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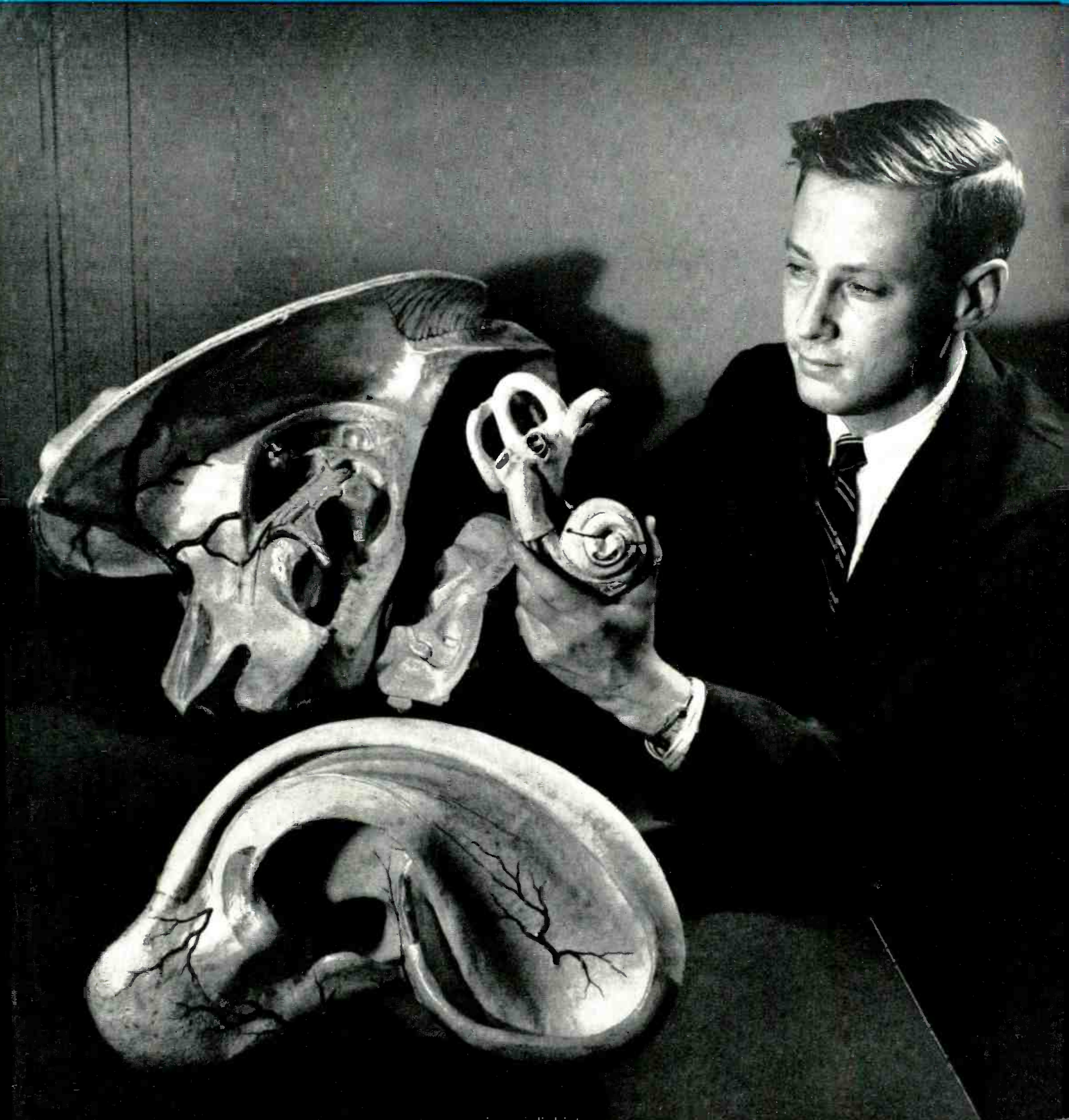

Bell Laboratories RECORD

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THE COVER: The mechanics of how we hear is an important consideration in acoustics research. Here, E. E. David, Jr., studies the construction of the inner ear portion of a large dissectable model of the ear. See page 281.

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Voice-Actuated Machines: Problems and Possibilities

E. E. DAVID, JR. *Acoustics Research*

Since the time of Alexander Graham Bell, acoustics research has produced an impressive fund of information concerning human speech. Paralleling this work has been an unceasing effort by communications engineers to transmit economically the essential information contained in speech over various forms of communication channels. Only recently, however, have scientists been able to measure the acoustic properties of speech which actually carry information to the listener's ear and brain. The discovery of these characteristics, and how to use them, shows great promise in the field of speech bandwidth compression. It also opens the possibility of machines which understand and react to voiced commands. Laboratories scientists, in their search for ways to keep Bell System telephone service the most advanced in the world, have designed and built several experimental machines that are actuated by voice signals.

Many of us have considered the possibility of a "voice typewriter" which could produce printed words directly and instantaneously from speech. Such a voice-actuated machine seems logically feasible, because we are all aware of devices which are counterparts of the physiological processes involved in translating speech into action. Microphones "hear"; computers "think"; and motors work. To combine such components into a voice-actuated machine, however, one must know exactly what type of computing or thought process is involved. In other words, how are the measurable, physical properties of a spoken command to the computer to be translated into phonetic information or meaning? It is this correspondence between acoustic properties and phonetic values that scientists at the Laboratories and elsewhere have endeavored for some time to establish.

Our own experience shows that the same words have something in common no matter who speaks them, for we understand them all. Dialects, variations in pitch and inflection, and most physical speech defects likewise do not seriously impair intelligibility. Understanding must therefore be based on certain meaningful characteristics of speech; other properties must be irrelevant. When we converse the former are utilized and the latter are ignored. A study of the elements of speech gives us an insight into this selective process.

A speaker can make all of the sounds used in his speech by manipulations of the vocal cords and the vocal tract (teeth, lips, tongue, etc.). Phoneticians estimate that a normal human can emit hundreds of distinct sounds which listeners can differentiate consistently. These unit sounds are called *phones*. It is interesting that the identity of a phone depends upon pronunciation or phonetic value but not upon properties like pitch and inflection. In other words, the phone is concerned only with pronunciation or "sound shape."

In English, many of the hundreds of phones are rarely or never used. Of those that are used, many can be classified into families. These related groups of phones are known as *phonemes.* For instance, the sounds, *heed, hid, head, had, hod, hawed, hood, who'd, hud* (as in Hudson), and *heard,* contain commonly used English vowel sounds preceded and followed by identical consonants. Each of these syllables can be pronounced in several different ways by altering the character of the spoken vowel. These versions of the vowel, which change the pronunciation of the word only slightly while retaining its identity, correspond to the phones classified as a particular phoneme. In other words, phonemes – the really *distinctive* elements of speech – produced one after the other, are the modules, or building blocks, of speech.

Phoneticians represent phonemes by a written symbol and record phonemic information by a series of these symbols as shown in Figure 1. Since there are only about forty such units used in our language, adopting phonemic building blocks to represent speech makes good sense. All of the words in the English language can be synthesized from these forty phonemes. Just as importantly, words can be analyzed and identified by the phonemes which they contain. Thus, the task of identifying of the thousands of words is greatly reduced.

Phoneticians are adept at identifying phonemes, but how can this ability be built into a voice-actuated machine? One thing that the designer of such a device must know is how to derive phonemic data from physical measurements of speech, for such a provision must be incorporated into the memory circuits of the machine's computing brain. Phoneticians are forced to depend on perception in making a phonemic transcription. Unfortunately, such mental processes are difficult, if not impossible, to reduce to an objective form. Nonetheless, knowledge of the auditory and articulatory aspects of speech studies by phoneticians has been important in investigations of the meaning – measurement relation. Similarly, physicists and communications engineers have contributed valuable measurement and analytical techniques. These combined efforts have resulted in considerable progress toward the goal of deriving phonemic information from measured speech data, but an entirely comprehensive understanding has not yet been achieved.

Our present understanding is based on certain properties of speech which change at a rate similar to the rate at which phonemes are emitted – about ten per second in normal speaking. These properties are revealed if we examine how the speech energy is distributed in frequency as time proceeds. Most of the energy is concentrated near a few frequencies; moreover, the energy distribution is relatively invariant over times of the order of 100 milliseconds, the average duration of phonemes. These characteristics are best appreciated through a visual display known as a *sound spectrogram** or *visible speech pattern*†. Here frequency is plotted on the vertical scale; time on the horizontal. The amount of energy at any frequency-

* RECORD, *November,* 1951, *page* 500. † RECORD, *January,* 1946, *page* 7.

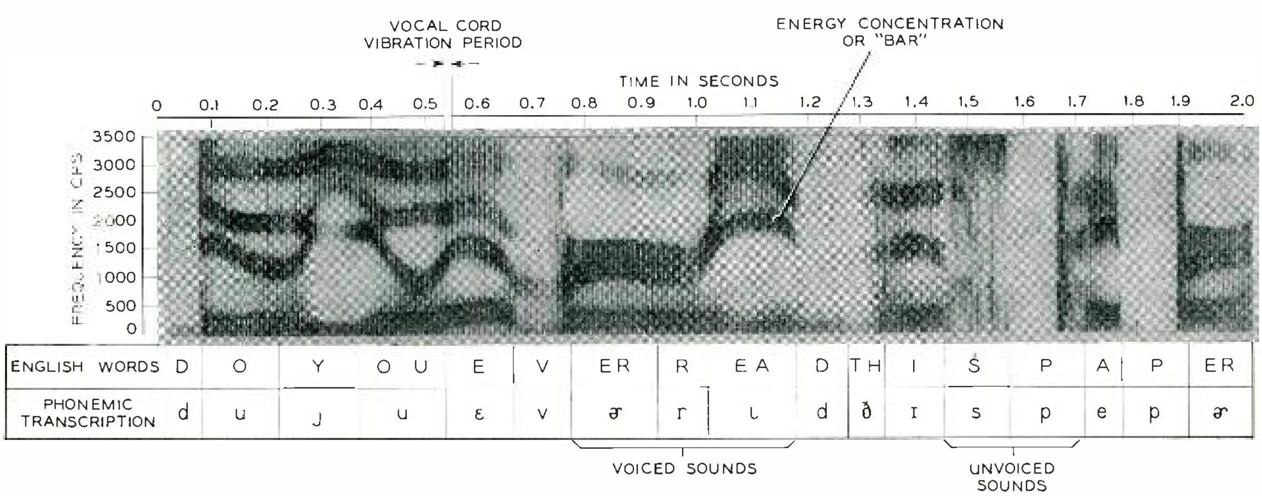


Fig. 1 — Sound spectrograms or "visible speech" patterns show the frequency-time distribution of energy in speech sounds. The relative position of the energy concentrations indicates the phonemic value of the corresponding sound. The spoken English words and phonemic transcription appear below.

time intercept is conveyed by the density of that area of the display. The blacker the area, the more energy is present. A typical spectrogram is shown in the upper-half of Figure 1. A three-dimensional sound spectogram, in which intensity is the third dimension, is shown in Figure 2. Such models have been called "solid sound." In Figure 1, sound energy concentrations, or "bars," appear as black bands running along the time dimension. In Figure 2 the similar concentrations resemble mountain ranges. These bars change their positions in frequency at about the same rate phonemes are emitted. Interpretation of such a spectogram is possible because a certain distribution or pattern of the bars in frequency – bar ratios – usually indicates that a particular phoneme is being spoken. Sounds which have no bar representation (for instance, the *s* in *this*) require modified techniques for identification, but the principle is still one of energy patterns.

The bar-ratio criterion could be used in a voice-actuated machine by means of electronic circuits. These would measure the incoming bar ratios and compare them against pre-determined ratios corresponding to the phoneme of the vocabulary being used. This phonemic information would then be stored in a second coincidence detector which would indicate when a certain series of phonemes was received. Under these conditions, a number of commands could then be carried out upon "hearing" the proper phoneme sequence.

These design principles are logical and would function as outlined except that the bar measure does not give completely reliable results. The relation between bar ratios and phonemic value has been examined in detail by G. E. Peterson and his collaborators at the Laboratories. Data showed that the bar ratios for different speakers do not *exactly* specify the phonemic value of their utterances, but in a large proportion of cases phonemes can be identified by the ratios.

It is possible that properties other than the bar ratios might better indicate phonemic value. Several investigations of the speech wave using different measures are currently under way. Of special significance is the work of K. N. Stevens and others at the Massachusetts Institute of Technology involving the positions of the organs in the vocal tract during formation of a phoneme. These positions might be used to classify sounds in a manner analogous to the energy concentration positions.

Most workers in the field of speech research, however, feel that static measurements on the speech wave are not sufficient for accurate phonemic measure. Indeed, it has been found that the dynamic aspects of speech carry considerable information. This means that we should consider not only the measure of the bar ratios at a given instant, but also its previous and future values. This "nearest neighbor" interaction among the phonemes will increase the complexity of an electronic brain, but it also promises to increase the accuracy of its response to spoken commands.

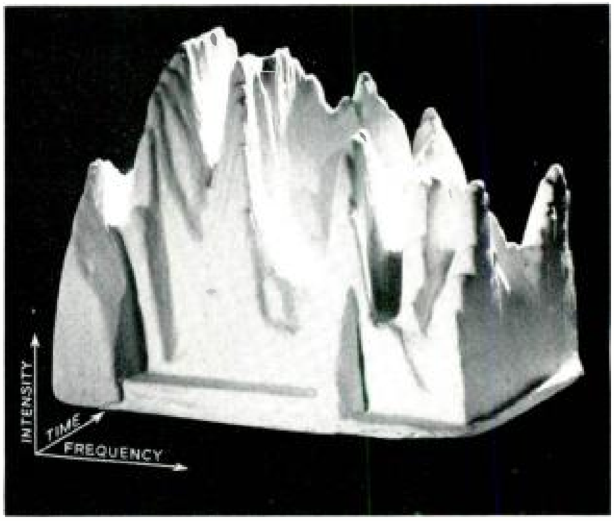


Fig. 2 — Three-dimensional model of the word "nine," relating frequency, time and intensity. Models of this type have been called "solid sound."

One of the most striking characteristics of speech is its redundancy. We use many more words (and consequently phonemes) than need be to communicate our ideas. To appreciate this, consider the contractions commonly used in telegraph and cable communications. The information carried by these messages is generally not impaired by a judicious reduction in number of words. Yet we use "wordiness" to good advantage when we are called upon to understand or interpret messages which have been partially garbled in transmission Similarly in speech, its redundancy permits us to understand spoken words even though they are distorted by emotions or masked by environmental noise, poor pronunciation, or speech defects. This property enables us to infer through context many of the words garbled by interference. Indeed, interference has relatively little effect on understanding, if the speech is sufficiently redundant. Conversely, unfamiliar topics discussed with unfamiliar words are less redundant to us and more difficult to understand in the presence of noise.

This important fact of speech points a way out of the present difficulties in finding the exact phonemic value of a sound. Our hypothetical voice-operated device can be considered a "perfect" machine in an imperfect speech environment. Such a machine could translate to written form the *ideas* intended with few exceptions, though it might make many mistakes on the individual phonemes or words that comprise the idea. These mistakes could be eliminated through context in most instances. Similarly, a machine, voice-actuated to perform a limited number of commands, could function if the commands were sufficiently different in phonemic content. For example, it would have little difficulty in discriminating between the commands "open" and "shut," since there are no common phonemes in the two. The words "shut" and "shoot," however, would be considerably more difficult since two of the three phonemes making up the words are common to both.

A device of this type has been built by the Laboratories. This voice-actuated machine is called the *Automatic Digit Recognizer* or AUDREY. A view of AUDREY with one of her inventors is shown on page 281. The circuitry was first demonstrated in 1952, and can distinguish the ten spoken decimal digits. In order to do this, energy concentration patterns typical of the phonemes making up the words are stored in it. Spoken numbers are first analyzed by a group of circuits which find their spectral distribution in much the same form as indicated in Figure 1. A computer then compares this information to each of the stored patterns and decides which is the nearest match. As the final step, the machine actuates a light to indicate which digit has been selected. The elapsed time for these three operations is about 200 milliseconds. If the incoming sound is a very poor match to any of the stored energy patterns, AUDREY makes no choice at all.

The patterns stored in the machine's brain were derived from the speech of its creator, K. H. Davis, who, along with his associates, S. Balashek and R. Biddulph, was responsible for the design and building of the machine. When Davis spoke to AUDREY, she made few mistakes. For other males, the accuracy drops to about 70 to 80 per cent from Davis' 93 per cent. More uniform performance would probably result if the stored patterns were the averages of a number of male voices. AUDREY does not respond well to females' or children's voices, though most men can learn to modify their pronunciation to approach Davis' facility.

The energy that AUDREY uses to actuate a light could readily be harnessed to an automatic printer, so we can say that one step toward the automatic translation of the spoken to the printed word has been realized. The popular concept of a voice-typewriter, however, will be difficult to accomplish. For a general vocabulary, the linguistic rules for transforming a series of phonetic symbols into written English words become extremely involved and numerous. In the foreseeable future, however, voice-typewriters producing a printed phonemic English, as easily read after a little train-

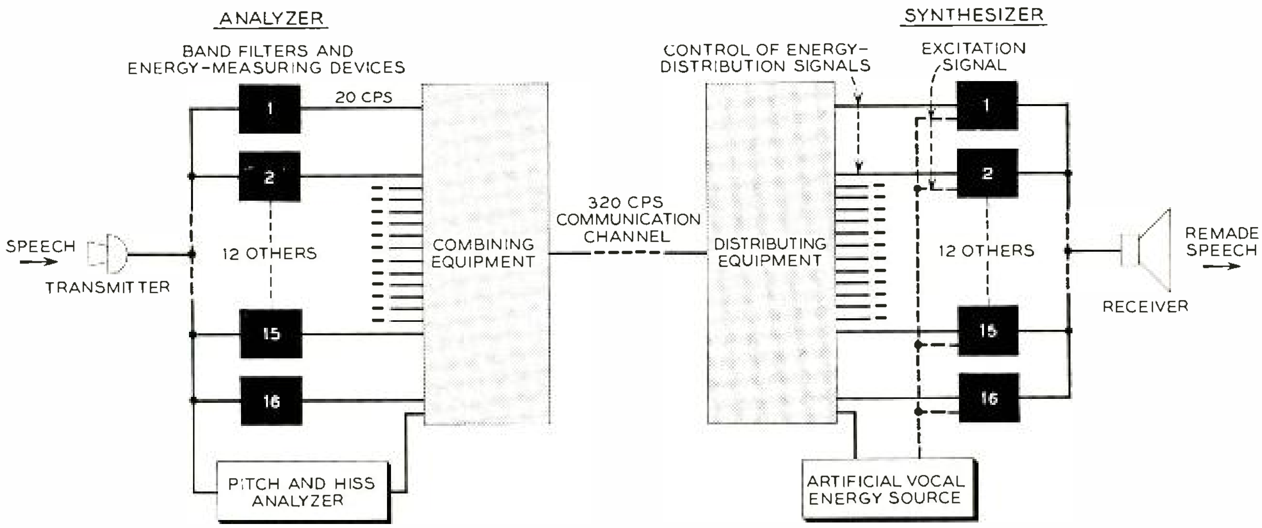


Fig. 3 — Functional diagram of the VOCODER. *This device sends an energy analysis of the incoming speech over a 320 cps band to the receiving terminal. Here the signals are distributed to a synthesizer which reconstructs the speech with its original inflection. The artificial energy source is controlled by a signal from the pitch circuit, synchronizing the source with the speaker's pitch.*

ing as ordinary printed English, seems reasonable.

