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Paramagnetic Resonance Absorption in Organic Free Radicals

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Physical Research

To assemble so many technical words in one title is to invite despair in the humble and derision from the arrogant. Perhaps both audiences can be recaptured by offering them the words piece-meal, as a table of contents of what follows. First, then, what is a "paramagnetic" material?

It is now a familiar picture that matter is composed of massive nuclei, positively charged, and of relatively light electrons, negatively charged. The nuclei have various masses and charges, depending on their atomic species, but the electrons are all alike, and are present in most bits of matter in just sufficient number to balance the total charge of the nuclei and make the whole business electrically neutral.

The electrons do two magnetically significant things. In the first place they circulate about the nuclei at high speed in orbits, some simple, some complicated, whose observable properties can always in principle, and sometimes in fact, be calculated by the laws of quantum mechanics. Electrons circulating in orbits can be likened to electric currents passing around loops of wire; in particular such a current will produce a magnetic field. When all the components of that field, contributed by all the electrons, are added together, the result is ordinarily just zero. But when an additional magnetic field is applied to the bit of matter from outside, by a coil around it or a magnet near it, the orbits are changed just a little, and the circulation of the electrons produces a field which opposes the applied field. It is not much of a field, but it is enough to measure: the magnetic permeability of such a bit of matter will be a little less than that of a vacuum, by an amount called the "diamagnetic susceptibility."

The other magnetic sort of thing the electrons do is to spin. Perhaps the electron is like a top or like the earth spinning on its axis; perhaps it is like a little current loop within itself; perhaps neither visualization is quite fair. In any case for most purposes it can be described as a thing having not only an electric charge but also a "spin" which makes it look like a little current loop or bar magnet with a fixed magnetic moment, the "Bohr magneton."

The spin of an electron, and the magnetic moment associated with it, can each have only one particular value, and in the presence of a magnetic field they can only have

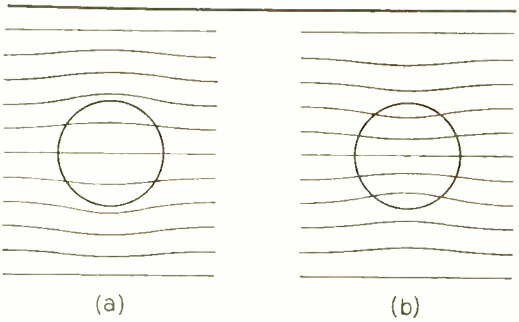


Fig. 1 – In a diamagnetic material (a) the orbital motions of the charged electrons tend to expel the lines of force of an applied magnetic field. In a paramagnetic material (b) the magnetic moments of the spinning electrons tend to suck in the lines of force.

one of two orientations, parallel or antiparallel to the direction of the field, if they are free of other encumbrances. Clearly an electron will have a lower energy in one of these directions than in the other, namely, in the direction which the corresponding little bar magnet would take if it was put in the same field, and in consequence it will prefer that direction. In that direction the field due to its spin will reinforce the applied field, rather than oppose it as did the field due to the electrons' orbital motion. In a bit of matter having spins which behave in that way, the reinforcing field due to the spins will usually outweigh the opposing field due to the orbits, and the permeability will be greater than that of a vacuum, by an amount called the "paramagnetic susceptibility." The assembly of independently acting single spins is a model for the simplest kind of paramagnetic material. The spins are not free to change their direction in all sorts of matter – the reason belongs later, with the chemical words in the table of contents – and matter divides into diamagnetic and paramagnetic sorts.

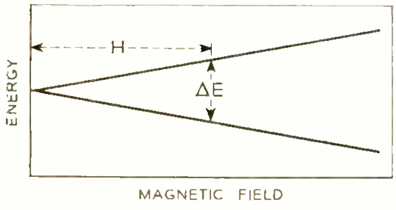


Fig. 2 – As one increases the magnetic field applied to a spinning electron, the energy difference ΔE between the two states of opposite spin increases.

Picture now a bit of paramagnetic matter in an externally applied magnetic field. A majority of the electron spins are directed along the field in the lower-energy direction; some of them are always being flipped over into the higher-energy direction by the random impacts and impulses of thermal motion, and are then losing their extra energy again and relaxing to their lower-energy state. But there is another way of flipping those spins into the higher energy state, a way more specific and selective than the crude, bumbling way of thermal excitation. Remember that electromagnetic radiation is emitted and absorbed by matter through many various processes, and that in any such process quantum theory says that the frequency of the radiation is proportional to the energy difference between the initial and final states of the process.

The flipping of spins in a fixed magnetic field is just such a process; if the energy difference between the two directions is the same for all spins, those in the low-energy state will absorb energy from an electromagnetic field which is oscillating at a certain single definite frequency and at no other (Figure 2). This is the "resonance absorption" of the title. Kicked thus into the higher-energy state, the spins will find ways of losing energy to the rest of the matter, or will reradiate it, and thus revert to energy levels at which they are candidates for a repetition of the process. The absorption depends on the existence of a net excess of spins in the lower-energy state, and is greater the lower the temperature.

Of course, if the process is really to occur, the spins must somehow be coupled to the exciting radiation. In this instance it will not be surprising that the coupling is to the magnetic, not the electric, component of the electromagnetic field. It is less obvious perhaps, that the coupling is a maximum if the oscillating magnetic field is at right angles to the fixed magnetic field; Figure 3 may make that fact seem reasonable. Since the energy difference responsible for the absorption is proportional to the strength of the fixed magnetic field, the resonance frequency can be put at any value you please by choosing a suitable field (Figure 4). In fact experimental work of this sort has been performed, both in these Laboratories and elsewhere, over a wide range of frequencies and corresponding fields. Since the intensity of the absorption turns out to increase rather strongly with frequency, it is advantageous to operate at a high frequency, even though the corresponding field is so high as to offer appreciable experimental inconvenience.

Most of the work at the Laboratories has been done at a frequency of about 24,000 megacycles (Figure 5). A bit of the substance to be studied is placed in a cavity associated with waveguides which supply the cavity with electromagnetic radiation from an oscillator. Waveguides also convey samples of electromagnetic radiation from the cavity to detectors which compare these samples with the radiation supplied. A powerful electromagnet places across the cavity a strong magnetic field which can be varied and measured. The oscillator is held at a definite frequency, the magnetic field is slowly varied, and when the field reaches the value for resonance absorption (Figure 4), the added conductance which the substance gives to the cavity is detected.

From the description thus far, one would expect that electrons should absorb energy by this process from the radiation at a single frequency, which was precisely predictable once the fixed magnetic field was known. This suggests that a single experiment should verify the prediction, and the investigator should then turn his attention elsewhere, for mere repetition of the result with different electron-bearing materials would be dull indeed. But fortunately for the interest of the work, though unfortunately for the simplicity of the story, the situation is more complicated. The electron spins, so far described as free, are not in fact unencumbered in a bit of matter. Their encumbrances are many; only three will be dealt with here.

The most important encumbrance comes from the "Pauli exclusion principle," which says that any one of the possible orbital motions in a bit of matter can be enjoyed by at most two electrons, and those two must have opposite spins. Suppose that a particular molecule has an even number of electrons. One will circulate in the orbit of lowest energy and a second will join it in that orbit but with opposite spin; another will occupy the orbit of next higher energy, in company with a fourth of opposite spin; and so on. And now the only way in which a magnetic field can flip a spin is by first promoting an electron to a higher-energy orbit, hitherto unoccupied; for if the spin flipped and the electron stayed in the same orbit, that orbit would be illegally occupied by two electrons with the same spin. But such a promotion requires an energy contribution far too large for the field to make, and hence no flipping occurs and the material is diamagnetic.

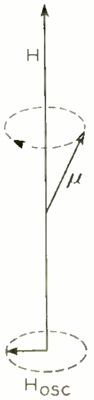


Fig. 3 — The magnetic moment μ of the electron precesses about the direction of the applied field H at the Larmor precession frequency. The magnetic field H_{osc} at right angles to H can exchange energy with the processing system when it also is alternating at the precession frequency.

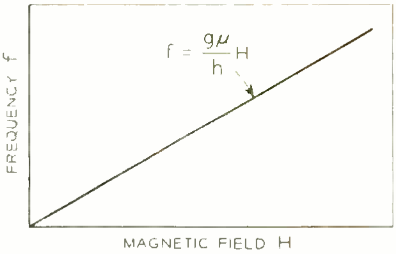


Fig. 4 — The resonance frequency f is related to the energy difference ΔE of Figure 2, and to the field H, by $f = \Delta E/h = (g\mu/h)H$, where μ is the Bohr magneton, g is the Lande splitting factor and h is Planck's constant. For a free electronic spin the slope of the line is 2.8 megacycles per oersted. Departures of the spin from freedom change the slope, and are usually described by assigning a different value to g.

Clearly one way in which a material can escape this restriction and become paramagnetic is to have an odd rather than an

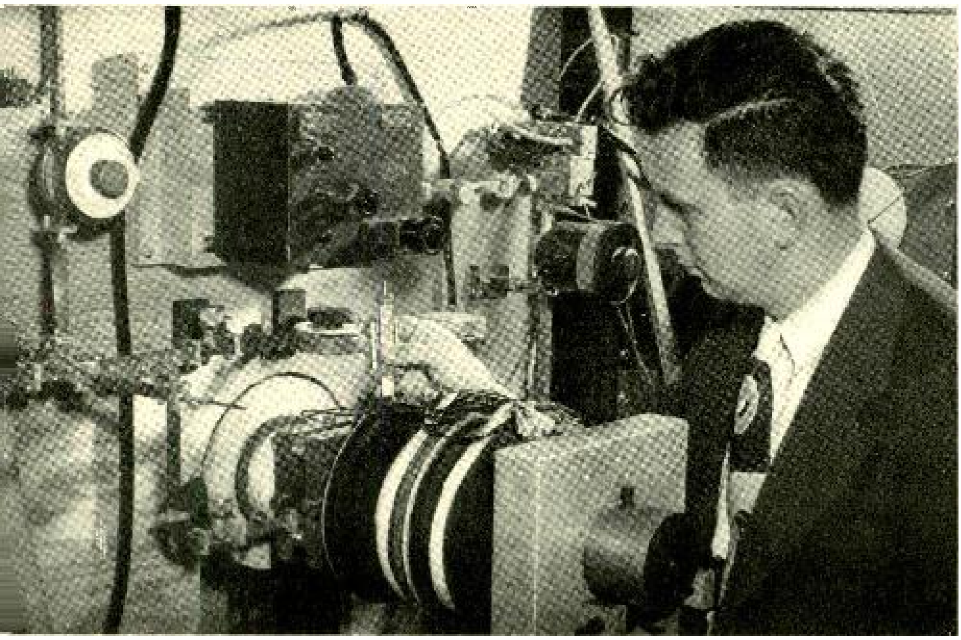


Fig. 5 — Paramagnetic resonance absorption measurements at K-band frequencies (1.25 centimeter wavelength) require magnetic fields of about 8600 oersteds. F. R. Merritt is ready to attach a resonant cavity containing a paramagnetic sample to the waveguide between pole pieces of an electromagnet.

even number of electrons. This is the escape taken by "organic free radicals," which indeed can be defined as organic molecules with an odd number of electrons. They are relatively rare among the great array of organic compounds: the astonished phrase "paramagnetische organische Verbindung!" in the Landolt-Bornstein Tabellen fathered the colloquial designation "P.O.V." They are rare because there is ordinarily a strong tendency for two molecules with an odd number of electrons to join hands and form a molecule twice as big with an even number of electrons. Commonly, in fact, the chemist thinks of a free radical as a half-molecule, a molecule which has come apart, and looks for the reason why it has broken, why the fragment is "stable relative to its dimer," not joining its opposite number.

Another escape from the restriction should be mentioned, although it is not ordinarily available to organic molecules. Sometimes the occupation of an orbit by two electrons is energetically unfavorable, by an amount sufficient to upset the earlier statement of the way in which orbits are successively filled in order of increasing energy by pairs of electrons. This upset begins with the heavier atoms, such as iron. In chemical compounds containing those elements it often turns out that the total energy is lower when some of the orbits are occupied by electrons singly, and here in consequence is another mine of paramagnetic substances, providing the more familiar materials of that sort. In organic molecules, made of the lighter elements hydrogen, carbon, nitrogen, and oxygen this situation seldom if ever occurs.

A second encumbrance to the spins comes from the fact that the electron sees not only the magnetic fields applied by the experimenter from outside but also the magnetic field due to its own orbital motion. To the electron it looks as if the charged nucleus were moving around it, just as to us it looks as if the sun were moving around the earth, and the electron will see a magnetic field produced by that moving charge. Thus the frequency of the resonance absorption will depend on the sum of the known external and the unknown internal fields. The experiment therefore furnishes a method for measuring that additional internal field, or "spin-orbit coupling," by observing the departure of the resonance from its expected value.

The third encumbrance flows from the fact that a single free-radical molecule, with its odd electron, is not the only pebble on the beach. It is surrounded by identical neighbors, and the neighbors interact with one another in several distinguishable ways. The most obvious of these interactions is that between the magnetic fields of the odd electrons, or uncompensated spins, in adjacent molecules. As in the case of spin-orbit coupling, any one spin sees additional fields: fields from its neighbors which add to the field the experimenter applies. In this case, however, the additional field is constantly changing in an irregular way because of the bumbling thermal flipping process described earlier, and at any particular instant each spin may see a total field slightly different from that seen by every other spin, and from that which it saw an instant before. Hence the absorption observed by the experimenter in a bit of matter will be broadened over a range of frequencies: the spectral line will have a finite width (Figure 6), which can be approximately calculated. The first observation that was made of a spectral line of a P.O.V. revealed an unexpected property; the line was extraordinarily narrow, nearly one hundred times sharper than would be calculated from the interaction just discussed. To explain this narrowness, a more mysterious interaction between neighbors must be invoked: "exchange interaction." The odd electrons in adjacent molecules of the free radical actually exchange places every once in a while, and the more frequently they do so, up to a certain point at any rate, the more the line will be narrowed as compared with the width it would have if they did not exchange places at all. Evidently if the electrons change places moderately frequently they will tend to experience an "average" environment, one more nearly the same for all. Thinking

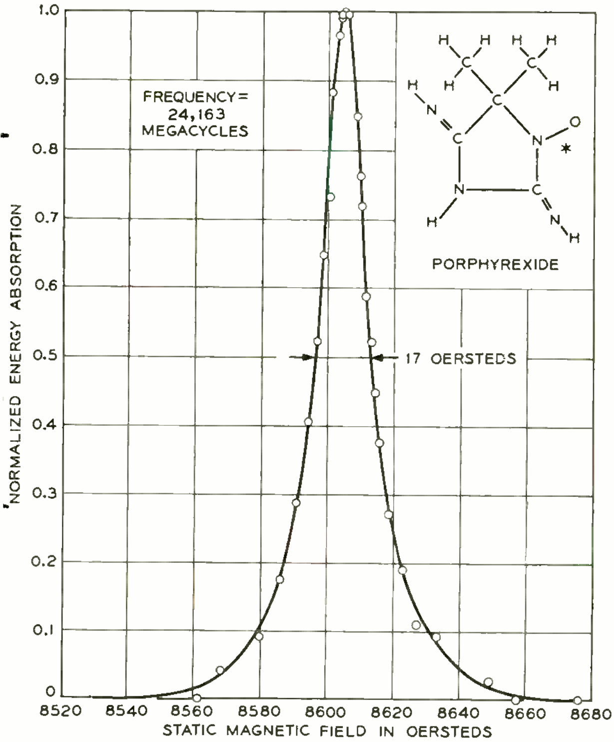


Fig. 6 – The spectral line, here shown for polycrystalline porphyrexide, is traced by holding the frequency fixed and observing the absorption as a function of the applied field. In the formula, the position of a three-electron bond is shown by an asterisk.

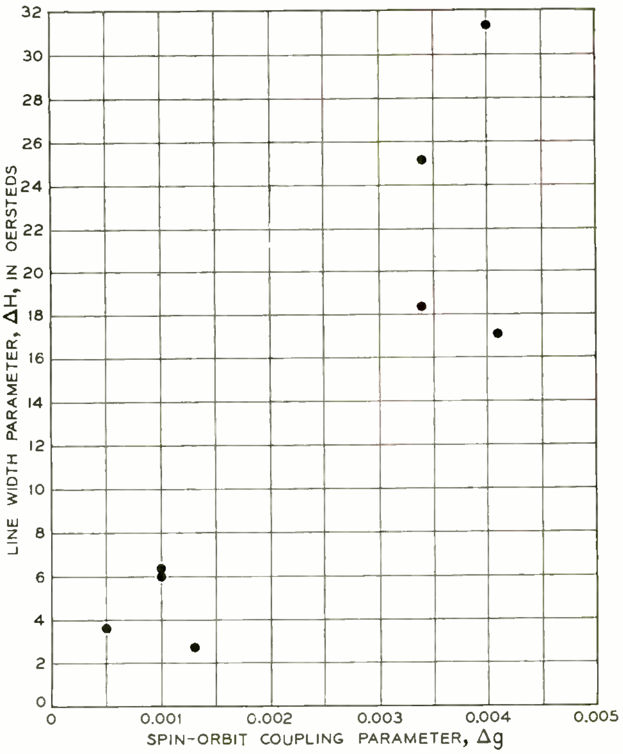


Fig. 7 – The line width parameter ΔH (width at half maximum absorption) and the departure Δg of the Lande splitting factor from its value for a free spin (2.0023) for polycrystalline samples of eight different organic free radicals.

