is based on an early idea of R. L. Miller of the Laboratories which has been brought to its present state through the efforts of B. P. Bogert.* It is called the Vobanc (for VOice BANd Compressor) and strives for only a 2 to 1 reduction in bandwidth. It is shown in Figure 3. Its operation depends upon the fact that when a particular vowel is sounded the mouth cavities resonate, so that some harmonics of the vocal cords are accentuated and others are suppressed. The strong frequency regions or resonances are called form-

* B. P. Bogert, The Vobanc, A Voice-Band Compressor, J. Acoust. Soc. Amer. 26, p. 137, 1954.

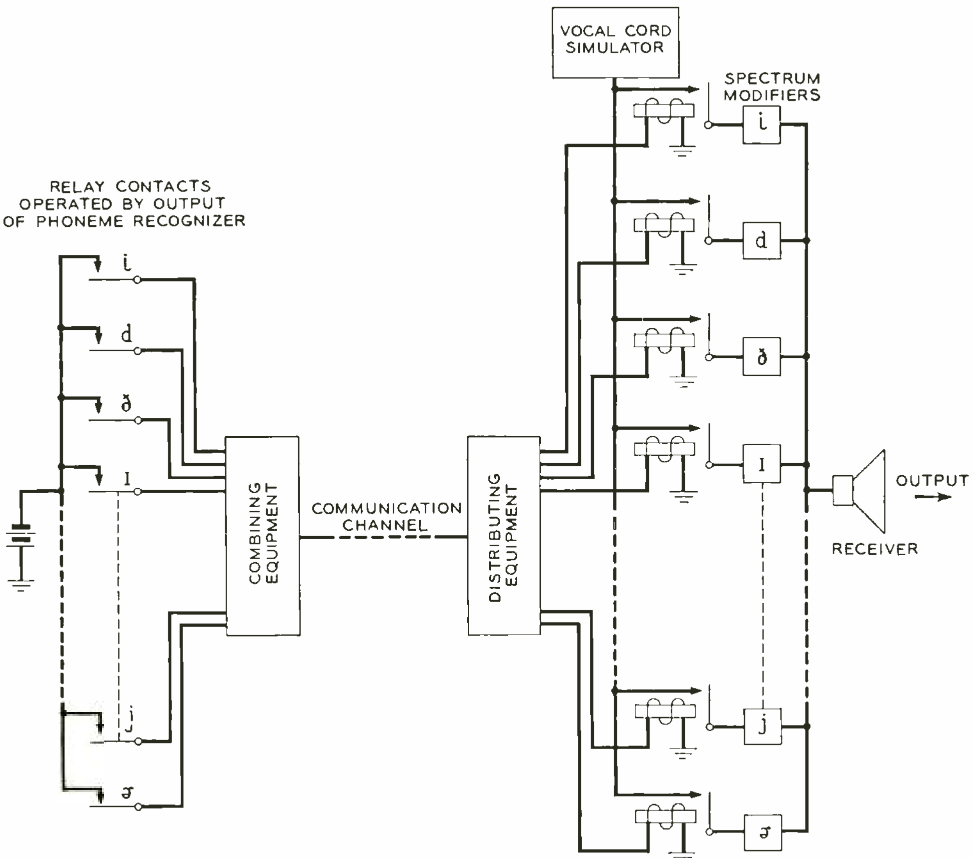


Fig. 5 — The method of recognizing the individual sounds (phonemes) as employed in Audrey can be used to instruct a synthetic speech device to recreate speech at the receiving end of a telephone line.

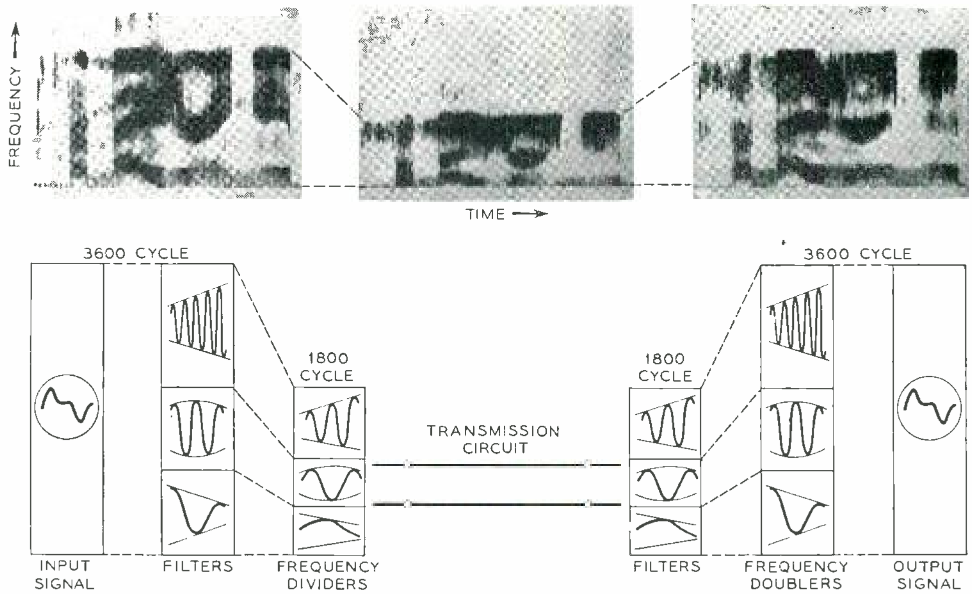


Fig. 7—In the Vobanc the speech band is compressed by a factor of 2 by halving the frequency of each of three bands at the sending end and doubling the frequency of these bands at the receiving end.

ants, and three of these are prominent in most of our vowel sounds. The first usually lies below 1,000 cycles, the second between 1,000 and 2,000, and the third above 2,000 cycles. In the Vobanc, filters divide the incoming speech signals into these three bands, and three frequency dividers act to halve the frequency of the strongest harmonic in each of these three bands. After the frequency division process, filters which are half as wide as the original pass the divided signals so that the sounds sent over the line comprise only half the bandwidth of the original speech sounds. At the receiving end of the line the bands are doubled by a frequency doubler, and the speech is thus restored to its original bandwidth. It is noted that in this process only that information is transmitted which is in the strongly resonant regions in the voice sounds; the intervening frequency regions are ignored. As the spectrograms in Figure 7 show, the restored speech is very similar to the original. This method has an advantage over both the Vocoder and Audrey processes in that it needs no pitch acquisition.

In general, speech bandwidth compression devices must effect a saving in transmission line cost in order to justify their use. Accordingly, their first application will probably occur on long transmission lines where an increase in transmission capabilities is economically important. Our transcontinental lines or the new transatlantic telephone cable may thus provide the first opportunity for applying some of these principles of bandwidth compression to telephony.

THE AUTHOR

Winston E. Kock received his E.E. and M.S. degrees at the University of Cincinnati in 1932 and 1933, and his Ph.D degree from the University of Berlin in 1934. After a year as Teaching Fellow at the University of Cincinnati, he continued his graduate study at the Princeton Institute for Advanced Study and at the Indian Institute of Science in Bangalore, India. He joined the Laboratories in 1942, where he engaged in research on radar antennas and on antennas for radio relay circuits. In 1948, he became Research Engineer in Charge of Acoustics, in 1952 Director of Acoustics Research and in 1956 Director of Audio and Video Systems Research, Dr. Kock was a member of the Hartwell Committee for the Office of Naval Research in 1950. He was awarded an honorary Doctor of Science degree by the University of Cincinnati in 1952. He is a Fellow of the Institute of Radio Engineers, the American Physical Society, and the Acoustical Society of America.

Ever since the Bell System announced mobile radio telephone service some years ago, the number of customers using dispatch service has increased remarkably. To provide these customers with better and faster service, the Laboratories has designed an automatic switching arrangement that permits direct dispatch service without requiring a special mobile service operator or individual ticketing of mobile telephone calls.

Direct Dispatching for Mobile Telephones

A. E. RUPPEL *Special Systems Engineering I (Formerly Special Systems Planning)*

Public mobile radio-telephone service, introduced in St. Louis on June 17, 1946,* is now an accepted part of the Bell System. Today, over 14,000 vehicles are equipped with radio-telephone, and in the more populous areas the service is over subscribed. Further expansion in these areas is restricted by the limited number of available radio channels.

Two approaches to making more efficient use of the available radio frequencies are constantly being pursued. One is that of improving both equipment and system operating techniques to permit closer spacing of the radio channels in a given area† without interchannel interference. The other is that of streamlining the services that are offered to permit more customers to be served by each channel.

At present, three classes of service are provided on any one mobile system. These are: General Service, the one most commonly thought of, where a mobile telephone user can call or answer any other telephone whether land-based or mobile; General Dispatch Service, which permits two-way conversations between a land-based dispatcher and mobile stations in any of the vehicles in his fleet; and Signaling Service, which provides a one-way notification to a mobile station that some prearranged instruction should be complied with, such as calling a certain office from the nearest public telephone. A recent survey indicated that about 25 per cent of the vehicles using the 152- to 162-mc mobile telephone service use the Dispatch class of service; in some of the larger cities, 80 per cent or more use Dispatch service.

To place a call through the General Dispatch Service, a dispatcher calls the mobile service operator over a direct wire line and requests a particular vehicle by its assigned telephone number. The operator then dials the number to reach the particular mobile station. Similarly, a person at a mobile station signals the operator that a call is desired by depressing the push-to-talk button on his handset for about two seconds. When the operator answers, she inquires as to which particular dispatcher is wanted and then rings him over the direct line to his office.

A dispatcher can call mobile stations other than in his particular fleet and the fleet units can call any regular telephone or mobile station. However, for any call in either direction the mobile service operator is required to write out a charge ticket for the elapsed time.

Most of the calls in the General Dispatch Service are of relatively short duration. Conversation time for an average call is about 65 seconds, yet the total time for a call, including signaling, averages about 135 seconds. Operate time, then, occupies better than half of the total channel holding time of most calls.

In view of the demand for Dispatch class of service and the high percentage of channel holding time required for handling calls in the present system, it was decided that more efficient use of the radio channels could be realized, and a service more suitable to customer requirements could be

* RECORD, *July,* 1946, *page* 267; *April,* 1947, *page* 137.
† *April,* 1950, *page* 153.

offered, with an automatic switching version of the General Dispatch Service. The outgrowth of this decision is Direct Dispatching Service (DDS). A field trial of the system is now in progress in Baltimore City, and another is planned for Chicago. The capacity of the trial system is nine customers or dispatcher stations, with a combined total of approximately 100 mobile stations. The number of mobile stations is determined by the traffic load rather than by equipment limitations.

Some idea of the type of customers who use the Dispatch class of service may be realized from the list of customers participating in the Baltimore City trial. These have included a dairy company, a department-store delivery service, a protection agency, a laundry delivery service, a fuel-oil supply company, a vending-machine service company, a trash-removing company, a bottled-gas delivery service, and a municipal dog shelter.

Basically DDS differs from General Dispatch Service in five ways: no mobile service operator is necessary; no individual ticketing of calls is required; each dispatcher has access only to the vehicles in his fleet; mobile stations have access only to their own dispatcher; and the radio channel used is free of other public mobile telephone services.

Signaling by a dispatcher to a mobile station and vice versa is group-selective, with an individual signaling tone assigned to each fleet. Once the fleet has been alerted to an incoming call the dispatcher orally requests a particular vehicle. Mobile stations also signal their dispatcher selectively by transmitting a tone distinctive to each fleet. This arrangement eliminates the need for an operator to signal and make connections. In addition, automatic cumulative timers for each fleet indicate the total amount of time used during the billing period, eliminating individual charge tickets.

Other features of DDS include busy-circuit indications at the dispatcher's station with automatic ring-back when the circuit is available for that customer's use; provision for a mobile station to indicate, while the channel is busy, that a call is waiting; equitable access to the channel for each dispatcher station and for each fleet as a unit, and central office alarms in the event of trouble.

A dispatcher originates a call to a mobile station in his fleet, Figure 1, by simply lifting his handset; this causes several things to happen. The elapsed-time meter for that fleet is activated, all other dispatchers are prevented from placing a call and will receive busy tone if an attempt is made, all mobile stations are prevented from completing a

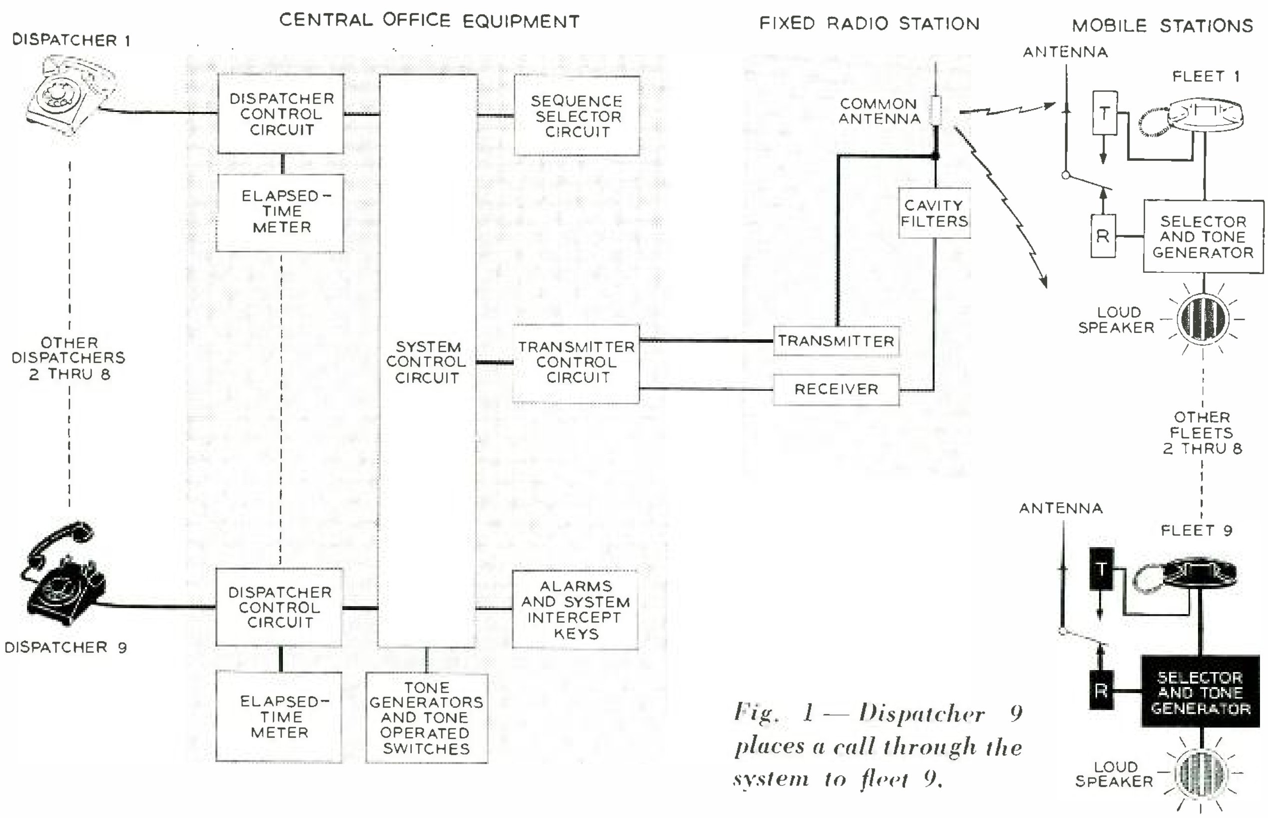


Fig. 1 — Dispatcher 9 places a call through the system to fleet 9.

call to a dispatcher, the fixed-station radio transmitter is turned on, and a 0.3-second burst of that fleet's particular signaling tone is transmitted. The received burst of signaling tone turns on a loudspeaker in each vehicle of that fleet, and the dispatcher then asks for a particular vehicle. Although the mobile stations are prevented from completing a call to their dispatcher during channel busy periods, they can, as with any party line service, request the use of the channel in cases of emergency.

Should the circuit be busy when a dispatcher tries to place a call, he will hear a busy tone and a sequence selection circuit will register the fact that he has a "call waiting." As soon as the channel is free, the sequence selection circuit connects to those dispatchers who have registered a demand for service in a progressive sequence, regardless of the order in which the calls were registered. This assures that each dispatcher will get a chance to talk with his fleet when it is his turn, even though other dispatchers have earlier "calls waiting." When it is a dispatcher's turn, the "calls waiting" circuit rings him back with two-second ringing intervals spaced four seconds apart. Since this ringing is different from that of an incoming call, he knows that he may now proceed with his call in the usual

Fig. 2 — Engineer C. L. Garrett checks operation of the transmitter used in the trial. Transmitters for other mobile services are in the foreground.

manner. If he does not place the call within about 40 seconds, he is disconnected and the dispatcher next in order gets his turn.

When the burst of tone turns on the loudspeakers and the dispatcher has requested a certain vehicle, the person in that vehicle answers the call by lifting his handset from its cradle and operating the push-to-talk button. This turns on the mobile transmitter, and a carrier-operated relay at the fixed station momentarily interrupts the fixed-station transmitter carrier to turn off the loudspeakers in all mobile stations in the fleet. The called person then carries on his conversation with the dispatcher, using his handset. The total time for completing the connection is only about 5 seconds, thus reducing the channel time required for handling a call through the General Dispatch Service by a factor of about 14.

A person at a mobile station can also originate a call by simply lifting his handset and operating the push-to-talk button. This turns on the mobile transmitter and sends a burst of signaling tone to the fixed station. Selective tone-operated switches at the central office determine which dispatcher is wanted, ring his station bell, lock out all other calls, turn on the fixed-station transmitter, and send a 998-cycle audible ringing signal to the mobile stations. Receiving this signal, the person at the mobile station knows that his call is being serviced. Other mobile stations that may try to use the channel at this time also hear the audible ringing signal and realize the channel is in use. Should the ringing continue for about 40 seconds and then stop, the person at the mobile station knows that the dispatcher is temporarily unavailable and cannot answer his telephone. If, as is the usual case, the dispatcher answers, the conversation proceeds in the usual manner.