Such a machine, be it AUDREY, an improved successor to AUDREY, or an idealized voice-typewriter, has important implications in the field of communications. Modern inter-city microwave relay systems have a bandwidth of four million cps per channel. This means that each channel can transmit one television program, or several hundred telephone messages each occupying about 4,000 cps, or several thousand telegraph signals each taking about 60 cps. If a transmission system of even wider band were built it would be even more versatile, but it would also be more expensive to build and operate. Thus, bandwidth in transmission links has a real economic value.

One way of increasing the signal-carrying capacity of a transmission channel would be to reduce the bandwidth of the signals so they would use a smaller portion of the channel. Processing of signals to accomplish this end is called *bandwidth compression**. Large scale efforts of communications engineers at the Laboratories and elsewhere have been bent in this direction.

The VOCODER, invented by H. W. Dudley of the Laboratories, was one of the first compression systems for speech signals. The operation of the VOCODER is diagrammed in Figure 3. The speech is passed through a series of sixteen filters which produce corresponding signals indicating the energy distribution in the input speech as a function of time. As seen on the sound spectrograms, such signals contain nearly all of the information present in the original speech. Yet each one occupies a band of only ten to twenty cps – the phonemic rate. Thus all sixteen of these signals can be made to fall into a 320 cps band. This is a very significant reduction over the 4,000 cps mentioned previously.

Phonemic-rate signals, transmitted over a 320 cps link, are then put through an "inverse VOCODER" which remakes the speech according to the energy picture it receives. Speech thus transmitted loses some voice quality compared to the original, but is perfectly understandable and quite satisfactory for most communications applications.

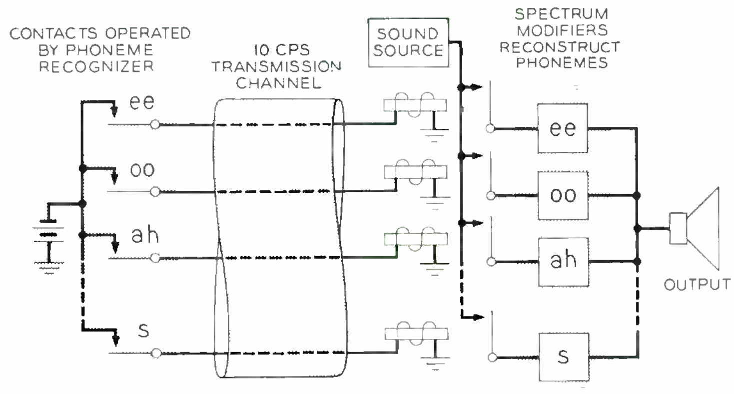


Fig. 4 — A bandwidth compression scheme based on a phoneme recognizer and a relay-operated artificial sound source. Relay signals permit transmission over a very narrow band.

An even more efficient system of bandwidth compression is outlined in Figure 4. The key to this system is a computer similar to AUDREY, proposed some years ago by Dudley, which could identify the forty English phonemes with reasonable accuracy. Such a machine would break speech into phonemes and send a keyed signal representing the spoken phoneme to the receiver. There, a facsimile of the original speech would be reproduced by utilizing the keyed signals as indicated

* RECORD, *March*, 1956, *page* 81.

THE AUTHOR

E. E. DAVID, JR., a native of Wilmington, North Carolina, received his B.E.E. degree from Georgia Institute of Technology in 1945. After serving in the U. S. Navy as a Fire Control Officer, he attended Massachusetts Institute of Technology from which he received an M.S. degree in 1947 and a Doctorate in 1950. During this period, he served as a research assistant at the M.I.T. Research Laboratory of Electronics where his work concerned microwave vacuum tubes and noise theory. During 1950 he was associated with the U. S. Navy project *Hartwell*, a summer-study activity sponsored jointly by Bell Laboratories and M.I.T. Shortly thereafter, Mr. David joined the Laboratories Transmission Research Department and engaged in acoustics and underwater sound projects. He was recently appointed engineer in charge of acoustics research, in which capacity his efforts have been directed toward the perception and coding of auditory information. In 1954, he received an award from the Eta Kappa Nu Society in their annual recognition of Outstanding Young Electrical Engineers.

in the illustration. For transmission, the phonemic information could be coded to match the available channel. The coding detail is not shown in Figure 4. However, since the phonemic rate is about ten per second, each phoneme being chosen from a forty-element vocabulary, the required channel capacity would be about fifty bits per second. Thus, an ideally coded system of this design could transmit speech over something less than a ten cps band. Such a drastic reduction, however, is probably not feasible because of engineering complexities and deviation from idealized transmission.

A recent modification of AUDREY to recognize individual phonemes as well as decimal digits has given understandable reproduction of words in a band of about 30 cycles. Progress toward the preservation of voice quality has also been made with the addition of a "pitch circuit," which conveys the original inflection of the speaker. This circuit requires an additional band of about 20 cps, but the improvement is well worth the sacrifice.

An interesting corollary to this discussion of voice-actuated machines is the translation of literal phonetic English to speech. This is not nearly so difficult as the inverse process. In the late 1930's, Bell Laboratories built an artificial talker, the VODER, actuated by a keyboard. The fundamental principle here is the same as that employed in the VOCODER. The speech parameters, such as pitch and short-time power spectrum, are controlled by electrical currents or by the fingers at the same rate as the vocal organs in producing speech. One of the first such artificial talkers was built by the German scientist Wolfgang von Kempelen, and described in an extensive book published in 1791. An engraving of his device is shown in Figure 5.

Voice-actuated machines applied to data processing, communications, and automatic control are a definite future possibility. The versatility of such machines will be limited initially by variability among speakers, as well as the complicated interrelation of phonemes, words and sentences. However, many groups throughout the country are engaged in basic speech research. Much of this work has been influenced by the emergence of Information or Communication Theory. This theory has reaffirmed the statistical nature of the communication process, a viewpoint which has for some time been applied to speech research. Such interest and activity, together with the steady progress being made in improving the versatility of computing machinery, will undoubtedly produce new knowledge concerning the speech process and new systems for translating speech into action.

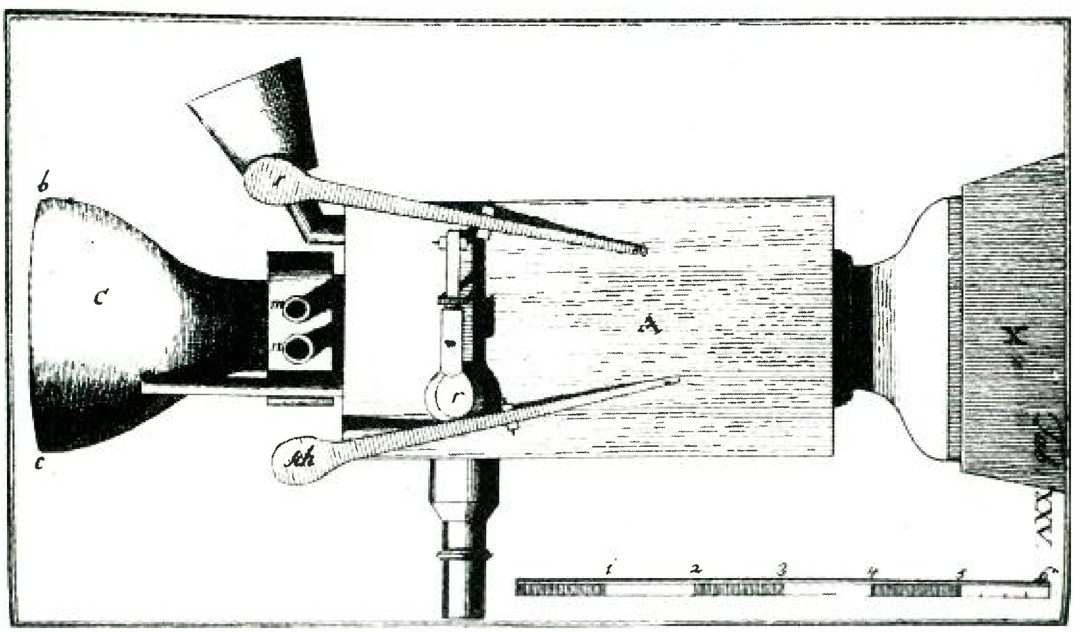
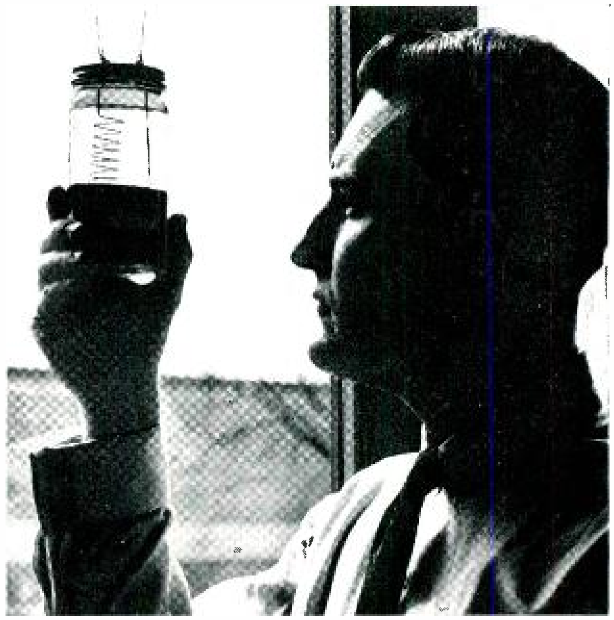


Fig. 5 — How von Kempelen's talking machine operated. The bellows, X, pumped by the operator's forearm builds up a steady pressure in the wind box, A. When making vowels, the two "nasal openings", m and n were blocked with the fingers of the pumping arm while the other hand was held in front of a reed tone resonator, C, in a fashion which produced the best sounds (empirically determined). Consonants were produced by depressing the keys s, sch and r, and by using the hands in appropriate gymnastics.

Marine Tests of Organic Materials



L. R. SNOKE *Outside Plant Development Dept.*

Marine animals and bacteria have great destructive power — a fact apparent to anyone who has noted the debris of sunken ships and old docks along a beach. For this reason, submarine cables must be highly resistant to such attack, and in this respect certain new organic materials — plastics, resins, and rubbers — have potentially useful properties. At present, little information exists on the reliability of these materials in submarine environments, but the Laboratories is now conducting intensive exposure and accelerated life tests that should contribute to the design of future cables.

There is a general, growing interest in the newer organic materials for potential use in submarine cables. It is quite possible that certain types of plastics, casting resins, and rubber elastomers will result in the greater cable efficiency and longer service life for which cable engineers are constantly striving. Unfortunately, however, there is little accurate information on the ability of these materials to withstand biological degradation from marine organisms.

In the ocean, there are many different marine environments and many species of marine life. The range of possible conditions is so broad, and the problem of specifying causes of deterioration is so complex, that a single test procedure could not be expected to yield all the necessary data. For this reason, a series of integrated tests has recently been undertaken by Bell Telephone Laboratories.

The test program is centered on the two broad categories of marine life from which deterioration might be anticipated – borers and bacteria. Borers are mollusks or crustaceans that attack materials either for shelter or as a source of food. The mollusks known as "pholads," for example, are burrowing clams that enter a material strictly for shelter. The borers known as "limnoria," on the other hand, are crustaceans that attack cellulose materials for both food and shelter. The bacteria of particular interest in the test program are single-celled microorganisms that attack organic materials and use them as a source of carbon or energy. Bacteria can also influence local chemical and physical environments and thus affect corrosion rates.

The organization of the test program is given in Table I. It should be noted that the investigation is broadly divided into laboratory and marine exposure tests, and that various specific activities are listed under these headings. The marine exposure tests are aimed primarily at obtaining information on attack by marine borers, but the specimens are exposed in such a way that information is obtained on microbiological activity as well. Supplementing these natural exposure tests, accelerated microbiological studies in the laboratory provide early basic data. Finally, and forming an important part of the general program, samples of submarine cable which have been in actual service are obtained for detailed study.

Table I — Individual Tests Comprising the Marine Biological Program

Biological Test Program

Laboratory Tests			Marine Exposure		
BOD Test	*Conductor Test*	*Soil Burial*	*Marine Borer Tests*		*Cable Analysis*
Respiration or by-products of organisms (weeks)	Breakdown of dielectric (months or years)	Electrical or physical measurements (months or years)	Wrightsville Beach, N. C.	Daytona Beach, Fla.	Samples from service

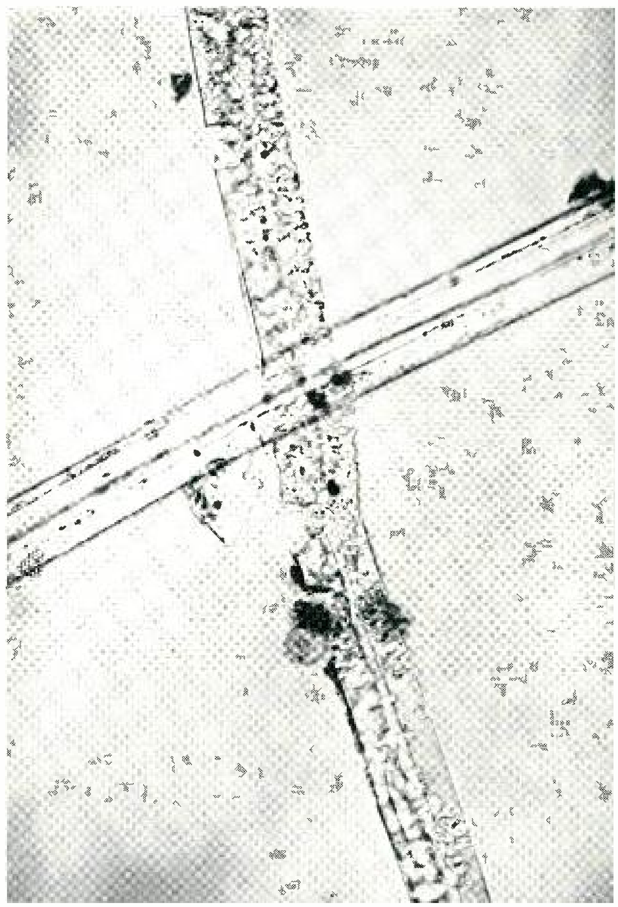
The Laboratories is conducting the marine exposure part of the program in cooperation with the William F. Clapp Laboratories of Duxbury, Massachusetts. Two exposure locations were selected — Wrightsville Beach in North Carolina and Daytona Beach in Florida — because these two areas present severe and diversified borer activity.

When the tests were started in 1954, 35 different materials were exposed, but since then the number has grown until now there are more than 50. These include plastics, rubber elastomers, and natural organic materials. Where possible, test specimens are in the form of solid rods or tubes about 1 inch in diameter and 3 feet long to simulate a cable. Fibers and tapes are wrapped on lucite rods, ¾ inch in diameter and 3 feet long. Rods of both types are assembled into racks of about 26 each. An untreated, southern pine two-by-four, which is susceptible to borer attack, is fitted around the samples at the mid-point to act as a bait piece and thus lead the borers into direct contact with each sample at that point. On those parts of the samples not covered by the bait piece, it is possible to determine whether the organisms can attack the samples directly from the water.

A test rack being lowered into the water at Wrightsville Beach is shown in Figure 6. The lower 10 inches of the rods are embedded in the bottom sediment where the bacterial population is particularly high. Thus, each test sample is subject to exposure and possible borer attack in the water, through the transition zone from water to sediment, and into the deeper sediment where little or no free oxygen is available — that is to say, where conditions are anaerobic.

The samples at Wrightsville Beach are inspected twice yearly, while those at Daytona Beach are examined only once a year. When the racks are removed from the water, the specimens are first rated according to the number and kind of fouling organisms present. After the bait pieces have been removed and the rods scraped clean, detailed observations are made. Following visual inspection, a section 1 inch long is cut from the top (water) and bottom (sediment) ends of one of the samples from each group of solid rod or tube specimens. To

Fig. 1 — Photomicrograph by F. G. Foster, Bell Laboratories, of deteriorated filaments of cellulose acetate showing characteristic surface erosion after six months marine exposure. (Original magnification 500 diameters.)



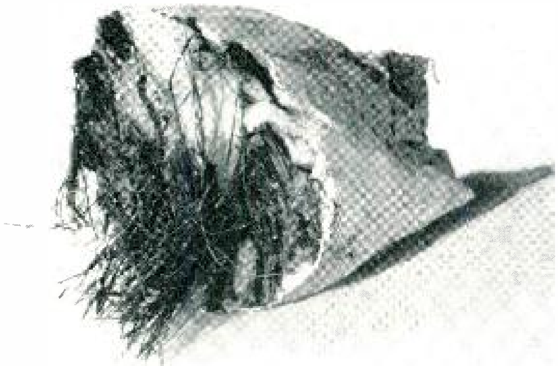


Fig. 2 — Barnacle removed from test rod wrapped with jute showing fibers cut and embedded in the calcareous base. Note sharp edges at rim of base. (Original magnification four diameters.)

preserve the integrity of the wrapping in the case of fibers and tapes, material is usually removed only when there is evidence of deterioration. These samples are returned to the Murray Hill Laboratory for detailed physical and chemical tests.

Because of the short time these natural tests have been in progress it is too early to draw extensive conclusions, but a few interesting examples of marine biological activity can be cited. Thus far, there has been no direct penetration by borers or microbiological deterioration of any of the plastics or rubber elastomers under test. Most of the natural fibers, however, have been degraded badly. This is particularly the case with jute, and it sometimes occurs even when fibers have been treated with preservatives. Cellulose acetate fibers have also been attacked, some of them showing severe surface erosion due apparently to bacterial attack. The extent of this pitting and surface erosion can be seen in Figure 1.

Fouling organisms — such as barnacles, oysters and serpulid worms which attach themselves to submerged surfaces — do not attack materials as a source of food, but they may do mechanical damage. Barnacles, for example, may penetrate a soft bituminous coating to a depth of several millimeters. The calcareous base of a barnacle, in which fibers of jute treated with anthracene oil and coal tar pitch were embedded in the course of the barnacle's growth, can be seen in Figure 2. As the sharp edges of the barnacle extended downward, the jute fibers were severed.