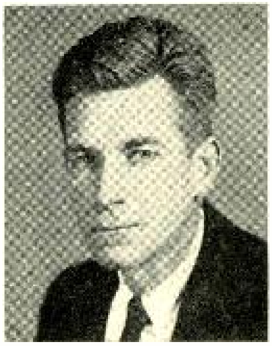
of the molecules which the electrons inhabit as like houses more or less close to one another which the electrons leave by the front door and enter by the rear, one can visualize that the electrons will change places more frequently the closer the houses are together, even though the electrons themselves may never get close to one another.

The interpretation which has been made of one set of paramagnetic resonance absorption measurements will serve to summarize these considerations. Figure 7 spots on a single diagram the values of g (Figure 4) and the widths of the lines observed in eight organic free radicals of widely differing types. The fact that lines are seen at all shows that the compounds do indeed contain unpaired electrons. Since the lines depart a little but only a little from the line expected for a free spin, spin-orbit coupling is present but small. For compounds of the metallic elements mentioned earlier, Δg would be 10 to 100 times larger. The fact that the lines are sharp shows that they are "exchange-narrowed." The more usual paramagnetic compounds give line-widths a hundred times greater.

A further deduction, of some chemical interest, can be made from the fact that the spots in Figure 7 fall in two separate groups. It turns out that the group of lines which are wider and whose "g-values" depart more from the free-spin value contains those and only those compounds which have in common a chemical structure in which two large groups of atoms and a single oxygen atom are bonded to a nitrogen atom. Now it is well known that the compounds NO (nitric oxide) and NO_2 (nitrogen dioxide) are among the very few simple odd-electron compounds. The molecules of those simple gaseous substances do not tend very strongly to join hands to form N_2O_2 and N_2O_4; the electrons seem to be happy in their unpaired state here, forming what is sometimes called a "three-electron bond" between nitrogen and oxygen. Apparently in the much more complicated free radicals of the >N-O type the odd electrons are still content to stay in the three-electron bond, and thus their houses are quite small and are held apart by the bulky remainders of the molecules, so that their spins are less free (Δg is greater), and their exchange interaction is smaller (ΔH is greater).

In addition to such applications to chemical theory, paramagnetic resonance absorption is beginning to receive practical application as a means of measuring strong magnetic fields accurately. Measurements of frequency are among the most accurate that can be made today, and by the use of a P.O.V. whose "g-value" (Figure 4) has been precisely determined, the field measurement is converted to a frequency measurement. The precision of such a measurement is primarily limited by the width of the spectral line, and the unexpected sharpness of the P.O.V. lines combines with their rather high intensity to provide a useful magnetometer.

THE AUTHOR: A. N. HOLDEN received an S.B. degree from Harvard University in 1925 and became a member of Bell Telephone Laboratories that year. After five years in the staff organization of the General Methods Department, and six years in the Publication Department, he transferred to the Research Department. From 1936 to 1945 he was in the Chemical Department and, after 1945, in the Solid State Group of Physical Research. Mr. Holden worked on originating new piezoelectric materials and perfecting methods of growing crystals for research investigations, a project which led to the development of the reciprocating rotary crystallizer and to the use of EDT as a substitute for quartz in some applications. For the past six years he has been engaged in the study of spectroscopy in the microwave region.



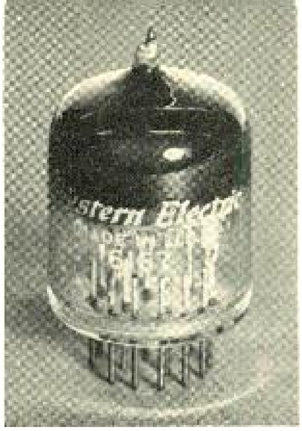


Fig. 1 – *The 6167 Western Electric counting tube.*

Cold Cathode Counting Tube

D. S. PECK
Electronic Apparatus Development

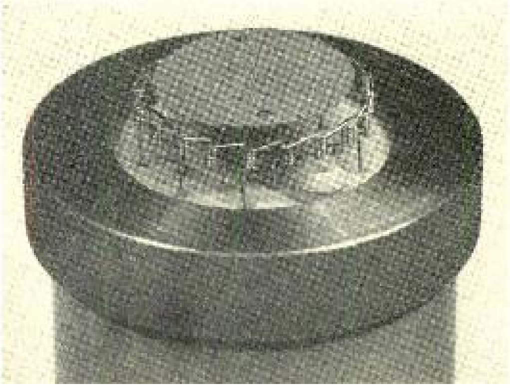
Counting has been a necessity of everyday living since the barter system of primitive man. Evolution of today's almost magical electrical counting machines has required only a relatively short period of time, yet advances in this field have been tremendous. Illustrative of this advance is the latest of the electrical devices for counting: the cold cathode counting tube. This tube utilizes twenty cathodes, instead of the one or two cathodes of more usual glow discharge tubes. The glow discharge is transferred from one cathode to another in succession thus providing output pulses to relays or other devices. In spite of its small size, the new 6167 counting tube (Figure 1) can replace a counting chain of relays or vacuum tubes plus their associated equipment. This permits a great reduction in both the quantity and size of the equipment required in counting machines. Versatility of the tube is such that it is being considered for use in several telephone applications.

Secret of the tube is the physical shape and positioning of the twenty cathodes. Made of a short length of molybdenum wire, each cathode is formed into a small coil, as evident in Figure 2, and diagrammatically in Figure 3. The cathodes are mounted in a ring, and the top turn of the coil is permitted to project tangentially for a short distance to a point just above the center of the cathode of its counter-clockwise neighbor. The anode is a flat metal plate above the cathodes, and the glow-discharge occurs between it and some one of the cathodes. The glow is transferred from the cathode that is operating to the next cathode by means of these short projecting wires. This process is repeated from one cathode to the next around the ring of twenty; the tube may be returned to its "zero" conditions from any of these cathodes for a new count.

The twenty cathodes in the ring are divided into two groups; the B group for effecting transfers, and the K group for signal outputs. The B cathodes are connected in two groups of five, but are connected together externally for counting. Each K cathode has a separate lead and may therefore be used as an individual output. A normal, or starting, cathode is added just outside the ring, adjacent to the B1 cathode. This maintains the discharge when the tube is in the "zero" counting condition.

A simplified schematic of the tube is given in Figure 4 indicating the method of operation. The resistor in the anode circuit

Fig. 2 – Arrangement of the anode and the cathodes in the 6167 tube.



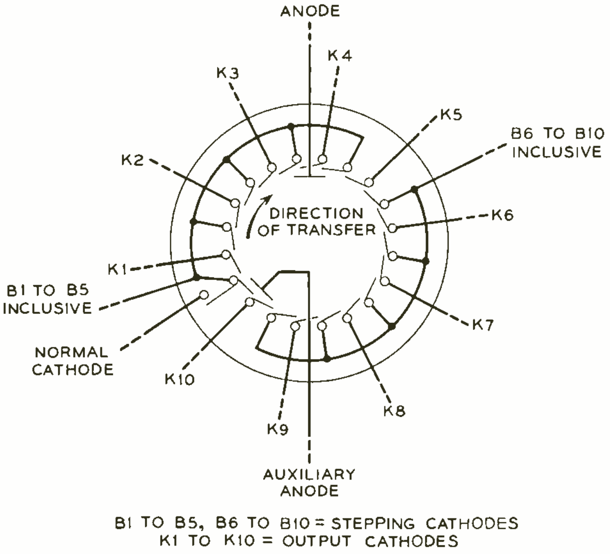


Fig. 3 – Diagram of connections of anode and cathodes in 6167 tube.

is for current limiting, the tube operating with only one to three milliamperes. A separate supply is used for the auxiliary anode adjacent to K10. This voltage may be applied at all times, but no current flows in the auxiliary anode circuit until the discharge has reached K10. Resistors in series with each K cathode develop voltage drops when the discharge current passes through them, thus giving the signal outputs. To "zero" the tube for starting a count, a large negative starting pulse is applied in series with the normal cathode, which is illustrated at the extreme left in Figure 4.

When voltage is first applied to the anode, the discharge may form to any of the cathodes. To start a count, a large negative pulse is applied to the normal cathode, which transfers the discharge to it. When this occurs, the tube is in its "zero" position, ready for a count. The first negative pulse to be counted is applied to the B bus, making the voltage from the anode to B1 greater than that to the normal cathode. Breakdown will occur from the anode to B1, and since the normal cathode is then positive with respect to the cathode potential of the new discharge, ionization is extinguished in this gap and transfer is thereby effected. The discharge on B1 initially occurs to its short projecting wire which was in the prior discharge. This wire maintains conduction so poorly, however, that the discharge travels to the coil, or high-efficiency portion of the cathode.

Upon removal of the pulse, B1 returns to a potential positive with respect to K1 so that the discharge is transferred to the projecting wire of K1 and travels along the wire to the K1 coil. Current flow through R1 then gives a signal to the first output lead. Subsequent pulsing of the B bus will transfer the discharge to B2, K2, B3, K3 and so on around the ring to K10. Forward transfer is assured in each case because of the fact that the coil of one cathode is closer to the projecting wire of the next forward cathode than to the preceding cathode.

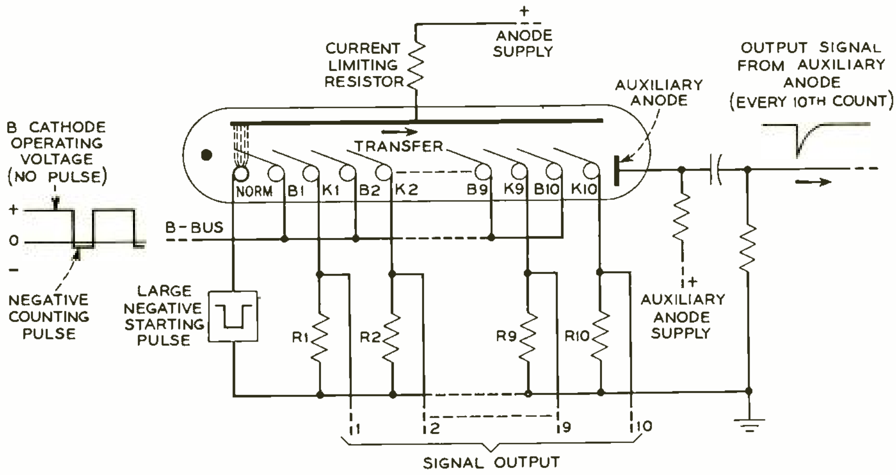


Fig. 4 – Elements of the 6167 tube arranged in a linear way to indicate method of operation.

Each output lead will maintain a signal as long as the discharge is to the cathode connected to that lead. If the auxiliary anode is used, an auxiliary discharge will occur to it as soon as K10 is reached. This extra pulse may be used for "carry" operations in counting or for special purposes.

Small in size and current requirements, the 6167 tube has been designed with reliability and long life as prime factors. When it is operated in such a fashion that each cathode conducts current regularly (or approximately so), no appreciable change in characteristics will occur during life. A small percentage change in transfer voltage may occur, however, near a cathode which conducts continuously with all others inoperative, but trials of such operation have run for thousands of hours without resulting in major changes or unreliability. Normal operating life would be greater than this by a factor representing the percentage of time any one cathode is used. Precise manufacturing techniques, in addition to proper choice and control of materials, preclude early failure and assure these good life characteristics.

In addition to counting applications, the 6167 tube may be used for frequency division, time measurement, pulse generation, and in other similar applications. If the auxiliary anode is not used, it can respond to pulses at frequencies up to 12,000 cps. Use of the auxiliary anode reduces this limit to about 2,000 cps, due to the extra ionization time required.

THE AUTHOR: D. S. Peck received a B.S.E. degree in E.E. from the University of Michigan in 1939 and an M.S. in E.E. the following year. He then worked for General Electric Company in Schenectady until 1947, when he joined the Laboratories. Here he has been concerned with the design for production of gas-filled electron tubes such as rectifiers, thyratrons, and cold-cathode tubes used in ringing, switching, and miscellaneous relay applications.

New Edition of Speech and Hearing Published

*Speech and Hearing in Communication** by Harvey Fletcher, the most recent addition to the Bell Telephone Laboratories Book Series, is a new edition based on *Speech and Hearing*, published in 1929. This second edition has been completely revised and rewritten to bring the book up to date. Six of the twenty chapters deal with new material not previously described.

This book discusses the results of a great volume of research that has been done during the past thirty-five years on speech and hearing and their relation to transmission systems. The general topics consist of a fundamental description of the speaking process, of the speech waves formed by talking, and the method of describing the characteristics of a talker; the hearing process, and the methods of describing the characteristics of a listener; and the interaction of a talker, a transmission system, and a listener. In developing the subject, the new Space-Time Pattern of hearing is presented. This includes a mathematical treatment that has contributed greatly to the formulation of an accurate picture of the hearing mechanism.

Prior to retirement in 1949, Dr. Fletcher was Acoustical Research Director at the Laboratories. He is now Director of Scientific Research at Brigham Young University.

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* *Speech and Hearing in Communication* by Harvey Fletcher. Price $9.75, 447 pages. D. Van Nostrand Company, Inc., New York.

Magnetic Adjustment of Receivers for the 500 Type Telephone Set

F. WEST
Station Apparatus Development

In a telephone receiver, motion of the diaphragm results from the modulation of the field of a permanent magnet by an alternating field from voice currents in the receiver winding. For maximum receiver efficiency, the strength of the permanent magnet must be adjusted to an optimum value. By means of a new technique, the U1 receiver of the 500 type telephone set can be rapidly and precisely adjusted while an operator watches the condition of the receiver on an oscilloscope screen.

For sustained receiver efficiency in service, an adjusted magnet should retain its optimum strength under the demagnetizing effects of mechanical and electrical shock and stray magnetic fields. Permanent magnets are more stable if initially magnetized to saturation and then demagnetized to operating strength. Therefore, to obtain maximum receiver efficiency, the practice is to adjust receiver magnets by demagnetizing them to the optimum value following magnetization to saturation. This process of adjustment is usually referred to as "stabilization" because of the stable condition that results from adjusting for maximum efficiency in this manner.

Fig. 1—The initial step in stabilizing a telephone receiver is to magnetize its magnet to saturation.

When the response of a receiver to a constant applied signal is observed while the strength of the magnet is reduced from a condition of over-magnetization, the response is seen to increase to a maximum, and thereafter to decrease as the magnet is still further weakened. In the past, adjustment of the HA1 receiver for the 300-type set has been accomplished by means of a machine that automatically reduces the strength of the magnet in small steps while comparing the response at a given step with that of the preceding step. At the peak point where further demagnetization begins to reduce the response, a detecting circuit stops the machine, indicating that the receiver is adjusted.

For two reasons this method is inapplicable to the U1 receiver for the 500-type set. One reason is that the region of peak response is not defined sharply enough for dependable detection by machine methods. The other is that unlike the HA1, which effectively has only one magnet, the U1 receiver involves two magnets which are

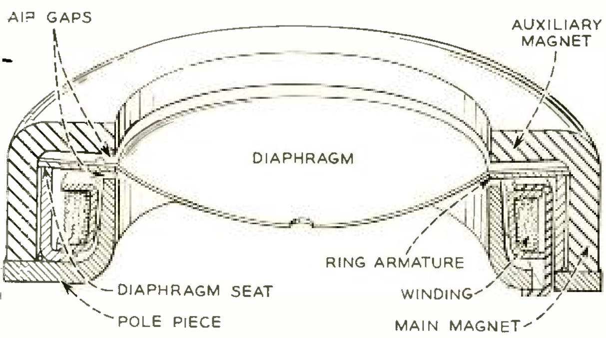

Fig. 2—Ring armature receiver.

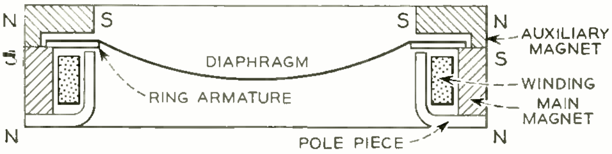

Fig. 3—Simplified view of ring armature receiver.