When the channel is in use and there are "calls waiting," a 15-second enforced idle channel period is provided at the completion of each call to allow mobile stations to register a "call waiting." During this enforced idle channel period, the fixed-station transmitter sends an "attention" tone (the same 998-cycle tone as for audible ringing) for about 15 seconds. All dispatchers are locked out during this interval, and any mobile station user can register a "call waiting" by lifting his handset, operating the push-to-talk button, and then replacing the handset. The fixed-station receiving equipment recognizes the mobile-station tone and through the fixed-station transmitter sends the identifying tone for that fleet, turning on the loudspeakers, and then continues to send both the identifying and attention tone for the remainder of the 15-second interval, to indicate that the "call waiting" has been registered. Should a mobile unit of another fleet register a "call waiting" during this interval, its identifying tone will also be heard in sequence with the other identifying tone. "Calls waiting" are handled in the same progressive sequence for the various fleets, whether they originate from mobile stations or dispatchers.

Alarm circuits provide indications when the fixed-station transmitter fails to radiate and when a dispatcher leaves his handset off its cradle for more than about 2 to 3 minutes without an answer from a mobile unit. The technical operator required for all radio transmitting stations, Figure 3, has keys with which he can break into the circuit at any time to ring, talk, or monitor on either mobile-station or dispatcher lines. He can also take the entire circuit out of operation when necessary for maintenance.

All of the selective signaling equipment used in the system has been procured from the General Electric Company. Three basic units are used: the central office tone generators, the central office tone-operated selective switches, and the mobile station selectors and tone generators. Frequencies used for signaling range from about 575 to 2,750 cycles per second and frequency selectivity is obtained by plug-in RC networks in the feedback path of the electron-tube oscillators or amplifiers that are a part of these units. Frequency stability of the tone generators is plus or minus 0.3 per cent and the pass band of the selectors and tone operated switches varies from plus or minus 1.5 cycles for a 600-cycle unit to plus or minus 6 cycles for a 2,400-cycle unit.

All of the central office equipment mounts in a standard telephone equipment bay. The transmitter output power of the Baltimore trial system is nominally 50 watts, with special cavity resonators used as radio-frequency filters between the transmitting and receiving antenna circuits to prevent interference, Figure 2. A mobile station comprises a combined transmitter-receiver unit, an antenna, a selector unit, and the handset with its cradle.

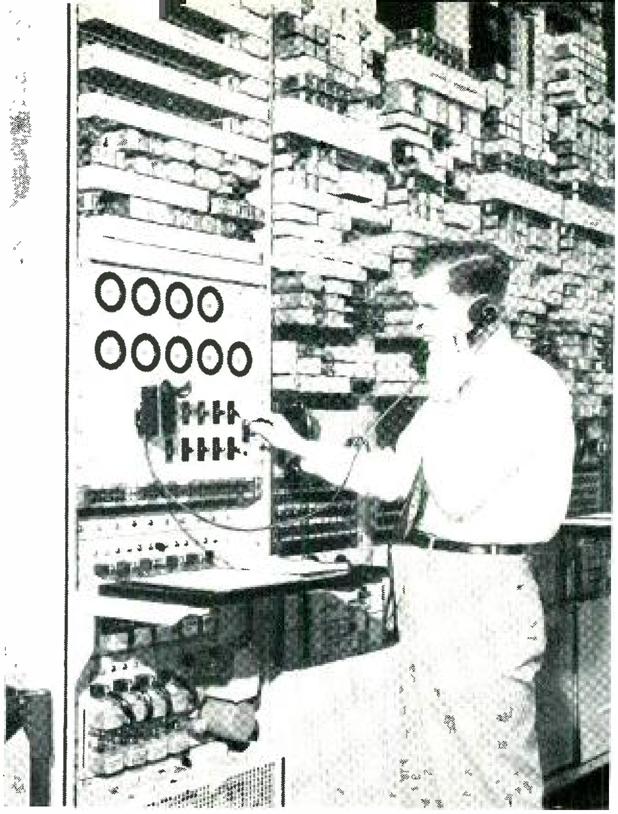


Fig. 3 — The central office equipment provides break-in and control keys for technical operator A. L. Evans of the Chesapeake and Potomac Telephone Company of Baltimore City.

V. A. Douglas was responsible for all the radio systems engineering for the trial system, and all the central office equipment was developed by R. W. Collins of the Switching Systems Development Department.

THE AUTHOR

Alfred E. Ruppel entered the Laboratories in 1935, engaging in the investigation of speech transmission over wire line networks and telephone instruments. He received a B.S. in E.E. from Brooklyn Polytechnic Institute in 1945 and the degree of E.E. in 1947. During the war he was engaged in a project for the National Defense Research Committee, and then entered a study of visual speech as an aid to the deaf, and the production of complex wave spectrograms as an aid to analysis. From 1947 to 1952 Mr. Ruppel was involved in the system engineering of mobile radio telephone systems and the integration of commercially-supplied radio equipment into such systems. In 1952 he aided in tests of over-the-horizon radio transmission, and has since been engaged in the DEW line and SAGE military projects.

Transistors and other semiconductor devices are rapidly assuming a major role in the Bell System, as continued research at the Laboratories provides improved methods for their construction. In this research, tiny contacts must be controlled and located within microscopic distances, and some tool had to be developed to effect such control. Micromanipulators were the answer, and several different types have been developed for use under various conditions.

Micromanipulators

W. L. BOND
Transistor Physics Research

In the early days of transistor research, one of the major problems was that of accurately placing one or more metal contact points on a semiconductor surface. The effectiveness of the research and the answers to many questions about semiconductor electrical activity depended to a great extent on how accurately the contacts could be located. Sometimes, they had to be placed within one one-thousandth of an inch of each other!

This seemed to be a task for which the micromanipulators used in micro-biological experiments might be well suited. A biological experimenter sometimes grasps an amoeba and holds it steady while he gives it a hypodermic injection of some particular fluid. Again, he may wish to withdraw a sample of the fluid contents of a single cell. In either case, he needs microscopically fine controls.

We were unable to buy micromanipulators suitable for our purposes, so we built our own. The first model is illustrated in Figure 1. Here, a piece of angle-iron is solidly bolted to the working surface, to act as a mounting bracket for the other parts. A flat metal plate is attached to the mounting bracket by a strong S-shaped spring. The spring is so made that in its normal position the "S" is collapsed, tending to hold the flat plate close against the mounting bracket. To prevent this, two knurled thumb-screws act as buffers, forcing the plate out a distance determined by the position of the screws. Fastened to the plate is an insulated block with a clamp to hold the contact wire. Adjusting screw A, then, causes the plate, block, and contact wire to rotate about the end of screw B as a center, Figure 1. Obviously, adjusting screw B will cause a similar rotation about the end of screw A. To make the two motions of the contact point occur at right angles, at least over small distances, the point is placed at the 90-degree apex of an equal-sided right triangle. The metal plate is the long side.

In addition, a metal tongue is attached to the flat plate and extends through a slot in the mounting bracket, where it is held against the end of a vertical thumb-screw. Since the ends of screws A and B are above the center of the S-shaped spring, a slight twist in that spring holds the tongue against the vertical thumb-screw. Adjusting the vertical screw causes the flat plate, and therefore the contact point, to rotate vertically about a line connecting screws A and B. If the contact point is in the same horizontal plane as screws A and B, its vertical motion will be perpendicular to the plane of its horizontal motion. This provides three directions of motion, all mutually perpendicular for small movements.

The clamp holding the contact wire can be loosened for an approximate first adjustment of the contact position, and then the fine controls can be used. Because of the physical shape of the micromanipulator, based on a right triangle, only four can be placed around a specimen at one time. Figure 2 shows four units mounted on a base-plate, under a microscope. The positions of the contacts are observed and adjusted easily by using the microscope.

Although this type of micromanipulator has seen much service, the obvious disadvantage of limited bend in the cantilever springs, and hence the vermotions soon prompted S. E. Michaels to build a second type. His design provides considerably greater motion in each of the three directions since the contact point moves in straight lines instead of circular arcs. Three sliding plates, mounted and guided by ball bearings in milled slots, can be individually adjusted with micrometer screws to give the desired motions. The piece of material being contacted may be mounted on a small rotatable base driven by a worm gear or, for extremely fine control of position, on a second micromanipulator.

Both of these micromanipulators are characterized by providing straight-line motions in three directions, each independently controlled. Another type provides more natural control of the contact point through the use of the kinesthetic sense. That is, the feeling that pushing a control lever in a certain direction should push the object being moved in exactly the same direction. This is accomplished through the use of a lever known as a "joy-stick," permitting an operator to make complicated motions quite naturally with one hand. With such a device, one could even write script — almost impossible to do with the screw-controlled types. Figure 3 shows a joy-stick type of micromanipulator in a fairly simple form.

A flat plate is securely mounted to the work surface, and carries a sliding frame. A second flat plate supports the contact point through an adjustable linkage, and is arranged to slide in a channel of the frame at right angles to the fixed plate. The frame, Figure 4, is milled so that it consists of two sets of guide bars connected together only at their corners. When the flat plates, one fixed and the other movable, are fitted into the guide frame, their two surfaces actually touch and they slide against each other. A diagonal metal spring outside each plate keeps them in close contact.

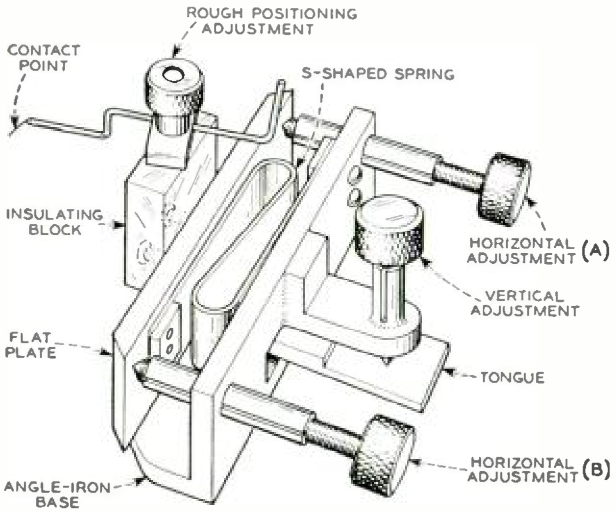


Fig. 1 — An S-spring micromanipulator.

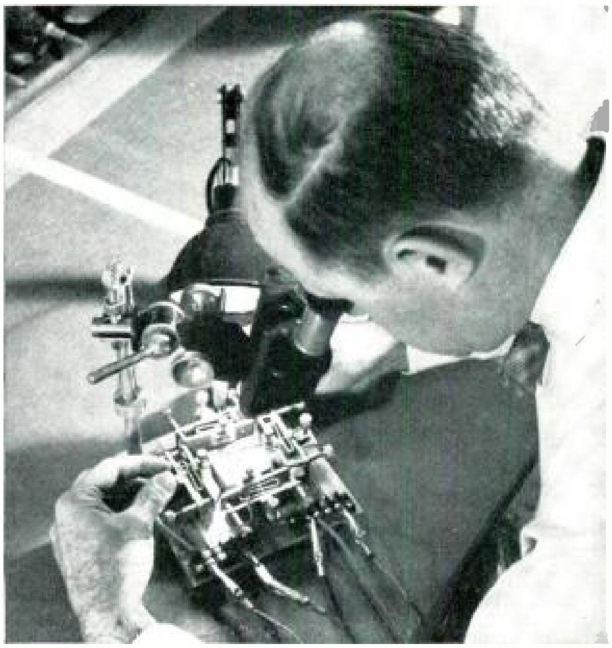


Fig. 2 — Four S-spring micromanipulators are grouped around this piece of semiconductor being studied by J. Andrus.

Some arrangement is necessary to move the frame along the fixed plate and to move the other plate in the frame. Here is where the joy-stick comes in. It is simply a metal rod with one end shaped like a dumb-bell. The extreme lower end is ball-shaped, with a radius of 3/32 inch. The upper part of the "dumb-bell" is slightly larger, having a radius of 1/8 inch. This "dumb-bell" is inserted into holes in the flat plates and is held in position by the shape of the holes. The joy-stick, then, acts as a lever with the fulcrum at the bottom and the object to be moved located between the fulcrum and the motive force. Since the bottom plate is fixed, any motion of the lever is transmitted to the movable frame and the movable plate in the ratio of the lever arms. Thus, the operator can move the lever in any direction and the contact point will move in the same direction, but a much smaller distance.

The contact point is attached to the movable plate by a mechanical linkage which, though adjustable, is quite solid. The point is a piece of metal at the tip of a rod, and the rod is firmly held to an insulating block by an adjustable clamp. This block is attached to another block on the movable plate by two cantilever springs. The amount of

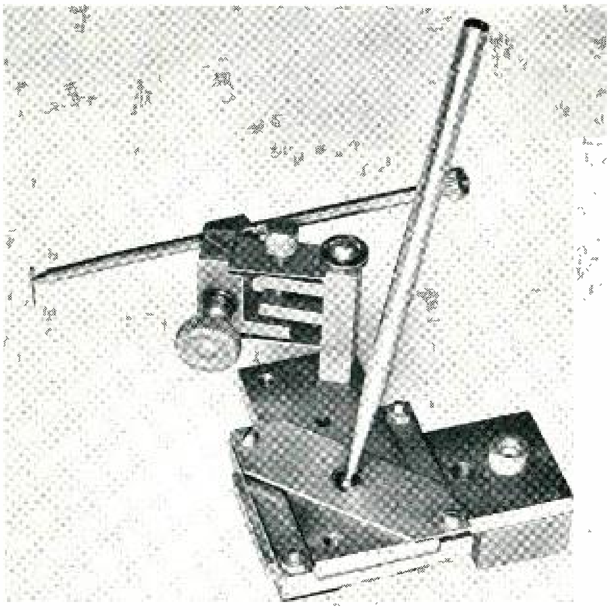


Fig. 3 — A joy-stick micromanipulator.

tical motion of the contact point, is controlled by an adjusting screw.

Ordinarily, a binocular microscope is used to observe the motion of the contact point as in the headpiece. However, when high magnification is required, a monocular microscope must be used. This inverts the motions and the tool seems to move in the opposite direction from that of the operator's hand; the kinesthetic sense is confused. To prevent this condition, extra holes are provided in the two flat plates, so that the assembly can be rearranged with the movable plate beneath the fixed plate. This actually causes the motions to be reversed, but the subsequent inversion of the image by the microscope makes them seem to be occurring in the correct directions.

One might ask what accuracy of movement can be obtained with such devices. It is the writer's experience that the average human hand with suitable support is easily controlled to about 0.003 inch – the approximate limit of visual acuity. Mechanical aids extend this considerably. For example, one can set the graduations of a micrometer to about 0.003 inch if the finger-grip is the same diameter as the calibrated cylinder. Assuming this diameter to be one-half inch, the setting can be made to $0.003/(\pi/2)$ or 1/523 turn. Since each turn is 0.025 inch, one can "set" to 0.025/523 or 0.000048 inch – about 48 *millionths* of an inch!

In the same way, the lever-arm, or joy-stick type of micro-manipulator can be set to 0.003 inch divided by the lever ratio. For a 5-inch arm, the distance between the centers of the two spheres being 1/4 inch, this ratio is 20-to-1; a setting can be made to 0.00015 inch quite readily. Simple changes in the dimensions of the lever can increase this ratio as desired.

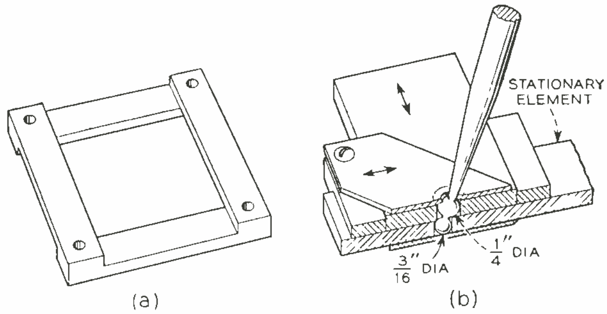
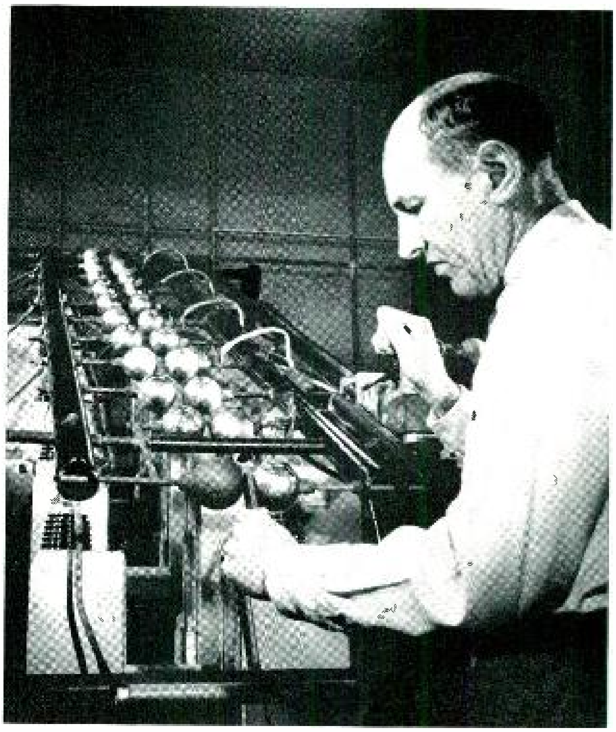


Fig. 4 — The milled frame (a) and a cutaway drawing showing the operation of the joy-stick (b).

THE AUTHOR

W. L. BOND entered the Laboratories in the fall of 1928, after receiving the degree of B.S. in physics in 1927 and the M.S. degree in 1928 from Washington State College. In studies of the piezo-electric effect in minerals, he surveyed the entire mineral field and made similar investigations of many synthetic crystals. He has designed optical, X-ray, and mechanical tools and instruments for the orientation, cutting, and processing of crystals. Mr. Bond also served as consultant on quartz crystals with the War Production Board. He is a member of the American Physical Society and the American Crystallographic Association.