Restricted areas under fouling organisms, particularly beneath the bases of the calcareous varieties, are ideal cells for bacterial activity. Conditions of acidity and aeration in these confined areas may be markedly different from those in the surrounding water. As an illustration, sulfate-reducing bacteria (anaerobic bacteria which do not require free oxygen) are common marine organisms which release hydrogen sulfide in the process of breaking down organic matter. They are prevalent in anaerobic areas with relatively high concentrations of organic matter — for example, under accumulations of fouling or in the bottom sediment. The effect of these organisms is rather dramatically shown by specimens of certain polyvinyl chloride compounds in which basic lead stabilizers were employed. In the right part of Figure 3, the splotchy appearance on the side of the polyvinyl chloride sample is due to black lead sulfide. The hydrogen sulfide released by the bacteria has reacted with lead salts in the compound. In this illustration, the cross-sectional view of the sediment end of the rod shows the uniformity and depth to which the sulfiding occurred in the sediment exposure area where these bacteria are particularly active. To date, however, there is no indication that this reaction has any adverse affect on the physical properties of the compound.

In the study of borer attacks, the physical rela-

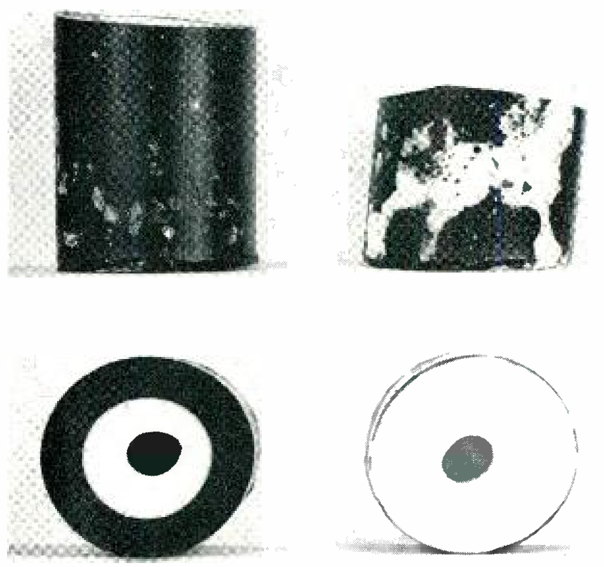


Fig. 3 — Samples cut from polyvinyl chloride test rod after two years of marine exposure at Daytona Beach. Black sulfided areas on right-hand sample from top of rod are related to accumulation of fouling. Left-hand sample from sediment end of same rod is completely black. Cross-sections of the same samples are shown below.

tionship of one material to another in a structure can often be very important. A piece of one of the lucite rods on which jute roving was wrapped for exposure is shown in Figure 4. Deep holes in the rod are readily apparent and, on the left-hand side, a small pholad can be seen embedded in the

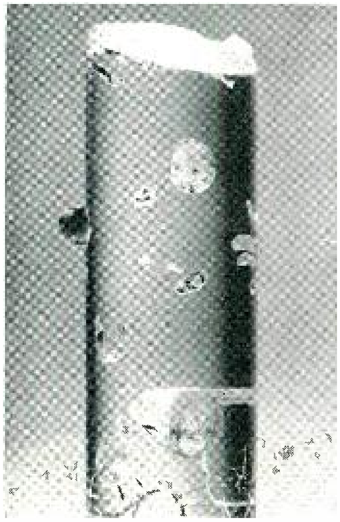


Fig. 4 — Section of lucite rod penetrated by pholads in marine test. Organisms became established in jute wrapping and progressed into rod. Pholad can be seen protruding from left.

lucite. In this case, the burrowing clams obtained their start in the jute and, as they grew, they were able to progress into the rod. There has been no evidence of penetration on exposed areas of lucite rod not covered with a susceptible material.

These few instances of biological activity serve to point up the need for careful design and exposure of test samples to meet different environmental conditions. Although the natural exposure tests have already provided some valuable early information, they will assume even more importance as exposure time increases.

As outlined in Table I, the second major part of the program consists of accelerated laboratory microbiological procedures. These tests are being used to provide early relative data on most of the same materials undergoing outdoor exposure. A first evaluation is made with a modified biochemical oxygen demand (BOD) test, as represented in Figure 5. The BOD test is a critical test which furnishes valuable basic data on the relative resistance of the materials to attack. Also, it is possible with aerobic organisms to obtain some idea of the relative rate of material deterioration by comparing the rates of oxidation per unit of time for a given surface area exposed to attack.

All that is needed is the material to be tested, aged sea water, raw sea water, and ocean bottom sediment. "Aged" sea water has been filtered and stored in the dark for 8 weeks or more so that it becomes essentially free of organic material (about one part per million). This sea water serves as the test medium. The test material is usually exposed in thin sheet form, although ground material can also be used to increase the surface area and hence accelerate attack. For each test material, enrichment cultures are prepared using ocean bottom sediment, raw sea water, and a small amount of test material. The enrichment culture serves as the source of inoculum.

In the test procedure, the aged sea water is first either saturated with oxygen, or all free oxygen is removed, depending on whether the intention is to determine the effect of aerobic or anaerobic organisms. The water is then inoculated with a few drops of solution from the enrichment cultures. Glass-stoppered bottles, which contain the test material, are filled with the prepared sea water, and the bottles are incubated in a constant-temperature water bath. Periodically, bottles are removed and the sea water analyzed — for oxygen consumption in the case of an aerobic test, or for hydrogen sulfide production in the case of an anaerobic test. Consumption of oxygen indicates the respiration of aerobic bacteria, while production of hydrogen sulfide is used as a criterion for the activity of anaerobic bacteria. Either situation means consequent use of the test material, which is the only source of carbon for the organisms.

This test has not been in operation at the Laboratories long enough to make extensive comparisons among the scores of organic materials in which there is an interest. To date, however, there has been no evidence of attack on any polyethylene

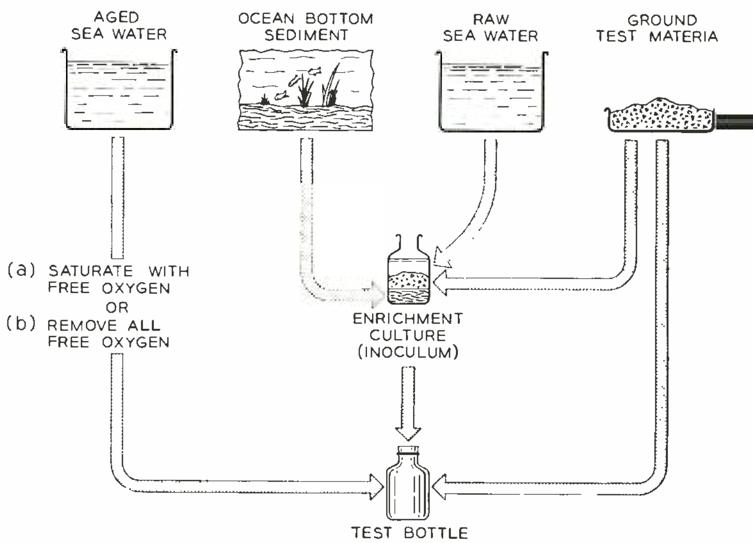


Fig. 5 — Flow chart of modified BOD test.

tested. With polyvinyl chloride compounds, attack varies according to the way in which the compound is plasticized. As illustrated in Figure 7, for example, the consumption of oxygen differs for two polyvinyl chloride compounds. In the test of compound 46-55, oxygen was consumed quickly from the sea water, which indicates that the material is relatively susceptible to attack by the aerobic bacteria, as opposed to compound 3,000 which was not attacked. The explanation is that these two polyvinyl chloride compounds are plasticized in different ways. Compound 46-55 contains an added polyester external plasticizer, while compound 3,000 is a copolymer type material which does not contain an added plasticizer. If we compare the oxygen-consumption curves for these two materials with that for the control bottles containing only inoculated sea water, we see that compound 3,000 was resistant to attack: the slope of its oxygen-consumption curve and that of the controls are essentially the same.

The rapid consumption of oxygen with compound 46-55 does not necessarily rule out this material for use in a marine environment. However, it does show that, all other factors being equal, it would be wise to use compound 3,000. Here again it should be pointed out that these results were obtained from only one laboratory test and so should not be looked upon as the final answer. Before the picture is complete, this information must be compared with that obtained using other test procedures employing different conditions and organism relationships.

To obtain somewhat more practical information, a test is employed which is intermediate to the BOD test and the natural exposure test in the ocean. Here the material is coated on a conductor to provide about 10 miles of insulation. A standard coil of this conductor is then exposed in a 16-ounce bottle so that half of the coil is in marine sediment, and half is in sea water as shown in the illustration on page 287. The ends of the coil are brought through holes in the jar lid and attached to terminals. The bottle is incubated at about 20°C, and capacitance measurements are taken periodically to indicate any change in the dielectric. Conductors are also placed in sterile sea water and sediment to serve as controls. The advantage of this type of test is that it can be continued for years.

These conductor tests are just in the process of being initiated. For several months, however, two materials have been under study in a "dry" run to establish biological procedure and measurement

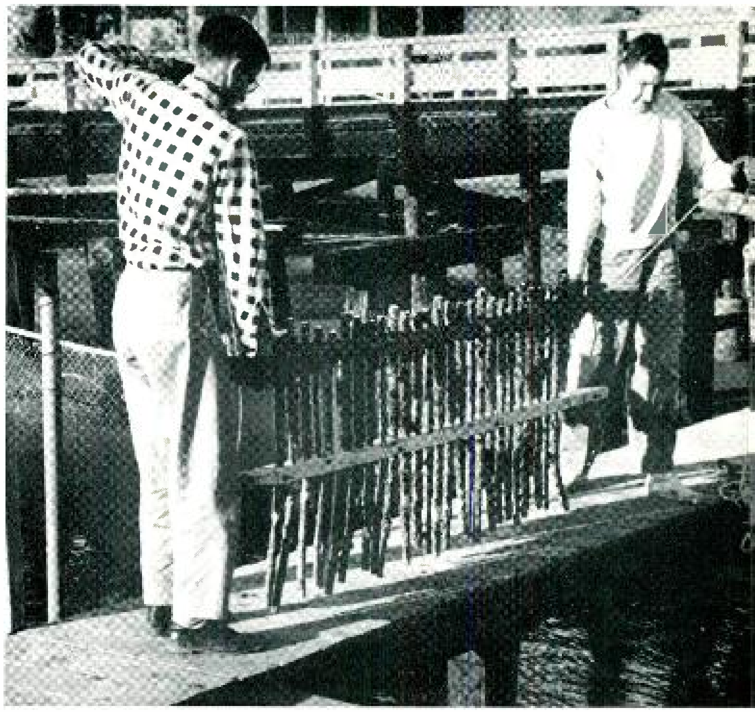


Fig. 6 — Member of Clapp Laboratories and L. R. Snoke lowering a test rack into position at Wrightsville Beach.

techniques, as well as to obtain sample data for analysis. In these preliminary studies, it has been found that with GRS rubber, capacitance values increased about 100 $\mu\mu$f in some six months, which indicates a substantial attack. With the second material, a rigid polyvinyl chloride, there has been no significant increase in capacitance values. When the materials are finally removed from test, they will be examined to determine the exact location of any deterioration, particularly with respect to location in water or sediment.

As indicated in Table I, another part of the laboratory test program involves soil burial of the same materials undergoing marine-type exposures. The question might logically be asked, Why soil burial? There is published information available on the relative susceptibility of some of the materials to terrestrial microorganisms such as bacteria and fungi. Some of this information was obtained in soil burial studies, and some by various laboratory tests. There is good reason to believe, however, that the general order of susceptibility to microbiological attack will be similar whether the environment is marine or terrestrial. The present program offers an opportunity to compare directly many of these materials in the two environments. Some data to indicate the degree of correlation will be of great value in bringing more published

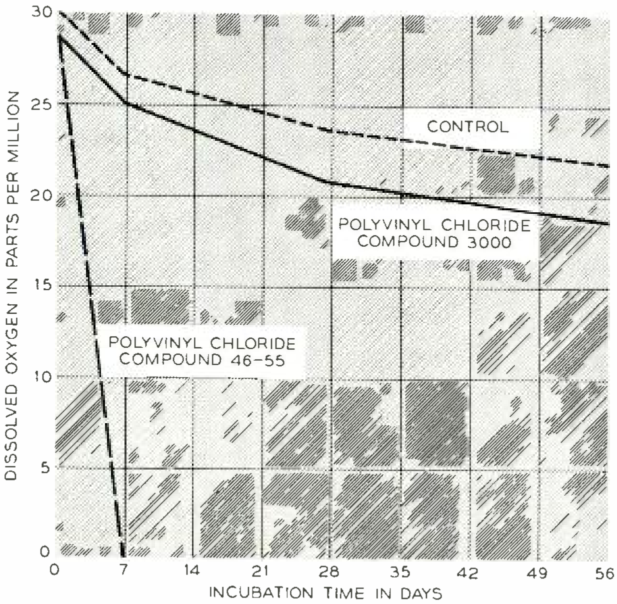


Fig. 7 — Consumption of oxygen by aerobic marine bacteria in BOD test with polyvinyl chloride compounds as the sole source of organic carbon.

information to bear on the problem at hand, and will also aid in other programs — for example a study being started to determine the resistance of structures and materials to deterioration in subterranean environments.

The marine tests will provide valuable basic data on the resistance of materials to biological attack, but they must eventually be calibrated with exposure data obtained under service conditions. Some headway is being made in this direction with the cooperation of the Western Union Telegraph Company, which has had telegraph cables crossing the ocean for many years. Whenever possible, when repairs are made in these cables, small sample sections are shipped to Bell Laboratories at Murray Hill for study. In addition, advantage is taken of any other source of samples which may provide data on the performance of materials in the natural submarine environment. Samples have been acquired of telephone cable laid in estuaries, and of other cables situated in the ocean.

The components from all these samples are subjected to detailed analyses to determine the extent and, if possible, the cause of any degradation. Although the acquisition of samples requires considerable time, some important information has already been obtained. For example, it is apparent that the impregnated outer jute wrapped over the armor wires plays an important part in preventing or limiting corrosion of the armor wires. Those samples which, after exposure, were still well coated with an asphaltic compound or similar material had little or no corrosion. On the other hand, those samples which showed any great degree of corrosion had little if any compound remaining. As more samples are obtained, there are indications of certain types of corrosion being repetitive. The action of sulphate-reducing bacteria has been evident in some of the cable samples that have been examined. It is hoped that through the study of such samples, it may be possible to correlate various types of degradation with local environments.

In any program of this size, it is evident that many different areas of effort are represented. Preparation of special materials for test, physical and chemical analyses of materials before and after natural exposure, and the evaluation of corrosion in samples from service are just a few of the areas where the combined resources of the Laboratories are being applied in the conduct of the program.

THE AUTHOR

LLOYD R. SNOKE, a native of Philadelphia, received a B.S. in Forestry degree from Pennsylvania State University in 1948 and joined the staff of Bell Telephone Laboratories that year. He specialized initially in the timber products used in the Bell System and their preservative treatment. Specifically, he was concerned with timber-treatment theory, including the application of radioactive isotope tracer techniques and the bioassay of wood preservatives. For the past four years, he has been also concerned with microbiological testing of materials, including laboratory, marine bacteriological studies and actual marine exposure tests. Mr. Snoke heads the Environmental Protection Group of the Outside Plant Department. He is a member of the American Association for the Advancement of Science, the Society for Industrial Microbiology, the American Wood-Preservers' Association, the American Society for Testing Materials, the Materials Advisory Board — Technical Panel on Miscellaneous Materials, and Zi Sigma Pi.

A Broad-Band Microwave Circulator

E. A. OHM *Radio Research*

The unique manner in which ferrite devices can rotate the polarization plane of an electromagnetic wave has proved to be the solution to many microwave transmission problems. For certain applications, however, such devices are not useful until they are designed to operate over a wide band of frequencies. By taking advantage of the "dielectric waveguide effect," it has been possible to construct a broad-band ferrite circulator — a device for routing microwave energy over a variety of waveguide transmission paths.

The new ceramic-like magnetic materials called "ferrites"* have a number of properties that make them useful for a wide variety of circuit and transmission applications. One particular property is especially interesting: when a ferrite is properly magnetized, it will rotate the plane of polarization of an electromagnetic wave with only one sense of rotation, regardless of whether the wave passes through the ferrite device in one direction or the reverse. That is, if we imagine a wave traveling away from an observer through such a device, the plane of polarization might be rotated in a clockwise manner, and rotation would also be clockwise if the wave traveled toward the observer. This property is called "Faraday rotation" after Michael Faraday, who described an analogous device using polarized light. It has been responsible for the design of a "one-way" transmission device called an isolator† which can be used to eliminate troublesome reflections from a microwave antenna. Recently, another component — termed a "circulator" — has also been built using this material. This device functions as a transmission "traffic circle" and as such can be used with standard components as a solution to many waveguide transmission problems.

It is well known that a waveguide that is circular in cross section will support an electromagnetic wave whose main line of electrostatic force is oriented at any angle in the transverse plane. It is also well known that this same waveguide will independently support a second electromagnetic wave whose main line of electrostatic force in the transverse plane is perpendicular to that of the first wave. Both waves can be completely and independently coupled to two external waveguide transmission lines with a component called a "polarization coupler" or "mode-selecting coupler". These characteristics, plus the rotation property of a magnetized ferrite "pencil", enable us to envision an ideal circulator of the type indicated in Figure 1.

In this illustration, consider a wave directed into arm number 1 at the left end of the circulator with the main line of electrostatic force, E_1, oriented as shown in the drawing. Since arm number 3 does not

* Record, *April*, 1957, *page* 126. † Record, *October* 1955, *page* 385.

have the orientation necessary to accept this electromagnetic energy, the wave will pass freely through the polarization coupler to the ferrite-loaded region, where it is shown as E'_1.

A ferrite pencil in the center of the device can be shaped and longitudinally magnetized in such a manner that the plane of polarization of this wave will be rotated 45° to the right as it passes through

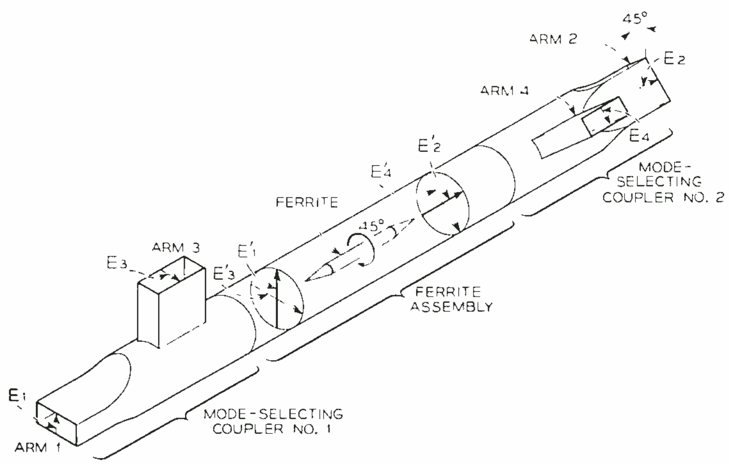


Fig. 1 — The ideal circulator — a central ferrite assembly with a mode-selecting coupler on other end.

the ferrite-loaded region. The new orientation of the wave is indicated as E'_2 in Figure 1. Now, since the circulator is so constructed that the second polarization coupler is also rotated 45° to the right, all of the wave energy will pass freely out of the circulator through arm number 2. None of this energy will pass out of arm number 4 because this arm does not have the orientation necessary to accept the wave indicated as E'_2.