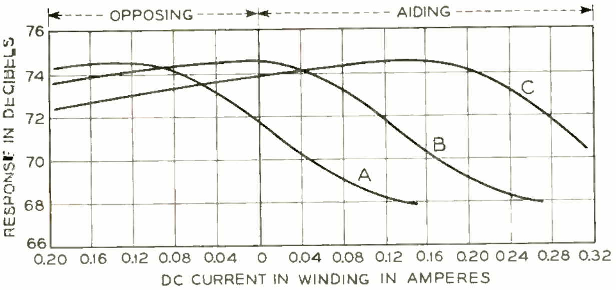

Fig. 4—U1 receiver response characteristics. A—Over-magnetized receiver. B—Correctly adjusted receiver. C—Under-magnetized receiver.

usually unequally magnetized. As shown in Figure 2, these magnets, known as the "main" and "auxiliary" magnets, are annular in shape and are mutually perpendicular. This design results in a more powerful magnetic field for voice current to modulate, and one capable of more precise adjustment. The result is a receiver which is three times as efficient. Also, since the effect of two magnets can be produced in a single piece of magnetic material by subjecting separate sections to unequal magnetizing influences, the main and auxiliary magnets can be combined into the single L-shaped section shown in Figure 2. This is done to simplify manufacture.

The dual magnetic adjustment required may be understood from a consideration of Figure 3 in which the two magnets are pictured as physically separate. The diaphragm is of plastic with a magnetic ring armature mounted at its periphery. The outer edge of this ring is seated firmly in position adjacent to the pole of the main magnet which supplies most of the controlling flux. By means of the pole-piece which is of soft magnetic material the other pole of the main magnet is brought around to operate underneath the inner edge of the armature. The armature is attracted downward toward the pole-piece and assumes an equilibrium position in which the magnetic pull is counterbalanced by the tension arising from flexure of the armature. With the main magnet over-magnetized the armature is pulled up tight against the pole-piece.

The efficiency of the receiver is controlled by the main magnet, and the first step in the adjustment is to weaken this magnet to the point of maximum receiver response. Generally, however, this initial adjustment does not insure sufficient clearance in the air-gap between the armature and the pole-piece to insure stable positioning of the diaphragm and to prevent possible interference from foreign particles. The gap is further widened by weakening the auxiliary magnet, changes in which do not significantly affect the location of the peak receiver response. The principles of the new adjusting technique may be understood by considering first how the effect of changing the magnetic field in a receiver is observed without actually altering the strength of the permanent magnet.

When direct current is made to flow in the receiver winding it will, depending on its direction, produce a magnetic field which aids or opposes that of the permanent magnet. If a signal of suitable frequency is also introduced into the receiver winding while this direct current is present, the response of the receiver to this signal for various values of the direct current may be plotted to produce curves like those in Figure 4, all of which show a point of maximum response at some value of direct current. Since the variation in response is the result of the change in magnetic field caused by the direct current, such a curve shows immediately what must be done to adjust the strength of the magnet to

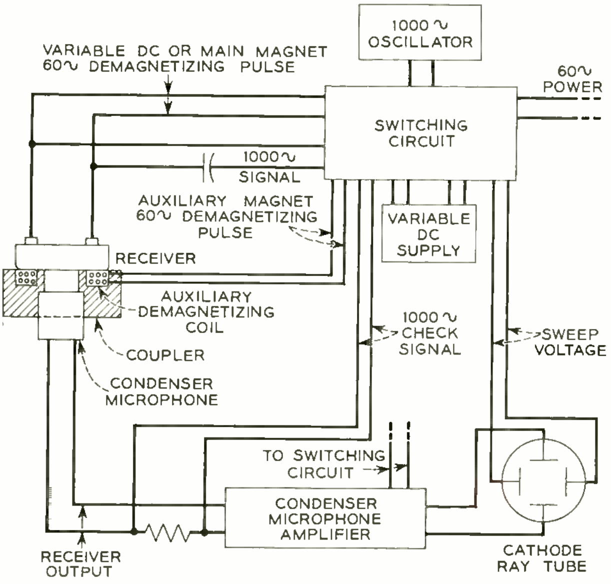

Fig. 5—Simplified diagram of receiver-stabilizer circuit. By the use of this circuit the curves shown in Figure 4 are directly portrayed on an oscilloscope screen.

Fig. 6—R. R. Kreisel watches shift in oscilloscope trace as he reduces strength of receiver magnet. Jig for coupling receiver to microphone is seen at right.

its optimum value for normal use which is with zero direct current. This is the condition represented by curve B in Figure 4. With the new technique, a block diagram for which is shown in Figure 5, these curves are directly portrayed on an oscilloscope screen.

A power source causes a voltage to vary, from a maximum positive value through zero to a maximum negative value, in about 0.65 seconds. This voltage is applied to the receiver winding to produce what is commonly called "variable dc." It is also impressed on the oscilloscope tube to produce the horizontal sweep voltage. The polarity of the horizontal sweep voltage is selected so that the oscilloscope spot is at its greatest right-hand deflection for maximum aiding current, and at its greatest left-hand deflection for maximum opposing current. By this arrangement, as the oscilloscope spot sweeps from right to left, the dc receiver current gradually falls from its maximum aiding value through zero, is reversed and then gradually rises to its maximum opposing value. Simultaneously with the dc, a constant 1000-cycle signal is applied to the receiver, and the acoustic output of the receiver resulting from this signal is impressed through a closed coupler on a condenser microphone. The condenser microphone output voltage is amplified and applied to the vertical deflection plates of the oscillograph tube to produce a vertical deflection proportional to the acoustic output of the receiver. By means of the rotating equipment which produces the horizontal deflection voltage, the vertical deflection voltage is applied at the time of maximum aiding current. It remains on until the maximum opposing current is reached.

As the oscilloscope spot shifts from right to left it oscillates vertically at the 1000-cycle signal rate and this rapid vertical motion and the use of an oscilloscope tube with a long persistence phosphor results in an illuminated area rather than a perceptible line trace. The boundaries of this area, somewhat brighter because of the slower spot travel at the end of its excursions, form an envelope trace which constitutes a plot of the receiver output versus dc and its characteristics indicate the magnetic condition of the receiver.

The demagnetizing operations required for the adjustment are automatically switched in only during the "fly back" portion of the cycle, from maximum opposing to maximum aiding current. During this time the receiver output circuit is opened, hence the receiver output is not impressed on the screen.

During the fly back period two calibrating traces are developed. Continuing to glow after the exciting voltages are removed, these marking traces persist as "bench marks" to guide the operator as he observes the receiver trace produced during right-to-left swing. One marking trace is produced by applying the receiver output for a brief interval as the dc voltage passes through zero. This marking, the 0 DC OUTPUT line in Figure 8, indicates the point at which the receiver output must be adjusted to peak efficiency. The other marking trace results from the application of a fixed oscillator voltage in series with the condenser microphone and equal to the voltage generated by a receiver of minimum acceptable efficiency. This marking signal being applied for a somewhat longer period than the first one produces the shaded area called the "Efficiency check band" in Figure 8. The 0 DC OUTPUT line and the CHECK BAND are distinguishable through varying gradations of luminescence depending on the different times during which they activate the screen. In addition to these two luminous traces, the face of the tube is marked with dc current-limit lines to provide the operator with allowable tolerance in adjusting the receiver. Maximum values of aiding and opposing dc over which the response of the receiver is examined during stabilization are preset in the machine, and determine the horizontal boundaries of the trace.

Demagnetization is accomplished by applying 60-cycle power to the receiver winding or to the auxiliary demagnetizing coil (Figure 5) depending on whether it is desired to demagnetize the main magnet or the auxiliary magnet. Figure 7 shows how the magnetizing fields for the main and auxiliary magnets operate independently. In each case the magnetic paths are restricted so that a negligible amount of interaction of the fields is experienced. In addition the coupler coil is wound with an air core and no magnetic material is used in the coupler so as to avoid magnetic shunting of the receiver magnets during adjustment.

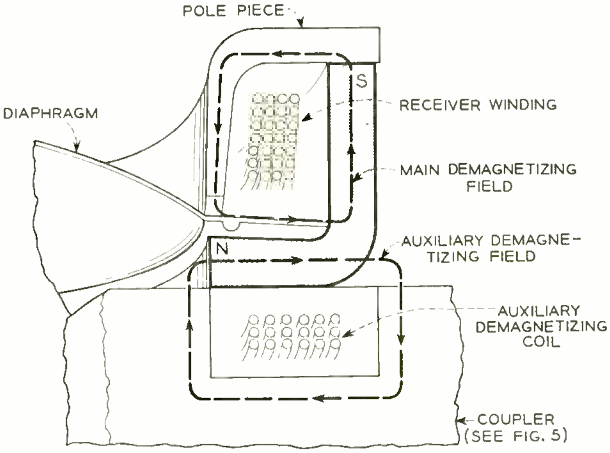

Fig. 7—Diagram illustrating independent action of demagnetizing fluxes on main and auxiliary magnets. Field from 60-cycle demagnetizing current flowing in receiver winding is concentrated in main magnet via pole-piece and diaphragm. Field from auxiliary demagnetizing coil concentrates in horizontal auxiliary magnet and does not perceptibly affect vertical section.

The first stage in the adjustment process is to demagnetize the main receiver magnet by applying 60-cycle power to the receiver winding in manually controlled increasing amounts. The principal stages of adjustment are illustrated by the oscilloscope traces in Figure 8.

With the initial state of high magnetization, the receiver is usually "frozen," that is, the diaphragm is held to the pole-piece by the flux, and the receiver has little or no output. This condition produces the trace of Figure 8a. Some reduction in the main magnet strength leads to Figure 8b in which a sharp peak registers the RELEASE POINT, or the point at which the main magnetic flux is weakened sufficiently to permit the sudden release of the armature from the pole-piece. The region of peak efficiency now appears at the far left of the trace. For current values to the right of the release point, the diaphragm continues to be held against the pole-piece. Only the portion of the characteristic to the left of the release point represents a receiver of operable condition. Further reduction of the main magnet flux moves the peak efficiency region and release point

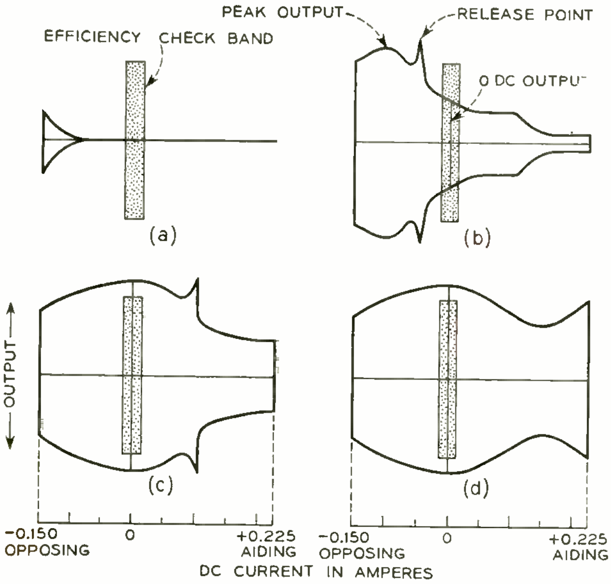

Fig. 8—Oscilloscope traces for various stages of receiver stabilization.

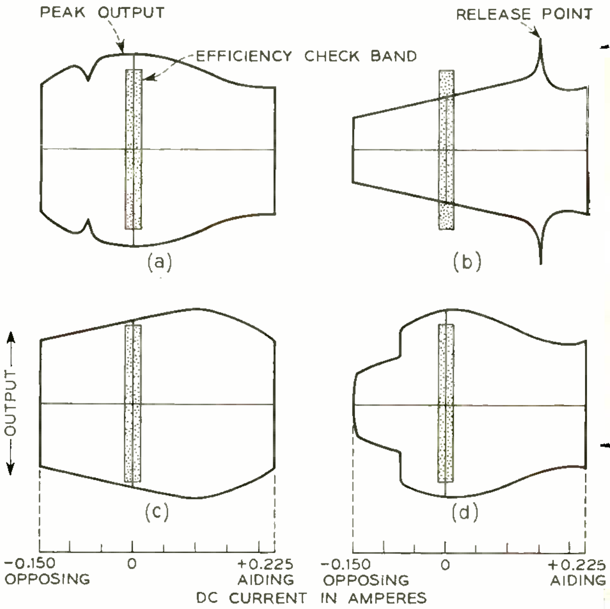

Fig. 9—Oscilloscope traces reveal mechanical flaws. A—Burrs or dirt on diaphragm seat. B—Ground separation too small. C—Weak magnet. D—Obstruction in auxiliary air-gap.

to the right as less and less opposing dc is required to produce peak efficiency. Adjustment is completed when the peak occurs at zero dc, Figure 8c.

The release point still remains as a discontinuity in the receiver output within the inspection range represented by the dc current limits of the oscilloscope trace. This condition indicates that the main air-gap remains too small and the armature might become "frozen" or blocked by any minute foreign particles which may be present. The next step, then, is to change the air-gap by demagnetizing the auxiliary magnet. This is done by applying automatically increasing steps of 60-cycle power to the auxiliary demagnetizing coil located in the receiver coupler, Figure 5. The start of the automatic stepping and the number of steps used is controlled manually and can be stopped at any step. Secondary adjustment can proceed as required from the last step used. As the auxiliary magnet is weakened, the release point is shifted toward the right

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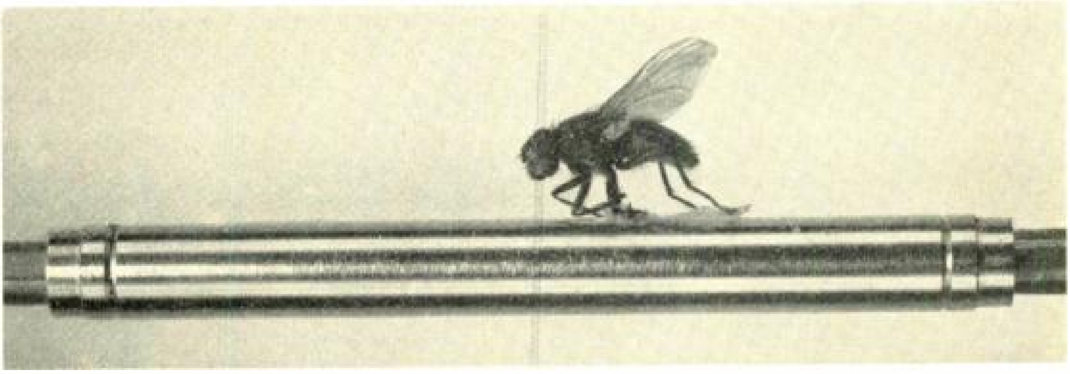
and just off the trace to produce Figure 8d which represents a completely adjusted receiver with an adequate air-gap.

Experience in the use of this machine results in ability to detect, through peculiarities of the output versus dc traces, numerous manufacturing irregularities which are not readily observed during assembly. Most important is the detection of foreign particles in the air-gap for which a separate test would otherwise have to be made. Other detectable faults are armature seat irregularities, bent armatures, burrs, low ground separation and weak magnets. Figure 9 shows some characteristic patterns which indicate the various assembly and piece-part faults as described in the caption.

A number of "stabilizers" of the type described in this article have been built by the Western Electric Company at the Shadeland plant and are in use on the assembly lines producing U1 receivers.



Comparison of the transistor repeater with an ordinary house fly — 3½ times actual size.

Tiny Transistor Repeater

Development of a new tetrode transistor for use in high-frequency equipment has resulted in the repeater seen in the illustration. Still in the experimental stage, the repeater is designed to operate as an integral part of a coaxial cable transmission system. Its diameter is only 0.15 of an inch and the length is approximately 1½ inches; comparison with the house-fly shows these dimensions much more graphically.

The small tubular case of the repeater contains fifteen components. In addition to the special tetrode transistor, a coupling capacitor, four resistors, an inductor, input and output transformers, input and output connectors, and two terminal plates, a pair of silicon diodes are used for voltage regulation. Power consumption is only about 0.1 watt, and could be reduced by half if voltage regulation were not used. Maximum undistorted power output is 10 milliwatts into a 75-ohm load, but normal output will be about 1 milliwatt. The repeater has a gain of 22 db, flat within ± 0.1 db, from 0.4 megacycles to 11 megacycles. Over this bandwidth of approximately 10 megacycles, the output noise level is about 72 db below 1 milliwatt. Although this particular model was designed to be powered by an extra wire running along with the coaxial cable, it can easily be modified to obtain power via the signal conductors of the coaxial.

As far as its transmission characteristics are concerned this repeater is capable of handling high-quality television. There are still questions concerning the best physical form for such subminiature units and how they might be employed in complete transmission systems.

A Signaling Circuit for N1 Carrier

L. A. WEBER
Switching Systems Development

Besides providing for satisfactorily transmitting voice frequencies, any carrier system must also provide for transmitting a variety of operating signals. The signaling method employed, will, of course, vary with the type of system to which it is to be applied.