Crushing of Buried Cable by "Cold" Lightning



D. W. BODLE *Outside Plant Development*

Lightning that frequently accompanies summer storms is classified as "hot" or "cold" depending on its electrical characteristics. So-called cold strokes are those that have relatively high surge currents and relatively short decay times. Such strokes can crush telephone cables buried three or four feet deep, even when they strike the ground a considerable distance away. This phenomenon has been studied in the laboratory to help develop protective methods and devices for buried cables.

There is a wide variation in the number of thunderstorms experienced in various sections of the United States. Along the Pacific Coast such storms occur rather infrequently, but in Florida and the Gulf States, the average number of thunderstorms is seventy to eighty each year, the highest in this country. Little of an accurate quantitative nature was known about lightning until the development of the cathode ray oscillograph in the early 1920's. This instrument, for the first time, enabled investigators to record the wave shape and magnitude of lightning discharges.

Lightning is an electrical discharge between oppositely poled centers of charge. Fortunately, many lightning discharges occur within, or between, clouds and do not constitute a physical hazard. A sufficiently large number, however, occur between a cloud and the earth so that lightning constitutes a force that man must constantly reckon with. It has been estimated that, in the United States alone, there are 25 to 30 million strokes to earth annually.

Reports are relatively common of buildings being ignited by lightning, and it is on the basis of these so-called "hot" strokes that the popular conception of lightning has developed. Those who have investigated the subject further, however, know that there is also a "cold" type of lightning that can produce very destructive explosive pressures, and yet leave practically no trace of fire or fusing on the materials subjected to the discharge.

Lightning current is primarily a surge, rising to its crest value in a few microseconds and decaying exponentially at a considerably slower rate. It is customary to define the wave shape of a lightning surge by two numbers such as 5 x 40 where both values express time in microseconds. The number 5 represents the rise time of the current from zero to crest value, and the number 40 is the time interval from zero to a point on the decaying wave tail at which the current has fallen to half of its crest value.

The difference between hot and cold lightning is illustrated graphically in Figure 1. The 5 x 20 microsecond surge of 60,000 crest amperes typifies the wave shape of cold lightning. The 5 x 60 microsecond, 20,000 crest ampere surge is characteristic of hot lightning. Coulomb values or area under the curves (the product of current and time) of these two waves are approximately equal.

The great majority of lightning strokes that reach the earth occur between a negatively charged cloud and corresponding positive charges in the earth. The conventional direction of stroke current flow is, therefore, from earth to cloud although it is common to speak of such lightning as "strokes to earth." Not all strokes to earth can be clearly classified as either hot or cold type. Occasionally there is a stroke having an unusually large coulomb value that is particularly destructive because it produces both explosive and burning effects. Such a stroke is characterized by a very high initial crest current followed by a continuing, lower magnitude current that may last as long as several milliseconds.

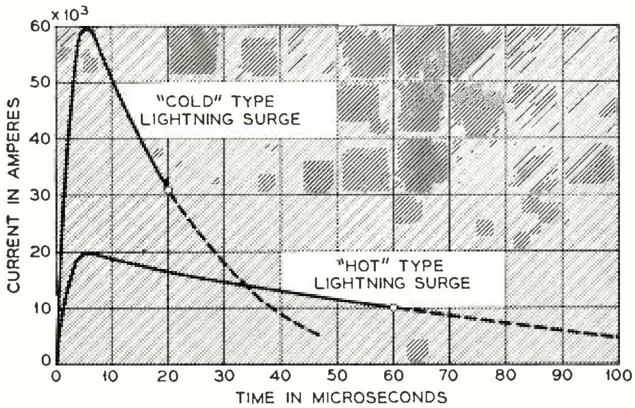


Fig. 1 — Typical current-versus-time curves for hot and cold lightning.

It may come as a surprise to some that lightning frequently damages objects that are buried in the earth. A telephone cable buried at a depth of three to four feet may be damaged by lightning that strikes the earth a considerable distance away. Although buried cables do not attract lightning in the popular sense, they do provide an attractive "sink" for strokes to earth since they are an excellent grounding medium. Consequently, lightning may arc to cables over distances of 30 to 40 feet. This frequently takes place over the surface of the ground because the potential gradient required to establish an ionized path over the surface of the earth is considerably less than that required to produce a similar path directly through the soil. It is quite common, therefore, to observe surface furrows running from the point of contact of a lightning stroke toward a cable. Also, a crater-like hole in the earth may sometimes be seen near the cable where the stroke current departed from the surface and arced through the soil to the cable sheath.

Metal fences are attractive targets for lightning and the stroke current may travel considerable distances on the fence wires to reach a metallic cable sheath where such a sheath offers the best ground in the area.

Cold lightning arcing to a buried cable will, in many instances, produce a dent in the sheath as shown in Fig. 2. The sizes of these depressions depend upon such factors as the resistance of the cable structure to crushing, the soil environment, and the characteristics of the lightning stroke. It is interesting to note that such dents frequently show little evidence of fusing on the external metal armour or the cable sheath. It is not uncommon for a representative coaxial cable, having an outside sheath diameter of approximately 2½ inches, to sustain sheath dents 5 inches long and ¾ inch deep. A cable of this type usually contains eight 0.375-inch diameter coaxial tubes surrounded by 19-gauge paper insulated conductors, all of which are enclosed in a lead sheath having a wall thickness of 0.113 inch. Various coverings such as steel tape or wire armor are sometimes applied over the sheath of buried cable to provide additional mechanical protection for various purposes. Tests indicate that, with the exception of the use of heavy wire armor, these coverings are able to provide little additional resistance to crushing.

Cable conductors having either paper or plastic insulation are less susceptible to failure from sheath denting than coaxial tubes, as the insulation can be damaged only by rather severe compression. Furthermore, the operating potential on such conductors is very low, and an appreciable reduction in dielectric strength may occur without affecting service. The tubes of Bell System coaxial cables, however, employ thin insulating discs spaced at one inch intervals to center the inner conductor. Consequently, the tubes are essentially hollow and relatively inflexible, and any external pressure tends to deform them permanently. Investigation has established that sheath dents exceeding about one-fourth of an inch in depth will impair the dielectric

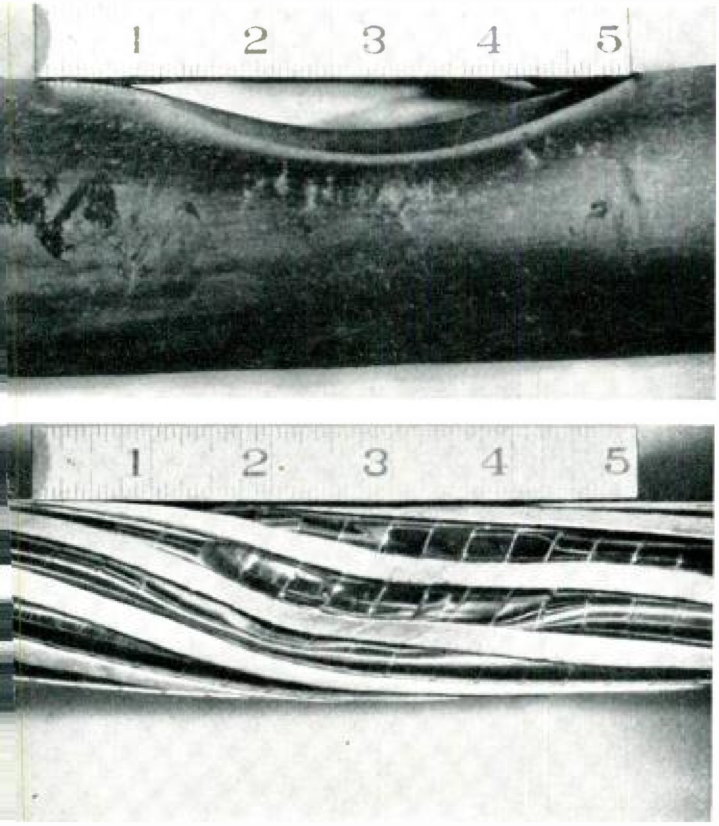


Fig. 2 — (Top) characteristic sheath dent produced by cold lightning generated in the laboratory; and, bottom, coaxial tube crushing produced by the dent shown above.

strength of the tube directly under the point of maximum compression. Adjacent tubes are affected as the depth of the sheath dent increases.

Type-L carrier will operate satisfactorily on these coaxial lines in spite of an occasional slight dent in the outer coaxial conductor. But 60-cycle power for the intermediate carrier repeaters is also transmitted on the coaxial lines, and a small reduction in the spacing between the inner and outer conductor may cause corona or flash-over from the power voltage and disable the carrier system. Power potential differences between the inner and outer coaxial conductors, measured close to a feed point, may be as high as 1,200 volts rms with L1 carrier, and about double this value with L3 carrier.

There are approximately 5,800 miles of buried coaxial cable in the Bell System, and most of the crushing troubles have occurred in only about half of this mileage. The highest rate of trouble occurs in the southeastern part of the country where the average incidence of thunderstorm days is high and the cables are frequently located in very damp soil. Cases of trouble in which coaxial tubes are crushed have run as high as 24 per year throughout the country. In ordinary telephone cable of the same mileage, this would not be considered a high trouble rate, but coaxial cables are a much busier transmission medium, and any trouble involving even a single coaxial line may cause a major traffic interruption. As would be expected, when coaxial cables are damaged, great effort is made by the field forces to restore service as quickly as possible by providing an emergency bridge around the fault. This is ordinarily accomplished by placing a section of coaxial cable on top of the ground. The task of locating the fault and splicing in temporary coaxial lines requires many hours of highly organized effort, and the permanent repairs require considerable additional time. When such cable failures occur, immediate steps are taken to reroute the affected service over alternate facilities.

Although buried cables are suseptible to crushing troubles from which aerial cables are immune, the amount of general lightning trouble does not differ materially between these two types of plant. Buried cables, however, are much less subject to troubles resulting from mechanical injury which constitute the major portion of all troubles in aerial plant.

The phenomenon of cable crushing has been du-

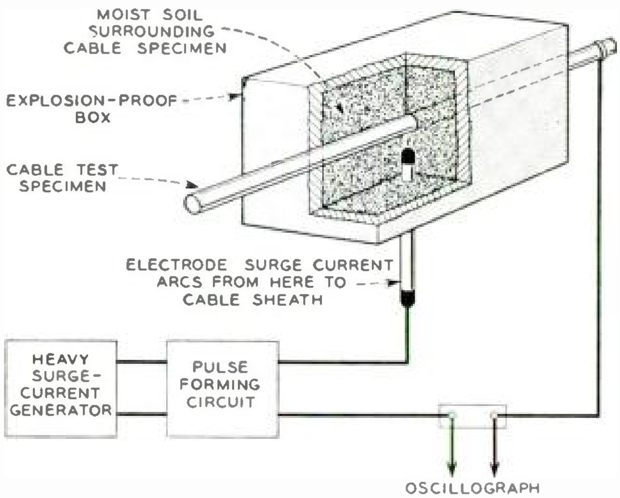


Fig. 3 — Laboratory set-up that is used in cable crushing investigations.

plicated in the laboratory by applying surge currents to cable specimens buried in various environments. To generate surge currents comparable to those of natural lightning requires a surge-current generator of exceptional capacity. Since few laboratories are equipped with such facilities, we were fortunate in securing the use of the heavy surge-current generator in the High Voltage Laboratory of the General Electric Company at Pittsfield, Massachusetts. Bell Telephone Laboratories engineers with the cooperation of members of the technical staff of the General Electric Company conducted a series of tests that yielded much significant data concerning this problem. A typical set-up for these tests is illustrated in Figure 3. It was found that water in the soil is vaporized with explosive violence by the heat of the lightning arc, and damaging pressure between the cable and the soil is developed by the expanding vapor. Consequently, a high moisture content in the soil is the principal environmental factor associated with cable crushing. In fact, it has been found that cable specimens immersed in water alone may be severely dented. It has also been found that compact clay soil is somewhat more conducive to the denting of cables than sandy soil.

Fig. 4 — D. G. Neumann and S. Harris of Bell Telephone Laboratories preparing a specimen of a cable to be tested in an explosive-proof box. Part of the heavy current generator can be seen in the background.

The significance of the rate of rise of lightning current wave fronts was investigated by surge tests in which the decay time and coulomb value of the applied surges were held approximately constant. It was found that variations in the rate of rise made no noticeable difference in the depth of sheath dents. It was subsequently established that a surge having a high crest current and a short decay time,

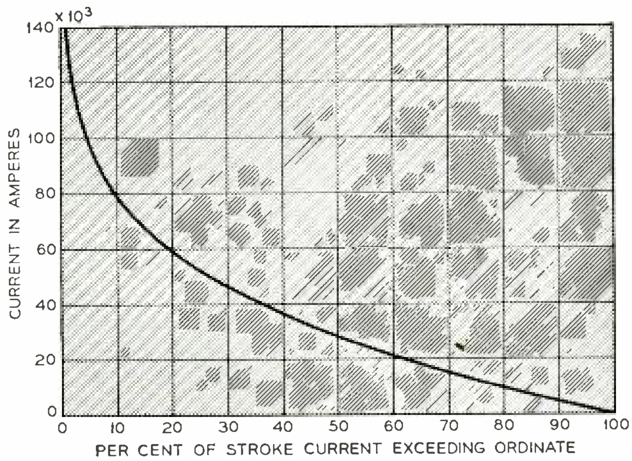


Fig. 5 — Current magnitude distribution in lightning strokes to buried cable.

such as 20 microseconds or less to half-crest value, will produce large sheath dents with negligible fusing. A surge of the same coulomb value but having a longer decay time and correspondingly lower crest magnitude will produce less denting but considerably more fusing of the sheath. When the soil adjacent to a cable is wet, it is estimated that about 30 per cent of the strokes arcing to that cable will produce crushing.

Bell System coaxial cables have sufficient mechanical strength to withstand denting pressures developed by strokes having critical wave shapes and current magnitudes up to about 40,000 amperes. These coaxial cables reflect a good economic balance among the various factors involved in cable design. Studies have established that it is economically impractical to construct cables having sufficient mechanical strength to withstand the crushing pressures developed by higher magnitude stroke currents. The most feasible remedial measure is the installation of a buried shield wire on each side of a cable in those sections where the rate of trouble justifies the expense entailed. A 0.162-inch bare copper conductor plowed into the earth on each side of a cable at a depth about two-thirds that of the cable, and spaced three to four feet from it, will intercept about 90 per cent of the strokes that would ordinarily arc directly to the cable. An appreciable amount of the stroke current will leak off to ground along this wire, but the higher magnitude strokes will produce sufficient potential between the shield wire and cable to cause subsequent arcing between them. The potential that produces such arcing is a function of the stroke current magnitude and the surge impedance of the shield wire. It is unlikely that strokes with less than about 80,000 amperes will produce sufficient voltage to ionize a path between a shield wire and a cable. Once such a path is established, however, about 60 per cent of the total stroke current will produce flashover to the cable.

This analysis might indicate, at first, that shield wires do not provide appreciable protection against cable crushing. As shown in Figure 5, however, the distribution of current magnitudes in strokes to buried cables is not a linear relation. This non-linear distribution provides an additional benefit, which is of considerable significance when applying protection. For example, it was previously mentioned that stroke currents exceeding 40,000 amperes may cause tube crushing. From this curve it may be seen that 37 per cent of the stroke currents equal or exceed 40,000 amperes. With a shield wire, the minimum current producing flashover to the cable is about 80,000 amperes, and this curve indicates that only 10 per cent of the strokes will attain this magnitude. In effect, therefore, the shield wire provides an improvement of 3.7 to 1. When the stroke current magnitudes exceed 80,000 amperes, subsequent arc-over to the cable will occur. Only about 60 per cent of the initial stroke current will reach the cable, however, and hence the degree of crushing will be materially reduced. The use of additional shield wires would provide some further reduction in the number and size of cable dents but the increased benefits generally do not justify the extra expense.

Coaxial cable crushing continues to be a disturbing operating problem. The rate of crushing trouble averages about eighteen occurrences per year, but because these troubles are randomly distributed, the installation of buried shield wires over many miles of cable appears to be uneconomical at this time. The economic balance, however, may shift in favor of shield-wire protection with greater use of L3 carrier.

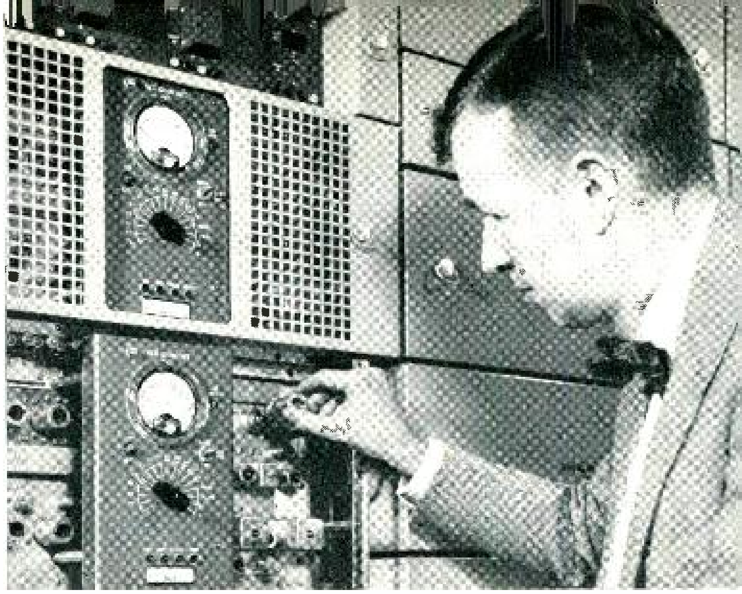
These tests and studies of the factors involved in the crushing of coaxial cable by lightning have added greatly to our knowledge of the subject. This knowledge has been applied in the development of suitable shield wire protection and will also be of value in future cable design.

Fig. 6 — Repairing a coaxial cable crushed by lightning that initially struck the tree at the left. Pumping was required to keep the pit dry during this operation.