As mentioned earlier, a special property of such ferrite devices depends upon the fundamental fact that an electromagnetic wave is rotated in the *same* direction when it passes through the ferrite-loaded region over the reverse path. Therefore, if we follow this line of reasoning for others of the possible inlets and outlets of the circulator, we notice the following: energy entering arm 2 will leave only through arm 3; energy entering arm 3 will leave only through arm 4, and energy entering arm 4 will leave only through arm 1.

This aspect of an ideal circulator can be indicated by the symbol in Figure 2(a), which is a convenient way of showing the possible paths within the device. With this symbol it is to be understood that energy can enter any arm and will be transmitted through to the next arm. If this second arm is perfectly matched, no energy will reach the third arm. If, however, the energy is partially or completely reflected in the second arm, the reflected energy will re-enter the second arm and then emerge through the third arm.

Thus, it is possible to guide the same or many energies simultaneously around this "traffic circle" to different exits by the proper choice of reflecting or non-reflecting components on each arm. Indeed, it is this property which has led to the term "circulator" for the assembly. Such a circulator can be used in a number of ways. For example, as in Figure 2(b), we could use it as a loss-less directional coupler for physically separating microwave energies traveling in opposite directions in the same waveguide. As indicated in Figure 2(c), we could also use it as a modulator: the carrier signal would enter arm 1, be delivered to arm 2 and be modulated, re-transmitted through arm 2, and emerge via arm 3 as the modulated signal. Or, as shown in Figure 2(d), a signal consisting of three frequencies could enter arm 1 and be directed to arm 2, where two of the frequencies would be accepted and the third reflected by a band-rejection filter back through arm 2 and out arm 3. A circulator is thus seen to be a very versatile device that could be used for a number of operations important to microwave technology.

This ideal picture is complicated, however, by several facts that have not yet been considered. In

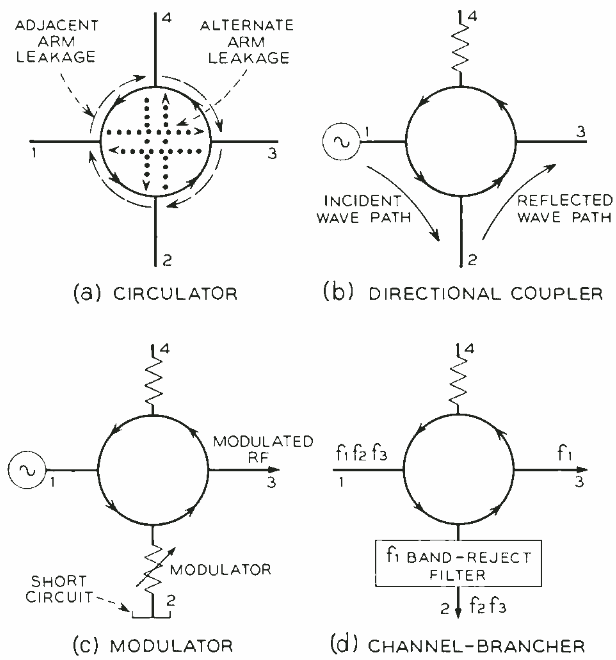
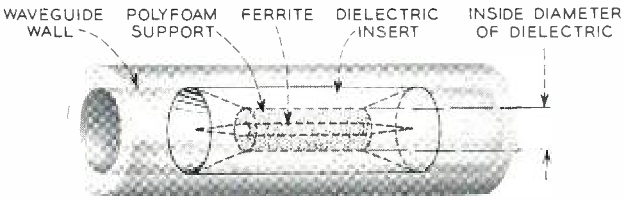


Fig. 2 — Symbol for the ideal circulator, showing two types of leakage (a), and symbols for three possible applications of this device.



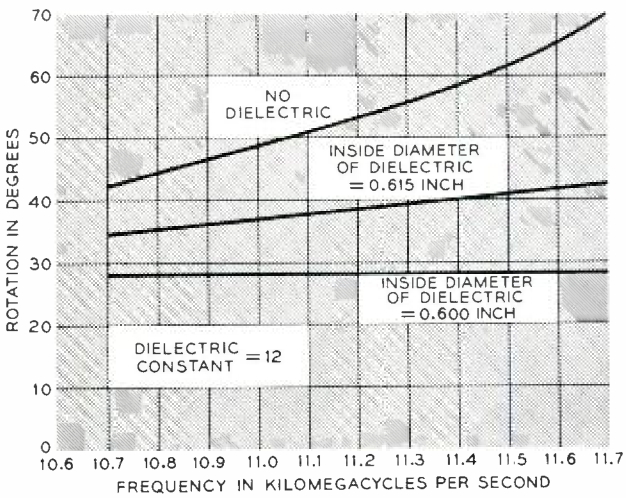


Fig. 3 — The "dielectric waveguide effect" on rotation: increased amount of high-dielectric material in waveguide flattens out the rotation characteristic.

practice, it turns out that even when special care is used to design the waveguide components, the circulator performance will still be limited mainly by three characteristics of the ferrite-loaded region:

1. *The insertion loss of the ferrite assembly* (that is, the loss from all of the materials inserted in the ferrite-loaded region). This, of course, causes transmission loss between the transmission arms of the microwave circulator.

2. *Reflection from the ferrite assembly.* This determines the reflection from each circulator arm, and what is more important, it causes alternate-arm leakages as shown by the dotted lines in Figure 2(a). For example, if in Figure 1 energy from arm 1 is partially reflected by the far end of the ferrite assembly, this reflected energy will reverse its direction, will rotate another 45° to the polarization of arm 3, and contrary to the desired performance will pass into arm 3.

3. *A variation of Faraday rotation with frequency.* This causes adjacent-arm leakages between nontransmission terminals, as shown by the dashed lines in Figure 2(a). For example, if in Figure 1 the E_1 energy entering arm 1 is not rotated exactly 45°, its polarization will not be completely in the plane of E_2 but will have a component in the E_4 direction. This unwanted E_4 component will pass directly into arm number 4 of the ferrite circulator.

Of these three factors, the third or adjacent-arm leakage due to a change in Faraday rotation with frequency has been the most serious obstacle to the design of a good broad-band circulator. The following paragraphs disclose a simple low-loss solution of this problem.

A ferrite cylinder properly tapered at the two ends and centered in a round waveguide exhibits a Faraday rotation that increases considerably with frequency. This is seen in the upper curve of Figure 3, where the nominal 55° rotation has varied from about 42° at 10.7 kilomegacycles to 70° at 11.7 kilomegacycles. This is a departure from the theoretical behavior of Faraday rotation predicted from an idealized infinite block of ferrite, because it can be shown that the rotation in such a block should be independent of frequency. Since ferrites have high dielectric constants, however, it has become apparent that as the frequency increases, a higher percentage of the microwave energy present in the waveguide concentrates in the ferrite at the expense of energy in the air-filled portions of the waveguide. This phenomenon is known as the "dielectric waveguide effect". The net result is that a greater percentage of the total transmitted power is channeled through the high-dielectric rotation-producing ferrite region. It is this phenomenon, producing an enhanced electromagnetic field in the ferrite region, which causes a greater Faraday rotation at the higher frequencies.

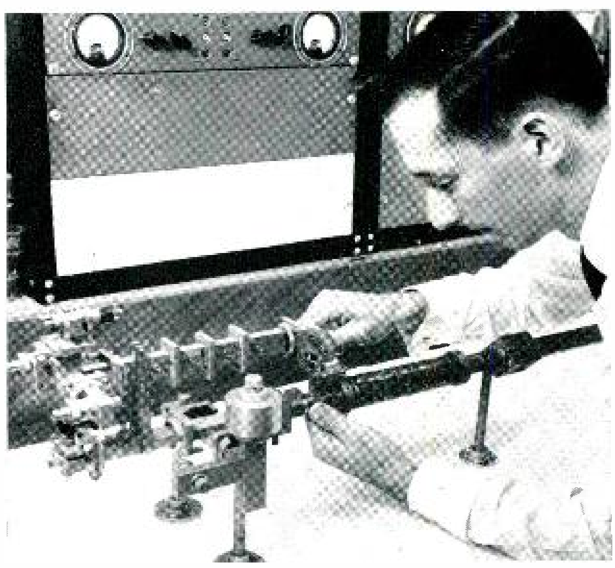


Fig. 4 — W. W. Snell, Jr., adjusting arm number 3 on an experimental 10.7- 11.7-kmc circulator incorporating magnetized ferrite as rotating element.

Therefore, to continue this line of reasoning, it seemed that a hollow concentric tube of high dielectric-constant material could be inserted with its outside diameter contiguous to the waveguide wall and that this material would produce in the central ferrite region a compensating dielectric waveguide effect. Both of these ideas were confirmed by experiments that yielded the data for the curves in Figure 3. As the inside diameter of the dielectric material was decreased (that is, as the amount of dielectric material was increased) the Faraday rotation decreased, the slope decreased, and in this manner it was even possible to obtain a negative slope. The lower curve of Figure 3 shows a rotation characteristic of zero slope, which means that here the rotation is completely independent of frequency over the band.

However, the insertion loss of the particular ferrite assembly shown in Figure 3 for 45° of rotation was too large for this application, and it was soon found that the major part of this loss was due to intrinsic loss in the relatively high dielectric-constant material ($\varepsilon_r = 12$). Since lower dielectric-constant materials generally have lower losses at these frequencies, an investigation soon revealed that the compensating dielectric waveguide effect could be obtained with lower insertion losses by using other materials with smaller dielectric constants. In particular, Figure 5 reveals the details of an optimized ferrite assembly which uses fused silica ($\varepsilon_r = 3.78$) for the compensating element. In this illustration a copper insert is also shown. The reason for this copper insert is that a short section of 0.750-inch I.D. waveguide loaded with dielectric can propagate more than the dominant wave, with the result that undesirable resonances will occur. The copper insert prevents this by decreasing the waveguide diameter in the region of the ferrite. When carefully tuned, this assembly transmits 96 per cent of the incident power, reflects 0.02 per cent of the incident power, and yields 45° ± 0.15° of Faraday rotation over the entire band from 10.7 kmc to 11.7 kmc.

This work showed that the ferrite assembly is not a limiting factor in the design of a broad-band circulator, but there remained the problem of incorporating such an assembly into an actual device. By the improved design of wide-band waveguide components, it was found possible to preserve the large

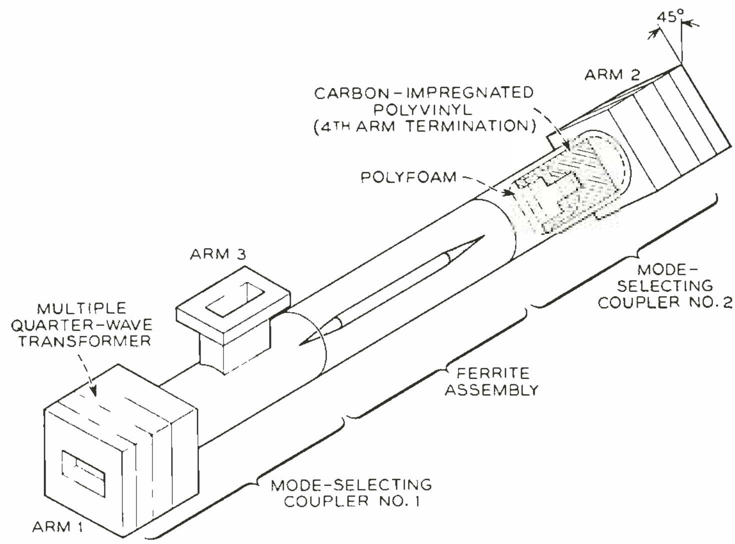


Fig. 6 — The actual circulator: the fourth arm is terminated and multiple quarter-wave transformers are used for arms one and two to decrease over-all length of the device.

isolations (that is, the exclusion of energy from non-transmitting paths) and to minimize the small reflections of each terminal.

Since Faraday rotation devices are usually built in round waveguide, and since common transmission lines utilize rectangular waveguide, it is often necessary to transfer energy from one type of guide to the other. This can be done with tapered sections, as shown in Figure 1, but requires a taper length which is impractical for many applications.

An alternative solution is to use what is termed a "multiple quarter-wave transformer". This component serves the same function as a tapered section,

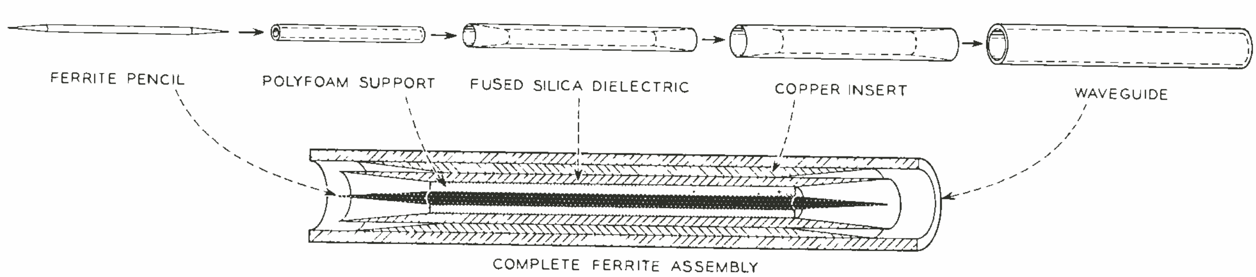


Fig. 5 — Construction of the ferrite assembly; fused silica provides the compensating waveguide effect.

and is designed in such a way that the reflections from its several discontinuities largely cancel one another over the frequency band of interest. Short transformers of this type are shown on arms 1 and 2 of Figure 6, where they have replaced the tapers shown in Figure 1. Such transformers can also be seen in the accompanying photographs. They have a negligible insertion loss and reflect at most only 0.004 per cent of the incident power at any frequency in the 10.7- to 11.7-kmc frequency band. This reflection is so small that it can hardly add to the reflections of the other components and can thus be safely neglected as a factor in circulator performance.

Figure 6 shows an actual circulator in which one arm (number 4) is non-reflectively terminated in the round waveguide, leaving only three external arms for use in circuit applications. This is sufficient in many cases, as implied by the three examples diagrammed in Figures 2(b), (c), and (d), where in each instance an external fourth arm is not required. The non-reflective termination is so designed that it has a negligible effect on the energy with the perpendicular polarization, and this energy therefore passes freely by as before.

The over-all measurements of this complete unit clearly showed that a practical broad-band Faraday-rotation circulator not more than 12 inches long can be built and adjusted with a moderate amount of care and a systematic tuning procedure. The essential measured characteristics of this general-purpose unit for the 10.7- to 11.7-kmc frequency band include:

1. A maximum reflection of 0.02 per cent (37-db return loss) of the incident energy at each terminal.
2. A maximum leakage of 0.02 per cent (37-db isolation) of the incident energy between non-transmission terminals, and
3. A 94 per cent (0.25-db loss) transmission of incident energy between transmission terminals.

For a yardstick of comparison, these insertion-loss and reflection measurements are generally about the same as those obtained for several short connected sections of waveguide, and the magnitude of leakage between non-transmission terminals is small enough to be neglected or tolerated in most waveguide applications. Therefore, although an "ideal" circulator has not yet been achieved, the present circulator characteristics are more than adequate for the design of broad-band transmission circuits.

THE AUTHOR

E. A. OHM, a native of Wauwatosa, Wis., spent 1944 to 1946 in the U. S. Navy, and after World War II began his studies at the University of Wisconsin. Here he received the B.S. degree in 1950, the M.S. in 1951 and the Ph.D. degree in 1953, all in Electrical Engineering. He joined the Radio Research Department of the Laboratories in 1953, and his major concern has been with microwave filtering problems. Among his particular projects have been work with isolators, circulators and an ultra-bandwidth mode-selecting coupler, and he is presently working on extremely broad-band microwave filter and channel-branching devices and systems, including many with ferrite materials. Mr. Ohm is a member of Sigma Xi and Tau Beta Pi, and is also an Associate Member of the IRE.

Wide Use of Short-Haul Microwave Predicted

Bell System Spokesmen Ask FCC for Adequate Common Carrier Frequencies

Microwave radio will be as important to short-haul traffic in the years ahead as it now is to long distance. This was predicted by spokesmen for the American Telephone and Telegraph Company at a hearing before the Federal Communications Commission in Washington, D. C., in June.

Present Use

The prediction was part of the testimony that Gordon Thayer, Chief Engineer, E. T. Lockwood, Assistant Vice President, and F. M. Ryan, Radio Engineer of A.T.&T., and J. B. Fisk, Executive Vice President of Bell Laboratories, gave before the Commission in presenting A.T.&T.'s position on the allocation of microwave frequencies. The Commission made the present allocation ten years ago. However, the rapid development of microwave and the possibilities of its large-scale use by private industry has required another look at the allocation of frequencies.

In his testimony, Mr. Thayer reported on how the telephone companies have used those frequencies available to "common carriers" (telephone and telegraph companies) in the past ten years. He illustrated how microwave has increased in importance, pointing out that microwave frequencies, in the years ahead, will have an important place in common carrier operations. As an example, he said that 22 per cent of the Bell System's long distance telephone circuit mileage is now furnished over microwave. In addition, 78 per cent of the Bell System's intercity TV channel mileage uses microwave facilities.

Future Needs

Bell System spokesmen also offered forecasts of future needs and asked for frequency allocations based on these forecasts. They predicted that in the years ahead, microwave radio would be as important to short-haul telephone service as it now is to long distance. In addition, they predicted large-scale use for both telephone and video services in local areas. For this local service, they asked the Commission to allocate bands in the frequency range from just above 16,000 to 30,000 megacycles.

During the proceedings, representatives for other groups advocated that private businesses be licensed to install and operate private microwave systems if they wished. A.T.&T. opposed this suggestion except for public-safety organizations and others involving services vital to the general public such as pipeline and power companies. These groups all have highly specialized communication needs.

Shortage of Frequencies

Licensing microwave for general industrial uses, Bell spokesmen said, could lead to a serious shortage of suitable frequencies – and to major problems of congestion and interference, particularly near large cities. As a result, unlimited licensing would make it hard for common carriers, public safety organizations and others to meet their responsibilities to the public.

Mr. Lockwood pointed out an economic danger inherent in unlimited licensing. He called it "cream-skimming." Private systems would be built only where construction and operating conditions were favorable and costs were low, leaving the common carriers to provide service where conditions were unfavorable and costs were high. Such "cream skimming" through the use of private systems would be unfair to the carriers and the general public. Whatever the owners of private systems might save through unlimited licensing would be more than offset by the added costs that would fall upon the general public, particularly individuals and small businesses.

A.T.&T. also pointed out that strong common carrier systems are vital to national defense and that fragmentation of the nation's communications resources – which would take place if private systems were authorized – would adversely affect our national security.

With direct distance dialing, uniformly good transmission must be provided whether a customer calls "across the street or across the continent." Since transmission is affected by the number of switching points between an originating and a terminating office, and since this number varies with the distance between the offices and the route selected, special provisions were made to maintain the necessary transmission quality. Through the development of the "fixed-pad" method of operation, transmission losses have been reduced appreciably.