On short toll trunks, dc signaling has been used in several forms — most frequently, the composite (CX) type*. On longer trunks, a 1,600 cycle signaling system has been used†. With the development of N1 carrier for short toll trunks, a new signaling arrangement was needed to fit into the particular requirements of the N1 system. Small size, low maintenance, and low cost without sacrifice of performance, were the design objectives of N1, and these applied as well to the signaling means.

An N1 carrier terminal consists of twelve "plug-in" channel units plus some common apparatus. One of these channel units is shown in Figure 1. Each unit consists of three sub-assembly frameworks fastened together and mounted with a slip-on can cover. The signaling circuit is in the middle sub-assembly of Figure 1. The same sub-assembly also contains the expandor in the voice frequency part of the carrier system. This expandor and the remainder of the apparatus are described in several other articles that will appear in subsequent issues of the RECORD.

All signaling circuits must be capable of transmitting two basic signals — supervisory and pulsing signals. Pulsing information in digital form is passed by relatively fast circuits to inform switching equipment of the telephone number to be reached; supervisory signals inform the switching equipment or operator of the progress of the call. When dial pulsing is employed, both supervisory and pulsing signals are transmitted by two conditions on the line which are established at various times and at varying rates. These two conditions are termed "on-hook" and "off-hook" — referring to the conditions on a local subscriber line. The "on-hook" signal occurs when the local line is idle; the "off-

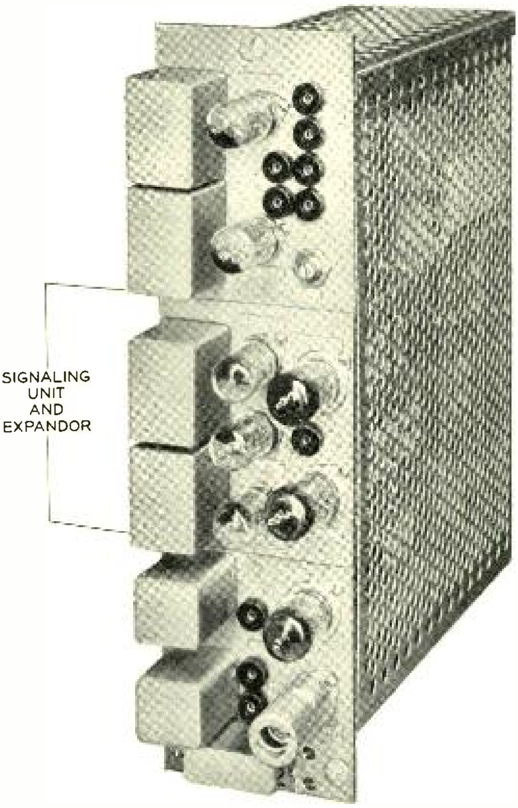


Fig. 1 — Channel unit for N1 carrier. The part containing the signaling circuit is indicated by the brackets.

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* RECORD, *October,* 1947, *page* 370. † RECORD, *July,* 1951, *page* 317.

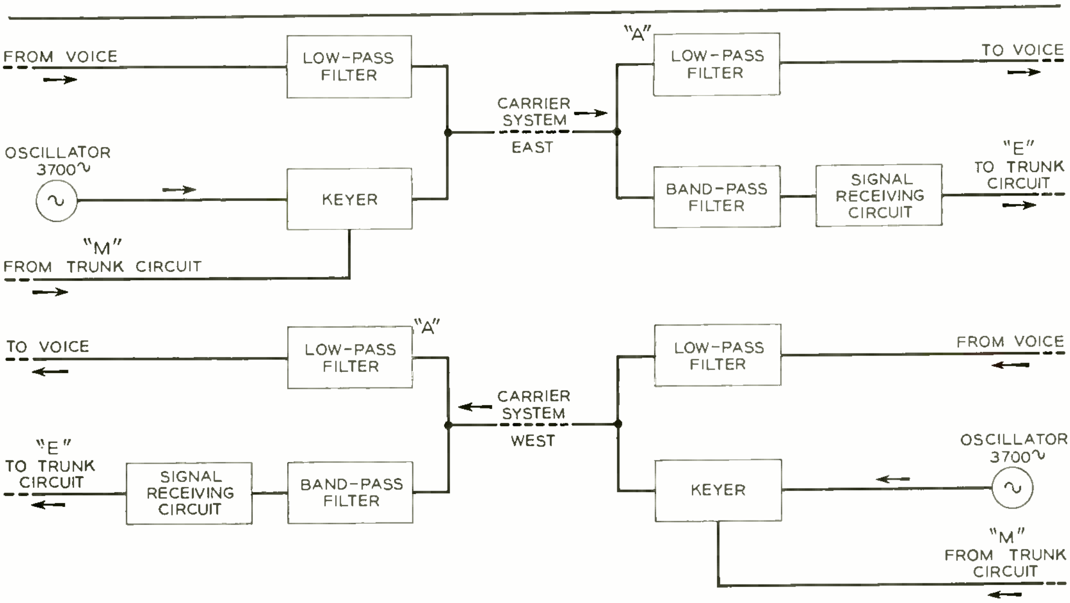

Fig. 2 – Block diagram of signaling system. Appropriate filters separate the voice channel frequencies from the signaling frequencies.

hook" signal occurs when the local line is busy, and rapid alternations of the two conditions (about 10 pulses per second) when dialing is taking place.

In the N1 carrier system, tone of 3,700 cycles *on* the carrier channel corresponds to the "on-hook" signal. Tone *removed* from the channel represents an "off-hook" signal. This particular combination of conditions was chosen rather than the reverse so that the tone would be off during conversation. Speech frequencies and signaling frequencies are made independent of each other by appropriately located filters, as shown in Figure 2. The discrimination characteristics, loss versus frequency, of the receiving low pass filter ("A" in Figure 2) are not required to be sharp.

The 3,700-cycle signaling tone on the line is controlled by the dc signals over the M lead from the trunk circuit (Figure 3). The M lead is grounded for an on-hook signal, and is connected to minus 48-volt battery for an off-hook signal. With the M lead grounded, point O becomes positive with respect to ground. This causes direct current to flow in the forward direction of the varistors, reducing their ac resistance to a low value, and thereby permitting signaling tone to be transmitted. When the M lead is connected to minus 48-volt battery (the off-hook condition), point O is negative with respect to ground, and the very small direct current flowing through the varistors in the opposite direction leaves the resistance at a high value. This removes the 3,700 cycle tone from the carrier channel. A keyer of this type has the advantage of translating pulses from dc to ac without changing the pulse length.

At the carrier terminal, the signal receiving circuit, shown in block form in Figure 4, translates the 3,700-cycle "tone-on" and "tone-off" conditions to dc open and ground conditions on the E lead for use by the switching equipment. The 3,700-cycle signals are separated from voice frequency components by the band pass filter, passed through an amplifier, and sent into a "flip-flop" limiter (to be described in detail later) from which they emerge as 3,700-cycle square waves of constant amplitude. These square waves are coupled through an impedance matching cathode follower to a detector that develops a voltage in response to the input 3,700-cycle signal. The dc voltage passes through a delay network to a dc amplifier, the output of which controls a polar relay. The relay responds to the signal input pulses by open-

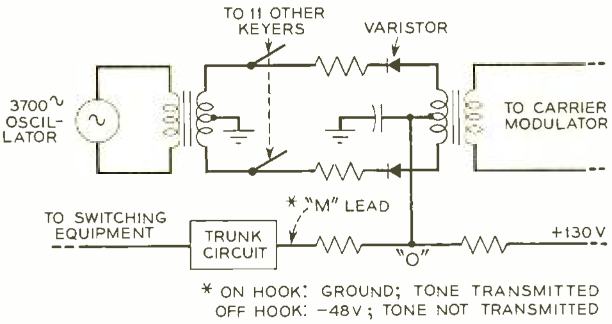

Fig. 3 — Control of the 3,700-cycle signaling tone is done by direct current over the "M" lead to the varistors in the signaling circuit.

ing or grounding the E lead to the trunk circuit, thus completing the signaling function.

Performance requirements of telephone circuits are vitally affected by the necessity of working with the vast number of other circuits existing in the telephone plant. Toll signaling circuits, in particular, must function with existing equipment to meet the objectives of the nationwide dialing plan*. This means that signals must be passed over a number of signaling circuits in tandem, since many trunks may be switched together to provide a path from the calling to the called subscriber. Requirements for the nationwide dialing plan call for dial pulses to be transmitted, without being regenerated, over a maximum of four trunks in series; supervisory signals must be passed over as many as ten trunk circuits in series. The reason why dial pulses need not be passed over the entire connection of a maximum of ten trunks is because the dialing plan envisages use of intermediate crossbar type offices where dial pulses will be registered and regenerated. Transmitting signals over a long built up circuit with acceptable over-all faithfulness requires that each signaling link be very nearly distortionless; hence features to limit distortion have been included in the N1 carrier signaling circuits.

In addition to reducing distortion in pulse length, it is also essential that the signaling circuit not be subject to false operation due to voltages from external sources — commonly referred to as noise. Such operation may result in wrong numbers. These induced voltages may arise from crosstalk coupling between circuits, or from atmospheric disturbances.

Early in the N1 carrier development it was found that noise due to disturbances within the signaling band could approach the amplitude of the signaling frequency. These disturbances usually occur in bursts of high amplitude, but do not generally exceed about 15 milliseconds duration. Protection of the receiver from false operation on these bursts is accomplished by introducing a delay in the circuit (the delay network of Figure 4), and requiring that all signals the circuit receives, persist for periods longer than 15 milliseconds.

These two problems, distortion and noise, work against each other. It is relatively easy to design a receiver that will be very stable from the standpoint of pulse-length distortion with fluctuations in input level

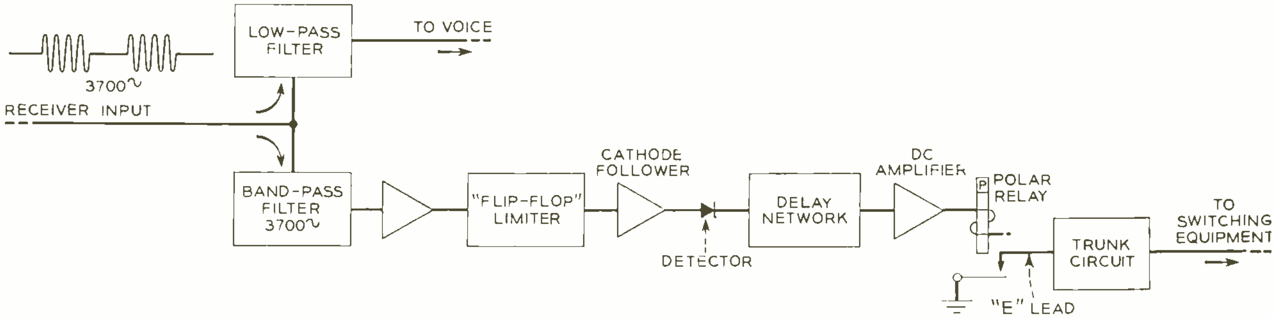

Fig. 4 — At the receiving carrier terminal, the 3,700-cycle "tone on" and "tone off" conditions are translated to dc open and ground connections at the polar relay.

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* RECORD, *October*, 1945, *page* 368.

and local voltage changes, simply by making it operate as fast as possible. On noisy lines, however, this circuit will not perform satisfactorily because of false signaling from the noise. Conversely, a receiver having delay characteristics will perform satisfactorily during noisy periods, but variations in line level and local voltage tend to introduce unmanageable pulsing distortion. By "engineering compromise," it was possible to solve both the noise and distortion problems.

First, the resistor-capacitor delay network, shown in Figure 4, was added to the basic receiver circuit to protect against noise. This network, plus other time delays in the circuit, make it necessary for any input voltage to persist for about 15 milliseconds before any output is obtained from the circuit.

Second, because of this delay network, a limiter was introduced so that transmission level fluctuations would not cause intolerable lengthening or shortening of the pulses.

Let us consider the operation of the limiter in detail. In the circuit of Figure 5(a), with no input voltage, no current flows in the left hand triode section of the electron tube. Current is flowing in the right hand section, however, and it produces a relatively high voltage drop across the cathode resistor C, making the cathode potential higher than that of the left hand triode grid. The plate voltage in the right hand section is at a low value because of this plate current flow.

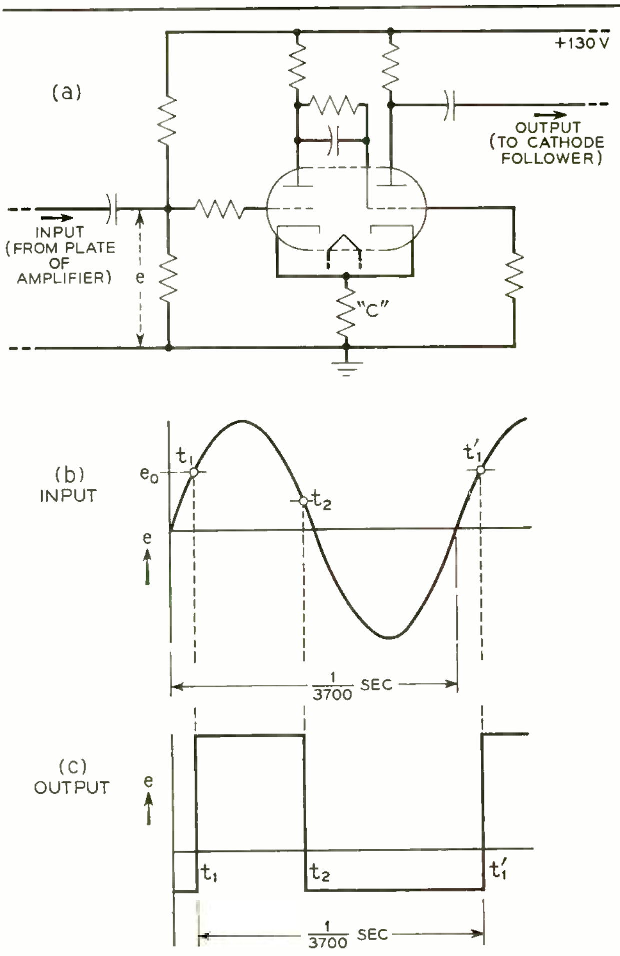

Fig. 5 – The "flip-flop" limiter (a), changes the signal input (b) to a rectangular output wave (c).

When a signal voltage is applied to the grid of the left triode, a value e_0 is reached at time t_1, Figure 5(b), when the left grid voltage will rise above the cut-off value of this triode, and plate current will then flow in the left side. Once conduction begins, the left plate voltage is lowered

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due to the drop in the plate resistor; this drop in voltage, being coupled directly to the grid of the right hand triode, causes a decrease in the plate current of the right side. This in turn reduces the voltage across the common cathode resistor c, and raises the left triode grid-cathode voltage, further increasing the left triode plate current. This is dc positive feed-back; and in a very short time, the right triode is cut off, while the left triode is conducting. When the right triode plate current is cut off, the output voltage immediately rises. As long as the input wave, Figure 5(b), remains above the critical value shown at time t_2, the triodes will remain in this condition.

At time t_2, Figure 5(b), the net voltage on the grid of the left hand triode has become low enough to begin cutting off this part of the tube. A reduction in plate current in this section raises its plate voltage, which in turn raises the grid voltage of the right hand triode, restoring the situation that existed at the beginning of the cycle.

The output wave is shown in Figure 5(c). The amplitude of this voltage is substantially independent of the input voltage as long as it exceeds the value e_0 shown in Figure 5(b). There will, of course, be some pulse width change as the input level varies, but the detector farther on in the circuit is insensitive to this change.

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Relay Vibration Studies

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Switching Systems Development

If two groups of identical relays are arranged to perform ten million operations, one group at slow operating speed and low pulsing rate, while the other group is at fast operating speed and high pulsing rate, it is very likely that the fast group will show a marked increase in wear of moving parts over the slow group. Observation of the contact action would also be likely to show substantially more chatter in the fast group. The difference in performance of the two groups is due primarily to the more severe vibrations set up in the component parts of the fast acting relays.

Studies showing these effects have been made by means of a new group of instruments developed under the direction of O. R. Miller. Formerly, the principal instrument for making relay vibration studies was the rapid record oscillograph equipped with auxiliary apparatus for making shadowgraphs.* In studying fast acting relays, however, and those that have high pulsing rates, the rapid record oscillograph is limited in time and amplitude scales. Some frequencies inherent in contact chatter may reach values in the order of a megacycle, which is far beyond the range of the rapid record oscillograph. Besides, resonant vibrations often occur only in a narrow band of pulsing rates, and they may be missed completely unless it is possible to observe continuously the effects of varying the pulsing rate. Resonance phenomena frequently come and go during a change in pulsing rate of one pulse per second, and it would be difficult to locate these effects if a series of permanent records had to be made and then analyzed.