THE AUTHOR

D. W. Bodle entered the Development and Research Department of the A.T.&T. Co. in December, 1929, where he was associated with a group studying inductive coordination and joint-use problems. He became a member of the Laboratories in 1934. Mr. Bodle's experience has been chiefly in the field of protection of equipment against foreign potentials and the protection of personnel from electric shock. In this connection he has engaged in several field investigations of the characteristics of natural lightning. During World War II he was concerned with the design of cathode-ray indicators for airborne radar. Mr. Bodle received a B.S. degree in Electrical Engineering from New York University, is a licensed professional engineer and a member of the A.I.E.E. and of the I.R.E.

Automatic Protection Switching for TD-2 Radio



B. C. BELLOWS, JR.
Transmission Systems Development I

The dependence of television programs and hundreds of telephone conversations on the reliability of the TD-2 microwave radio relay system makes it mandatory that transmission over the system be uninterrupted. Automatic protection switching, developed at the Laboratories, acts as a super-watchman with very fast reflexes. Should fading or other trouble occur on the microwave system, this watchman takes the necessary action to substitute a protection channel for the channel in trouble, and does it so fast that television viewers and telephone users are usually unaware of the change.

Thousands of long-haul telephone conversations and many network television programs are transmitted daily over more than nine million miles of telephone circuits and fifty thousand miles of television circuits by the Bell System's TD-2 microwave radio relay system. Obviously, the system must be kept as free as possible from interruptions of any kind. Unfortunately, atmospheric conditions sometimes interfere with microwave transmission, causing the signals to fade out for seconds at a time. Even when atmospheric conditions are perfect, failure of the radio equipment in one of the many stations through which the signals pass may cause an interruption. From coast to coast, for example, a signal must pass through 105 TD-2 radio stations. Failure of any one of more than 2,500 electron tubes, 21,000 capacitors, or 18,000 resistors could interrupt such a channel and mean the loss of a TV program or several hundred telephone conversations.

Aging tubes and parts about to become defective can usually be found and replaced during routine tests without interrupting service. There are, however, a certain number of unpredictable equipment failures that can affect service. Although such failures are few, the problem of fading is always with us. To make radio relaying meet Bell System standards, a way had to be found to overcome these problems.

It seemed fairly obvious that a spare channel would protect against equipment failures, but for fading the answer was at first not quite so obvious. Suppose all channels faded at once; what good would a spare channel be then? It was found from many measurements, however, that fading at microwave frequencies is generally selective – it affects only one channel at a time and shifts rapidly from one channel to another. A spare channel would be sufficient protection against fading if it could be substituted rapidly enough for a channel in trouble. This substitution is accomplished automatically by protection switching equipment, Figure 1, developed at the Laboratories, the protection equipment acting as a watchman who keeps his eyes open for trouble on the microwave channels.

Each channel of the TD-2 microwave system can transmit either a TV signal or hundreds of telephone signals that are "stacked" frequency-wise. This baseband is frequency-modulated onto a 70-mc carrier, known as the IF carrier, by the transmitting terminal. Repeater equipment at the terminal then converts the 70-mc signal into a microwave (4,000 mc) signal for transmission. At each intermediate station the received microwave signal is converted back to 70 mc, amplified, and converted to microwave again for further transmission. At the receiving terminal station, the 70-mc IF signal is fed to receiving terminal equipment that extracts the base-band TV or "stacked" telephone signal. The automatic switching equipment, Figure 2, operates at 70 mc and protects against failures in the microwave terminals and repeaters, and against fading in the transmission paths. Other means are employed to protect against failures in the FM transmitting and receiving terminals and in entrance-link equipment. "Program" switching — switching required to meet TV program needs — is also done at 70 mc.

Two different sets of switches are needed for the automatic switching job. The upper part of Figure 4 shows how the switches operate to substitute the protection channel for a regular channel. When a channel encounters trouble, the protection channel is switched so as to parallel the troubled channel; *both* then carry the same signal. At the receiving station, the switching equipment determines which of the two channels — regular or protection — is better and connects it to the next repeater or the receiving terminal. If the protection channel should be in use, or should happen to be unsatisfactory for transmission, the regular channel is continued in operation.

If operators in the two terminals could communicate with each other, the switching system could be operated manually. However, to minimize interference with TV, with telephone conversations, and particularly with long-distance dialing, the entire operation of recognizing trouble and substituting the protection channel should be completed in less than one-twentieth of a second. What was needed

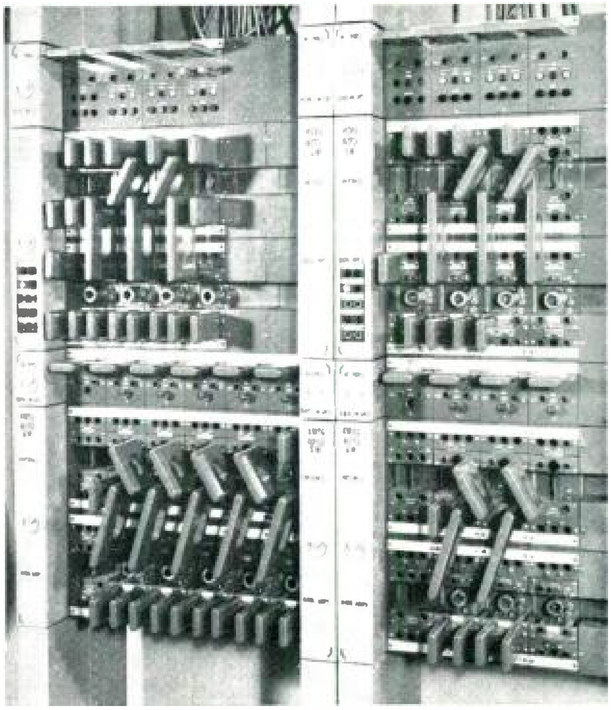
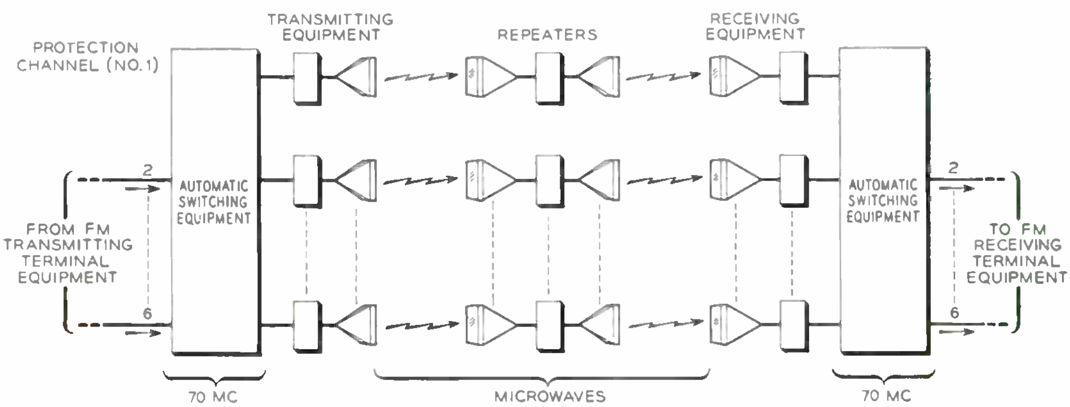


Fig. 1 — Part of the automatic protection switching equipment, showing coaxial switches, bridging amplifiers, and the new coaxial patching plugs.

for this switching system was a sort of "superman" to watch the transmission, a superman whose long arms could operate the switches at both ends of the microwave link with super-human speed. The automatic switching system as finally developed does just this.

How does the switching system know when a switch is necessary? The "brain," shown in block form in the lower part of Figure 4, determines this from the signal-to-noise ratio of the channel in trouble. When the signal input to a repeater falls off because of fading, the repeater automatically increases its gain to bring the signal up to normal

Fig. 2 — The automatic switching equipment protects against failures in all but the FM terminal equipment and entrance-link equipment.



strength. This, however, also increases the amplification of noise that is always present in the repeater input circuits. As the signal weakens, the noise becomes proportionally greater and may eventually overpower the signal completely.

Although the base-band signal frequencies usually extend only up to about 5 mc, the noise modulation extends to about 10 mc. The switching system samples the incoming 70-mc signal, demodulates it to base-band, and samples the base-band energy in a narrow band centered at 8.89 mc. Since there should be no signal energy at this frequency, any energy present is assumed to be noise. If this energy exceeds a predetermined amount, the system decides that the channel is too noisy and must be switched.

Each channel, including the protection channel, is watched over at the receiving end of a switching section by a device called an initiator, Figure 5. Its job is to watch the quality of transmission and "initiate" the switching operation when its channel fails. When a failure occurs, it indicates to a receiving control circuit that its particular channel is in trouble. Normally, the control circuit transmits a continuous 700-cycle "all is well" tone over a voice-frequency circuit to the station at the transmitting end of the switching section. When a channel fails, the 700-cycle tone is replaced by a tone indicating the number of the channel in trouble—

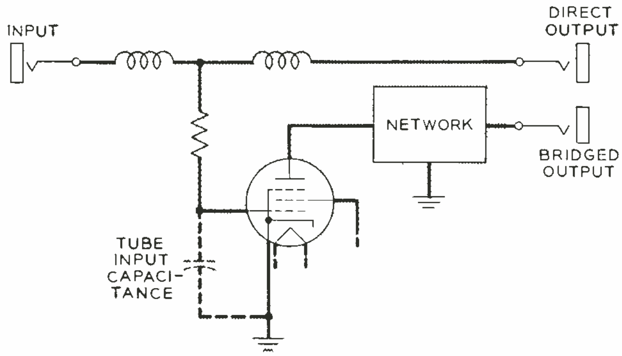


Fig. 3—The input capacitance of a bridging amplifier acts as part of a filter circuit.

900 cycles for channel 2, 1100 cycles for channel 3, and so on. At the same time, the control circuit prepares to operate the receiving switch in the troubled channel.

At the transmitting station, the protection channel is normally fed a signal from an "IF pilot resupply" unit. This signal is a 70-mc carrier, frequency-modulated by an 8.52-mc pilot. The initiator, watching the protection channel at the receiving station, recognizes the 8.52-mc pilot as indicating that the protection channel is idle. When the tone on the voice-frequency circuit changes from 700 cycles to another frequency that identifies a particular channel, the transmitting control circuit

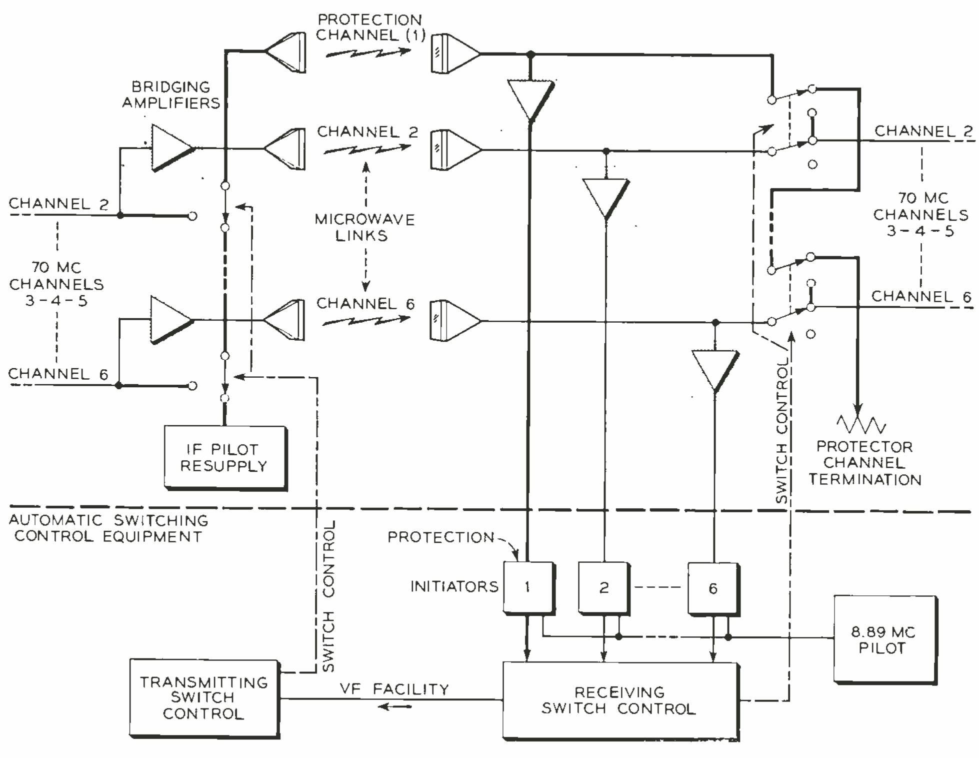


Fig. 4—Transmitting and receiving switch controls operate the switches to substitute the protection channel for a regular channel in trouble.

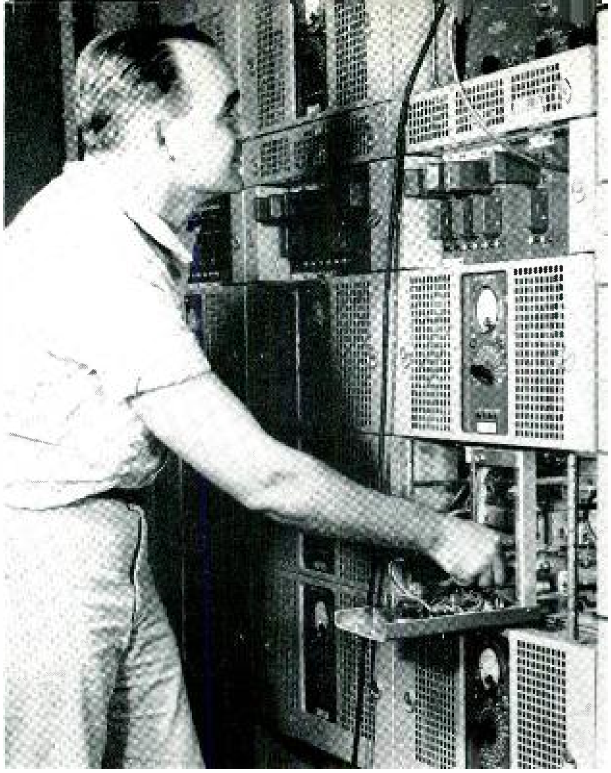


Fig. 5 — Donald H. Depew of the Long Lines Department of A.T.&T. adjusts an initiator while watching the test meter.

operates the transmitting switch in that channel. This disconnects the protection channel from the IF pilot resupply and bridges it across the channel whose switch has been operated.

When the protection-channel initiator finds a good signal without the IF pilot on the protection channel, it knows that a transmitting switch has operated and passes this information on to the receiving control circuit. The control circuit then operates the proper receiving switch, feeding the 70-mc equipment from the protection channel instead of from the channel in trouble.

The entire series of events — discovering a noisy channel, changing the voice-frequency tone, operating the transmitting switch, recognizing this at the receiving station, and operating the receiving switch — takes less than one-twentieth of a second.

As soon as the regular channel recovers, its initiator indicates the fact to the receiving control circuit, which releases the receiving switch. The 700-cycle "all is well" tone is restored, causing the transmitting control circuit to release the transmitting switch and return the protection channel to the IF pilot resupply. When this pilot is recognized at the receiving station, the receiving control circuit completes its restoration to normal and the system is ready for another switching operation.

The receiving control circuit also provides the maintenance force with information on the state of the microwave system. Alarms are sent out if any channel needs protection for longer than about one-half minute, if any channel does not get needed protection because the protection channel is in use or in trouble, or if certain internal failures occur in the switching system. The transmitting control circuit provides an alarm if at any time it receives no tone over the voice-frequency circuit, and maintains the transmitting switches in "status quo" until the tone is again received.

Three new devices were developed especially for the switching system: a coaxial switch, a bridging amplifier, and the initiator. Although the system could have been developed to use electronic switching equipment, the coaxial switch permitted a reduction in the size of the equipment and made it economically more attractive. In this switch, glass-sealed mercury switch elements* are inserted in metal castings, specially shaped to maintain the characteristics of a 75-ohm coaxial line. A coil, wound around each switch element, magnetizes the armature to operate it. Since there is enough capacitance between the open contacts to pass some 70-mc signal, switch elements are arranged in groups so that temporarily unused contacts are terminated by short-circuited pieces of coaxial line.

A bridging amplifier was needed because the protection channel at the transmitting station and the initiators at the receiving station must be bridged across regular channels without affecting their transmission. The obvious method of bridging the grid of an electron tube across the line is unsuitable because the input capacitance of the tube shunts the line too heavily at 70 mc. The problem was solved, Figure 3, by inserting in the line a low-pass filter that has negligible effect on the

* RECORD, *September*, 1947, *page* 342.

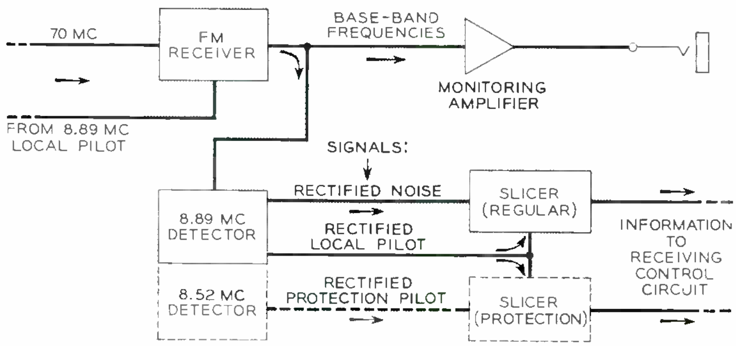


Fig. 6 — DC signals representing the noise and pilot amplitudes are compared in an initiator.

through transmission, and using the input capacitance of the tube as one of the filter elements. The branch output is then taken from the plate circuit of the tube.

The third device – the initiator – measures the quality of transmission on a channel. After the incoming signal is reduced to base-band, Figure 6, a narrow band centered on about 8.89 mc is examined for noise content. To minimize variations in detector sensitivity, an 8.89-mc pilot signal is added to the received FM signal so that it appears in the base-band output only when an FM signal is present. The detector then compares the channel noise with this pilot signal; any change in the detector gain affects both signals equally and so does not change their amplitude ratio. The noise-to-pilot ratio is indicated by the "rectified noise" output while a second output indicates "rectified pilot." Since the local pilot signal appears at the detector only when an FM signal is present, the "rectified pilot" indicates the presence of a received signal on the channel being served by the initiator.