Improvements in Toll Connecting Circuits for Nationwide Dialing

V. W. WAGNER *Switching Systems Development II* **H. H. FELDER** *Transmission Engineering II*

Steady expansion of customer direct distance dialing (DDD) and operator distance dialing (ODD) is unifying the United States and Canada into a giant telephone network in which customers and operators can reach people at distant points almost as easily as those nearby. The new toll switching plan* that makes this possible introduced the problem of providing circuits to give uniformly good transmission whether calls are directed to nearby telephones or to others at widely scattered locations. The desired results were obtained by setting new standards of precision for the design and maintenance of telephone transmission circuits.

The nature of the problem involved may be seen by comparing manual toll switching operations with the new mechanized procedures. Under the old plan, the outward operator builds up a toll connection according to a fixed routing specified on route bulletins. She verbally directs distant operators who make connections as required. To reduce operating time to a minimum, the routes are designed to include as few switches as possible within economic limits. An alternate route is rarely used, but if one is provided it usually involves no more switches, or only one more switch than the first route. If the routes are busy, the operator can notify the customer and arrange for a subsequent attempt to complete the call. Since operators talk over the trunks, they are able to detect poor transmission, substitute satisfactory trunks and report the identity of defective trunks.

The new method of fast automatic switching of DDD or ODD calls uses alternate routes † freely to make trunking more economical and to minimize delays. On the average, more intertoll trunks are

* Record, *May*, 1951, *page* 197, *and October*, 1953, *page* 369. † Record, *February*, 1954, *page* 51.

impedance matching to give higher return losses, especially in the upper and lower voice-frequency ranges where the return losses are usually inferior to those of middle range.

Impedance matching at lower frequencies is improved by choosing the proper capacitance for use with the repeating coils. For example, a 1-microfarad capacitor is substituted for the 4-microfarad midpoint capacitor formerly used on the switch or switchboard side of the most commonly used repeating coils in the toll-connecting circuits as shown in Figure 4. This change improves the return loss at 300 cycles by as much as 6 db without appreciably impairing transmission.

For certain types of loaded-cable trunks which normally have low return losses in the upper voice-frequency range, improvement is obtained through the use of an impedance compensator shown in Figure 5. Typical improvement obtained with an impedance compensator under ideal conditions is shown in Table I.

Fine-gauge loaded cables have poor return loss at low frequencies in spite of the use of a 1-microfarad capacitor at the midpoint of the repeating coil. For these cables, a low-frequency impedance corrector is used to supplement the impedance compensator, as shown in Figure 5. This inductor-capacitor combination makes the line impedance more like the compromise network impedance.

Another improvement in return loss is obtained under some conditions by the use of building-out capacitors. The use of such capacitors has been common practice in two-wire "through" switching to match the compromise network to the office cables and switching equipment. Variations in the

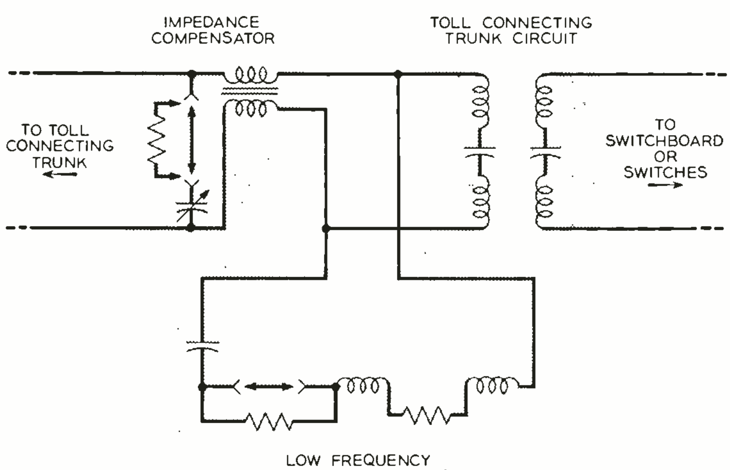


Fig. 5 — Impedance compensator used with certain types of loaded cables for improved transmission.

TABLE I — COMPARISON OF RETURN LOSS ON TRUNKS WITH AND WITHOUT IMPEDANCE COMPENSATOR.

Frequency	*Without Impedance Compensator Return Loss (db)*	*With Impedance Compensator Return Loss (db)*
300	16	17
500	19	21
1000	21	25
2000	17	23
3000	9	25

shunt capacitance of the cables and switching paths cause appreciable differences in return losses. To maintain uniformity, the capacitance between two interconnected trunk terminating circuits is "built out" to a common value by the use of adjustable capacitors. The network building-out capacitors (NBO) in all the trunks are than adjusted to equal the common value.

With the intertoll trunk networks built out as described, a serious capacitance unbalance would occur if a terminating link with low office cable capacitance were switched to an intertoll trunk on which the NBO capacitor had been set to a large value for through switching. To prevent such unbalanced conditions, building-out capacitors for central office cables are now provided in the terminating link.

New mountings for the loading coils used as the inductors and new multi-unit capacitors were developed for the impedance compensator. Twelve 638-type loading coils, each with two windings, are embedded in a block of casting compound* (styrene polyester) and coded as a 175A loading-coil case. Two cases mount on a standard 2- by 23-inch mounting plate on a relay rack bay. A similar arrangement is used for the new multi-unit capacitor shown in the upper part of Figure 3. It consists of twelve adjustable capacitors encased in a block of casting compound and is coded as a 525A capacitor. Each capacitor is adjustable in steps by changes in the strapping of seven terminals. The terminals of the capacitors and the loading coils have been designed for the use of solderless wrapped connections.†

Since an impedance compensator requires a loading coil and a capacitor (one-twelfth of a 525A), the combination of a mounting plate of loading coils and a mounting plate of capacitors provides twenty-four compensators, and one bay

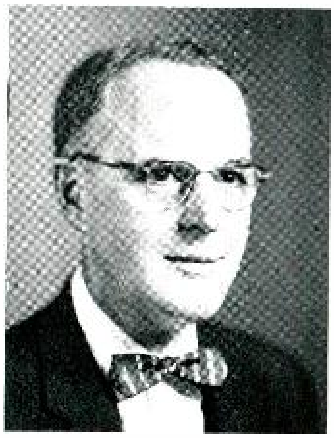
* RECORD, *December*, 1954, *page* 447. † RECORD, *February*, 1954, *page* 41.

provides a total of 720. A typical installation is shown in the photograph at the head of this article. Resistors are required in series with the capacitor for certain loaded trunks with a low, upper frequency cut-off valve. When this is the case, a "pigtail" type is furnished which requires no additional mounting-plate space.

The new 525A capacitor is also furnished as a building-out capacitor in crossbar tandem offices for those terminating links that require no trunk circuits and are therefore wired directly to the switches. When a building-out capacitor is required, it is wired to either an impedance compensator or a 2-db pad connected to the trunk. Shop-wired units have been designed for crossbar tandem combining the building-out capacitors with pads, with impedance compensators, or with combined impedance compensators and low-frequency correctors.

Circuit and equipment development to cover the application of these fixed-pad devices has been completed for more than one hundred intertoll and toll-connecting circuits associated with crossbar tandem, No. 5 crossbar, step-by-step and manual toll offices. These facilities will improve transmission considerably in the 2-wire toll switching plant at a time when it is urgently needed because of the rapid expansion of direct distance dialing.

THE AUTHORS



V. W. Wagner, a native of Brooklyn, N. Y., received the B.S. degree from Cornell University in 1920, and the Electrical Engineering degree from Brooklyn Polytechnic in 1932. He joined Western Electric Company in 1921 and installed and tested panel equipment until 1928. He then transferred to the New York Telephone Company, where he engaged in central office maintenance work and methods studies until 1941. Later, while on the Operating Staff of the New York Company, Mr. Wagner was concerned with special studies of plant and engineering problems. In 1953 he joined Bell Telephone Laboratories, where he has been engaged in switching development work on crossbar tandem and toll switchboard circuits. He is a member of the A.I.E.E.

H. H. Felder, a native of Vance, S. C., came to the A.T.&T. Co. from the U. S. Signal Corps, where he spent six months after being graduated from Clemson A. & M. College in 1918. He transferred to the Laboratories in 1934 with the Development and Research Department of the A.T.&T. Co. He has worked on general transmission problems associated with repeater development, loading, intertoll trunk design and maintenance. During World War II, he assisted in several Laboratories national defense projects. Since the war Mr. Felder has resumed his activities on general transmission matters. He conducted the field trial on the transmission test and control circuit, which automatically selects and makes two-way transmission tests on intertoll trunks. He is currently working on transmission problems incident to direct-distance dialing.

Rapid, precision testing is an indispensable requirement for the development of varistors, and later for their production. Because of the nature of these devices, the tests must also cover a wide range of currents and voltages. A semi-automatic test set has been designed to measure and plot rapidly varistor potentials from a few millivolts to several hundred volts and the tests are performed with currents ranging from a few microamperes to hundreds of milliamperes.

Semi-Automatic Test Set For Varistors

H. F. DIENEL *Electron Device Development*

During the exploratory and final development of semiconductor devices, many problems arise concerning the proper methods and instruments for measuring their electrical characteristics.* With semiconductor devices, variables are often highly non-linear; that is, there is usually no simple straight-line relationship between variables. In addition, voltage, current and frequency may vary over very wide ranges. Further, the demands of precision and reliability, or of other special circumstances, often prohibit the use of the usual commercial instruments. Another reason for considerable care in the choice of methods and instruments is that procedures used during development at Bell Laboratories frequently establish those used by the Western Electric Company for the manufactured product. Thus, it is important that Laboratories-developed measurement techniques and instruments be characterized by a high degree of precision, reliability, and reproducibility. When large numbers of units are involved, speed of testing is an additional requirement.

Special methods and apparatus were required, for example, in the development of silicon carbide varistors,† millions of which are produced annually for use in the 500-type telephone set. One of the items of test equipment is a semi-automatic test set which, though designed specifically for these varistors, is versatile enough to be used with little or no modification for similar devices such as copper oxide varistors, thermistors, or diodes.

Production of varistors is a complex process, and the development of this process required large-scale, statistically designed experiments. The experiments

* Record, *August*, 1954, *page* 301. † Record, *November*, 1956, *page* 407.

were necessary to evaluate the initial characteristics of the varistors as well as their performance or life characteristics. Initial voltage-current requirements were to be held within ± 10 per cent of the average characteristics of the varistors, and it was therefore desirable to measure values with an accuracy of one per cent or better. Comprehensive life-testing was also required in view of the close limits on the electrical characteristics of the varistors and the long life expected of them. For example, a failure rate of only 0.01 per cent means 100 defective varistors out of a million. Since about six million telephone sets are produced annually, and since two varistors are used in each, one can readily appreciate how very reliable the test data must be to be useful in predicting future performance on the basis of laboratory-produced units.

The semi-automatic test set was designed with several specific requirements in mind. The apparatus was required to provide precisely controlled constant currents from the microampere region to hundreds of milliamperes, and to measure voltages from the millivolt region to several hundred volts. Measurement of the very small voltages was necessary in determining the outputs from thermocouples used to measure the temperatures in the furnaces where the varistors are fired. Very small voltages are also measured in studies of varistor power dissipation. The high voltage range was required in the testing of varistors used in high voltage applications. Further, the test set had to record data rapidly, so that statistical analyses could be made immediately upon completion of experiments. And finally, the apparatus had to provide semi-automatic or automatic programing of the measurement of varistor discs, or of varistors that are placed in remote locations such as environmental chambers.

Fig. 1 — M. D. Patterson using test set for measuring varistors. Contactor has made connection to the sixth varistor from the left. Life-test rack can be seen in the background of the illustration.

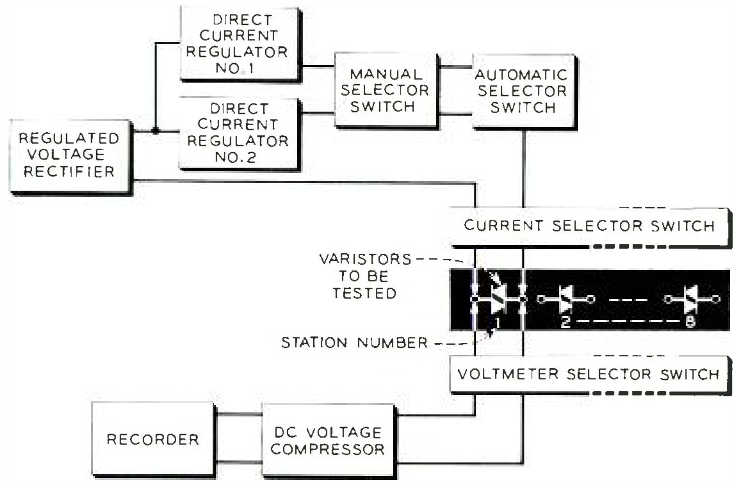


Fig. 2 — Diagram of test circuit as arranged for obtaining current-voltage characteristics of varistors.

In equipment such as this, power supplies giving constant current (instead of constant voltage) are more suitable for testing varistors, because in these devices the current may vary in proportion to as much as the sixth power of the voltage. That is, an error of one per cent in the indicated value of current will result in an error of perhaps as small as one-sixth per cent in the measured value of voltage, whereas a one per cent error in the indicated voltage could produce as much as a six per cent error in the measured value of current.

The apparatus used for the tests is shown in the headpiece. The components are assembled on a standard relay rack, mounted on wheels for portability. A Leeds and Northrup "Speedomax" recorder is used to print the data, and can be seen in the photograph near the top of the unit. The data are printed on a 10-inch wide strip chart having 100 divisions. Just below the recorder is a voltage-measuring circuit, and below the shelf are the constant-current supplies. Switching circuits — used for automatically advancing the testing operation through a series of steps — are located in the recorder, and interconnections among various components of the test set are accomplished with patch cables in the rear of the apparatus. The sequences of the measurement steps and the times of measurement are also determined by these interconnections, as well as by the gear trains in the recorder.

A close-up photograph showing varistor discs being measured is seen in Figure 1. A bank of eight electro-pneumatic contactors makes connections, one at a time, to the discs. In the photo the sixth contactor from the left is shown making contact to the disc in that position. The varistors may also be located in a position remote from the test set; for example, they might be placed in a life-test rack like the one seen in the background of Figure 1. In such instances, a cable is used to connect the remote equipment with the test set, and switching circuits in the recorder automatically accomplish the sequential selection and connections of currents and potentials.

A block diagram of the test circuit as arranged for making current-voltage measurements is shown in Figure 2, and a typical record of such measurements is seen in Figure 5. The record shows voltages recorded at two currents, 5 ma and 50 ma. The currents are selected automatically once the correct interconnections have been made. As many as eight individually variable currents may be selected automatically from the supplies of constant currents. Thus, highly detailed voltage-current characteristics of groups of varistors can readily be obtained. The speed of testing and the number

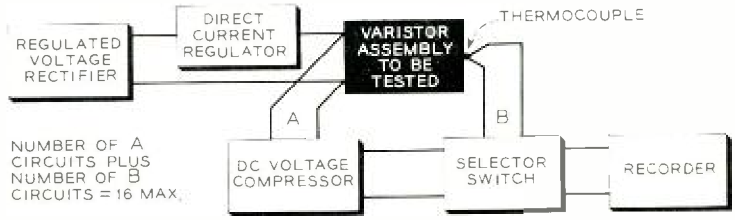


Fig. 3 — Diagram of test circuit as arranged for measuring power dissipation of varistors in an assembly. Temperatures and voltages are plotted.

of currents selected depend on the nature of the information desired. It is evident that statistical attributes of the data are easily determined from these records.

For power-dissipation studies on varistors, where it is necessary to measure temperatures and voltages simultaneously as a function of time, a different cir-

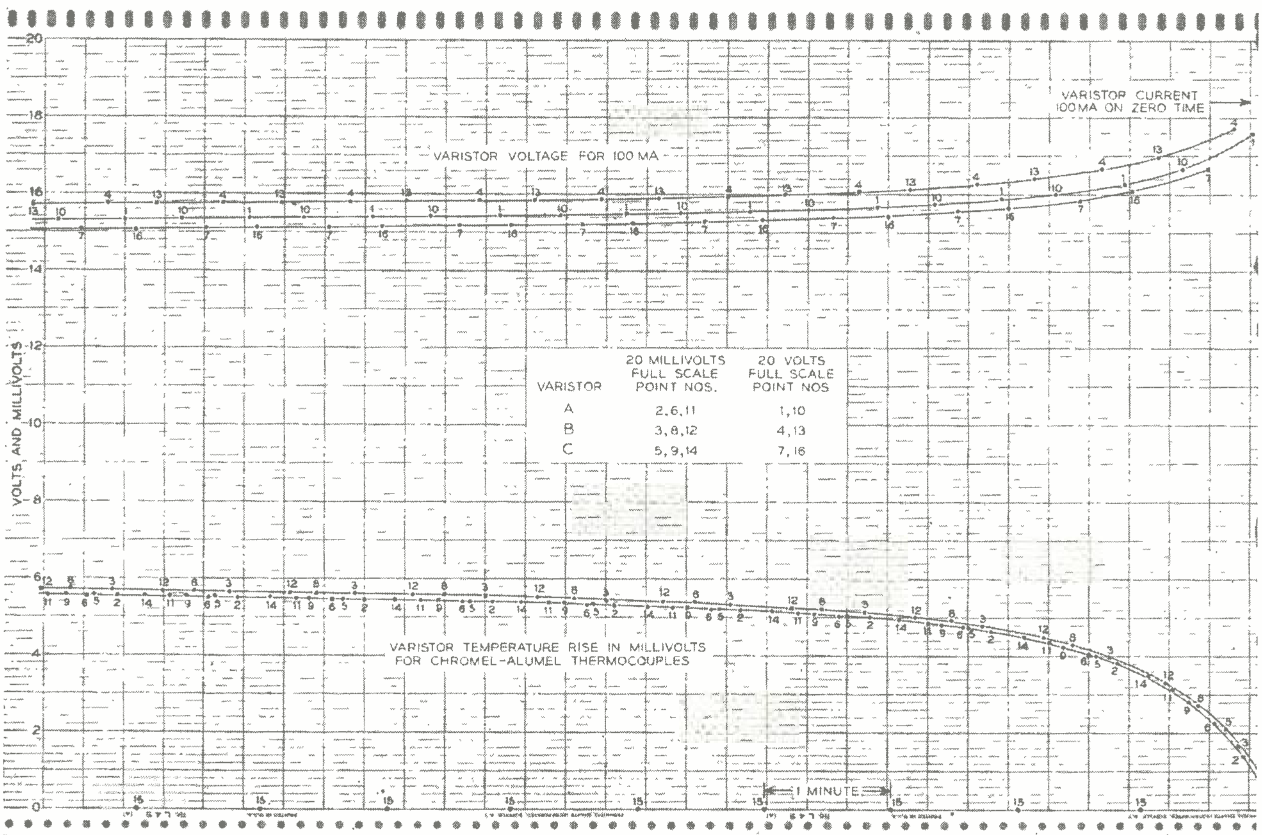


Fig. 4 — Record of varistor voltage (top curves) and thermocouple voltage (bottom curves) versus time for three varistors. Thermocouple voltages trace temperatures in furnaces where varistors are fired.