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* Record, *September*, 1937, *page* 26, and *May*, 1952, *page* 223.

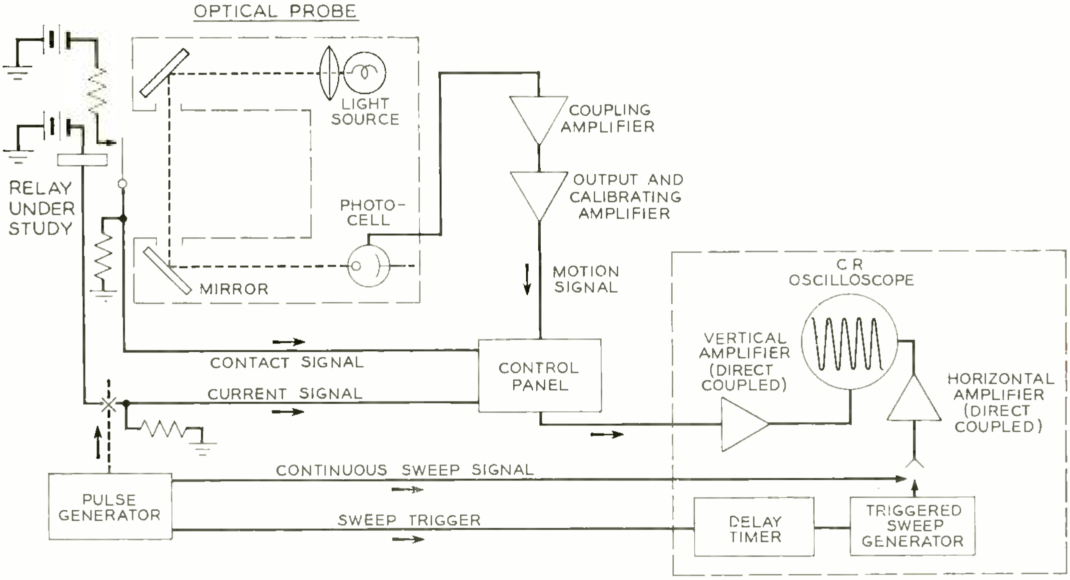


Fig. 1—Block diagram of the instruments used in making relay vibration studies.

Vibration studies of relays have assumed considerable importance in recent years because of the growing proportion of relays that must be fast operating, must function at high pulsing rates, and must perform hundreds of millions of operations during their useful lives. Fast acting relays are used, for example, in central office marker circuits and in automatic message accounting center circuits. In such applications, the speed of the relays used largely determines the speed of operation of the circuits and hence the number of such circuits required for a particular application. Obviously, the use of fast relays in these circuits can effect considerable economy.

A block diagram of the instruments used in making relay vibration studies is shown in Figure 1. As indicated in the diagram, the instruments consist essentially of a pulse generator, an optical probe, a control panel, and a CR oscilloscope.

The electronic pulse generator is capable of pulsing the relay under test at continuously variable pulsing rates from zero, or single operation, to 200 pulses per second. The break period in a pulse can be adjusted from zero (continuous operation) to 100 per cent (non-operation). The pulse generator is capable of providing trains of 1 to 10 impulses either continuously or in groups as required. Another feature of the pulse generator is that it can also supply a "sawtooth" signal, synchronized with the pulses that operate the relay, and this signal may be used as a constant velocity horizontal sweep signal for the oscilloscope.

Mechanical motions of the relay parts are observed by means of the optical probe. It is illustrated schematically in Figure 1. Figure 2 is a photograph showing the probe in position for observing the movement of the armature or core of a UB-type relay. The probe has a light source that produces a rectangular beam of parallel rays of light. This beam is directed by mirrors to the receiving part of the probe in which a photoelectric cell measures the amount of light that it receives. If the rectangular beam of light is intercepted by the edge of the object whose motion is being studied, the probe can be adjusted so that the motion will produce a proportionate variation in the amount of light arriving at the phototube, and consequently a corresponding variation in current through the phototube. The armature motion is thus translated into vertical deflection of the oscilloscope trace. Calibration of the optical probe is accomplished by moving the probe, using its associated micrometer screw, measured distances past a fixed object that intercepts the light beam. The ratio of the cathode ray tube deflection to the motion of the probe gives the calibration. Horizontal deflection is proportional to time in the usual manner.

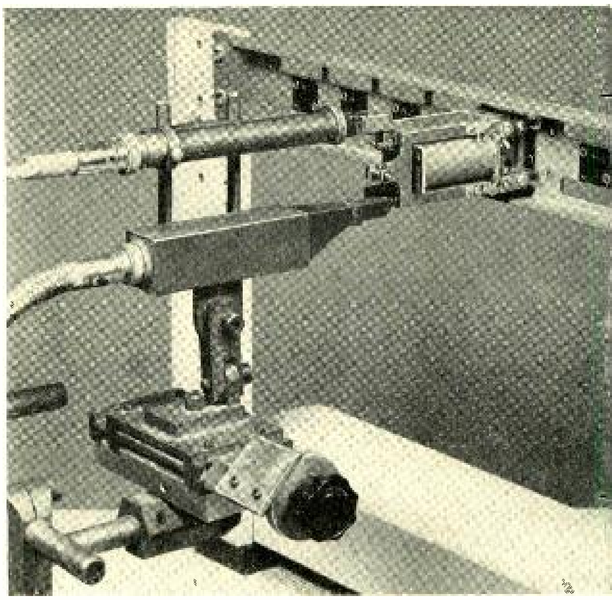


Fig. 2—The optical probe in position for observing the relative movement of armature and core on a UB type relay.

Relative motion between two parts can also be observed if one edge of each part can simultaneously be made to cut off part of the light beam. Observation of armature rebound on a relay is generally made in this manner by noting the relative motion of armature and core (Figure 3).

A coupling amplifier located near the probe amplifies the signal from the optical probe. A second amplifier (of three stages) further strengthens the signal, passing it along through a signal control panel and then to the vertical deflection amplifier of the cathode ray oscilloscope. All amplifiers in the optical probe system are of the dc type because most of the observed phenomena contain such low frequencies that serious distortion would result from any ac type amplifier. The frequency response of the optical probe, with the pre-amplifier, is from 0 to about 10,000 cycles per second.

For observing the associated electrical contact phenomena, a simple resistance-battery network, shown in Figure 1, provides a signal of zero volts when the contacts are open and 1.5 volts when the contacts are closed. The contact signal is also fed through the control panel to the vertical deflection amplifier of the oscilloscope. Frequency components of contact chatter can be measured as high as one megacycle.

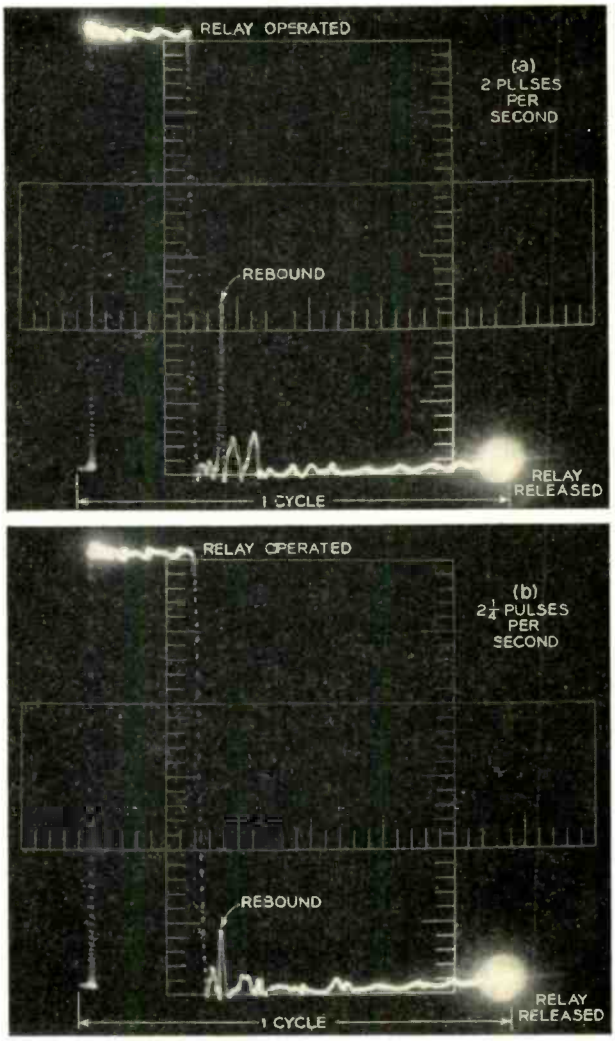
Current through the relay winding is determined by using a small variable resistor located in the control panel, which can be switched into the operating path of the relay. The voltage developed across this resistor represents the current being fed into the relay circuit. This voltage may also be connected to the vertical amplifier when desired.

By means of the control panel, the operator may select either the optical probe signal, contact signal, or operating current signal for display on the oscilloscope screen. In addition, an arrangement is provided so that the contact signal may be added to either of the other signals as desired. This ability to superimpose the contact signal upon the optical probe signal is very convenient for determining the relationship between vibration and contact phenomena. This is illustrated by Figure 4, in which the large oscillatory signal represents the resonant vibration of a contact spring (observed at about the middle of the spring) and the small jagged signal superimposed represents the contact action of the same spring. Figure 5 shows the expanded time scale for a portion of the contact signal. Since the worst chatter always occurs at the peak of spring vibration, and occurs only when the vibration amplitude is relatively large, it is safe to say in this case that the chatter was caused largely by the vibration. A similar procedure can be used to determine if armature rebound is causing contact chatter.

Combination of the coil current signal with the contact signal superimposed is convenient for determining operate time of the relay, since it is only necessary to determine the time difference between the two initial indications on the oscilloscope.

The pulse generator supplies a continuous sweep signal that can be used as a measure of time, but usually the time interval to be measured is much smaller than the cycle time. A much more accurate time measurement can be obtained by means of the sweep delay timer and triggered sweep generator indicated in Figure 1. At either the start of operation or release of the output relay in the pulse generator, a start pulse is transmitted to the sweep delay timer. The sweep delay timer introduces a controllable delay before passing along the start pulse to the triggered sweep generator. The latter then

Fig. 3—Photograph of the oscillograph trace showing relative motion of armature and core of a UB type relay. A change of as little as ¼ pulse per second results in a large change in rebound for this relay.



generates an output voltage that increases at a constant rate, so that a constant velocity horizontal sweep signal is applied to the oscilloscope tube (through the horizontal amplifier).

Duration of the triggered sweep can be precisely controlled in the range from 0.1 to 100 milliseconds. Almost any desired interval during the relay cycle can be selected and displayed across the full width of the oscilloscope. Instantaneous velocity at any point can readily be determined by measuring the slope of the time-displacement curve at that point, since, with the horizontal sweep moving at constant speed and the optical probe calibrated, velocity is a simple function of slope and probe calibration.

Frequency response of the vertical amplifier is from zero to one megacycle, and that of the horizontal sweep amplifier about one-third as much. It is characteristic of both amplifiers that any desired segment of the input signal can be expanded and examined in detail on the oscilloscope. This results in great flexibility. For instance, by changing a few controls, the oscilloscope pattern can be changed from one that represents the complete cycle of a relay operating at one pulse per second, to a pattern that represents the first contact closure of a U-type relay contact lasting perhaps 15 microseconds.

One of the principal advantages of the optical probe system in studying relay vibration problems is that of providing means for observing vibration while continuously scanning the range of pulsing rates of interest. Where resonant pulsing rates are suspected of causing relay troubles, the observer can watch for the trouble condition to produce a pattern on the oscilloscope, while slowly changing the pulsing rate, and he can immediately backtrack if it appears that the pulsing rate change passes the critical spot. Permanent records of observations can usually be made by photographing the oscilloscope screen. Very few of these phenomena show identical patterns on subsequent operations, and so multiple exposure photographs are generally impractical.

Typical of the conditions under which general purpose telephone relays operate are those of the U and UB relays. Pulsing rates for these relays range up to 20 or 30 pulses per second. Armature travels run from 0.025" to 0.071", and relay core vibration amplitudes have been observed as high as 0.040" at resonant frequencies of 60 to 200 cycles per second. Amplitude and fre-

Fig. 4—The large oscillograph trace represents the resonant vibration of a contact spring. The small jagged trace is the superimposed contact signal.

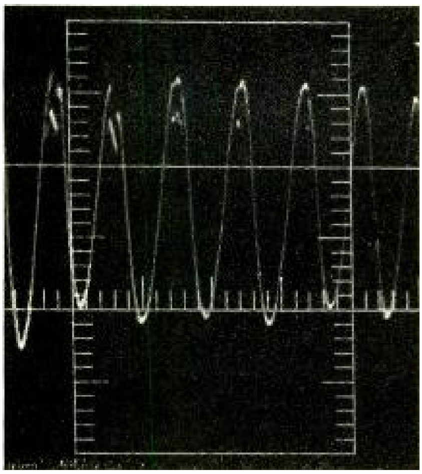
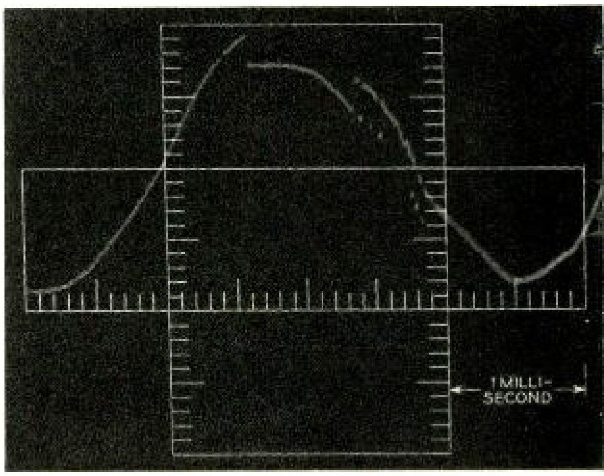


Fig. 5—Expanded time scale for a portion of the contact signal of Figure 4. The broken portion of the oscilloscope trace, about one millisecond long, represents an open contact during that interval. If several contacts in tandem and slightly out of phase were to have this chatter, the circuit might remain open long enough to cause circuit failure.



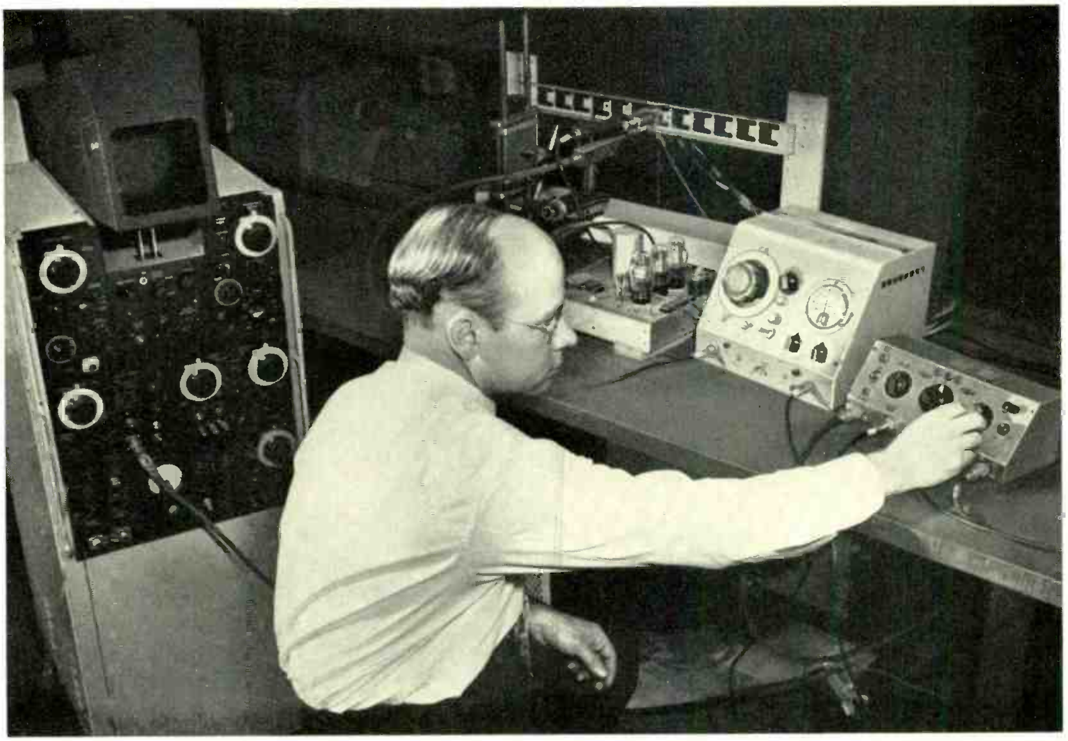


Fig. 6—The author adjusting the contact signal amplitude on the control panel. At his left is a cabinet containing the sweep generators and the oscilloscope.

quency of core vibrations are both greatly affected by the way in which the relay is mounted. Armature rebound is intimately associated with core resonance; critical rebound frequencies are encountered at as low as 2 pulses per second. In going from 2 to 2¼ pulses per second, for example, armature rebound variation may be as much as three to one. This is illustrated in Figure 3 by the relative heights of the trace that is marked REBOUND.