A "slicer" circuit compares portions of the two outputs and tells the receiving control circuit when either of the dc outputs is not within prescribed limits, indicating that a channel is in trouble. The initiator for the protection channel also has a second narrow-band detector tuned to 8.52 mc to determine when the protection channel is idle. The initiators, then, tell the receiving control circuit when an FM signal is present, when the noise on some channel is excessive, and when the protection channel is idle.

This automatic protection switching system was first placed in service between Chicago and Sacramento, Cal. Careful studies are now being made on the effectiveness of the system in reducing interruptions to service. Present indications are that the improvement is substantial, and the reliability of television and telephone service routed over the TD-2 microwave radio relay system is well within the requirements of Bell System service.

THE AUTHOR

B. C. Bellows, Jr., received the degree of B.S. from Cornell University in 1936 and then spent three years with the General Electric Company before joining the Laboratories. From 1939 to 1941 he was engaged in engineering trial installations of telephone equipment, particularly multi-channel coaxial-cable equipment. During the war he was involved in mechanical design and gave engineering assistance to Western Electric on airborne radar for the Armed Forces. Since 1945 Mr. Bellows has been engaged in the design of circuits and equipment for point-to-point microwave radio relay systems for telephone and television.

Improving Mobile Radio System on New York Thruway

The Laboratories, in cooperation with the New York Telephone Company, has made extensive tests designed to find ways of minimizing interference or "hash" between adjacent base stations which transmit on the same nominal frequency in the New York Thruway mobile radio system.

Remedial measures will consist of equalizing the transmission delay in the connecting wire lines and providing precise oscillators at the base stations. The oscillators are being designed to maintain a frequency stability of one part per million per month. By these means, the two signals received from adjacent base stations will be close enough together so that the resultant signals will be much more intelligible.

Extensive tests made by the Laboratories Transmission Engineering I Department, and confirmed by the New York Telephone Company, indicate that a significant improvement can be expected in the affected areas.

An electron tube operating in an assumed safe environment may actually be subject to shock or vibrations beyond its rating because of local conditions in the tube's immediate vicinity. By using suitable accelerometers, it is possible to determine the actual mechanical disturbances at a tube's socket. This knowledge becomes the basis for corrective action leading to higher reliability through improvement of tube or equipment structure.

Vibration and Electron Tube Reliability

F. W. STUBNER *Electron Tube Development*

Modern electron tubes are astonishingly rugged and durable compared with their counterparts of only a few years ago, yet some important questions about tube shock and vibration resistance still remain unanswered. If we choose an item of electronic equipment for test, say a radio receiver, and if we subject it to a mechanical shock, we can determine very accurately the magnitude of the shock as it affects the entire unit. But what are the mechanical forces that apply to the individual electron tubes of the receiver, and, within these tubes, what magnitude of shock applies even to the internal components like cathodes, grids, and plates?

Often not fully appreciated is the fact that the effect of such smaller-scale, individual impacts or vibrations can be far greater than would be suspected from a knowledge of the more general environment. Much adverse criticism of poor tube performance is actually due to unsuspected disturbances that exceed the tube's rating.

Measuring mechanical vibrations and shocks at the tube sockets is difficult because of the possible effect of the measuring equipment itself, and investigation has become possible only recently through the development of special accelerometers. At present, barium titanate, a ferro-electric ceramic, is generally used for the sensitive elements in these devices. This material, acting as an electromechanical transducer, converts mechanical motion into an electrical signal that can be recorded or viewed on an oscilloscope.

For small tubes, accelerometers are made with nearly the same size, shape, weight, and weight distribution as the tube being tested. When substituted for a tube in actual or simulated field conditions, the accelerometer thus reflects the mechanical conditions that the tube itself will encounter. Figure 1 shows several accelerometers made to resemble electron tubes. For larger tubes, small accelerometers can be attached directly to the tube envelopes without seriously affecting the magnitude and frequency of the mechanical forces being measured. Since the accelerometers have one or more sensitive axes, they must be properly oriented to measure accelerations in the desired directions.

Sustained equipment vibrations are probably the major cause of unsatisfactory tube noise and mechanical failure. Vibrations, if they are severe enough and if they have the right frequency components, may excite relative motion between tube elements which, in turn, will produce unwanted signals in the tube output. This phenomenon is called microphonism. Such motion can lead to a rapid deterioration of tube characteristics. The left part of Figure 2 shows the microphonic response of a W. E. 436A tube (lower trace) to a vibratory disturbance (upper trace) having a fundamental frequency of 280 cycles per second.

Naturally, the best way to determine a tube's response to mechanical disturbances is to observe its behavior in actual field conditions. This procedure, of course, is often difficult and costly, and is

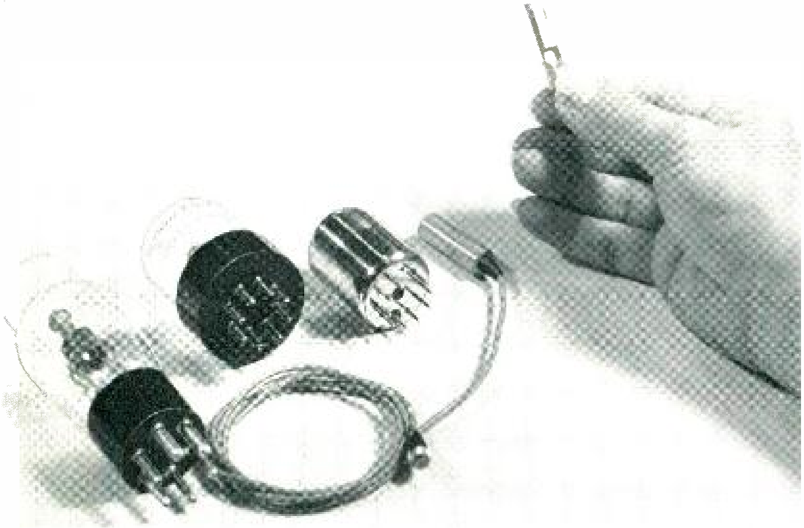


Fig. 1 — Various types of barium titanate accelerometers: these duplicate actual electron tubes in size, shape, weight, and weight distribution.

sometimes impossible, but for many cases a good substitute is available. Accelerometers can be placed in field equipment, and, instead of observing performance on the spot, a tape recording of the output signal is made. The tape can then be brought into the laboratory and the recorded signal used to operate a dynamic vibration machine. The vibrations are thus "played back" to achieve an approximation of actual conditions. The play-back apparatus is seen in the illustration at the head of this article, and oscilloscope records of a signal and its played-back counterpart are seen in Figure 3, left. Since the play-back is a replica of the initial disturbance, a tube's response to the environment depicted can be checked on the test equipment.

The play-back method, though it sounds simple, requires careful laboratory technique. Since faithful reproduction is limited by the capability of the recording and reproducing systems, the play-back of complicated waveforms requires equipment especially designed for the purpose. However, it has been possible to explore the feasibility of this technique with relatively simple waveforms on the available equipment.

To ease the task of play-back, some of the components of a complex wave may be omitted in many cases. The possibility of such simplification is illustrated in the right part of Figure 2. The upper trace shows the vibration at the left in the figure with its high-frequency component suppressed. The lower trace again is the response of the W. E. 436A tube to this simplified wave. It can be seen that it is identical with the response resulting from exposure to the complex waveform at the left. Therefore, for the purpose of determining the response of this tube, the inclusion of the high frequency component in the play-back is not essential. By using adjustable filters, the influence of each component of a complex wave on the tubes under test can be determined. It must be kept in mind that in actual use, vibrations can occur in many dimensions, whereas a vibration machine will play back the vibration in only one dimension at a time. This requires the determination of the direction (or directions) that are most damaging to the tube.

Investigations of equipment disturbances experienced by tubes are usually prompted by malfunctioning of circuits or by mechanical tube failures. It has been found that in some cases the disturbances exceed the specification limits of the tubes employed. These conditions are not always foreseen in the initial design stages, and a true picture can be obtained only by acceleration measurements during equipment tests or field trials. As mentioned above, such measurements are made by substituting a suitable accelerometer for the tube under investigation. The resulting recording can be analyzed to determine the magnitudes and nature of the forces acting on the tube. Frequently, equipment changes suggest themselves to reduce these forces, obviating the need of expensive tube redesign or a change in tube codes.

Two examples will illustrate the type of disturbance to which tubes may be exposed. The first is a problem of maintenance handling of electronic equipment. Frequently, a unit of equipment is not delivered to a customer until it passes a "drop test" intended to simulate transportation environmental conditions — for instance, it may have to withstand a drop of several feet onto a hard floor without impairing the performance. In the example chosen, an accelerometer was substituted for one

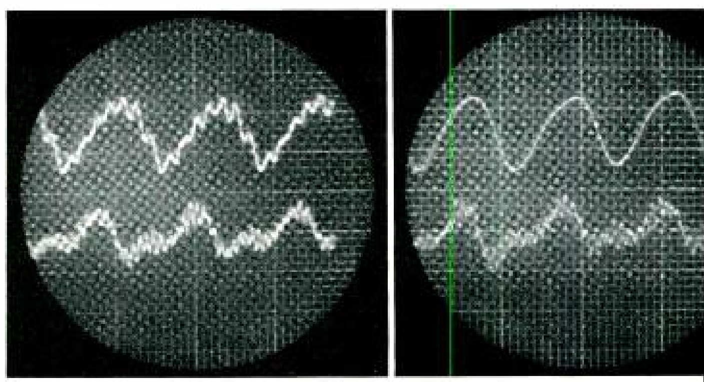


Fig. 2 — Left: forced vibration, above, and resulting microphonic response of W. E. 436A tube, below; right: fundamental of the forced vibration, above, and identical tube response, below.

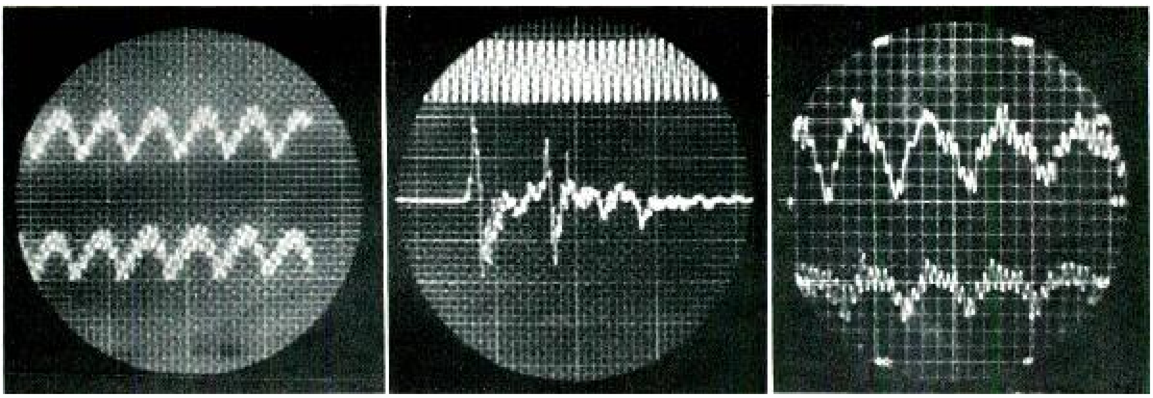


Fig. 3 — Left: oscilloscope photo showing (above) signal as recorded on tape, and (below) signal recorded from vibration-table play-back. Fig. 4 — Center: oscilloscope record of mechanical shock on electron tube when amplifier is dropped to floor. Timing signal above. Fig. 5 — Right: high-acceleration vibrations of a rectifier tube at simulated altitudes of 50,000 feet (above) and 60,000 feet (below).

of the tubes and an oscilloscope record was made of the impact. Figure 4, center, shows such a shock pattern. The lower trace in this figure represents the transient accelerations experienced by the tube, reaching a maximum value of 150g. The upper trace is a 1000-cycle timing wave.

The second example has to do with a unit of airborne equipment. A rectifier tube in this unit was found to have a high rate of mechanical failure. Accelerometer measurements showed that during simulated altitude tests at 50,000 to 60,000 feet, the rectifier was exposed to destructive vibrations exceeding 10g (see Figure 5, right). After the magnitude and frequencies of these vibrations had been determined by accelerometer measurements, the task of locating the source of trouble was simplified. The cause was traced to air blowers, which, when they speeded up to deliver the required volume of air at high altitudes, set up the destructive vibrations. In the absence of the accelerometer data, one might have called for an expensive change of tube design, but the problem was solved by an alteration in the vibration mounting of the blowers involved.

Investigations of mechanical environment have only begun. Although many of the present tests are useful for certain checks — especially for economical production testing — more realistic tests will have to be added to investigate the tubes' performance under actual service conditions. The trend is away from short-duration, fixed-frequency vibration tests toward fatigue vibration cycling tests over a large portion of the audio frequency spectrum. Shock machines and tapping devices are now being improved to probe the tubes' response to well defined conditions.

For a better utilization of simulated environmental testing, improvements will have to be made in existing machines and auxiliary equipment for accurate reproductions of complex waveforms. It is expected that the complicated disturbances can be reduced to include only those components essential to the testing of the particular type tube. This will keep requirements in tube specifications and demands on test equipment at a minimum.

THE AUTHOR

F. W. Stubner received his B.S. degree from Cooper Union in 1930. The preceding year he had become a member of the Laboratories' research drafting department. Later, in the capacity of design engineer he was concerned with the design and building of apparatus and testing equipment for telephone instruments and submarine cable. Transferring to the Electronics Apparatus Development Department in 1940, he worked on the design of electron tubes, magnetic switches, and glasswork for the deposited carbon resistors. Since 1944 he has been associated with the applied mechanics laboratory, responsible for mechanical tests on electron tubes, shock and vibration studies, and associated design assignments. Since 1948, he has been located at Allentown, Pa. Mr. Stubner is a member of the I.R.E. and the Society for Experimental Stress Analysis.

The need for more toll circuits up to about 200 miles in length has increased rapidly in recent years. A large number of long-haul type-K systems, already in use on toll cables, were not suitable for these shorter distances. Type-N carrier, originally designed for exchange-area trunks, was capable of providing the needed circuits but could not be used because of incompatibility with type K. Engineering studies of the problem, made at the Laboratories, resulted in engineering practices for joint applications that permit the use of type-N carrier on the same cables with type K.

LESTER HOCHGRAF *Systems Engineering*

N and K Carrier Systems in the Same Cables

Telephone carrier systems, whether of the same or different types, must be compatible when used together over the same transmission medium. To carrier engineers, this means that no system causes undue interference, malfunctioning of gain-regulating circuits, or overloading of repeater or terminal equipment in channels of the other systems. Since they were intended for use on different types of cables, short-haul type-N* and long-haul type-K† carrier systems were designed for specific applications without regard to compatibility. There was no evidence that two such different systems could be made to work together over pairs in a single cable.

Type-N carrier was originally designed as a way to provide intra-city telephone circuits using conductor pairs in exchange-type cables. No other carrier system used this type of cable, so the N-system designers were not plagued by the problem of compatibility with existing systems. However, as design of the N system got under way in 1950, it became apparent that it would be an extremely useful tool in meeting the need for shorter toll circuits up to 200 miles in length. Type-K carrier, designed for long-haul circuits and large trunk groups, could have been used for such service but was not as economical a solution. For one thing, it requires a pair in each of two cables; type-N, using two pairs in a single cable, was in addition a much more economical system and was put into widespread use on fairly short toll lines.

As long as the N and K systems operated in different cables, there was no problem of interference. The Operating Companies, however, soon began to inquire about the possibility of putting N carrier on pairs in the same cable with K systems. The number of such possible joint applications was

* RECORD, *July*, 1952, *page* 277. † RECORD, *April*, 1938, *page* 260.

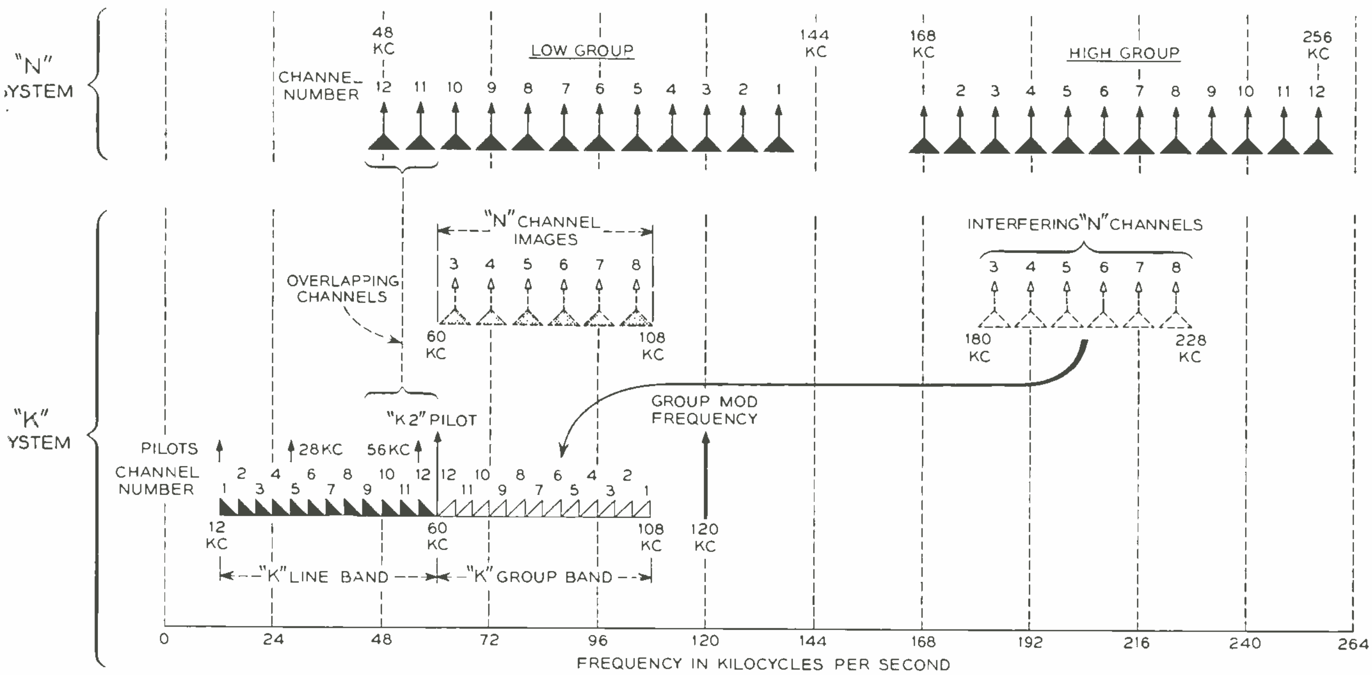


Fig. 1 — Interference between N and K carrier can be direct, because of overlapping channels, or indirect, through images of N channels 3 through 8 being modulated by the 120-kc group modulator of the K system.