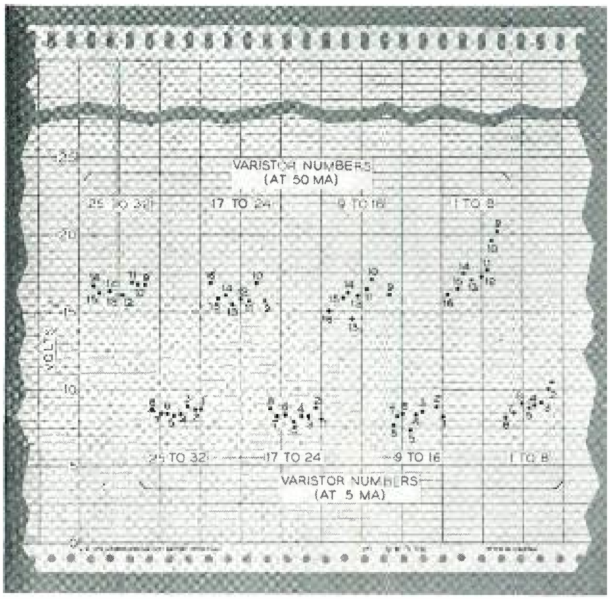


Fig. 5 — Record of measurements: thirty-two voltage datum points for each of the two current values, fifty and five milliamperes, used for this test.

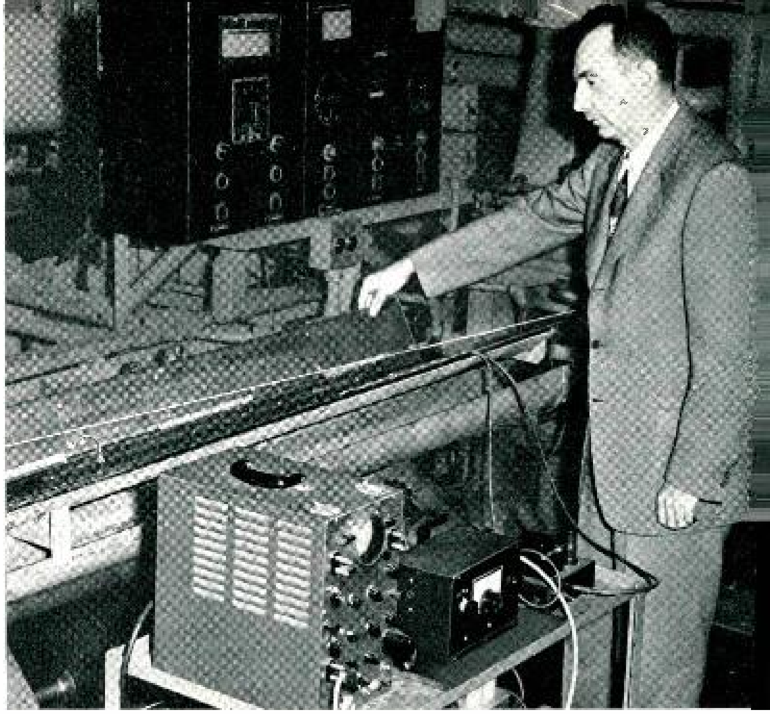
cuit arrangement is set up, as shown in block form in Figure 3. As many as 16 circuits can be sampled in one minute. A typical record, Figure 4, shows an upper trace which represents the varistor voltage at 100 ma, and a lower trace which represents the temperature in terms of thermocouple voltages. Intervals of one minute are printed at the bottom of the record, and each datum point is four seconds from the adjacent one. The two voltage scales, 20 millivolts and 20 volts, are switched automatically. The chart speed is variable over a twenty-to-one range to satisfy different time requirements.

The recording voltmeter has nine input ranges from 1 to 500 volts full scale with a 100-megohm input resistance. The zero can be placed anywhere on the scale. Potentiometer inputs of 0.02 and 0.20 volts are also available for low-voltage measurements, and the input resistance of the potentiometer when balanced is practically infinite. The voltmeter is capable of recording with a precision of better than ± 0.3 per cent of full scale without corrections. This degree of precision is maintained by monitoring with a standard cell and standard resistors. The recorder can print as many as 900 datum points in an hour. The supplies of constant currents regulate the pre-set current values to better than ± 0.1 per cent within the range from about 20 microamperes to several hundred milliamperes for voltages across the load not greater than 250 volts. When transient characteristics are to be measured, the recorder, instead of printing datum points, can be arranged to trace continuous curves by replacing the print wheel with a pen.

In the Laboratories development programs for silicon carbide varistors, this equipment has for many years been reliable and easy to operate. It proved to be so useful that a duplicate set was built by the Western Electric Company in the Allentown plant to measure production varistors.

THE AUTHOR

H. F. Dienel, a native of Detroit, Mich., was graduated from the University of Michigan in 1938, where he received the degree of B.S.E. in physics. After several years in the University of Michigan Engineering Research Laboratory and in industry, he joined the staff of Harvard University in 1941. At Harvard's Cruft Laboratory he was engaged in a project for the National Defense Research Committee in the field of electro-acoustics. Mr. Dienel joined Bell Telephone Laboratories in 1947 and worked on the development, design and application of silicon carbide varistors. From 1955 to the present time he has been studying the reliability of semiconductor devices at the Allentown, Pa., Laboratory.



A Capacitance Monitor for Plastic Insulated Wire

M. C. BISKEBORN AND R. A. KEMPF
Outside Plant Development

Whenever two conductors of electricity or a conductor and a "ground" are in reasonably close proximity, electrical capacitance exists between them. Variations in this interconductor capacitance can seriously degrade the transmission quality of a cable. These variations have been minimized in Bell System multipair telephone cable and solid-dielectric coaxial cable through the use of plastic insulation applied under the control of a capacitance monitor developed by the Laboratories.

One of the important advantages offered by plastic insulation for the conductors of multipair telephone cable or for the central conductor of solid dielectric coaxial cable is the feasibility of controlling the insulating process to attain repeatable and uniform capacitance. With paper or pulp insulated conductors, cable performance is limited because only the physical dimensions of the insulation are subject to control.

A capacitance monitoring system was developed for Bell System use in the measurement of the capacitance of a defined length of plastic insulated wire while it passes through the cooling water trough which follows the extruder applying the insulation. With this system, it is now possible to compare the capacitance of an insulated wire with that of a calibrated reference capacitor and to use the error signal to adjust automatically the speed of the wire or of the extruder screw to hold the capacitance of the wire within specified limits.

The objective for control of insulation of multipair cable is to achieve uniform capacitance along the length of the cable, among the many conductors, and between each conductor and all others, including the cable sheath. Uniformity of capacitance in paired cable serves to control (1) the susceptibility of the cable circuits to external electrical fields and to mutual interference from each other and (2) the electrical transmission characteristics of the circuits. For solid dielectric coaxial cable, uniform capacitance assures that signals will arrive at their destination without impairment due to reflections from impedance irregularities. Such reflections may cause "ghosts" in TV pictures.

The essential features of an extruder for insulating wire are indicated in Figure 1. Cold plastic material, usually in granular form, is fed into the hopper of the machine. The driven screw pushes the plastic forward into heated zones where it is softened and worked into a homogeneous mass. After it has traveled along the screw, the hot plastic is delivered, under appreciable pressure, to the core tube and die at the head of the machine.

The extruder may be considered to be a high pressure pump. The only place for the molten plastic to escape from the pump is the annular space between the wire and the round die. If the wire is drawn through the head of the extruder, a cylinder of insulation will be formed around the wire and carried to the cooling trough which chills the plastic until it becomes a hard and tough sheath. If the wire is pulled through at high speed, a thin wall of insulation will be picked up; a slow speed will result in a thick wall. Corresponding changes may also be made by driving the pump (screw) slowly or rapidly. Thus, at least two means are available for controlling the amount of insulation.

Figure 1 also includes a simplified block diagram showing the capacitance monitor coupled into an automatic servo system to control wire speed and thus achieve uniform capacitance. The bridge compares the measured capacitance of the insulated wire with the capacitance of the reference standard. If the capacitance of the wire does not match the standard, the detector develops an error signal which adjusts the speed of the capstan drive motor.

The operation of the capacitance monitor is based on a monitoring electrode which uses water to provide a tight-fitting conducting sheath over the exterior surface of the insulation. In the usual procedure, the coaxial capacitance of an insulated conductor is measured with voltage on the wire and with the outer conductor grounded. During extrusion, however, the wire is necessarily grounded by the metal parts of the extruder; therefore, the coaxial capacitance is measured on an "inside-out" basis, with voltage on the outer conductor and with the center wire grounded.

The electrode uses a system of several smaller guard electrodes to confine the measured length of wire to a precisely known value. The water is thus made to serve both as an insulator and as a conductor at the same time. Measurement accuracies in the order of ± 0.05 per cent are readily obtainable. The measurements are unaffected by the position of the wire in the electrode, as long as it remains covered with water. Depth of water may be varied, but its conductivity must be held within rather broad limits.

Figure 2 shows a laboratory setup of a monitoring electrode, a console for the servo equipment and an operator's remote control panel. Several such sets were constructed for use in the manufacture of the conductors for the transatlantic cable.

The capacitance, C, of an insulated wire to a coaxial conducting sheath which fits tightly over the insulation is expressed by the following relationship: $C = a\varepsilon / \log (D/d)$ farads per unit length, where ε is the dielectric constant of the insulating material, d the diameter of the wire, D the outside diameter of the insulation and a is a coefficient depending on the units used.

With solid plastic such as polyethylene, the normal variation in dielectric constant is very small. Controlled capacitance largely assures the the diameter ratio D/d is held constant. With expanded polyethylene, however, the dielectric constant is an inverse function of the degree of expansion. Two

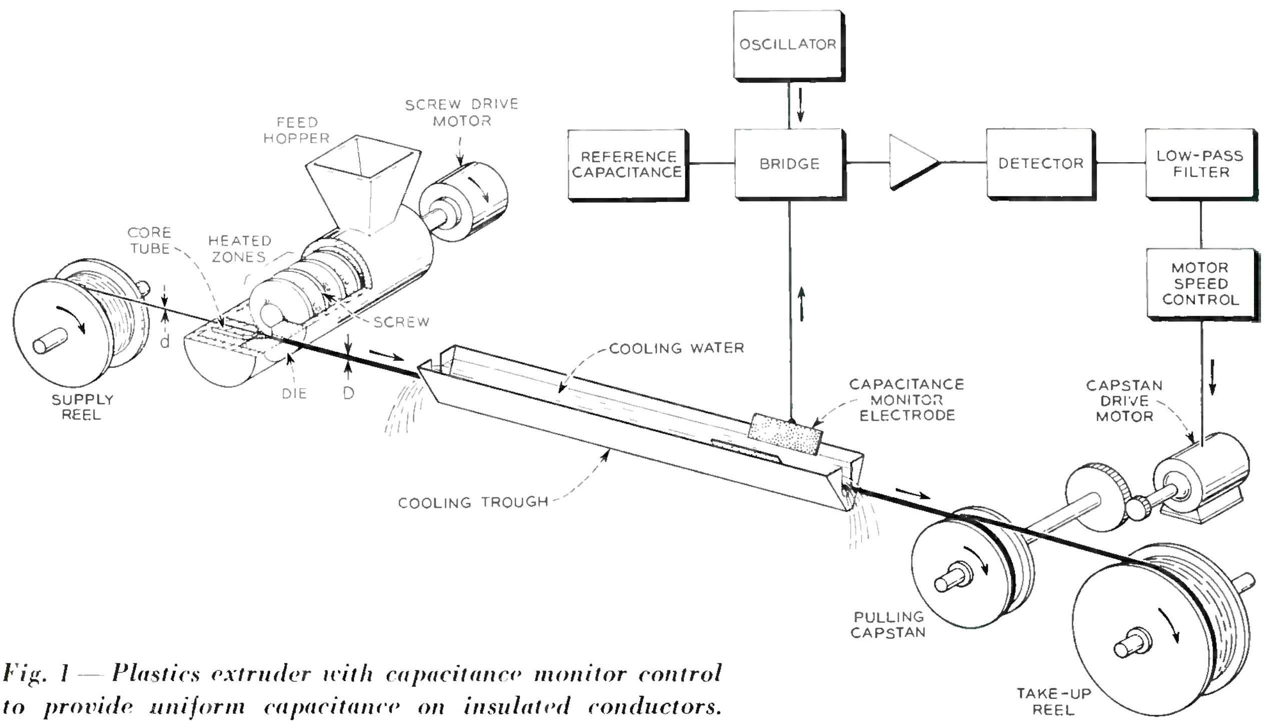


Fig. 1 — Plastics extruder with capacitance monitor control to provide uniform capacitance on insulated conductors.

Fig. 2 — Laboratory set-up including capacitance monitoring electrode (foreground), servo console, and operator's remote control panel (left background). S. C. Shores of the Laboratories demonstrates the use of the monitor in measuring the capacitance uniformity of an insulated wire.

variables, D and ε, must be controlled simultaneously. If the diameter, D, is held constant by appropriate means, control of capacitance then amounts to control of ε, or the degree of expansion. Without the capacitance monitor, making high quality cable with expanded polyethylene is impracticable.

Control of capacitance (as compared to control of D only, for example) results in several important advantages in the manufacture of multipair plastic cable. The effect of small changes in ε and d are minimized. The adverse effect of eccentricity of the insulation sheath on the electrical balance of a pair is also reduced to some extent. Analysis confirmed by data indicates that a given level of electrical quality in the final cable can be attained with relatively coarse tolerances on ε and d, as compared

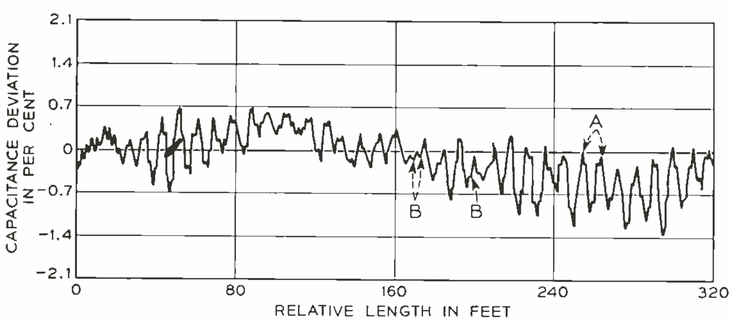


Fig. 3 — Deviations in capacitance of plastic insulated wire as a function of length. Periodicity due to eccentricity of capstan indicated by A, and low amplitude periodicity due to eccentricity of worm gear indicated by B.

to the severe tolerances required if diameter, D, instead of capacitance control is employed. The economic worth of broad tolerances is appreciable in large-scale production; alternatively, the improved electrical performance of cable made possible by capacitance control may spell the difference between success and failure of a system.

The need for a means of obtaining continous capacitance data during extrusion of expanded material provided the original stimulus which led to the development of the monitor. One of the earliest commercial uses of the capacitance monitor was the control of the extrusion process for the conductors of video pairs* having expanded polyethylene insulation. Since its first commercial use, the monitor has been employed on many projects.

The insulation produced by the usual extrusion set-up is subject to many sources and forms of periodic irregularities in diameter which alter the shape of the desired perfect cylinder. As an ex-

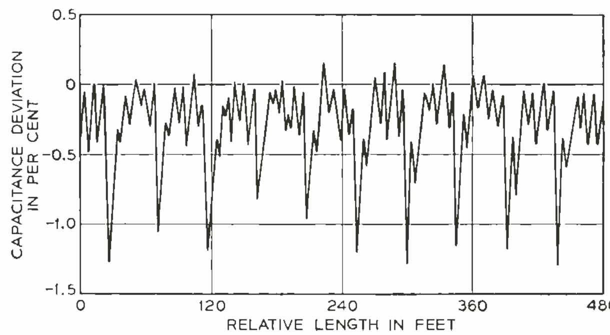


Fig. 4 — Capacitance record for large wire with thick plastic insulation showing negative pips caused by minute voids between wire and plastic.

ample, the hills and dales imprinted on the surface of the insulation may be caused by deficiencies in the extruder which result in an irregular rate of delivery of molten plastic to the head of the machine. Because the capacitance monitor facilitates obtaining a recorded trace of the deviations in capacitance along the length of insulated wires, it has been found useful in the study and elimination of undesirable systematic effects.

An example of the capacitance deviations along the length of an insulated wire is shown in Figure 3. The total spread in capacitance amounts to about 2 per cent. The capacitance trace is characterized by a large amplitude periodicity, designated by A, which was caused by an eccentricity in the face of the take-up capstan with respect to its axis of rotation. This caused the wire to speed up and slow

* RECORD, *May*, 1948, *page* 201.

down once each capstan revolution, with corresponding changes in capacitance. A fine grained periodicity of low amplitude, designated B, was caused by an eccentricity of the worm gear which drove the pinion of the extruder screw.

An unusual type of capacitance deviation is shown in Figure 4. The large negative pips were observed during the prove-in of one of the extrusion lines used for the manufacture of the transatlantic cable. The sudden negative excursions were found to be due to the periodic occurrence of an air void about 0.001 inch thick, between the insulation and the central conductor. A capacitance monitor showed the hot insulation to be satisfactory as it left the extruder. The voids formed during the cooling of the insulation, due to a deficiency in the control of the cooling water temperatures. The periodicity shown between the large negative excursions was caused by a periodicity in the rate of delivery of plastic due to the thread of the extruder screw. With proper adjustment of the extruder, the pulsing due to the screw thread would be much less than that shown in this trace.

Figure 5 is presented as an example of especially uniform wire manufactured for high frequency coaxial cable. The total deviation is only 0.15 per cent. The trace shows no periodic deviations. At high frequencies, the transmission loss and characteristic impedance are degraded by systematic deviations in capacitance, even though the deviations may be relatively small. The capacitance monitor was of appreciable value in setting up and adjusting a special extrusion line for producing smooth wire.

The capacitance monitor has made it possible to increase greatly the precision when polyethylene or other plastics are applied to conductors. The use of the monitor is essential in the production of

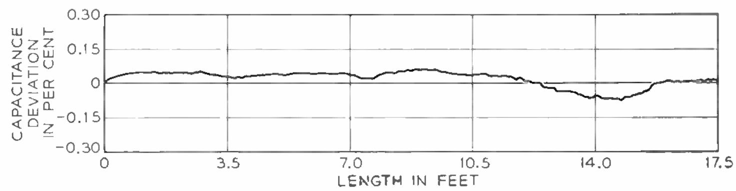


Fig. 5 — Capacitance record for plastic insulated wire manufactured by extrusion process.

expanded polyethylene insulated conductors for use in cable circuits and, indeed, has made such conductors practicable. It has also proved to be an excellent tool for examining the performance of any extruded insulation process and for determining the factors which affect the final objective — constant capacitance per unit length — for the millions of miles of insulated conductor used.