Although rebound of the armature has been used as an example of the kind of vibration studies that have been made, similar investigations can easily be carried on to determine the effects of shock, flexural vibration of springs, methods of mounting the relay, or the "hesitation" of the armature as it operates, due to abrupt load changes before the magnetic pull has reached a value sufficient to cause full operation. In actual telephone circuits, very few

THE AUTHOR: Following his graduation from Lehigh University in 1937 with a B.S. degree in Engineering Physics, K. K. KENNEDY spent the next five years in geophysical explorations for an oil company. His activities carried him to several states in this country, to New Zealand, and to the Dutch East Indies, where, in 1942, he entered the U. S. Army as a First Lieutenant. For the next four years he served in Australia, New Guinea, and the United States, and was in this country when the war ended. Coming to the Laboratories in December, 1945, he spent the first three years on fundamental relay studies. Since that time he has been engaged in circuit design work for automatic message accounting and tandem crossbar offices.

relays are subjected to the most severe conditions under which laboratory studies are made, but these latter conditions are possible field conditions, and general purpose relays must be able to perform satisfactorily under them. If a relay is not capable of satisfactory performance under certain conditions, the circuit designer should know if the relay is likely to fail, and take the necessary steps to avoid it.

The purpose of making relay vibration studies is thus two-fold. First, by studying the performance of accepted designs and the prototypes of future designs, the best features of each can be recognized and incorporated in new developments. Second, by finding out what relays can and cannot do, relay vibration studies can assist the circuit designer in arriving at the best possible relay circuits by making full use of their good characteristics and avoiding their weaknesses.

Talks by Members of the Laboratories

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

Becker, J. A., Physical and Chemical Forces Involved in the Adsorption of Gases on Metals, Sigma Xi Chapter, University of Alabama, University, Ala. Georgia Institute of Technology, Atlanta, Ga.

Bennett, A. F., 1953 Development Program on Station Apparatus, Northern Electrical Personnel, Montreal, Canada.

Bozorth, R. M., Behavior of Magnetic Ferrites, Physics Colloquium Brown University, Providence.

Felch, E. P., see R. A. Kelley.

Fleckenstein, W. O., Switching, I. R. E. – A. I. E. E. Sections, Lehigh University, Bethlehem, Pa.

Goldstein, H. L., An Introduction to the Principles and Applications of the Magnetic Amplifier, I. R. E. Section, Franklin Institute of Technology, Philadelphia, Pa.

Hagstrum, H. D., Theory and Experiment Concerning Ejection of Electrons from Metals by Ions, Physics Department Seminar, University of Minnesota, Minneapolis, Minn.

Hogan, C. L., The Ferromagnetic Faraday Effect at Microwave Frequencies, A. I. E. E. New York Communication Division, New York, N. Y.

Honaman, R. K., Annual Edison Lecture, Electrical Board of Trade, St. Louis, Mo.

Janssen, W. F., Precision Ceramics, American Ceramic Society, New York, N. Y.

Keister, W., Switching Circuits for Automatic Control, I. R. E. Fort Worth Section, Dallas, Texas, I. R. E. Connecticut Valley Section, New Haven.

Kelley, R. A., and E. P. Felch, Putting Transistors to Work, A. I. E. E. – I. R. E. Student Sections, Purdue University, Lafayette, Ind.

Kircher, R. J., Transistor Properties and Applications, Rensselaer Polytechnic Institute, Troy.

Lewis, H. W., Search for the Hall Effect in a Super-Conductor, University of Illinois, Urbana, Ill.

Ling, D. P., Mathematics, Hunter College, New York, N. Y.

Lundry, W. R., Transmission Network Synthesis via the Logarithmic Potential, Purdue University, Lafayette, Ind., University of Illinois, Urbana, Ill.

May, J. E., Jr., Gamma Rays from Mg^{26}, Physical Society Meeting, Cambridge, Mass.

McMillan, B., Mathematical Aspects of Information Theory, University of Pittsburgh, Pittsburgh.

Mendizza, A., Protective Castings (Metal and Organic) Fundamentals and Selections, University of California, Berkeley, Cal.

Prescott, R. E., Application of Mechanical Engineering Principles to Development of Telephone Dial, A. S. M. E. Section, Rensselaer Polytechnic Institute, Troy, N. Y.

Raisbeck, G., Developments in Transistor Circuitry, Brooklyn Navy Yard, Brooklyn, N. Y., Transistor Operating Characteristics, I. R. E. Long Island Subsection, Garden City, Long Island, N. Y.

Rigterink, M. D., Ceramics for Deposited Carbon Resistor Cores, Symposium on Ceramic Dielectrics, Rutgers University, New Brunswick, N. J.

Schumacher, E. E., Communications Metallurgy, Telephone Companies, Los Angeles, San Francisco, Salt Lake City, Utah, Denver, and Omaha.

Smith, K. D., Properties and Applications of Transistors, A. I. E. E. – I. R. E. Sections, Atlanta, Ga.

Teal, G. K., A Simplified Discussion of the Basic Phenomena in Semi-Conductors, Electrochemical Society, Chicago, Ill.

Townsend, M. A., Cold-Cathode Gas-Filled Tubes for Switching and Control, I. R. E. New Jersey Section, Nutley, N. J.

Tyne, G. F. J., Miniaturized Components and Their Applications in Transistor Electronics, Sylvania Engineering Club, Buffalo Chapter, Buffalo.

Vacca, G. N., Rubber, Lions Club, Plainfield.

Walker, A. C., Growing of Crystals, American Chemical Society, Pennsylvania State College, State College, Pa.

Wallace, R. L., Characteristics of the New Junction Transistor Tetrode, I. R. E., Southwest Conference and Electronics Show, Austin, Texas.

Washburn, S. H., The Design of Switching Circuits for Automatic Control, A. I. E. E. Section, Madison, Milwaukee and Appleton, Wis.

Wiebusch, C. F., From Research to Production, University of Texas, Austin, Texas.

Wood, E. A., Exhibit and Demonstration on Crystals of Barium Titanate, New York Microscopical Society, New York, N. Y.

Appointments

James B. Fisk and Willard Deming Lewis began a three-year term as members of the Frank B. Jewett Fellowship Committee on February 1, 1953. Dr. Fisk has also accepted an appointment as a member of the Committee on Future Housing of the American Institute of Physics.

L-3 Carrier Enters Service

Coaxial cable message handling capacity has been increased by development of the L-3 carrier system by the Laboratories. Field trials of this new system have been in operation for some time, and it has now been placed in regular service on the New York-Philadelphia route.

New wide-band amplifiers were installed in twelve existing repeater stations and eleven new repeaters were added. Using the L-3 system, one pair of coaxial tubes can handle 1,800 telephone conversations at once or a television program in each direction plus 600 conversations.

Although the New York-Philadelphia route is the first to include L-3 in its regular service, a second route is under construction. Work has begun on six additional repeater stations on the Chicago-South Bend, Indiana, section of the Chicago-Philadelphia coaxial cable. L-3 equipment will be housed in these buildings after their completion in April.

Transistor School at the University of Illinois

Three graduate-level courses on semiconductors and transistors will be offered this summer at the University of Illinois. The courses, on Semiconductor Materials, Transistor Devices, and Transistor Circuit Fundamentals, will be held concurrently, each meeting four to six times per week for a period of four weeks. It is expected that each visiting lecturer will devote about one week to discussing his portion of the program.

Bell Telephone Laboratories, in addition to men from four other companies and the University, will be represented on the Advisory Committee by William Shockley, who might well be called "the man behind the transistor," and J. A. Morton, transistor development engineer. John Bardeen, formerly with the Laboratories and co-inventor of the point-contact transistor, is one of the University members of the Advisory Committee. Other lecturers from the Laboratories include R. M. Ryder, R. L. Wallace, Jr., and J. H. Felker.

Belgian Professor Visits Murray Hill

Professor Ilya Prigogine, Head of the Department of Physical Chemistry at the Free University of Brussels, paid a visit to Murray Hill on March 11. Although born in Russia, he has been in Belgium since the age of four, and is a citizen of that country. His work has been in the fields of statistical mechanics of the liquid state, irreversible phenomena in thermo-dynamics, and catalysis. Professor Prigogine is delivering the Fauk-Plaut lectures for 1953 at Columbia University, and he spoke informally in the Arnold Auditorium on *The Law of Corresponding States for Polyatomic Molecules.*

Historic Firsts:

Single-Sideband Transmission

One of the great contributions to electrical communication was the invention* of single-sideband transmission – by John R. Carson in 1915. Without this effective yet simple method of reducing the width of the band of frequencies required to transmit speech by carrier methods, only half as many channels could be provided within any given range of frequencies. Carson's invention also included the elimination of the carrier, and besides economizing on frequency space it thus considerably reduced the amount of power transmitted. On transoceanic radio channels, with large amounts of power, this elimination of the carrier results in important savings.

Until about the time of Carson's invention in 1915 there seems to have been no general, clear cut recognition outside the Bell System that the modulation of a carrier results in two sidebands as modulation products. Fleming in his *Electric Wave Telegraphy and Telephony*† treats the modulated carrier as a wave of constant frequency but varying amplitude, while as late as October, 1912, John Stone Stone, in an article in the *Journal of the Franklin Institute*‡ says, "There is, in fact, in the transmission of a given message, (by carrier) but a single frequency of current involved." At this early stage in the development of carrier telephony, this way of regarding modulation is easy to understand. With a single-frequency carrier varied in amplitude by the action of a telephone transmitter, there seemed no obvious reason to expect that the frequency would be changed. Moreover the voice band is only a small percentage of a high-frequency carrier, and would have been difficult to detect with means then available. From a practical point of view, therefore, the voice signal transmitted by radio in the experiments of that time was a wave of essentially a single frequency.

As soon as one analyzes mathematically what occurs when the amplitude of a constant frequency is varied, however, it is seen that the result is a signal with three major components – the original carrier and a voice band on each side. Such an analysis was undoubtedly carried out by a number of engineers during the early teens, and in isolated cases, perhaps earlier. When Carson joined the Engineering Department of the American Telephone and Telegraph Company in 1914 and became involved in the study of radio transmission carried on in preparation for the trans-Atlantic radio telephone experiments§ of 1915, this analysis was known by a few of his associates. Studying it with respect to transmission and recognizing that of the total power transmitted, the largest part was in the component of carrier frequency, and that it conveyed no necessary information over the transmitting path, he first suggested that the carrier frequency component be eliminated at the transmitter by a balancing-out modulator circuit, thereby very considerably reducing the amount of power transmitted. Since carrier frequency was needed for demodulating at the distant end, however, he suggested that it be generated anew at the receiver.

He further recognized that all the information transmitted was in each of the sidebands, and that thus only one of them was required at the receiver for demodulation. This led him to propose that one of the sidebands be eliminated at the transmitter by a filter. This would cut in half the width of the frequency band required. Along with this reduction in transmission band

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* Patent No. 1,449,382.

† Longmans, Green and Company, London, Second Edition, 1910.

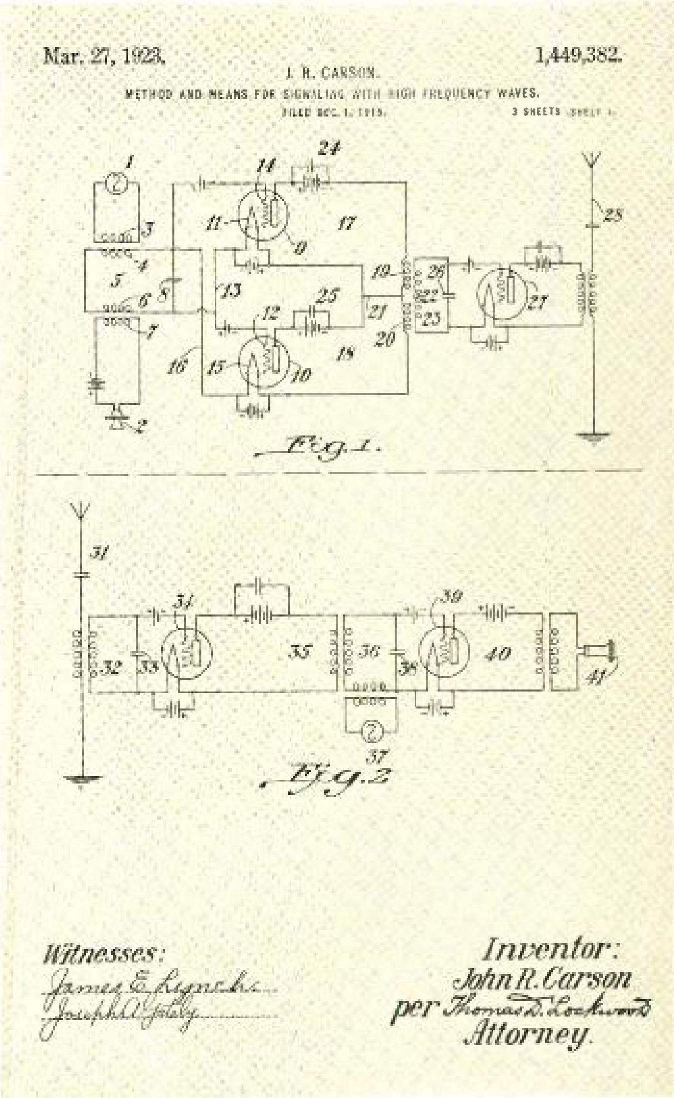
‡ Volume 174, page 353.

§ Record, *September*, 1943, *page* 5.

width there would be a reduction in received noise, which would also be important. This is an interesting contrast to some techniques such as pulse code modulation and wide-band frequency modulation which have been used more recently in special systems and which achieve noise reduction at the cost of greater band width rather than with a reduced band width.

This invention has proved of inestimable value in carrier development since that time. Besides making twice as many channels available over a given frequency band, it also reduces the noise and the load on the repeaters. The amount of power required for single-sideband carrier-eliminated transmission comes out to be only about one-eighth of that required for double sideband transmission with the carrier retained for the same signal-to-noise ratio.

Advantage of this new invention was taken in the Type-A carrier system*, which was developed during World War I and went into commercial service in 1918. Without it, the first trans-oceanic telephone service could not have been established in 1927. This long wave system involved resonant antennas which could barely transmit an acceptable amount of one sideband. With three exceptions, where the economy of frequency space was overbalanced by other considerations, single-sideband transmission has been used in every Bell System carrier system since that time, including the J and K systems – the most widely used systems at the present time – and the L coaxial system.



Part of the patent issued to J. R. Carson covering single-sideband transmission.

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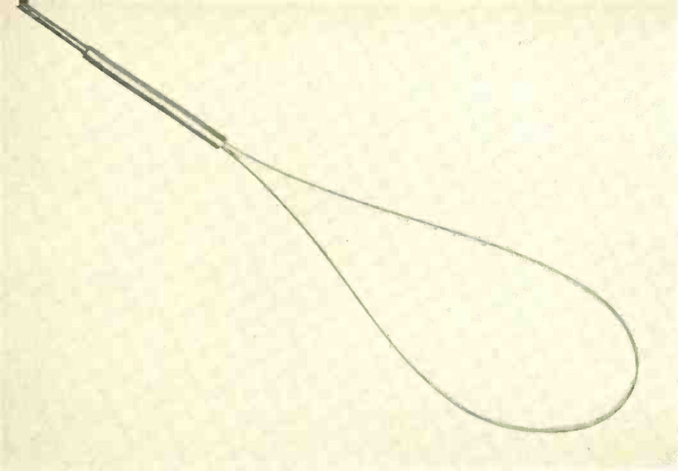
* Record, *December*, 1925, *page* 154.

Fortune Magazine Cites Bell Laboratories Work

An article in the February issue of *Fortune Magazine* cites Bell Telephone Laboratories as a leader in the movement to prevent deterioration. Titled *The Battle of Decay,* the article specifically mentions development of neoprene, polyvinylchloride, and polyethylene as insulation for wire in place of shorter-lived natural rubber, and praises the continuing research that is being done along these lines.

Conclusion of the article says "it is perhaps utopian to hope that all organizations will some day worry as much about deterioration as the Bell System. Firms with products to sell cannot have the same incentive. Nevertheless, manufacturers will deceive themselves if they underestimate the public's desire for maximum life expectancy per dollar of investment. It is one of the basic criteria of fair value."