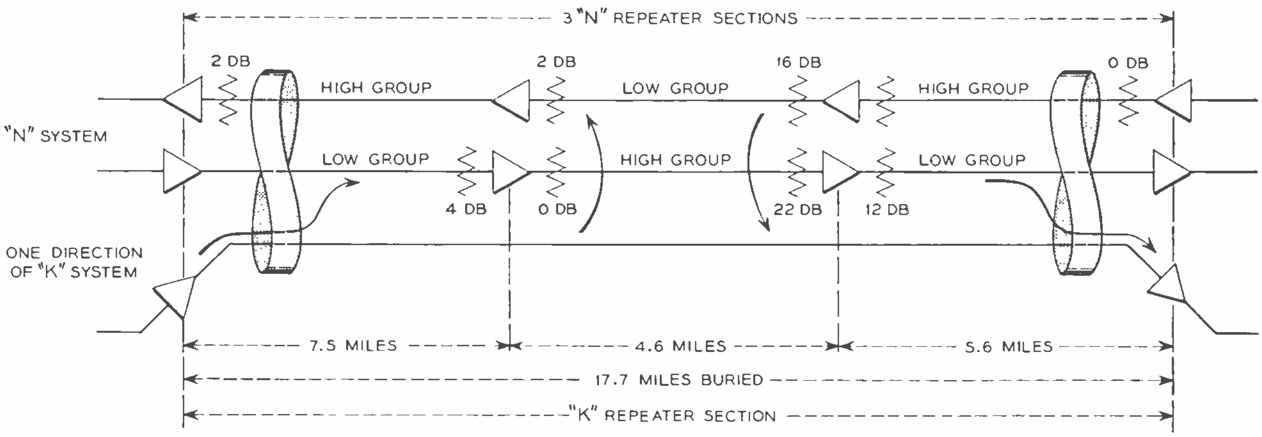


Fig. 2 — Interference is reduced by apportioning the lengths of N sections and proper use of span pads.

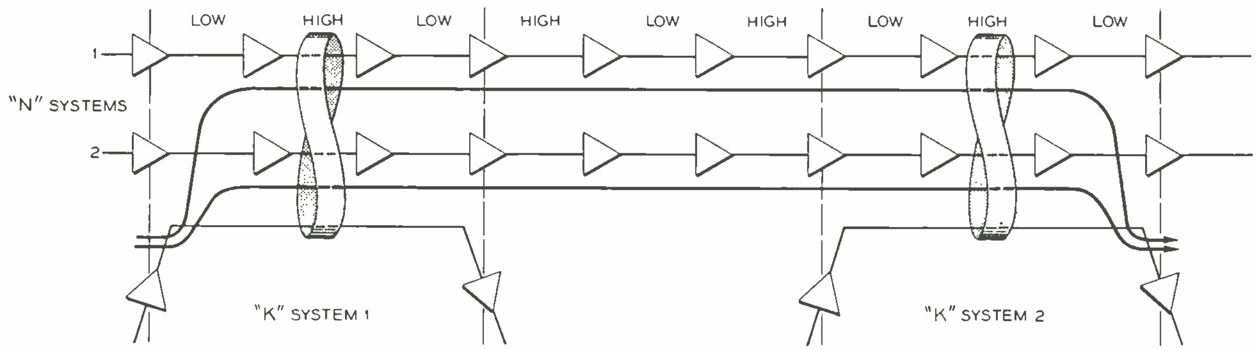


Fig. 3 — K systems can interfere with each other by being carried "piggy-back" on long N systems.

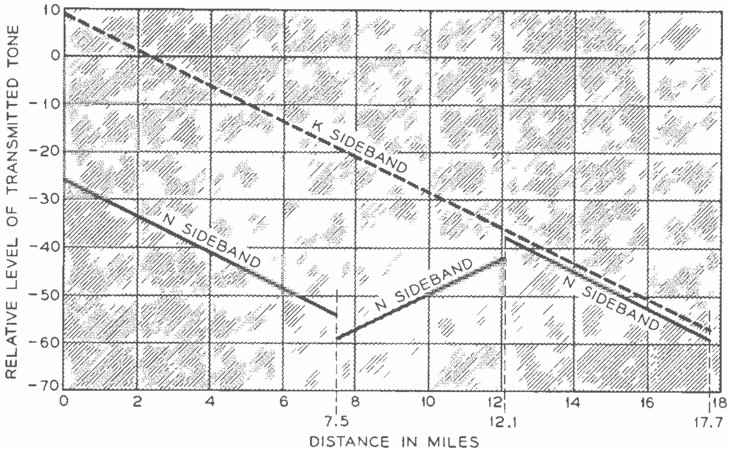


Fig. 4 — Transmission levels in overlapping channels resulting from the arrangement in Figure 2.

large because on many of the toll routes where there had originally been only one cable for voice-frequency circuits, a second cable had been added to provide the return path for K-carrier operation and this second cable was almost invariably smaller than the original. In a typical case, the original cable might have had 300 pairs and the added cable only 60 pairs. With 60 K systems operating (720 voice channels), the new cable and the K repeater houses were filled to capacity while 240 pairs in the larger cable still were carrying only voice-frequency channels. The Operating Companies looked longingly at N carrier as a possible means of increasing circuit capacity on these pairs.

Adding N carrier to pairs in a cable already utilizing K carrier was not just a matter of engineering the N systems in the usual way. There is a frequency overlap between the two systems, Figure 1. This, plus the different repeater-section lengths and transmission levels for the two systems, indicated that N systems could not be applied indiscriminately to pairs in cables already using K carrier without creating severe interference between the two systems. Even if the two overlapping N channels were abandoned, overloading, false gain regulation, and other forms of interference in both systems would still have to be considered. Table I shows that N and K carrier are normally far from compatible systems.

The first approach to joint operation was to select the location of N repeaters with respect to existing K repeaters and arrange the N-system direction of transmission for the least difference in level between the two systems in the band of overlapping frequencies. Compandors* are used in the N channels, permitting them to operate at somewhat lower levels than the K channels. The N repeater sections being 6 to 8 miles long and K sections 14 to 18 miles long, there could have been either 2 or 3 N sections for each K section.

The most acceptable arrangement is shown in Figure 2, where the direction of transmission in each of 3 N sections has been specifically set up for joint operation so as to minimize differences in level between N and K in the same frequency bands. This arrangement is used, even though the N repeater sections are shortened to 4 or 5 miles in

Table 1 — Comparison of Transmission Characteristics of Type K and N Carrier Systems

	K System	*N System*
Type of Facilities	1 pair in each of 2 cables	2 pairs in 1 cable
Number of Channels	12	12
Type of Modulation	AM single-sideband; carrier suppressed	AM double-sideband; carrier transmitted
Frequency Bands Used	12-60 kc in both directions	44-140 kc 164-260 kc
Pilot Channels	Yes	No — uses carrier as pilot
Sideband Output	+9 db	low group −20 to −27 db high group −12 to −19 db
Repeater Section	15-20 miles	8 miles (max.)
Type of Repeater	Straight amplifier (sloped gain)	Modulates low group to high group and high to low (flat gain)
Compandors	No	Yes
Crosstalk Balancing of Cable Pairs	Yes	No

* Record, *November*, 1953, *page* 452.

length. However, this arrangement of itself does not give adequate control of inter-system interference. Further control is obtained by proportioning the length of the N sections within each K repeater section and by rearranging the "span" pads of the N system.

Span pads are available because it is the practice in N systems to build out short repeater sections with pads or artificial cable to be equivalent in loss to typical 8-mile cable sections. Normally these span pads are placed at the repeater inputs to keep the signal level on the line as high as possible to override any noise. With joint operation, the pads are placed at either end or divided between input and output ends of an N section to achieve the lowest crosstalk between systems in the overlapping channels. The combination of coordinated layout, unequal N sections, and pad juggling provides sufficient crosstalk control so that the overlapping N channels have sometimes been used without causing excessive speech crosstalk in the K channels or vice versa.

Another disturbing effect may be caused by crosstalk from the N channel-11 carrier at 56 kc disturbing the 56-kc pilot regulators of the K systems. This added energy in the pilot channel tends to lower the level of the K channels. An even worse condition can occur, however, as a result of the carrier and pilot frequencies beating together. In the K system, the pilot frequency usually lies between 55,998 and 56,002 cycles per second while the N channel-11 carrier may differ from 56 kc by as much as plus or minus 20 cycles. As long as the difference in frequency between pilot and carrier is greater than about 5 cycles, the error in regulation is small because of the slow action of the K regulators. Unfortunately, when the frequency

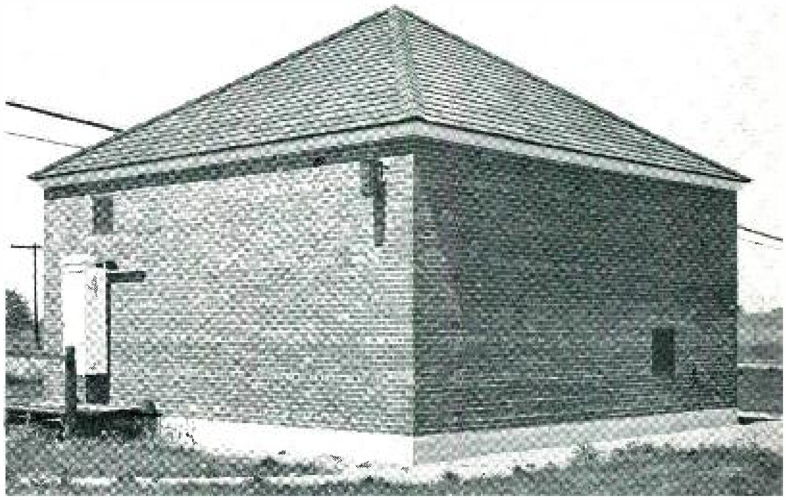


Fig. 5 — An N repeater cabinet mounted on the outside of an unattended K repeater station.

difference is less than 5 cycles, and especially below 3 cycles, the regulator adjusts the gain of the K channels to follow the instantaneous addition and subtraction of the pilot and carrier frequencies.

This interference with the pilot channels is not serious as long as the carrier crosstalk into a K pair is about 30 db below the K pilot level. However, variations in net loss up to plus or minus 0.4 db have been observed on certain K channels; added to other variations, this amount is undesirable.

The disconcerting thing about this interference is that the crosstalk may get a "free ride" on the K systems for a long distance and cause trouble at a point remote from the crosstalk exposure. Furthermore, trouble may not be experienced until temperature changes cause the N carrier to drift into near synchronism with the K pilot. Because of such interference, it may be necessary to forego the use

THE AUTHOR

LESTER HOCHGRAF received the degree of E.E. from Rensselaer Polytechnic Institute in 1926 and a D.Eng. in 1929. He then joined the Development and Research Department of A.T.&T. where he engaged in studies of crosstalk on open-wire lines. After transferring to the Laboratories with his department in 1934, he continued with crosstalk studies, particularly in connection with crosstalk balancing for the type-K cable carrier system. During the war period he was occupied with special military projects, and then transferred his attention to carrier and microwave transmission systems. Dr. Hochgraf was involved in the design and development of the lens antenna for microwave radio relay, and then became a part of a project planning group doing anticipatory and exploratory work. Since 1951 he has again been engaged in crosstalk studies and the engineering of exchange systems.

of N channel 11 on pairs with a higher than average crosstalk to some K pair.

Another possibility for crosstalk arises from one system's signal "hitch-hiking" a free ride on the other system. Sideband energy from a K system may crosstalk into N facilities and be transmitted through several N repeater sections; at some point where the crosstalk coupling is fairly high, this energy can then crosstalk back into a different K system, Figure 3. Thus there would be crosstalk between two K systems but via N transmission paths. This effect is not expected to be noticeable except where there is a large joint application of the two systems over long distances. The compandors in the N channel equipment effectively reduce similar crosstalk between N systems via K paths.

Still a third effect occurs at a K terminal point. In the K system, line frequencies extend from 12 to 60 kc, but no "roof" filter is used to avoid the reception of higher frequencies; normal attenuation characteristics of the line and repeaters hold such transmission to a low level. However, at a terminal, "image" interference can occur from N-system high groups appearing on K pairs at a fairly high level. As shown in Figure 1, N channels 3 to 8 (180 to 228 kc), if received in the K terminal, are demodulated by the 120-kc group carrier to appear in the K channel banks between 60 and 108 kc. This frequency range is the same as that of the K group, and the double-sideband crosstalk of the N channels will cause interference from both intelligible and inverted speech.

In addition to pad juggling, two methods can be used to control this image interference. One is the use of the 167Y filter, developed for this purpose, ahead of all receiving K terminals at points where needed. This filter, the only equipment item that need be added to K systems, is designed to have a high loss to frequencies in the image band.

After the coordination arrangement and problems had been worked out and the solutions field-tested, a major part of the job was the careful drafting of procedures to enable plant engineers to lay out N systems for joint application. These procedures, incorporated into Bell System Practices for engineering N systems for use on K cables, have been successfully applied and there has been widespread use of the coordination plan.

E. I. Green Delivers Bell System Endorsement of Technical School Plan

E. I. Green, Laboratories Vice President – Systems Engineering, recently attended a hearing in Albany, New York, on a proposal to establish a state-supported college and graduate school on Long Island. This school would be devoted to education in mathematics, science and engineering, and teacher training in science and mathematics. At the hearing, he delivered verbal and written statements endorsing the plan on the part of the Laboratories and the Bell System.

Mr. Green said in part, "Our national shortage of engineers and scientists, its immediate consequences, and its long-range implications have been ably and forcefully presented both here and elsewhere. In the employ of the Bell System, including the American Telephone and Telegraph Company, the Operating Telephone Companies, the Western Electric Company, and the Bell Telephone Laboratories, we have about 12,000 engineering graduates, and some 2,000 graduates in physical science. In the Laboratories alone, we now have almost 3,000 engineers and scientists.

"In planning our research and development we look ahead for many years. As far as the human eye can see, our communications job is going to multiply, not only in size but much more in complexity. Requirements for technically trained personnel are going to increase correspondingly.

"The national shortage of scientific manpower involves many problems. It will be solved only by powerful attacks on many fronts. But the proposed science center on Long Island is an important step in the right direction. It will augment the available supply of technically trained people, and will tie in effectively with technological developments in the area.

"I am glad to place on record the wholehearted endorsement of the Laboratories and the Bell System for this proposed science center," Mr. Green said in conclusion.

Ralph Bown Completes Distinguished Bell Laboratories Career

After a distinguished career of thirty-seven years service to the Bell System, including twenty-two years with the Laboratories, Dr. Ralph Bown retired on March 1. For the past two years, his

Ralph Bown

position as Vice President in charge of patent activities and long-range planning has made it possible for Dr. Bown to apply his wide experience and recognized ability in the administration of industrial research toward helping direct the present and future course of Laboratories activities. Prior to this most recent appointment, Dr. Bown was Vice President in charge of Research.

In addition to recognition by the Bell System, Dr. Bown has been honored by others including the U. S. Government and prominent professional societies. In November, 1955, he was appointed chairman of the U. S. Patent Office Advisory Committee. He is also chairman of a technical advisory committee on electricity and electronics to the National Bureau of Standards, and a member of the Army Scientific Advisory Panel.

Dr. Bown, who has been widely acclaimed for his pioneering work in the broad field of communications engineering, was awarded the 1926 Morris Liebmann Memorial Prize by the Institute of Radio Engineers for his distinguished researches into wave transmission phenomena. He served as president of the I.R.E. in 1927, and in 1949 received the Institute's Annual Medal of Honor for his extensive contributions to the field of radio and for his leadership in Institute affairs.

Much of Dr. Bown's technical work has been concerned with various aspects of radio broadcasting, and overseas telephony and microwave radio relay systems. He pioneered transmission studies carried out by the A.T.&T. Co. on early broadcasting. Among these was a study directed toward clearing up selective fading that was due to transmitter instability. The results of these studies were carried over into the transoceanic short wave radio field to help establish limits for transatlantic radio transmitters. Dr. Bown directed the entire New York-Boston radio relay project, opened for experimental service in November 1947, which was the first link in the transcontinental radio relay system.

Dr. Bown received the degrees of Mechanical Engineer, M.M.E., and Ph.D. from Cornell University. After serving as a captain in the Signal Corps during World War I, he began his telephone career in 1919 with the Development and Research Department of the American Telephone and Telegraph Company. There he specialized in various aspects of radio broadcasting, and ship-to-shore and overseas telephony.

In 1934, he was appointed Assistant Director of Radio Research at the Laboratories, Director of Radio and Television Research in 1936, and in 1944, Assistant Director of Research. In 1946, he was appointed Director of Research succeeding Dr. M. J. Kelly. Dr. Bown was appointed Vice President – Research in 1951.

During World War II, Dr. Bown served as a division member of and consultant to the National Defense Research Committee, specializing in radar, and in 1941 he visited England to study radar operations under combat conditions. He also served as expert consultant to the Secretary of War.

Dr. Bown is a member and past chairman of the Joint Technical Advisory Committee sponsored by the I.R.E. and the Radio-Electronics-Television Manufacturers Association. He is a fellow of the I.R.E., the American Association for the Advancement of Science, the Acoustical Society of America, the American Physical Society, and the American Institute of Electrical Engineers.