THE AUTHORS

R. A. Kempf, a native of Washington, Illinois, came to the Outside Plant Department of the Laboratories in 1937 after graduating from the University of Illinois with the B.S.E.E. degree. Except for the years 1941 through 1945, when he was on active duty as an officer in the Navy, Mr. Kempf has been assigned to the toll-cable development group at the Point Breeze Laboratory in Baltimore. His work with this group has included development of specialized cable instrumentation as well as the evaluation of performance characteristics of experimental cable structures for toll applications.

M. C. Biskeborn, a native of Scotia, Nebraska, received the B.S. degree in E.E. from the South Dakota School of Mines and Technology in 1930, and joined the Laboratories the same year. He transferred briefly to the Western Electric Company during 1942-1944. His early work at the Laboratories was concerned with the development of multi-pair carrier and coaxial cables. During World War II, he assisted in the development of one of the first automatic radars, microwave resonant cavities and microwave coaxial cable for the Bureau of Ships. He later worked on apparatus for high-frequency measurements on cable. At present Mr. Biskeborn heads a subdepartment on cable development, and as part of these responsibilities, was engaged in the design of the transatlantic cable. He is a member of the A.I.E.E. and author of an A.I.E.E. prize paper.

CAMA for Step-By-Step Areas

E. GOLDSTEIN
Data Processing Development

With direct dialing of long distance calls by all its customers as the Bell System's ultimate objective, a major step was the development of centralized automatic message accounting (CAMA). Since about one-half the customers of the Bell System are served by step-by-step offices, it was imperative that CAMA be made available to such offices. Therefore, the Laboratories has developed circuits to permit step-by-step offices served by crossbar tandem to take their place in the long-distance dialing plan.

Despite the increase in common-control switching offices like No. 1 and No. 5 crossbar, step-by-step systems still provide service for about one-half the telephone customers of the Bell System. Obviously, any comprehensive plan for nationwide direct distance dialing* must permit participation by these customers. This requires, first, switching facilities for proper routing of calls into and through the national toll network, and second, some means for recording information on extra-charge calls so that accurate bills can be rendered.

One of the most efficient gateways into the toll switching network for calls from all types of local offices is a crossbar tandem office.† It contains features to interconnect local offices, and also to connect them to the toll network. In 1953 its usefulness was further increased by the introduction of centralized automatic message accounting (CAMA).‡ A crossbar tandem office with CAMA as originally designed can record charging and billing information on extra-charge traffic from as many as two hundred common-control local offices.

At the tandem office a sender receives and stores the called number. It also brings in an operator who obtains the calling customer's number verbally and keys it into the sender. The sender then passes both the called and calling customers' numbers to the CAMA recording equipment, which records this and the additional information needed for billing on punched paper tape. The tape is processed in an automatic accounting center to produce the customer's bill.

CAMA operation allows customers to dial many calls which they would otherwise have to place with an operator, making it a real service improvement to the customers. It also reduces accounting effort and frees Operating Company personnel for other work. For these reasons it was decided to develop equipment and methods for making CAMA operation in crossbar tandem available to customers served by step-by-step equipment.

When common-control local offices operate with CAMA, they segregate those calls on which billing information must be recorded, and route them to the crossbar tandem office. They can do this because they store and decode the dialed number and have facilities for sending it to other offices. A step-by-step office, unlike common control offices, performs its functions under direct control of the customer's dial. When the customer removes his handset from its cradle, the step-by-step office connects a selector switch to his line. The dial, by interrupting the line current once for each pulse, sends the selector to a level corresponding to the first dialed digit. This selector then seeks an idle second selector connected to that level and extends the dial pulsing to it. The second selector is driven

* Record, *May*, 1951, *page* 197 and *October*, 1953, *page* 369. † Record, *April*, 1956, *page* 143. ‡Record, *July*, 1954, *page* 241.

to a position corresponding to the second digit, and so on. Each digit serves only to control one selector. Since it is "used up" in the process, it cannot be used for any further purpose.

To perform its function, the CAMA tandem office must have the called customer's number. It gets this number automatically from common-control local offices when these offices route calls requiring CAMA treatment to the tandem office. Since step-by-step offices work under direct control of the customer, it is he who must direct the call to the tandem office. His directory tells him which calls need this treatment, and instructs him to dial a directing code – usually 112 – followed by the number he wishes to reach. The 112 code is used up in reaching the tandem office; all succeeding digits are then registered in that office.

One of the requirements for this development of CAMA for step-by-step areas was that it should be possible for the customer to dial all digits without pausing. Fast dialers may allow as little as 0.6 second between digits. After the customer dials the 112 directing code, the last selector in the step-by-step office must recognize the end of the third digit and find an idle trunk to the tandem office. These operations in the step-by-step office may consume as much as 0.5 second. This allows only about 0.1 second for the tandem office to recognize that a call is coming in and attach some means for receiving and storing the next dialed digit – normally, the first digit of the area or office code.

The conventional two-stage sender link used in crossbar tandem takes about one second to attach a sender and prepare it to receive pulses. It is evident that the sender cannot be ready in time for the first digit. In fact, one cannot be reasonably sure that a sender will be ready until after the customer has had time to dial as many as three digits into the tandem office. To design a new, extremely fast sender link, and to provide enough of the complex and relatively expensive senders to insure that a sender would always be immediately available to an incoming call, was found to be uneconomical. So was a scheme to provide equipment for each incoming trunk circuit to register the first few digits. It was therefore decided to connect another piece of equipment – an incoming register – very quickly. This register, with a capacity of three digits, is relatively simple and inexpensive; enough of them could be provided so that normally one would be available immediately.

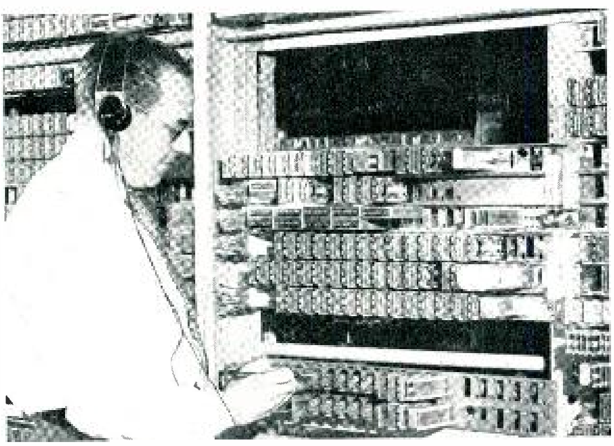


Fig. 1 — E. F. Weight, wire chief of the University office at San Diego, does some final checking on new senders just before the cutover.

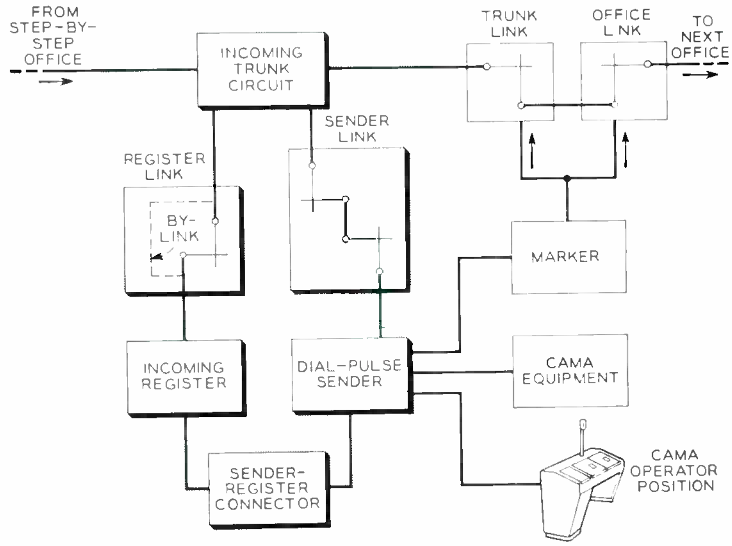


Fig. 2 — Block diagram of the arrangement in a crossbar tandem office for CAMA to work with step-by-step offices.

This method is illustrated in Figure 2. As soon as the incoming trunk circuit recognizes a seizure, it signals simultaneously to the register link and sender link to attach a register and sender. The register link is very fast, using only a single stage of crossbar switches. But, even the time necessary to operate and check the operation of a single crossbar switch is too long for this purpose. This link therefore uses "bylink" operation; that is, it temporarily uses contacts on its high-speed control relays to connect one lead (shown in dashed lines in the figure) from the trunk to the selected register while it is setting up the regular connection through the crossbar switch. This lead carries pulsing into the register until the connector crosspoint is closed.

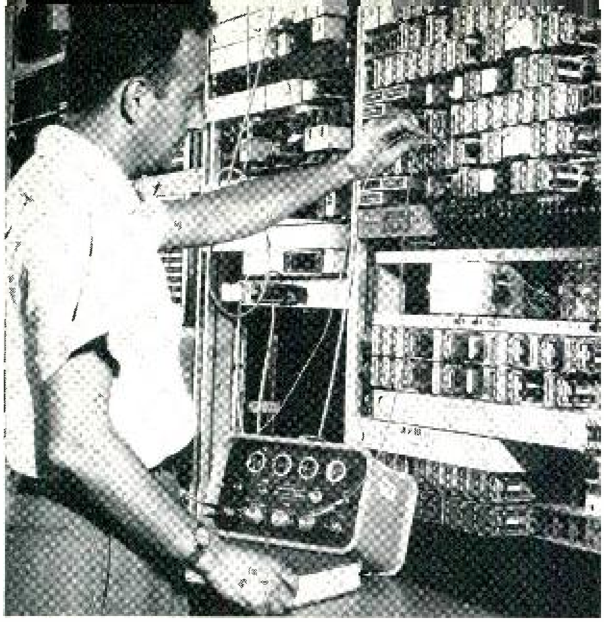


Fig. 3 — A. P. Famiglietti measures the operate time of a relay in a CAMA incoming register.

While the customer is dialing three digits into the register, the sender link has time to connect a sender to the trunk. After receiving three digits, the register signals the sender through the trunk circuit to accept all following digits.

At this stage, the register contains three digits which the sender will need to finish its job. Both the sender and the register have been independently chosen, but they have one thing in common – they are connected to the same trunk circuit and can exchange signals over leads through that circuit. With the aid of these signals, another circuit, the sender-register connector, is brought into play to connect many leads from register to sender for a very short time so that the three stored digits can be transferred all at once while dialing continues.

There are four sender-register connectors in an office. One-fourth of the senders can reach each connector, but every connector can reach every register. Taking its turn after other senders, if necessary, the sender takes sole possession of the connector that serves it. The connector operates a 30-contact relay to connect the sender to a multiple consisting of leads to which any sender served by the connector and any register can be connected. It then "reaches through" the sender, trunk and register to operate a relay that also connects the register to the same multiple.

Fifteen leads, which now extend from the register through the connector into the sender, transmit the three digits stored in the register to the sender. Using five additional leads, the connector identifies the register to the sender, so that any troubles found after the register has been released can be traced back to it. Other leads are used for controlling the connector, register, and sender. Because of this "parallel" method of operation, the connector holding time is short enough – about 50 milliseconds – for four connectors to serve all the senders and registers without appreciable delay.

The register has now completed its job on the call and is freed to serve other calls. The sender calls in a marker, which connects it to the next switching office through the trunk link and office link in the usual manner. The remaining digits are dialed into the sender by the customer and it continues its job, now very similar to that of the other CAMA senders in the tandem office. It connects the customer to an operator who keys the number of the calling telephone into the sender, passes the called and calling customers' numbers to the CAMA recording equipment, and then pulses the called customer's number to the next office, and releases.

The adaptation of CAMA in crossbar tandem to serve step-by-step areas is another major step toward full direct distance dialing by all telephone customers in the Bell System. Similar arrangements are now under development to permit CAMA operation in No. 5 crossbar and 4A toll crossbar offices to serve step-by-step areas.

THE AUTHOR

E. Goldstein, a resident of Summit, N. J., joined the Laboratories in 1949 following graduation from the University of Minnesota with the B.E.E. degree. From 1949 to 1956 he was engaged in the development of CAMA and the direct distance dialing features of crossbar tandem offices. During this time, he also completed the Communication Development Training Program. For the past year he has been teaching switching circuit design to technical aides, and has recently transferred to the Bell System Data Processing project. A Captain in the U. S. Army Signal Corps Reserve, Mr. Goldstein served on active duty from 1944 to 1948, and was recalled in 1950-1952 for the Korean Emergency. He is a member of Tau Beta Pi and Eta Kappa Nu.

Five Awarded Honorary Degrees

During June commencement exercises at five leading educational institutions, honorary degrees were conferred upon Dr. M. J. Kelly and Dr. Walter H. Brattain, upon former Vice Presidents of Bell Laboratories D. A. Quarles and W. H. Martin, and upon retired member of the Laboratories L. Espenschied.

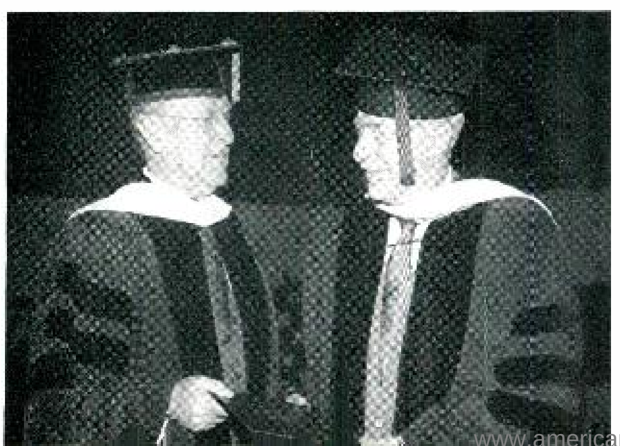
An honorary Doctor of Science degree was presented to Dr. Kelly by the University of Pittsburgh on June 12. University of Pittsburgh Chancellor Edward H. Litchfield read the following citation as he conferred the degree on Dr. Kelly:

"For your contributions to modern science, for your insistence upon ever higher standards of professional education and for your outstanding assistance in the growth of corporate understanding of the role of research in modern industry, I confer upon you the degree of Doctor of Science."

Dr. Brattain, Laboratories physicist and recent co-winner of the Nobel Prize for physics, returned to the campus where he earned his Ph.D. degree when he received an honorary Doctor of Science degree from the University of Minnesota on June 15. Dr. Brattain's citation reads: "Because your scientific achievements have added in ways that are fundamental and epochal to an understanding of electron-physics, and thereby have strengthened our ability to maintain the national security; and because what you have done in your brilliant career enhances the well-being of men wherever scientific knowledge has impact on human lives, the Regents of the University of Minnesota, upon recommendation of the faculties, confer upon you the degree of Doctor of Science."

Mr. Quarles, former Vice President of the Laboratories, Vice President of Western Electric Co., President of the Sandia Corporation and now Deputy Secretary of Defense, received an honorary doctorate from Yale University on June 10. He was one of thirteen civic, military and professional leaders cited by the university. Conferred by Yale President Dr. A. Whitney Griswold, the degree was accompanied by a citation which honored Mr. Quarles as "leader in electronic research, administrator, public servant," and as one who has "shown special qualities of wisdom and statesmanship which bring strength to the nation and can mean peace to the world."

Dr. W. H. Brattain, right, receives degree from University of Minnesota President J. J. Morrow.



At the commencement exercises at the University of Pittsburgh. Front row, Chancellor E. H. Litchfield and Dr. M. J. Kelly. At rear, A. B. Scaife of the University Board and A. B. Van Buskirk of T. Mellon and Sons, who also received degree.

Former Vice President of the Laboratories William H. Martin received on June 11 the honorary Doctor of Science Degree from his alma mater, Johns Hopkins University. He was honored for the accomplishments of his telephone career, including his numerous publications and patents, his scientific contributions during World War II, and for his more recent governmental services. Mr. Martin, who retired as Vice President of the Laboratories in 1954, was Deputy Assistant Secretary of Defense until assuming the position of Director of Research and Development for the Army in September, 1955.

Mr. Espenschied, co-inventor of the coaxial cable system, who retired from the Laboratories in 1954, was awarded an honorary Doctor of Science degree by Pratt Institute on June 7. The degree was presented to Mr. Espenschied "in recognition of the outstanding service rendered to industry and the nation through his substantial contributions to the field of communications and his notable achievements in fundamental and applied research."

Research physicists H. Suhl (left) and M. T. Weiss discuss ferrite microwave amplifier. Electromagnet used to produce dc field is in background.

New Ferrite Microwave Amplifier

A new solid-state microwave amplifier using a ferrite material as the active element has been successfully operated at Bell Telephone Laboratories. The ferromagnetic amplifier was predicted on theoretical grounds by Dr. H. Suhl and the experimental program was carried out by Dr. M. T. Weiss, research physicists at Bell Laboratories.

Although still in the laboratory stage, this amplifier is an important addition to the growing family of solid-state devices. It operates at room temperature and is expected to have a much lower noise level than conventional microwave amplifiers. Thus it has exciting possibilities as an amplifier for very weak microwave signals such as may be encountered in the fields of radio astronomy, microwave radio relay and radar.

Operating Principles

This amplifier has certain superficial similarities to the solid-state spin oscillator proposed by Prof. N. Bloembergen of Harvard University and first made to oscillate by Drs. H. E. D. Scovil, G. Feher and H. Seidel of Bell Laboratories.* Both types must be supplied power from an oscillator operating at a higher frequency than the signal to be amplified, but the principles of operation of the two devices are quite different.

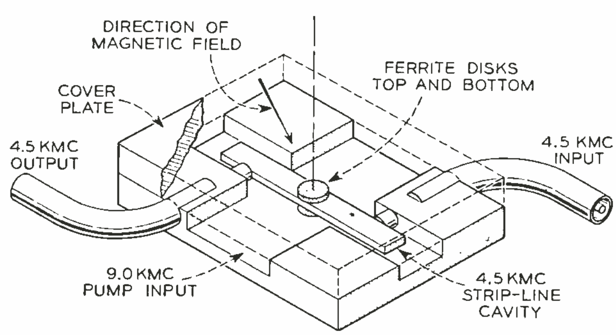
In principle, the present device requires that a ferrite sample be placed in a microwave cavity which is simultaneously resonant to two signal frequencies. Microwave power at the higher frequency – equal to the sum of the two signal frequencies – is then pumped into the cavity. A dc magnetic field, properly oriented and of sufficient intensity to cause gyromagnetic resonance at this sum frequency, must also be applied. Through nonlinear coupling in the ferrite, amplification or oscillation will be exhibited at either of the lower frequencies, or frequency conversion of a microwave signal can take place between them.

Experiments

One experiment conducted at Bell Laboratories is indicated in the accompanying diagram. To simplify the circuitry, the two signal frequencies were each made approximately 4.5 kilomegacycles. The pumping power of 9 kilomegacycles was fed into the resonant cavity as shown, and the signal power was taken in and out by means of coaxial cable. With sufficient pumping power, oscillations took place at 4.5 kilomegacycles. When the pumping power was reduced somewhat, amplification was observed at this frequency.

In the experimental setup, the dc magnetic field (about 2500 gauss) was provided by an electromagnet, but a permanent magnet could be employed if desired. The field is parallel to the plane of the strip-line cavity and is oriented at an angle of about 45 degrees with the cavity.