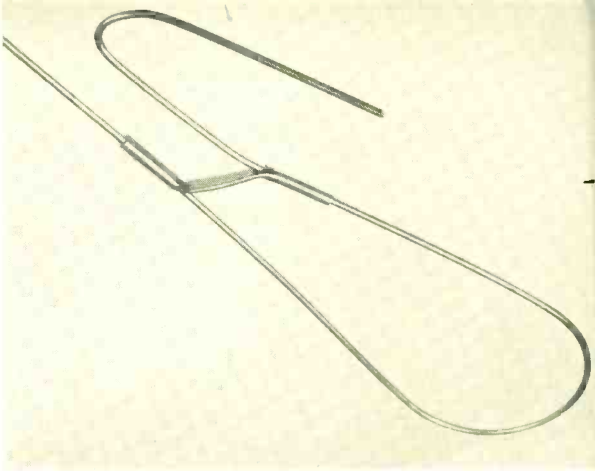


Fig. 1 (left)—With the former methods of dead-ending, a single sleeve was used with a line wire inserted in one end and the two ends of the half-round nickel steel dead-end loop, in the other. Fig. 2 (right)—With the substitute method, a two-bore sleeve is used, and the line wire itself is looped around the insulator.

A Substitute Method for Dead-Ending Line Wire

Schedule A of Order M-80, issued in August, 1951, by the National Production Authority of the U. S. Department of Commerce, prohibited the use of steel containing nickel for pole line hardware. As a result, the Bell System faced the necessity of developing a new method of dead-ending the conductors of an open-wire line because no substitute for the stainless steel dead-end wires, 8 per cent nickel, was available having the desired properties of corrosion resistance and strength.

The standard method of dead-ending makes use of a short length of half-round wire which is looped around the insulator, and then the free ends, with the flat surfaces together, are inserted in a straight single bore tubular sleeve. The line wire to be dead-ended is then inserted in the other end of the sleeve and the dead-end completed by compressing the sleeve on the wire with the sleeve rolling tool. This dead-end assembly develops the full strength of the line wire. It is an adaptation of the single tube method of making joints in line wires which was described in an earlier article*. The completed dead-end is shown in Figure 1; it provides a simple, effective, and inexpensive way to terminate the wires.

The newly developed method makes use of a tubular sleeve having two parallel bores offset with respect to each other that permits the dead-end to be completed by passing the line wire through one bore of

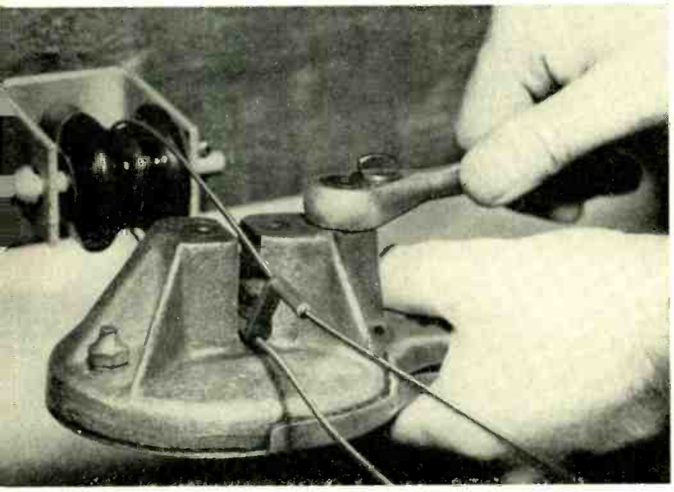


Fig. 3—The rolling tool used with the new method of dead-ending.

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* Record, *November*, 1931, *page* 74.

the sleeve, looping it around the insulator and then passing the free end through the other bore of the sleeve, as is evident in Figure 2. The two offset sections of the sleeve are then constricted individually on the line wire by means of the sleeve rolling tool as shown in Figure 3. To improve the holding power of the sleeve, the bores have a light coating of fine emery held in place with lacquer.

This method of dead-ending line wire had been considered before but the half-round wire and single tube sleeve shown in Figure 1 was favored as long as nickel was available. The new type dead-end has been employed outside the Bell System with sleeves requiring pressing type tools. These sleeves are not suitable for use with the rolling tool and it has been necessary, therefore, particularly for the copper and copper-steel line wires, to design a new sleeve for the purpose. Design information has been furnished to Western Electric Company and it is now expected that the new sleeves will be available before existing stocks of the replaced dead-end wires are exhausted. Cooperation of the Laboratories, American Telephone and Telegraph Company and Western Electric has made possible the rapid development of this line terminating method without delaying the furnishing of service to new subscribers, and without requiring the use of new types of tools or the acceptance of an inferior dead-end.

C. C. Kingsley,
Outside Plant Development

Patents Issued to Members of Bell Telephone Laboratories During January

Cesareo, O. — *Automatic Code Translating System* — 2,625,328.

Curry, R. O. L. — *Method of Fitting Hearing Aids* — 2,625,233.

Edson, J. O. — *Quantized Pulse Transmission with Few Amplitude Steps* — 2,625,604.

Holman, E. W. — *Signal Delay Device* — 2,626,992.

Houghton, E. W. — *System for Measuring Phase and Gain* — 2,625,589.

Joel, A. E., Jr. — *Relay Permutation-Type Switching System* — 2,625,610.

Kempf, R. A. — *Automatic Bridge* — 2,625,587.

Kock, W. E. — *Non-Reflective Radio Refractor* — 2,627,027.

Lakatos, E., and B. McMillan — *Thermistor Control Circuit* — 2,625,606.

Lander, J. J. — *Apparatus for Measuring Gas Pressures* — 2,625,586.

Lavery, G. G. — *Magnetic Testing Apparatus* — 2,626,983.

MacWilliams, W. H., Jr. — *Gating Circuits* — 2,627,039.

McMillan, B., see E. Lakatos.

Pierce, J. R. — *Guided Wave Frequency Range Transducer* — 2,626,990.

Rea, W. T. — *Telegraph Signal Distortion Measuring Apparatus* — 2,624,805.

Schelleng, J. C. — *Envelope Delay Scanning System* — 2,625,614.

Shive, J. N. — *Apparatus for and Method of Treating Selenium Rectifiers* — 2,626,448.

Townsend, M. A. — *Cold Cathode Gaseous Discharge Devices and Circuits Therefor* — 2,627,053.

Treptow, F. W. — *Telephone Switchboard* — D-168,663.

Weaver, A. — *Multiplex Telegraph System* — 2,626,994.

Wier, A. J. — *Switchboard Plug* — 2,625,577.

Relay Computer For Network Analysis

R. S. GRAHAM
Transmission Networks

The busy clatter of relays and the noise of teletype apparatus during overtime hours, with no human being in sight, might lead an observer to believe in ghosts. This is the situation at Murray Hill, in the digital computer room. Working an average of twenty hours a day, seven days a week, this electrical genius performs calculations that would require dozens of human computers to duplicate. Moreover, it doesn't make mistakes or take time off for a cup of coffee. Designed primarily for solving network analysis problems, the computer is used for many other problems. Such things as simultaneous equations, matrix multiplications, continued expansion of fractions, and even some forms of non-linear differential equations do not even slow it down. At any point in the computations it can exercise choice between two courses of action, based on the algebraic sign of a test number. It has a memory that permits it to choose its instructions from a group of programs that have previously been set up. Finally, it is completely self-checking; it doesn't make mistakes.

Although the computer is the seventh built by the Laboratories, it is known as Model VI. The fifth and sixth* were built for military installations and were twins. Using ten digit numbers, it can perform the five elementary arithmetic operations: addition, subtraction, multiplication, division, and square root. Square roots are obtained by using subtraction as is commonly done with mechanical desk calculators, but the process is permanently programmed into the computer. Temporary storage of twelve numbers is possible using relay storage registers. These have a function similar to small blackboards; they must be erased before a new number may be "writ-

Above, one corner of the computer control room showing June Jensen preparing a problem tape. When the problem is to be started through the computer, the tape will be fed to the tape reader at the left on the table at the right. The solutions are recorded on the printer.

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* Record, *February*, 1947, *page* 49.

ten." Three teletype storage tapes are also provided on which data can be held in the form of perforations of the teletype code. The computer can search for data on the tapes and read it back into the calculator registers for further operations. Instructions and original data are read from a problem tape punched by the human operator, and answers are printed on a teletype page-printer. In addition to the numerical answers, the printer can write the name of the problem and its originator in letters, for identification purposes.

Although the computer may perform some of the processes of ordinary "thinking," it does not have original thought. All "thinking" is due to programmed operation sequences, and each type of problem must be programmed in detail. The location of each number of the problem must be specified and each step of the solution must not be more complicated than an elementary operation ($+$, $-$, $\times$, $\div$, $\sqrt{\ }$) involving at most two numbers. Such items as complex numbers are put into rectangular form; the computer can then operate on the real and imaginary parts separately, treating them as real numbers and giving an answer in the same form. Numbers entering the computer are written with the first digit after the decimal point and the proper power of ten is added to determine its correct position. Answers are written in the same manner. The algebraic sign precedes the decimal point, or the computer will not accept the data.

Memory in a computer is the ability of the machine to retain either numbers or instructions, the latter generally being grouped into routines. Previous relay computers have had routine memories consisting of wired connections to relays, or of special storage tapes. The former give rapid operation, but the latter, while considerably slower, can be changed easily. The best features of both are combined in the routine memory of the Model VI computer, which is a modification of the AMA translator* and uses the Dimond ring coils. This memory provides instructions to the computer at relay speeds and yet can be changed easily. Instead of the complex wiring changes which would be required for a change in a relay memory, a single wire is passed through a number of coils in the proper sequence and connected to a terminal plate with a special fast-action connector. Changes in programming which would take hours to wire on relays, may be made in minutes. Once the program has been wired, all that is necessary to utilize

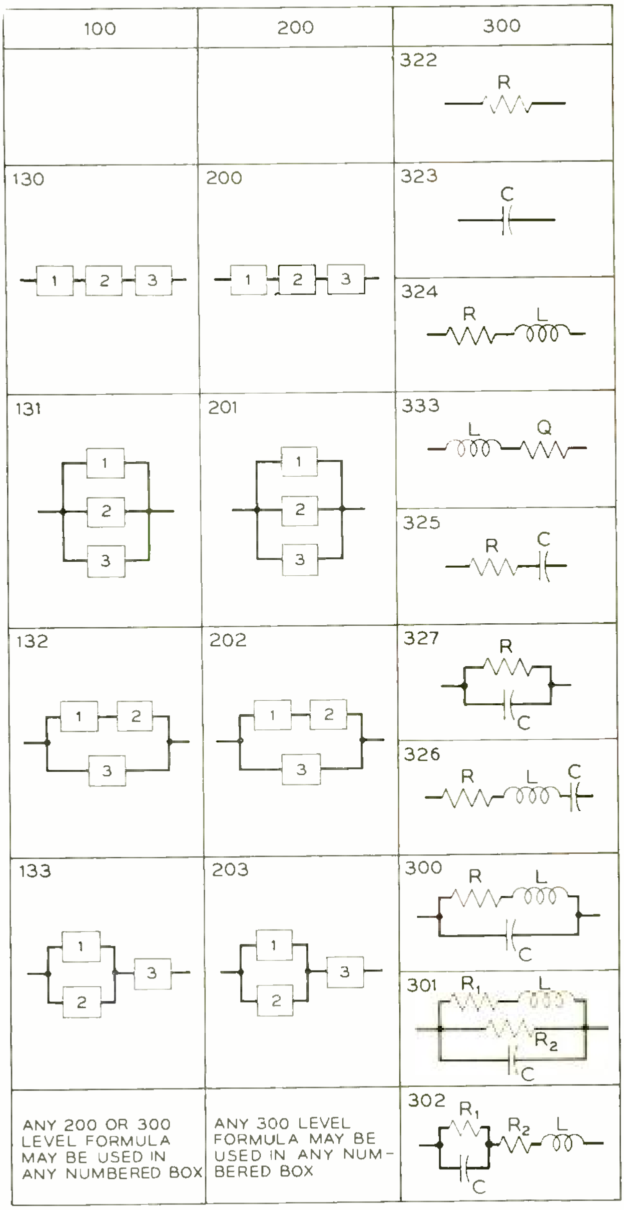

Fig. 1 – Typical sub-routines used in network calculations.

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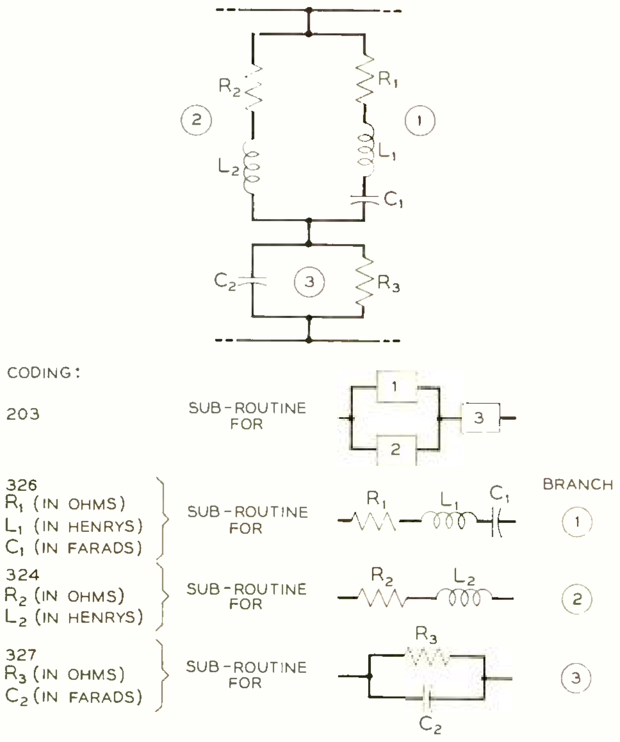
* RECORD, *February*, 1951, *page* 62.



CODING FOR ONE BRANCH OF A NETWORK. THE NUMERICAL VALUES FOR THE QUANTITIES IN LEFT-HAND COLUMN ARE ONLY DATA PERFORATED ON PROBLEM TAPE

Fig. 2 — A typical network section above, and the various sub-routines used in solving it.

it is to punch the tape with the program number; the computer does the rest.

The memory organ of the computer operates from punched program numbers, and four different levels of routines and sub-routines are wired in. A high order routine may then call on a lower order sub-routine as a single step in its program. If required, the sub-routine may in turn call on a still lower order. Each sub-routine returns the computer to the control of the higher order routine originating the instructions. Although problems that may be reduced to the elementary algebraic operations are relatively straightforward, much opportunity exists for ingenuity on the part of the operator in devising routines that are rapid and do not require an excessive amount of memory capacity.

About one-third of the computer's working time is spent in solving network analysis problems. The design of such networks as filters and fixed or variable equalizers entails the calculation of performance at several frequencies over the range to be covered. The computer will solve for such items as impedance, phase shift, or insertion loss for a given frequency and then repeat the operations for any number of other frequencies with no further instructions. Schematic arrangements, reduced to a series of program numbers, and the network element values are punched on one of the three storage tapes. The computer per-

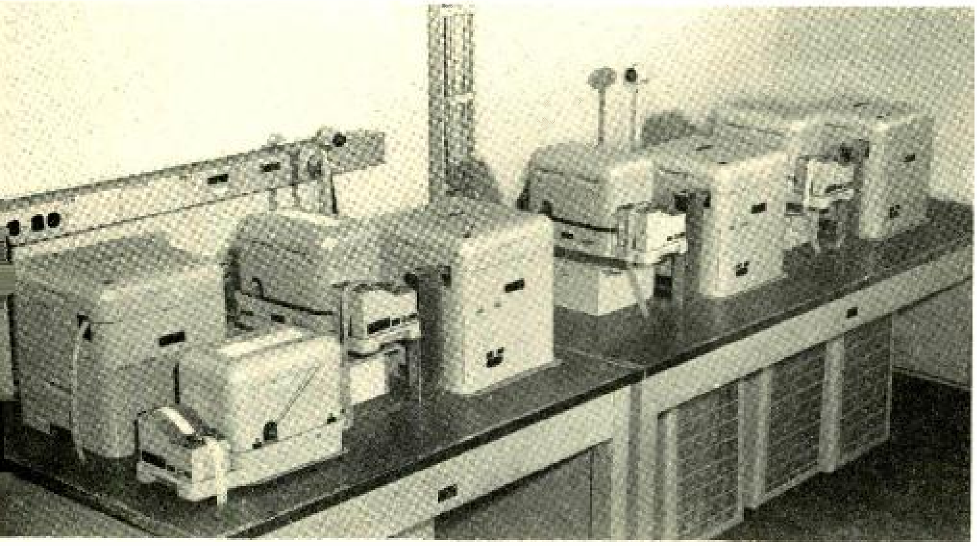


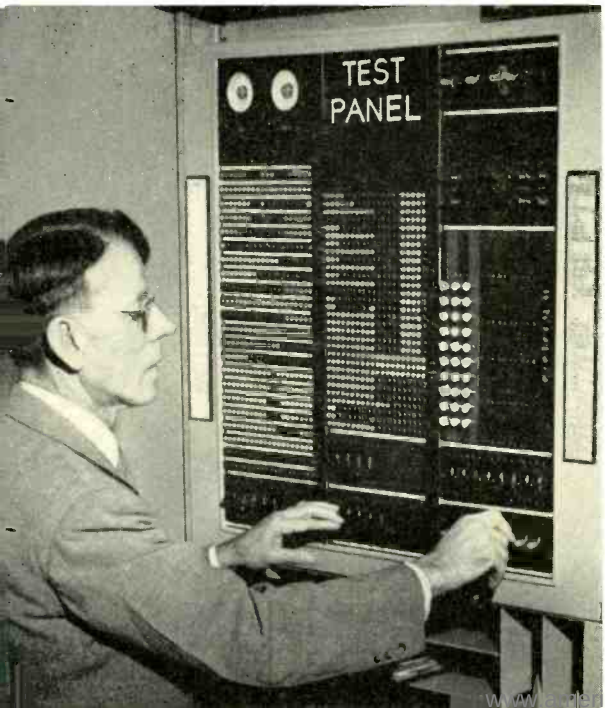
Fig. 3 — Also in the control room are the three storage tape perforators and their readers. A spare unit at the left is used for duplicating problem tapes.

forms the necessary operations in the correct order according to the program set by the problem tape. Sub-routines corresponding to simple electrical circuits have previously been wired in and may be called upon by simply punching the tape with the correct program number.