Highlights from the A.T.&T. Annual Report

1955 annual report

AMERICAN TELEPHONE AND TELEGRAPH COMPANY

Bell System earnings on American Telephone and Telegraph Company stock were $13.10 a share on the average number of shares in 1955, President Cleo F. Craig said in the company's annual report, recently mailed to 1,409,000 share owners. Return on invested capital was 6.8 per cent, compared with 6.2 per cent in 1954, when earnings were $11.92. Nearly 6 million more shares were issued during the year – mainly from conversions of debentures – and the number of share owners increased by 102,000, the largest increase of any company during 1955.

More than 85 per cent of the year's earnings were needed to pay dividends and maintain the retained earnings protecting each share, leaving less than 15 per cent available to increase retained earnings per share, Mr. Craig said. "These are still quite low and needed strengthening in a good year like 1955 if we are to make prudent provision for future years when business conditions may be less favorable," he said. The higher earnings were mainly the result of the rapidly expanding economy, the unprecedented prosperity generally, and "vigorous promotion of telephone services."

In describing Bell System service progress, Mr. Craig said: "increasing numbers of telephone users in 1955 were able to dial their own calls to nearby points beyond the local service area. In addition, about 500,000 people in 65 exchanges—40 more than a year ago—can now dial directly to 16,000,000 telephones in 17 metropolitan centers all over the country. Customers like the speed and convenience of this *direct distance dialing*. We expect to expand it steadily; by the end of this year people in some 250 exchanges will be dialing nationwide. Within a few years most telephone users will be able to call across the country as quickly and easily as they now dial neighbors across the street.

"The network of long distance lines continues to grow. Last year for example we established another 'backbone' route across the country. This uses both radio relay and coaxial cables, which can carry hundreds of conversations as well as television. To make even surer that essential services will be maintained in time of disaster, and also to provide for continuing growth, we are working on construction of 5,500 miles of new 'express' routes. These will bypass congested areas that might be primary targets in event of war, and will connect with existing routes outside such areas.

"More conversations crossed the oceans in 1955 than in any other year – 1,200,000 of them between the United States and 108 other countries or territories. This was four times as many as ten years ago and 25 times as many as 15 years ago.

"In cooperation with British and Canadian government communication agencies, we are now building the first transatlantic telephone cable. This will not only provide more voice paths but will also make service more dependable. Last summer the first of two cables (one for each direction of talking) was laid from Newfoundland to Scotland. Tests show the voice quality is excellent. Cable-laying work will be completed next summer so that service can begin before the end of the year. By that time also a submarine cable between the mainland of the United States and Ketchikan, Alaska, will be ready for operation.

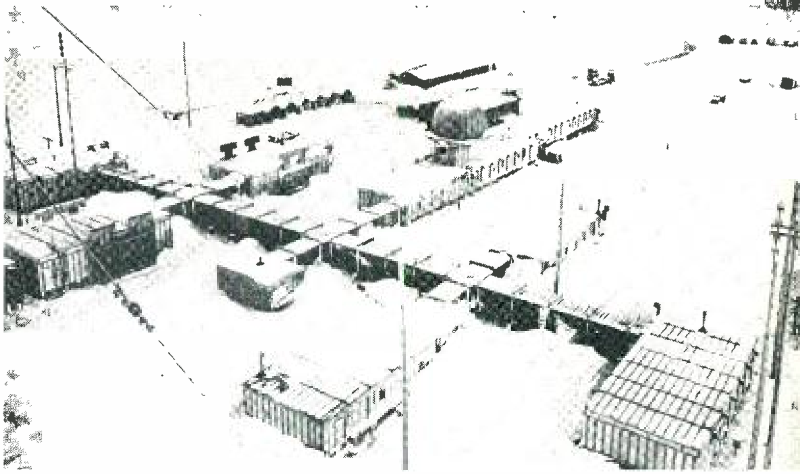
"Another big project is now in the making. In order to strengthen the national defense, the Government has requested that we advance the laying of a cable between the mainland and Hawaii. With the Hawaiian Telephone Company, we are now working on such a cable. This will be similar to the Atlantic cable in design and construction, and we expect to put it in service early in 1958.

"Our network serving the television industry continued to grow in 1955. The network now reaches nearly 390 stations in some 260 cities, and can carry color programs to about 270 stations in more than 150 cities. In addition to television broadcasting, there is considerable use of 'closed-circuit' networks for sports events and sales meetings. Last year for example there were more than 25 closed-circuit programs, each going to theaters, hotels, or other locations in cities across the country. For sales meetings, color shows merchandise to best advantage. In 1955 we used closed-circuit color television ourselves to promote a nationwide telephone sales program, and to good effect.

"A big new field for communication service to industry is just now opening up," Mr. Craig continued. "It goes by the somewhat difficult name of 'integrated data processing,' or IDP for short. Taken apart, the simplest meaning of this is doing repetitive paper work mechanically. Only those parts of the job which are different each time are done by hand. Then machines put together or 'process' the constant and variable data. Such automatic processing may range all the way from keeping routine records to the operation of electronic computers which absorb great quantities of data and turn out answers with astonishing speed.

"Two other important developments may be briefly mentioned. In Americus, Georgia, we have been testing new equipment which carries five conversations at the same time over one pair of rural telephone wires. This will soon go into regular manufacture and will help us do an even better job in rural areas. Instead of vacuum tubes, the equipment uses transistors, the wonderful new electronic devices invented a few years ago at Bell Laboratories. Also at Americus, we have been experimentally using the Bell Solar Battery, another invention of our Laboratories, to supply part of the electric power to operate the new equipment. This battery converts sunlight directly into electricity.

The zone-melting process, developed by the Laboratories, provides the extremely pure semiconductor crystals used to make transistors.



Post on the Distant Early Warning Line in the Arctic, now being built for the Air Force.

"Last year's report told of experimental work on a new kind of high-power radio system between Florida and Cuba. This can send both telephone conversations and television up to 250 miles, across areas where intermediate relay stations are not practical. We expect to have it ready for regular telephone service to Cuba early in 1957 in cooperation with the telephone company there. Experiments in sending TV programs over this kind of system will be continued.

"What we are always trying to do is to keep expansion and improvement going along together. One of the greatest aids to this is that the people who design our equipment, those who make and install it, and those who operate it, are all members of the unified organization which is the Bell System," Mr. Craig said.

"Scientists at Bell Laboratories invent and develop for service. Western Electric manufactures and installs for service. The people of the telephone companies plan and provide the service day by day. This continuous teamwork contributes immensely to the forward motion of the business. It was never more effective than in 1955.

"Two-thirds of all the equipment Western now produces for the Bell System is of types newly developed in the last ten years. This is the practical, concrete translation of scientific discovery into better and more valuable telephone service.

"This process of transforming our physical plant is never-ending. And it will be even greater in the next 20 years than in the last. This will be a gradual

Street-corner box used in a new emergency telephone system developed at the Laboratories.

evolution, not a revolution. But it is surely under way.

"There are two main technical problems in our business. One is to transmit intelligence clearly over any distance. The other is to switch calls so that any customer can quickly reach any other. In both fields progress at Bell Laboratories holds great promise for the future.

"In the first field, for example, we are working on a new system that we hope will do the same kind of thing for short, local lines within cities that we have been able to do for years on long lines—that is, multiply the number of conversations which each can carry at the same time. Up to now such 'carrier' systems have been little used locally. The reason is that they have depended on vacuum tube equipment and the costs of operation have been too high to justify installing them for local exchange service. The proposed new system, however, will use transistors. We expect it to bring lowered costs, better talking quality on many lines, and opportunities for completely new telephone services.

"In the second field also (that of switching) the remarkable properties of transistors open the door to a new era. Their small size and low power consumption, their long life, and the fact that they will operate in millionths of a second—all these characteristics offer great potential advantages. The Laboratories are therefore hard at work on an entirely new electronic switching system which will exploit these advantages. The first telephone central office of this kind will be in Morris, Illinois, and we expect it will be ready for service sometime in 1958.

"This is new telephone art. As indicated, it is being built around Bell Laboratories' fundamental invention of the transistor, first announced a few years ago. And in 1955 Bell scientists made another discovery in the same field, second in importance only to the first. This is a new process for making transistors with superior properties, and the most efficient power rectifiers ever built. We are confident this will promote mass production, reduce costs and make all these devices more widely useful.

Concerning Bell System developments for the armed forces, Mr. Craig said: "An essential part of telephone service is in aiding the nation's defense. Recently the Director of Communications of the Air Force said, 'As an assistance to national defense, particularly in the air defense aspects, the telephone system is becoming a greater national asset each year.'

"In 1955 Bell Laboratories continued to work on electronic methods for the control of new defense weapons, and Western Electric maintained high-level production of 'Nike' guided missile systems to protect American cities. Completed during the year was a 1,500-mile submarine cable system to serve a guided-missile test range over tropical waters north of the Caribbean; this was largely engineered by the Laboratories and was built by Western. In the far north, construction proceeded on the Distant Early Warning Line of radar stations, and also on related military communication facilities in Alaska.

"The Air Force has asked us to provide certain services for its proposed semi-automatic air warning and control system known as SAGE. This is a system for tying together radars and defense weapons through a chain of electronic computing centers. It is not a new air defense system but an improvement over the existing system for which the telephone companies now provide communications. Western Electric has been called on to design and supervise construction of key government-owned buildings, and to coordinate engineering and administrative work. The Bell telephone companies, and the non-Bell companies likewise, are to provide the interconnecting communication facilities and services. The rates for these are established under the supervision of public regulatory bodies and will be the same as those charged any other customer.

"Looking ahead, we are sure the country's communication needs will continue to grow. We are confident that future improvements in service will make the telephone even more widely wanted and used. And we are convinced that the way to meet our obligations to you fully is to go straight ahead to satisfy all community needs with the best, the most complete, and the most valuable telephone service in the world," Mr. Craig concluded.

A. T. & T. Announces Organization Changes

E. H. Wasson

J. W. Cook

C. W. Phalen

The American Telephone and Telegraph Company recently announced three organization changes among vice-presidential posts. Clifton W. Phalen was elected an Executive Vice President by the Board of Directors. Mr. Phalen, who has been President of the Michigan Bell Telephone Company, will assist the President in the over-all operation of the business and perform such other duties as the president may assign him. Also, James W. Cook, formerly Vice President in charge of Rates and Revenues, has been appointed Vice President in charge of Merchandising to succeed Bartlett T. Miller on his retirement. E. Hornsby Wasson, Vice President in charge of Operations, took over the duties of Mr. Cook. These three appointments were effective March 1.

Born in Washington, D. C., and a graduate of Yale University, Mr. Phalen has spent his entire business career in the Bell System. He started in 1928 as a lineman for the New York Telephone Company in Syracuse, N. Y., and after filling various assignments in the Plant Department, he was appointed Division Plant Superintendent at Albany in 1939. In 1943 he became Assistant Vice President of Personnel, in 1944 he was made Vice President – Personnel, and in 1945 Vice President – Public Relations, all with the New York Company.

In 1948 Mr. Phalen was elected Vice President of A.T.&T., serving first in charge of Public Relations, then in charge of Rates and Revenues, and later in charge of Personnel Relations. From September, 1951, to September, 1952, he was also a member of the Board of Directors of the Laboratories. He was elected President of the Michigan Bell Telephone Company September 1, 1952.

Mr. Cook began his business career in 1929, as a traffic student with New Jersey Bell. He later held various assignments in A.T.&T., the Pacific Telephone and Telegraph Company, and the Northwestern Bell Telephone Company in Omaha. He became Operating Vice President of the Northwestern Company in 1953. A year later Mr. Cook returned to A.T.&T. in charge of rates and revenues.

Mr. Wasson started in the telephone business in 1926 as a salesman for Southern Bell Telephone Company in Chattanooga, Tenn. He was appointed General Commercial Manager in 1947. Three years later, Mr. Wasson became Vice President – Public Relations of the Northwestern Bell Company in Omaha and the following year was placed in charge of the Company's Minnesota area. He was named Vice President of A.T.&T. in 1952 and assumed responsibility for Operations in April, 1955.

Recent Addresses By Dr. Kelly

Dr. M. J. Kelly delivered talks covering a variety of subjects in Cambridge, Massachusetts; New York City; Albuquerque, New Mexico; and Cleveland, Ohio, during the past few weeks.

"Factors Promoting Productivity in Research and Development at Bell Telephone Laboratories" was the subject of a talk Dr. Kelly delivered to the I.R.E. Joint Boston Section Engineering-Management Meeting held at Harvard University on January 26. The following day, he addressed a session of the Engineers Joint Council General Assembly at the Hotel Statler in New York City. This session was devoted to a review of the engineering aspects of the Hoover Commission Reports. Dr. Kelly spoke on "Research and Development."

On February 6, Dr. Kelly talked on "Our Military Strength" to the supervisory group at the Sandia Corporation, and the next day, "A Scientist's Look at Our Developing Military Strength" was his subject at a meeting of the Council on World Affairs in Cleveland, Ohio.

A. D. Knowlton Honored by ASA

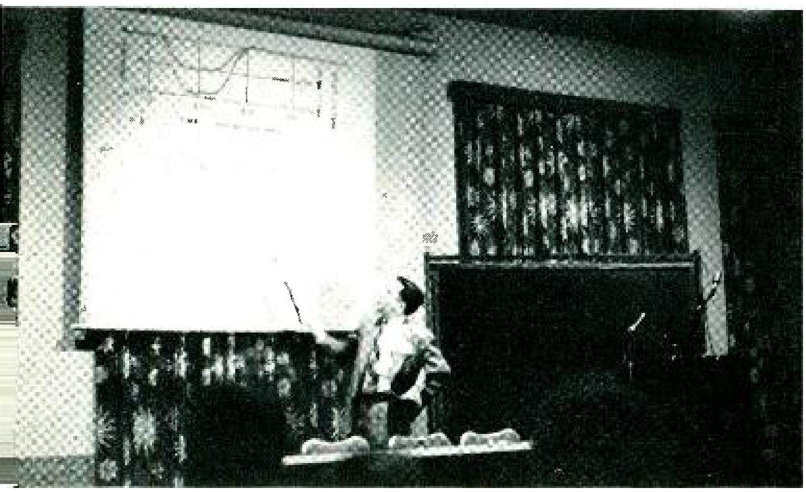
A. D. Knowlton, Laboratories Director of Design Engineering, was honored by the American Standards Association recently in recognition of his work in the development of American Standards.

The citation read: "The American Standards Association presents this certificate in recognition of contributions to the establishment of voluntary standards and in appreciation of sound advice and devotion of energy to the furtherance of the standards movement as a means of advancing the national economy.

Mr. Knowlton represents the Telephone Group, comprised of the Bell Telephone System and the U. S. Independent Telephone Association, on the Standards Council of the American Standards Association. The Council is responsible for the technical program of the A.S.A.

Members of Laboratories Participate in A.I.E.E. General Meeting

Twenty-seven members of the Laboratories participated by delivering papers or presiding over Technical Sessions at the Winter General Meeting of the American Institute of Electrical Engineers, held at the Hotel Statler in New York City from January 30 through February 3.



J. M. Early delivers one of twenty-two papers that were presented by members of the Laboratories at the A.I.E.E. Winter General Meeting.

Five Technical Sessions were directed by members of the Laboratories: the session on Communications Switching Systems was directed by W. Keister; Telegraph Systems by R. B. Shanck; Communication Theory by L. G. Abraham; Metallic Rectifiers by D. E. Trucksess; and Industrial Television and Broadcast Transmitters by H. A. Affel. In addition, the Laboratories was represented by papers in other sessions including the following: Wire Communications, Transmission and Distribution; Solid State Devices; Solid Dielectrics; Magnetic Amplifiers; Wire Communications; and Electronic Circuits and Systems.

Titles and authors of papers delivered at these sessions are listed on page 118 of this issue.

B.S.T.J. CONTENTS

The March, 1956 issue of the Bell System Technical Journal contains the following articles:

An Experimental Remote Controlled Line Concentrator by A. E. Joel, Jr.

Transistor Circuits for Analog and Digital Systems by F. H. Blecher.

Electrolytic Shaping of Germanium and Silicon by A. Uhlir, Jr.

A Large Signal Theory of Traveling-Wave Amplifiers by P. K. Tien.

A Detailed Analysis of Beam Formation with Electron Guns of the Pierce Type by W. E. Danielson, J. L. Rosenfeld and J. A. Saloom.

Theories for Toll Traffic Engineering in the U. S. A. by R. I. Wilkinson.

Crosstalk on Open-Wire Lines by W. C. Babcock, Esther Rentrop and C. S. Thaeler.

Tone Ringer May Replace Telephone Bell

The Laboratories has recently described experiments on a new musical "tone ringer" which may ultimately replace the telephone bell if it meets technical standards and customers' approval. The musical tone equipment uses transistors which are rapidly taking over many functions in telephone communications.

The first major field trial of the new device will be held in the Crystal Lake, Illinois, area this spring. The experimental site was selected for the variety of telephone equipment it affords. Some 300 customers on 100 telephone lines, ranging from individual to eight-party rural service, will be asked to participate.

In this field trial the tones will be transmitted with the same amount of power required for a

Miss M. A. Lageda of the Laboratories demonstrates a 500-type set equipped with a tone ringer.

telephone conversation – considerably less than is needed to make a telephone ring. The ordinary telephone bell requires 85 volts; the transistorized device operates on less than a volt.

The experimental telephone sets in Crystal Lake will be almost identical in appearance with the 500-type models placed in service by the Bell System. The only apparent change in the set is a louvered section at the side of the base through which the sound is radiated. Alterations in the telephone central office at Crystal Lake and on telephone lines there will not affect the customer.

Limited field trials and laboratory tests already indicate some of the advantages of the musical tone. Reactions of a panel of men and women participating in laboratory tests indicated that the musical tone can be heard at relatively great distances. It stands out above general room noise and can be distinguished from such sounds as the ringing of doorbells, alarm clocks and fire alarms. Still it was judged to be a distinctive and pleasant sound.