In another experiment, a cavity was designed to be resonant to 4.0 and 4.8 kilomegacycles, with the pumping frequency set at 8.8 kilomegacycles. Oscillations and frequency conversion were observed at both the lower frequencies.



Cavity arrangement for experiment using 4.5-kmc input and output with 9.0-kmc pump.

* Record, *March*, 1957, *page* 109.

The action of the ferromagnetic amplifier can be simulated at low frequencies by a pair of ordinary resonant circuits coupled by a variable inductance or capacitance. Since certain very high frequency atomic phenomena also have this circuit analog, it is possible that the same amplification principle will find applications at frequencies much higher than those presently in use.

It appears that ferromagnetic amplifiers can be designed for operation in practically any portion of the microwave spectrum. Preliminary results indicate that the bandwidth is adequate for many applications. Thus, although the new device is still in the experimental stage in the research laboratory, this discovery may lead the way to an entirely new group of ferrite microwave devices.

Dr. M. J. Kelly to Serve in Foundation and Air University Posts

Dr. M. J. Kelly has recently accepted two positions, one as Vice-Chairman of the Advisory Council of the Patent, Trade-Mark and Copyright Foundation for the coming year, and the other as member for a three-year term of the Board of Visitors to the Air University at Montgomery, Ala.

A non-profit educational organization, the Patent, Trade-Mark and Copyright Foundation was established at George Washington University to increase the understanding and knowledge of the people of the United States of the nature and value of the incentives granted under the Constitution to authors and inventors to promote the progress of science and the useful arts. In his capacity as member of the Air University Board of Visitors, Dr. Kelly will participate in determining policies for the institution. The Board reports directly to the Chief of Staff of the Air Force.

C.D.T. Graduates Ninety-three

Ninety-three young Members of Technical Staff received certificates marking their successful completion of the Communications Development Training Program in ceremonies in Arnold Auditorium at Murray Hill on June 24.

Dr. John R. Dunning, Dean of the School of Engineering at Columbia and distinguished nuclear scientist, addressed the graduates. He spoke on "Communications in the Atomic Age."

The certificates were presented by Vice President E. I. Green, chairman of the Educational Policy Committee of the Laboratories. F. D. Leamer, Personnel Director, welcomed the graduates and the guests, and S. B. Ingram, Director of Education and Training, was chairman.

Some 325 persons were present for the ceremonies, which marked the seventh annual C.D.T. graduation. The C.D.T. program was started in 1948 as a three-year course to provide additional training for young engineers who had recently received their bachelor's and master's degrees.

Study opportunities will be expanded this fall when New York University opens a graduate study center at the Laboratories where C.D.T. students may earn graduate credits by taking courses offered by N.Y.U.'s College of Engineering.

New Member of Laboratories Board

T. E. Shea, Vice President – Engineering, Western Electric Co., has been elected to the Bell Laboratories Board of Directors. He replaces H. V. Schmidt, Western's Vice President – Plant Design and Construction, who submitted his resignation to the Board at its meeting on June 24.

Mr. Shea joined the Western Electric Co. in 1920 as a development engineer at Hawthorne. With the incorporation of the Laboratories in 1925 Mr. Shea became a Member of Technical Staff, remaining here until he rejoined Western in 1939. He served as Vice President of the Laboratories for several months in 1952 before joining the Sandia Corporation. He was recalled to Western in 1954 and has served as Vice President since that time.

Contents of the June, 1957, Bell System Technical Journal

The June, 1957, issue of THE BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Noise Spectrum of Electron Beam in Longitudinal Magnetic Field: Part I – The Growing Noise Phenomenon and *Part II – The UHF Noise Spectrum* by W. W. Rigrod.

Distortion Produced in a Noise Modulated FM Signal by Non-linear Attenuation and Phase Shift by S. O. Rice.

Self-Timing Regenerative Repeaters by E. D. Sunde.

A Sufficient Set of Statistics for a Simple Telephone Exchange Model by V. E. Benes.

Fluctuations of Telephone Traffic by V. E. Benes.

High-Voltage Conductivity Modulated Silicon Rectifier by H. S. Veloric and M. B. Prince.

Coincidences in Poisson Patterns by E. N. Gilbert and H. O. Pollak.

Talks by Members of the Laboratories

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

Electron Tube Research Conference, Berkeley, California

Bowers, K. D., and Mims, W. B., *Three-Level Maser without Magnetic Field.*

Feinstein, J., and Kino, G. S., *The Large Signal Behavior of Crossed-Field Traveling-Wave Devices.*

Feinstein, J., *A New Family of Slow Wave Structures Intended for Crossed-Field Tubes.*

Gordon, J. P., *Noise Figure of Negative Resistance Maser Amplifiers.*

Hines, M. E., *Amplification in a Nonlinear-Reactance Modulator.*

Kino, G. S., see Feinstein, J.

Mims, W. B., see Bowers, K. D.

Suhl, H., *A Ferromagnetic Microwave Amplifier.*

Weiss, M. T., *A Solid State Microwave Amplifier and Oscillator Using Ferrites.*

White, A. D., *A New "Hollow" Cathode Gas Tube.*

A.I.E.E. Summer General Meeting, Montreal, Canada

Curtis, H. E., Strahlendorf, U. C. P., and Wade, A. J., *The Simultaneous Transmission of Television and Telephone Multiplex Over a Single Microwave Channel on the Trans-Canada TD-2 System.*

Distler, R. J., and Sturzenbecker, C., *A Magnetic Amplifier Voltage Current Overload Protection Circuit.*

Joel, A. E., *An Experimental Remote-Controlled Line Concentrator for No. 5 Crossbar System.*

Mertz, P., *Information Theory Impact on Modern Communications.*

Michel, W. S., *Statistical Encoding for Text and Picture Communication.*

Schwenker, J. E., *Experimental Data Transmission Digital Subset Using Magnetic Tape.*

Strahlendorf, U. C. P., see Curtis, H. E.

Sturzenbecker, C., see Distler, R. J.

Wade, A. J., see Curtis, H. E.

1957 Biennial Electronic Materials Symposium, I.R.E., Philadelphia, Pa.

Benson, K. E., see Wernick, J. H.

Geller, S., see Wernick, J. H.

Mason, W. P., and Thurston, R. N., *Use of Piezoresistive Materials in the Measurement of Displacement, Force and Torque.*

Thurston, R. N., see Mason, W. P.

Van Uitert, L. G., *Ferrites for Microwave Applications.*

Wernick, J. H., Geller, S., and Benson, K. E., *New Semiconductors.*

3rd Biennial Carbon Conference, Buffalo, N. Y.

Calbick, C. J., *Evaporated Carbon Films.*

Galt, J. K., Yager, W. A., and Merritt, F. R., *Cyclotron Resonance in Graphite (Experimental).*

Hellman, M. Y., see Lundberg, J. L.

Lundberg, J. L., Nelson, L. S., and Hellman, M. Y., *Carbon Formation by the Flash Illumination of Polymers.*

Merritt, F. R., see Galt, J. K.

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

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

American Physical Society, Notre Dame, Indiana

Collins, R. J., and Thomas, D. G., *Photoconductivity of Zinc Oxide.*

Dransfeld, K., *Sound Absorption in Liquid Helium.*

Lander, J. J., *Physical and Chemical Properties of Solid Solutions of* H_2*, Zn, and Li in ZnO.*

Thomas, D. G., see Collins, R. J.

Field Emission Symposium, Pennsylvania State University, University Park, Pa.

Allen, F. G., *Field Emission from Silicon (Theory).*

D'Asaro, L. A., *Field Emission from Silicon (Experiment).*

Becker, J. A., *Some Adsorption and Field Emission Effects for Oxygen on Tungsten.*

Other Talks

Baker, W. O., *The Small Forces of Nature,* International Symposium on Science, Industry and Education, Oklahoma City.

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

Berger, U. S., *New Facilities in the Bell System,* Haverhill Kiwanis Club, Haverhill, Mass.

Bommel, H. E., *Ultrasonic Measurements in Normal and Superconducting Metals,* Technische Hochschule, Stuttgart, Germany.

Compton, K. G., *Fundamentals of Underground Corrosion of Lead Cable Sheath*, West Virginia University, School of Mines, Morgantown, W. Va.

Dodd, Miss D. M., see Wood, D. L.

Fisk, J. B., *Today's Science – Tomorrow's Promise*, Alumni Day, Massachusetts Institute of Technology, Cambridge.

Guldner, W. G., and Beach, A. L., *The Application of Vacuum Fusion to Gas-Metal Studies*, American Society for Testing Materials, Symposium on Gases in Metals, Atlantic City, N. J.

Hake, E. A., *A 10-Kw Rectifier for Automatic Power Plants*, A.I.E.E., Conference on Rectifiers in Industry, Chicago.

Hall, A. D., *The Systems Engineering of a Microwave Radio Relay System*, Johns Hopkins University, Baltimore, Md.

Hamming, R. W., *Numerical Analysis*, Western Electric Co. Operations Research and Computer Applications Program, New York City.

Harvey, F. K., *Speech, Music and Hearing*, Emporium Section, I.R.E., Emporium, Pa.

Hittinger, W. C., *Diffused Silicon Transistors*, Low-Level Solid State Circuits Meeting, I.R.E., Princeton, N. J.

Hopkins, I. L., *Stress-Strain Relations in Polyethylene*, Polymer Clinic, Polytechnic Institute of Brooklyn, N. Y.

Houtz, C. C., see Struthers, J. D.

Kelly, M. J., *The Trends of Telecommunications as Affected by Solid State Electronic Instrumentation*, European Symposium on Radio Links, Rome, Italy.

Lee, C. Y., *Some Bounds on Binary Logical Expressions*, Association of Computing Machinery, Houston, Texas.

Maddox, H. D., *Basic Principles of Radar*, Kiwanis Club, Greensboro, N. C.

Mardis, T. E., *Science or Fiction*, Kiwanis Club, Greensboro, N. C.

Mason, W. P., *Relaxation in Polymers*, Gordon Conference on the Chemistry and Physics of Relaxations, New Hampton School, New Hampton, N. H.

McDavitt, M. B., *6000 Megacycles/Sec. Radio Relay System for Broad-Band, Long Haul Service in the Bell System*, European Symposium on Radio Links, Rome, Italy.

Miller, J. A., *Functions of the North Carolina Laboratories*, Western Electric Co. Summer Technical Employees, North Carolina Works.

Mumford, W. W., *Microwave Noise Figures*, Baltimore Section, I.R.E., Baltimore, Md.

Pearson, G. L., *Silicon in Modern Communications*, American Society for Engineering Education, Cornell University, Ithaca, N. Y.

Phair, R. J., *Physical Testing of Organic Coatings*, Course on Paint and Varnish Technology, Purdue University, Lafayette, Ind.

Pitts, J. E., Jr., *Amateur Radio Teletype*, Somerset Hills Radio Club, Summit, N. J.

Reiss, H., *Precipitation of Lithium in Germanium*, Argonne National Laboratories, Chicago, Ill.

Reiss, H., *Chemical Interaction Among Defects in Semiconductors*, Hoffman Semiconductor Division, Chicago, Ill.; Iowa State College, Ames, Iowa; and Shockley Semiconductor Laboratories, Mt. View, Calif.

Rose, D. J., *Secondary Mechanisms of the Glow Discharge*, Third International Conference on Ionization Phenomena in Gases, Venice, Italy.

Scovil, H. E. D., *Solid State Maser*, Solid State Circuits Subcommittee, I.R.E., Princeton, N. J.

Struthers, J. D., and Houtz, C. C., *Leak Testing of Transatlantic Cable Repeaters*, Purdue University, Lafayette, Ind.

Tuffnell, W. L., *Highlights of 500 Telephone Set Development*, Optimists Club, Indianapolis, Ind.

Wood, D. L., and Dodd, Miss D. M., *Infrared Bands in Crystalline Alpha-Quartz*, Symposium on Molecular Structure and Spectroscope, Ohio State University, Columbus, Ohio.

Papers Published by Members of the Laboratories

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

Becker, G. E., *Dependence of Magnetron Operation on the Radial Centering of the Cathode*, Trans. I.R.E. PGED, **ED-4**, pp. 126-131, April, 1957.

Boothby, O. L., see Williams, H. J.

Bowers, F. K., *What Use Is Delta Modulation to the Transmission Engineer?*, Commun. and Electronics, **30**, pp. 142-147, May, 1957.

Bozorth, R. M., *The Physics of Magnetic Materials*, in "The Science of Engineering Materials," published by John Wiley & Sons, pp. 302-335, 1957.

Buck, T. M., and McKim, F. S., *Experiments on the Photomagnetoelectric Effect in Germanium*, Phys. Rev., **106** pp. 904-909, June 1, 1957.

Buehler, E., *Contribution to the Floating Zone Refining of Silicon*, Rev. Sci. Instr., **28**, pp. 453-460, June, 1957.

Clemency, W. F., Romanow, F. F., and Rose, A. F., *The Bell System Speakerphone*, Commun. and Electronics, **30**, pp. 148-153, May, 1957.

Emling, J. W., *General Aspects of Hands-Free Telephony*, Commun. and Electronics, **30**, pp. 201-205, May, 1957.

Feldman, W. L., see Pearson, G. L.

Freudenstein, F., Warthman, K. L., and Watrous, A. B., *Designing Gear-Train Limit Stops for Control of Shaft Rotation*, Machine Design, **11**, pp. 84-86, May 30, 1957.

Geller, S., *Comments on Pauling's Paper on Effective Metallic Radii for Use in the β-Wolfram Structure*, Acta Crys., **10**, pp. 380-382, May 10, 1957.

Gerard, H. B., *Some Effects of Status, Role Clarity and Group Goal Clarity upon the Individual's Relations to Group Process*, J. Personality, **25**, pp. 475-488, June, 1957.

Papers Published by Members of the Laboratories, Continued

Green, E. I., *Evaluating Scientific Personnel,* Elec. Engg., **76,** pp. 578-584, July, 1957.

Green, E. I., *The Telephone,* "Encyclopaedia Britannica," **21**, pp. 895-906, 1957.

Hake, E. A., *A 10-kw Germanium Rectifier for Automatic Power Plants,* A.I.E.E. Conf. Publication "Rectifiers in Industry," **T-93**, pp. 119-128, June, 1957.

Harker, K. J., *Non-laminar Flow in Cylindrical Electron Beams,* J. Appl. Phys., **28**, pp. 645-650, June, 1957.

Herrmann, G., *Transverse Scaling of Electron Beams,* J. Appl. Phys., **28**, pp. 474-478, April, 1957.

Lumsden, G. Q., *Wood Poles for Communication Lines,* A.S.T.M. Bulletin, **222**, pp. 19-24, May, 1957.

McCall, D. W., *Cell for the Determination of Pressure Coefficients of Dielectric Constant and Loss of Liquids and Solids to 10,000 psi,* Rev. Sci. Instr., **28**, pp. 345-351, May, 1957.

McCall, D. W., *Dielectric Properties of Polythene,* in "Polythene, The Technology and Uses of Ethylene Polymers," edited by A. Renfrew and P. Morgan, published for "British Plastics" by Iliffe and Sons Ldt., London, 1957.

McCall, D. W., see Slichter, W. P.

McKim, F. S., see Buck, T. M.

McSkimin, H. J., *Use of High Frequency Ultrasound for Determining the Elastic Moduli of Small Specimens,* Proc. National Electronics Conference, **12**, pp. 351-362, April 15, 1957.

O'Brien, J. A., *Unit Distance Binary-Decimal Code Translators,* Letter to the Editor. Trans. I.R.E. PGEC, **EC-6,** pp. 122-123, June, 1957.

Pearson, G. L., Read, W. T., Jr., and Feldman, W. L., *Deformation and Fracture of Small Silicon Crystals,* Acta Met., **5**, pp. 181-191, April, 1957.

Pederson, C. W., *Crystal Clock for Airborne Computer,* Electronics, **30**, pp. 196-198, June 1, 1957.

Read, W. T., Jr., see Pearson, G. L.

Romanow, F. F., see Clemency, W. F.

Scaff, J. H., *Impurities in Semiconductors, Effect of Residual Elements on the Properties of Metals,* (A.S.M. Special Vol.) pp. 88-132, 1957.

Sherwood, R. C., see Williams, H. J.

Slichter, W. P., and McCall, D. W., *Note on the Degree of Crystallinity in Polymers as Found by Nuclear Magnetic Resonance,* J. Poly. Sci., Letter to the Editor, **25**, pp. 230-234, July, 1957.

Snoke, L. R., *Some Needed Basic Research on Wood Deterioration Problems,* Appl. Microbiology, **5**, pp. 188-193, May, 1957.

Van Uitert, L. G., *Effects of Annealing on the Saturation Induction of Ferrites Containing Nickel and/or Copper,* J. Appl. Phys., **28**, pp. 478-481, April, 1957.

Warthman, K. L., see Freudenstein, F.

Watrous, A. B., see Freudenstein, F.

Weinreich, G., and White, H. G., *Observation of the Acoustoelectric Effect,* Phys. Rev., Letter to the Editor, **106**, pp. 1104-1106, June 1, 1957.

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

Williams, H. J., Sherwood, R. C., and Boothby, O. L., *Magnetostriction and Magnetic Anisotropy of MnBi,* J. Appl. Phys., **28**, pp. 445-447, April, 1957.

Patents Issued to Members of Bell Telephone Laboratories During May

Augustadt, H. W., and Kannenberg, W. F. – *Telephone Answering and Message Recording System* – 2,793,252.

Bjornson, B. G. – *Lockout Circuit* – 2,794,121.

Bobis, S. – *Attenuation Equalizer* – 2,792,552.

Brown, W. L. – *Semiconductive Device* – 2,791,759.

Glass, M. S. – *Magnetic Structure for Traveling Wave Tubes* – 2,791,718.

Hoppe, G. E. – *Cross Bar Translator Switch* – 2,794,073.

Johnston, R. L., and Rulison, R. L. – *Electrical Contacts to Silicon* – 2,793,420.

Kannenberg, W. F., see Augustadt, H. W.

Kock, W. E. – *Signal Routing Apparatus* – 2,794,172.

Looney, D. H. – *Semiconductive Translating Device* – 2,791,758.

Morton, J. A. – *Electrical Switching and Storage* – 2,791,761.

Pfann, W. G. – *Semiconductor Translating Devices with Embedded Electrode* – 2,792,538.

Pfann, W. G. – *Junction Transistor* – 2,792,540.

Pierce, J. R. – *Ribbon Helix Traveling Wave Tube* – 2,792,519.

Platow, R. C. – *Sealing Electrical Apparatus* – 2,792,441.

Quate, C. F. – *Low Noise Velocity Modulation Tube* – 2,792,518.

Ross, I. M. – *Semiconductive Translating Device* – 2,791,760.

Rulison, R. L., see Johnston, R. L.

Smith, K. D. – *Electro-Optical System* – 2,793,299.

Yaeger, R. E. – *Pulse Code Resolution* – 2,793,807.

Younker, E. L. – *Electrical Delay Circuits* – 2,794,123.