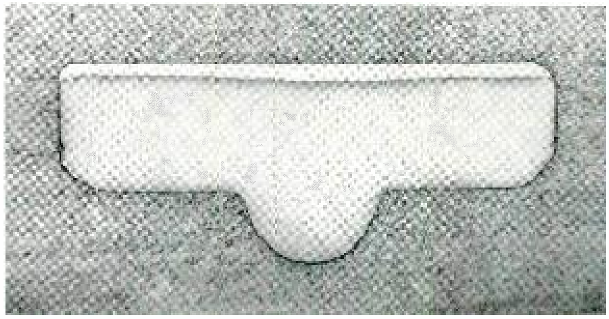
The wire-spring relay, in which electrical contacts now have a thin gold overlay. Tiny contact at left.

Wayne University Honors J. A. Morton

Jack A. Morton, Laboratories Director of Device Development, received an honorary Doctor of Science degree from Wayne University, Detroit, at its Commencement exercises Jan. 31. Dr. Morton was graduated from Wayne in 1935 with a B.S. degree in Electrical Engineering, and received an M.S. degree in engineering from the University of Michigan in 1936. He joined the Laboratories in 1936, and has been Director of Device Development since May, 1955. He also holds an honorary Doctor of Science degree from Ohio State University.

New Contacts for Wire-Spring Relay

The efficiency and dependability of wire-spring relays have recently been enhanced by the Laboratories development of a gold overlay for palladium contacts. Relays with the new type of contact are



Photomicrograph of cross-section of metallic tape used for relay contacts. Palladium has thin layer of gold at top. Magnification about 50 diameters.

now being produced by the Hawthorne Works of Western Electric for use in No. 5 crossbar and automatic message accounting equipment.

The overlay protects palladium contacts from difficulties caused by a "brown powder." With the older relays, this brown powder – derived from organic vapors in the air – was not particularly troublesome, although it sometimes resulted in a "banjo" or strumming sound heard by people using the telephone. However, the new wire-spring relays provide a smaller pressure to close the electrical contacts than do the older types, with the result that the brown powder, in addition to producing the banjo sound, sometimes rendered the relay contacts inoperative. The very small amount of gold applied over the palladium solves the problem. Most relays require gold overlays on only one contact of a pair, but for some circuits handling voice signals, gold is applied to the palladium of both contacts.

Talks by Members of the Laboratories

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

American Chemical Society, North Jersey Section

Ambrose, J. F., The Angstrom Approximation as a Possible Method for the Spectrophotometric Determination of Carbon Black Dispersion.

Ambrose, J. F., Studies on the Dielectric Dispersion of Polymer Suspensions of Carbon Black.

Flaschen, S. S., see Sauer, H. A.

Goehner, W. R., see Peters, H.

Kowalchik, M., see Trumbore, F. A.

Lockwood, W. H., see Peters, H.

Loomis, T. C., End-Point Detection Via Polarization Effects.

Lundberg, C. V., see Vacca, G. N.

Lundberg, J. L., Molecular Clustering in Solutions of High Polymers.

Nelson, L. S., Sapphire as a Material for Lamp Construction: A New Light Source for the Schumann Ultraviolet.

Peters, H., Goehner, W. R., and Lockwood, W. H., Magnetic Elastomers for Telephone Answering Devices.

Sauer, H. A., and Flaschen, S. S., Crystal Chemistry of Barium Titanate Semiconductors.

Sparks, M., Chemistry in Modern Communications.

Thurmond, C. D., The Distribution of Copper between Germanium and Ternary Melts Saturated with Germanium.

Thurmond, C. D., see Trumbore, F. A.

Trumbore, F. A., Thurmond, C. D., and Kowalchik, M., Liquid-Solid Equilibria in the Ge-GeO_2 System.

Vacca, G. N., and Lundberg, C. V., Comparison of Outdoor and Accelerated Evaluation of Ozone Resistance of Rubber Compounds.

A.I.E.E. Winter General Meeting, New York City

Albrecht, E. G., see Dietz, A. E.

Anderson, F. W., A Line-Voltage Regulator Having Magnetic Amplifier Control.

Bachelet, A. E., Collins, C. A., and Taylor, E. R., Television Network Switching Facilities.

Barley, H., see Swezey, B. S.

Bashkow, T. R., see Blecher, F. H.

Blecher, F. H. (presented for Bashkow, T. R.), DC Graphical Analysis of Junction Transistor Flip-Flops.

Boyd, R. C., Objectives and General Description of the Type P1 Carrier System.

Chen, W. H., see Lee, C. Y.

Christoferson, E. W., see Dietz, A. E.

Collins, C. A., see Bachelet, A. E.

Dietz, A. E., Albrecht, E. G. Christoferson, E. W., and Slothower, J. C., Coordinated Protection for Open-Wire Joint Use – Minneapolis Tests.

Early, J. M., High-Frequency Junction Transistors.

Eberhart, E. K., see Perkins, E. H.

Ellis, H. M., see Phelps, J. W.

Hallenbeck, F. J., see Perkins, E. H.

Joel, A. E., Jr., see Yostpille, J. J.

Katz, D., A Magnetic Amplifier Switching Matrix.

Lee, C. Y., and Chen, W. H., Several-Valued Combinational Switching Circuits.

McCall, D. W., The Dielectric Properties of Polyethylene.

McMahon, W., Dielectric Effects Produced by Solidifying Certain Organic Compounds in Electric or Magnetic Fields.

O'Brien, J. A., Cyclic Decimal Codes for Analog to Digital Converters.

Perkins, E. H., Eberhart, E. K., and Hallenbeck, F. J., Circuit and Equipment Descriptions of Type P1 Carrier System.

Perry, D. B., see Swezey, B. S.

Phelps, J. W., Roach, C. L., Ellis, H. M., and Treen, R. E., Coordinated Protection for Open-Wire Joint Use – Ontario Tests.

Rice, S. O., A First Look at Random Noise.

Roach, C. L., see Phelps, J. W.

Slothower, J. C., see Dietz, A. E.

Smith, D. H., Power Supplies for the Type P1 Carrier System.

Swezey, B. S., Barley, H., and Perry, D. B., Static Elimination on Bell System Teletypewriters.

Taylor, E. R., see Bachelet, A. E.

Thatcher, T. W., Jr., Field Trial Experience with the Type P1 Carrier System.

Treen, R. E., see Phelps, J. W.

Van Haste, W., Application of Statistical Techniques to Electron Tubes for Use in a 4,000-Mile Transmission System.

Yostpille, J. J., and Joel, A. E., Jr., A Serial Method for Numbering the Slots on a Magnetic Drum.

Other Talks

Arnold, S. M., Metal Whiskers, American Electroplaters Society, Newark Branch, N. J.

Berger, U. S., A Method for Computing the Signal to Noise Ratio in Multichannel FM Radio Communication Systems, I.R.E., Student Section, Ohio State University; and TD-2 Microwave Radio Relay System, I.R.E., Columbus Section, Ohio State University.

Bullington, K., see Tidd, W. H.

Chapin, D. M., The Bell Solar Battery, Boy Scout Explorers, Post 68, Berkeley Heights, N. J.; A.I.E.E., Pensicola-Mobile Section; and Kiwanis Club, Mobile, Ala.

Dodge, H. F., Sampling Inspection and Quality Control, Air Force Reserve Officers, Research and Development

Flight, 9255th Air Reserve Squadron, Drew University, Madison, N. J.

Giloth, P. K., A Simulator for Analysis of Sampled Data Control System, National Simulation Conference, Dallas, Texas.

Graham, R. E., The Information Aspects of Television, I.R.E., Syracuse, N. Y.

Harvey, F. K., Sound and Microwave Analogies, I.R.E., Mid-Hudson Subsection, Poughkeepsie, N. Y.

Hermann, G. F., ND_3 Inversion Spectrum, American Physical Society, N. Y. City.

Joel, A. E., Jr., Electronics in Telephone Switching Systems, A.I.E.E., Chicago Section.

Karlin, J. E., User Preference Research in Engineering, A.I.E.E., Cincinnati, Ohio; and I.R.E., Minneapolis, Minn.

Kock, W. E., Speech, Music and Hearing, Franklin and Marshall College, Lancaster, Pa.

Lax, M., Radiationless Transitions in Solids, Solid State Seminar, Physics Department, University of California, Berkeley.

Lewis, H. W., Theory of Superconductivity, Physics Colloquium, University of Wisconsin, Madison.

Matthias, B. T., Superconductivity, Seminar on Superconductivity, University of Maryland, College Park.

McKay, K. G., "Gaseous" Electronics in Silicon, McGill University Physical Society, Montreal, P.Q., Canada.

Miller, S. E., Low-Loss Waveguides, Naval Reserve Electronics Company, New York City.

Moll, J. L., Junction Transistor Switches, I.R.E., Toledo Section, Ohio.

Monro, S., Mixing Common Sense with Statistics, American Society for Quality Control and American Statistical Association, Joint Meeting, Albany, N. Y.

Morgan, S. O., Chemistry at Bell Laboratories, Seminar, Laboratory for Insulation Research, Massachusetts Institute of Technology, Cambridge; and Solar Energy, Summit Rotary Club, N. J.

Morrison, L. W., NIKE – A Guided Missile Defense System, Men's Club – Churches of Madison, Presbyterian Church, Madison, N. J.

Nimmcke, F. E., The Birth of Television in Bell Telephone Laboratories, April 7, 1927, I.R.E., Piedmont Subsection, Winston-Salem, N. C.

Owens, C. D., Modern Magnetic Ferrites and Their Engineering Applications, A.I.E.E., Basic Science Section, Chicago; and Ferrites and Their Applications, Seminar, Electrical Engineering Department, Northwestern University, Evanston, Ill.

Paterson, E. G. D., The Bell System Quality Assurance Plan, American Society for Quality Control, Baltimore, Md.

Pearson, G. L., Silicon in Modern Communications, Physics Seminar, Purdue University, Lafayette, Ind.

Romanow, F. F., Mechanical Engineering Problems in Telephone Engineering, American Society of Mechanical Engineers, Student Branch, Polytechnic Institute of Brooklyn, New York.

Ross, I. M., Transistors and Related Devices, A.I.E.E. – I.R.E. Joint Student Branch, North Carolina State College, Raleigh.

Ryder, R. M., Transistors, A.I.E.E. Communication Section, and American Society for Testing Materials, New York City.

Schaefer, J. W., Some Characteristics of Guided Missiles, Men's Club, First Methodist Church, Plainfield, N. J.

Stanton, C. I., see Van Wynen, K. G.

Thayer, P. H., Jr., NIKE I, A Guided Missile System for AA Defense, A.I.E.E. Communication Section, and American Society for Testing Materials, New York City.

Tidd, W. H. (presented for Bullington, K.), Beyond-Horizon Radio Transmission, I.R.E., Long Island Section; and I.R.E., Symposium on "Scatter," New York City.

Timus, W. C., Functions of Management in Research and Development, Seminar, Army Management School, Rock Island Arsenal, Ill.

Tukey, J. W., Conclusions Versus Decisions, American Society for Quality Control, Metropolitan Section, New York City.

Van Wynen, K. G., and Stanton, C. I., Distribution and Movement of Air Traffic, Institute of Aeronautical Sciences, New York City.

Wernick, J. H., Temperature-Gradient Zone-Melting, Metallurgy Seminar, Pennsylvania State University.

Papers Published by Members of the Laboratories

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

Anderson, P. W., and Suhl, H., Instability in the Motion of Ferromagnets at High Microwave Power Levels, Phys. Rev., Letter to the Editor, **100**, pp. 1788-1789, Dec. 15, 1955.

Beck, A. C., and Mandeville, G. D., Microwave Traveling Wave Tube Millimicrosecond Pulse Generators, I.R.E. Trans., **MTT-3**, pp. 48-51, Dec., 1955.

Bennett, W. R., Application of the Fourier Integral in Circuit Theory and Circuit Problems, I.R.E. Trans., **CT-2**, **3**, pp. 237-243, Sept., 1955.

Biondi, F. J., Corrosion-Proofing Electronic Parts Against Ozone, Cer Age, **66**, p. 39, Oct., 1955.

Boyle, W. S., see Germer, L. H.

Bozorth, R. M., The Physics of Magnetic Materials, Elec. Engg., **75**, 134-140, Feb., 1956.

Chynoweth, A. G., Dynamic Method for Measuring the Pyroelectric Effect with Special Reference to Barium Titanate, J. Appl. Phys., **27**, pp. 78-84, Jan., 1956.

Cutler, C. C., Spurious Modulation of Electron Beams, Proc. I.R.E., **44**, pp. 61-64, Jan., 1956.

Duncan, R. S., and Stone, H. A., Jr., A Survey of the Application of Ferrites to Inductor Design, Proc. I.R.E., **44**, pp. 4-13, Jan., 1956.

Feher, G., Fletcher, R. C., and Gere, E. A., Exchange Effects in Spin Resonance of Impurity Atoms in Silicon, Phys. Rev., Letter to the Editor, **100**, pp. 1784-1785, Dec. 15, 1955.

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

Fewer, D. R., Design Principles for Junction Transistor Audio Power Amplifiers, I.R.E. Trans., **AU-3**, 183-201, Nov.-Dec., 1955.

Fletcher, R. C., see Feher, G.

Geballe, T. H., see Hrostowski, H. J.

Gere, E. A., see Feher, G.

Germer, L. H., and Boyle, W. S., Short Arcs, Nature, Letter to the Editor, **176**, p. 1019, Nov. 26, 1955.

Germer, L. H., and Boyle, W. S., Two Distinct Types of Short Arcs, J. Appl. Phys., **27**, pp. 32-39, Jan., 1956.

Gianola, U. F., Photovoltaic Noise in Silicon Broad Area p-n Junctions, J. Appl. Phys., **27**, pp. 51-53, Jan., 1956.

Hagelbarger, D. W., see Pfann, W. G., and Shannon, C. E.

Heidenreich, R. D., see Williams, H. J.

Herrmann, D. B., see Williams, J. C.

Hrostowski, H. J., Morin, F. J., Geballe, T. H., and Wheatley, G. H., Hall Effect and Conductivity of InSb., Phys. Rev., **100**, pp. 1672-1677, Dec. 15, 1955.

Ingram, S. B., The Graduate Engineer – His Training and Utilization in Industry, Elec. Engg., **75**, pp. 167-170, Feb., 1956.

Kaplan, E. L., Transformation of Stationary Random Sequences, Mathematica Scandinavica, 3, FASC1, pp. 127-149, June, 1955.

Mandeville, G. D., see Beck, A. C.

Miller, L. E., Negative Resistance Regions in the Collector Characteristics of the Point-Contact Transistor, Proc. I.R.E., **44**, pp. 65-72, Jan., 1956.

Moll, J. L., and Ross, I. M., The Dependence of Transistor Parameters on the Distribution of Base Layer Resistivity, Proc. I.R.E., **44**, pp. 72-78, Jan., 1956.

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

Morin, F. J., see Hrostowski, H. J.

Mumford, W. W., and Schafersman, R. L., Data on the Temperature Dependence of X-Band Fluorescent Lamp Noise Sources, I.R.E. Trans., **MTT-3**, pp. 12-16, Dec., 1955.

Nesbitt, E. A., see Williams, H. J.

Pearson, G. L., Montgomery, H. C., and Feldmann, W. L., Noise in Silicon p-n Junction Photocells, J. Appl. Phys., **27**, pp. 91-92, Jan., 1956.

Pfann, W. G., and Hagelbarger, D. W., Electromagnetic Suspension of a Molten Zone, J. Appl. Phys., **27**, pp. 12-17, Jan., 1956.

Ross, I. M., see Moll, J. L.

Schafersman, R. L., see Mumford, W. W.

Schawlow, A. L., and Townes, C. H., Effect on X-Ray Fine Structure of Deviations from a Coulomb Field near the Nucleus, Phys. Rev., **100**, pp. 1273-1280, Dec. 1, 1955.

Shannon, C. E., and Hagelbarger, D. W., Concavity of Resistance Functions, J. Appl. Phys., **27**, pp. 42-43, Jan., 1956.

Simkins, Q. W., and Vogelsong, J. H., Transistor Amplifiers for Use in a Digital Computer, Proc. I.R.E., **44**, pp. 43-54, Jan., 1956.

Stone, H. A., Jr., see Duncan, R. S.

Suhl, H., see Anderson, P. W.

Townsend, M. A., A Hollow Cathode Glow Discharge with Negative Resistance, Appl. Sci. Research, Sec. B, **5**, pp. 75-78, 1955.

Vogelsong, J. H., see Simkins, Q. W.

Weibel, E. S., Strains and the Energy in Thin Elastic Shells of Arbitrary Shape for Arbitrary Deformation, Zeitchrift f. Mathematik and Physik, **6**, pp. 153-189, May 25, 1955.

Wheatley, G. H., see Hrostowski, H. J.

Williams, J. C., Heidenreich, R. D., and Nesbitt, E. A., Mechanism by which Cobalt Ferrite Heat Treats in a Magnetic Field, J. Appl. Phys., **27**, pp. 85-89, Jan., 1956.

Williams, J. C., and Hermann, D. B., Surface Resistivity of Non-Porous Ceramic and Organic Insulating Materials at High Humidity with Observations of Assocated Silver Migration, I.R.E., Trans., **PGROC-6**, pp. 11-20, Feb., 1956.

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

Bangert, J. T., and Green, E. I. – *Broad-Band Phase-Shifting Circuit* – 2,726,368.

Bangert, J. T. – *Transmission Network Using Transistors* – 2,728,053.

Barber, C. C. – *Click Eliminating Means for Three-Position Type Keys* – 2,727,103.

Cahill, H. D. – *Transverter (Recorder-Controller)* – 2,727,092.

Cesareo, O. – *Community Alarm System* – 2,728,074.

Clogston, A. M. – *Binary Storage System* – 2,726,328.

Green, E. I., see Bangert, J. T.

Ketchledge, R. W. – *Acceleration Measuring System* – 2,726,074.

Kinsley, T. G. – *Relay Armature Spring* – 2,727,191.

Kuhn, J. J., Jr., and Watrous, A. B. – *Plotting Arm* – 2,727,308.

Linvill, J. G., and Wallace, R. L., Jr. – *Negative Impedance Converters Employing Transistors* – 2,726,370.

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