Complex networks are formed of simple circuits. Some examples of these simple circuits and the program numbers assigned them are shown in Figure 1. The highest level of "intelligence" is the series of routines numbered from 000 to 099, which are not shown in Figure 1. Below this are the sub-routines of the 100, 200, and 300 series. The higher the number, the lower the intelligence level. Thus a program number such as 045 could call in a sub-routine in any of the other levels as one of its steps, and that level could in turn call for any lower-level sub-routine. As each sub-routine is finished, control reverts to the higher level of which the sub-routine was one step.

Figure 2 shows a typical network and the program required for computing its impedance. The code number 203 indicates that the network is basically a series-parallel circuit as shown. Each of the numbered boxes (elements) of the circuit might be any simple circuit. For the case shown, the sub-routine number 326 will permit the computer to solve the series resonant circuit in one branch of the parallel element, on the 300 level. This is followed by the number 324 which solves the resistance-inductance branch. The third number is 327 which solves the parallel combination of resistance and capacitance, representing the series element of the 203 routine. Each of these sub-routines on the 300 level is a single step of the 203 routine. This coding combines these single steps in the proper way to solve the original series-parallel circuit.

Fig. 4 – C. M. Hebbert at the computer test panel.



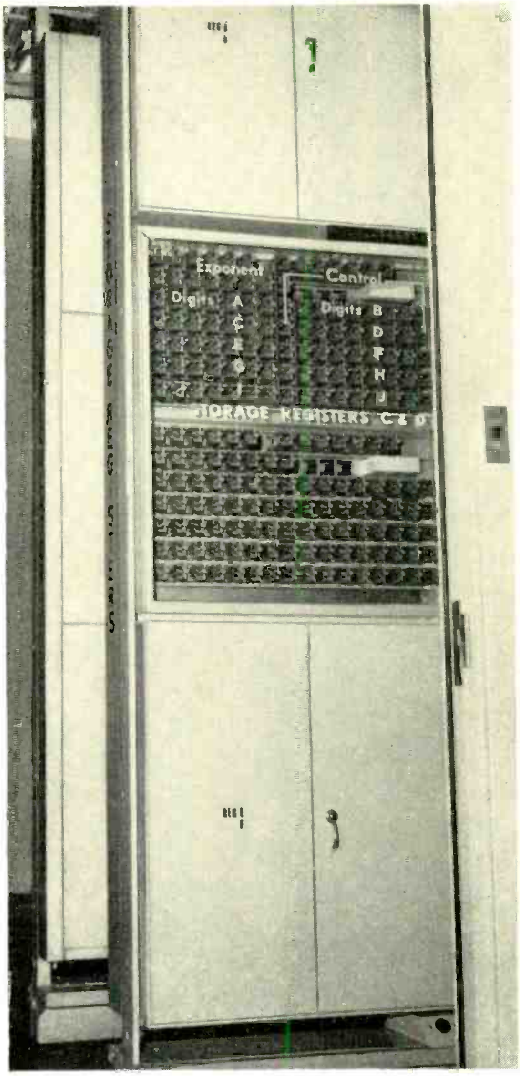


Fig. 5 – Standing in the control room and looking through the door to the computer, one sees the ends of two rows of bays of computer equipment.

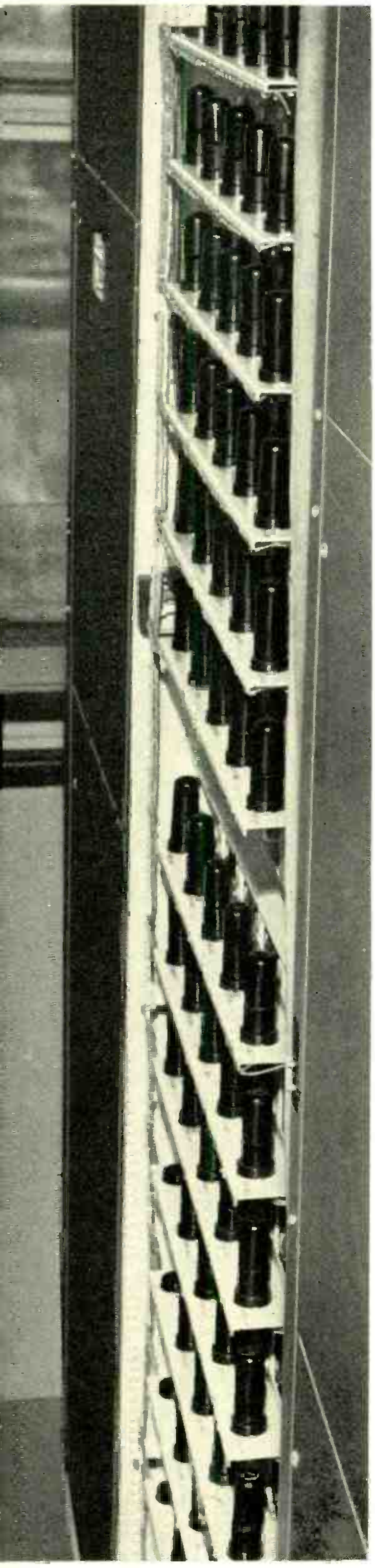
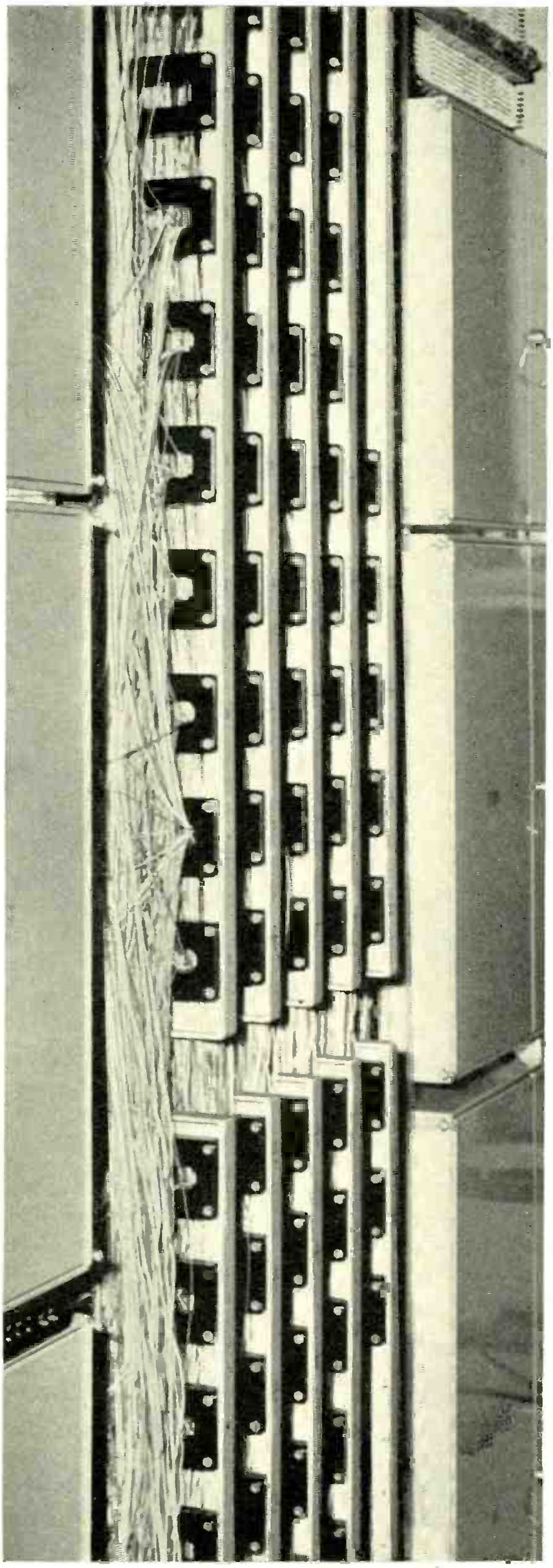


Fig. 6 — The two sides of the memory bay of the computer. The Dimond-ring coils are evident at the right and the cold cathode tubes they are associated with, at the left.



Each of the 300 level operations is in itself a pre-wired sub-routine, called in by the proper program number. The 327 sub-routine, for example, consists of several steps. Upon receiving the values of the two electrical elements in their correct units, the reciprocal of the resistance is found, the correct ohmic value of the capacitative reactance is derived for the frequency involved and its reciprocal found. The two reciprocals form the complex admittance and the reciprocal of this is derived, giving the impedance of the combination. All this is done in the computer by simply punching the tape with the program number 327. Each of the other sub-routines is made up of similarly detailed steps, and the over-all 203 routine uses these answers as steps in its own operation.

Each sub-routine ends with the complex impedance stored on two registers. To compute the input-to-output ratio of voltages of a ladder network, sub-routines in the lower levels compute the branch impedances. From these, using complex arithmetic sub-routines, the complex voltages and currents are found at points along the network, and finally the input-output voltage ratio is derived and printed on the output printer. The entire cycle is then repeated for another frequency. Certain routines are used to convert lattice and bridged-T sections to equivalent T-sections which may then be used in the ladder network routine as before. More complicated sections must be solved by special programming. It is sometimes necessary to add "dummy" elements to a circuit to make it fit a standard routine. The ladder network routine is designed for shunt-terminated networks. If a series-terminated network is to be solved, an infinite resistance is used for the shunt termination in the problem. This is 0.9×10^{19} ohms to the computer, since it is the largest number that may be handled. Similarly, the smallest number is 0.1×10^{-19} or the computer's idea of zero.

Perhaps the most interesting feature of the Model VI is that it is almost completely self-checking. Computing is done by a modified bi-quinary system, with all answers for addition and subtraction being prewired. The insertion of two numbers to be added will automatically give the correct answer without the necessity of counting chains or other counting devices. When an error is discovered by the computer, it stops the operation it is performing and starts it over. If the condition has been cleared, it continues normally. If the condition still exists, it goes on to the next problem. In the case of a network solution, it will simply skip the frequency being checked and go to the next frequency. If the trouble continues to exist after all problems have been tried, it will shut itself off. Approximately 600 small lamps give a continuous indication of the numbers being handled and the progress of the calculation. If a trouble condition occurs during attended operation, the lamps will indicate the approximate location of the difficulty.

The computer was designed by a group working under E. G. Andrews. Most of the wired-in routines were designed by C. L. Semmelman and the author. C. M. Hebbert has been responsible for the operation of the computer, and a group under Miss J. D. Goeltz prepares the problems for it.

THE AUTHOR: Since joining the Laboratories in 1937, R. S. GRAHAM has been principally concerned with the design of equalizers, electrical wave filters, and similar apparatus for use on long distance coaxial cable circuits for both telephone and television transmission and is currently in charge of a group working on these problems. During World War II he designed circuits for electronic fire control computers for military use, and later developed methods for computing network and similar problems on a digital relay computer. Mr. Graham received a B.S. degree in E.E. from the University of Pennsylvania in 1937.

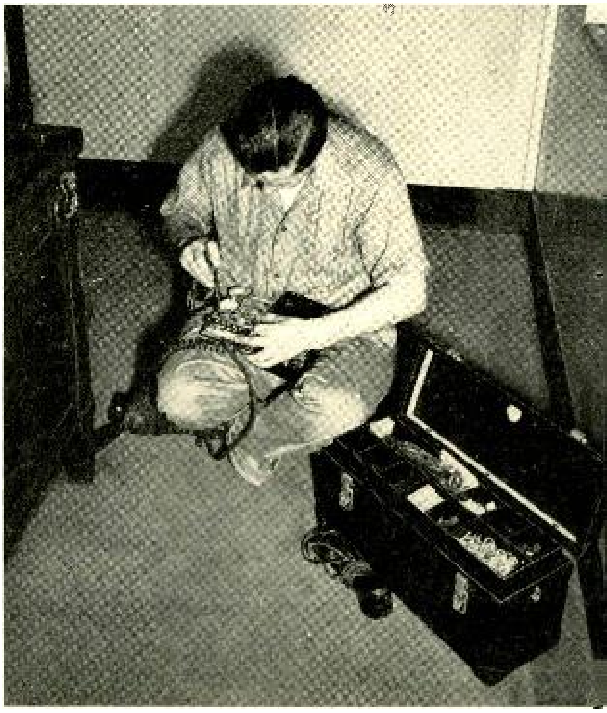
Station Installer's Tool Case

A newly designed vulcanized-fibre installer's tool case, for storing and carrying the many tools and smaller material items needed for installing telephones, is now being furnished to replace the collapsible leather bag previously used. The fibre case not only is easy to carry but it makes the tools and material readily available and presents a better appearance. In addition its outer surface can easily be kept clean, while field experience with the old type soft leather bag showed it tended to collect dirt.

More than one hundred tools in all are available for station installation work, but generally about fifty are needed by the installer in his daily work. Small tools such as screwdrivers, wire cutters, pliers, gauges and items of small hardware including nails, screws, drive rings, and staples are conveniently accessible in the various compartments of the removable tray. Such tools as hammers, files, soldering iron, drills, saws, ratchet brace, stapler, and a small first aid kit are housed in the space below the tray.

The new case is a modification of a design used by a few of the Operating Telephone Companies for several years. It measures 19¾ by 7 by 9 inches (high). Each catch of the case is equipped with a locking ear to permit securing the case with a padlock. Built-in locks introduced problems in maintenance and replacement of locks and keys that are largely avoided with the present design.

S. R. King
Outside Plant Development



M.I.T. Professor Visits Murray Hill

Professor Jerrold R. Zacharias of Massachusetts Institute of Technology paid a visit to Murray Hill on February 13. While there, he held a conference with representatives of the Laboratories on magnetic resonance of molecular beams. Experiments in this field indicate the possibility of constructing an extremely accurate atomic clock and of demonstrating on the surface of the earth, the gravitational frequency shift of spectral lines.

Born in 1905, Professor Zacharias received his Ph.D. in solid state physics in 1933 from Columbia University. He has taught at City College of New York and at Hunter College, and is now head of the Laboratory of Nuclear Science and Engineering at M.I.T. His published work has dealt chiefly with the investigation of nuclear spins and magnetic moments by molecular beam methods.

New Audio Publication

A new publication of interest to some members of the Laboratories made its debut in March. The *Journal of the Audio Engineering Society* is the official organ of the Society and will be published four times a year. Edited by Lewis S. Goodfriend, the *Journal* will present technical papers on broadcast audio equipment, recording and reproduction of sound and music, and related subjects. In addition, book reviews, activities of the Society, and news notes will be featured.

Radiotelephone Service Extended

The radiotelephone directory was enlarged again by the inclusion of Turkey and Syria during February. Subscribers in the United States can now reach over eighty million telephones in 101 countries and territories via radiotelephone. Service to the Republic of Syria was opened on February 13, and calls from the U. S. are routed from New York via Rome, Italy. Syria may be reached from any part of the U. S. for three minutes for $15 plus tax.

Calls to Turkey are beamed from the Long Lines radio station at Lawrenceville, N. J., to the new radio station at Ankara, operated by the Turkish Government. This new station is an outgrowth of an extensive reorganization and expansion program for Turkey's communication system. The Mutual Security Agency of the U. S. co-operated with the Turkish Economic Mission to aid the program. Engineers were sent to Turkey in 1951, and at the same time a group of young Turkish engineers under MSA sponsorship came to this country for intensive training in telephony.

Network TV Grows

Toronto, Canada, joined the Bell System television network in January. The 66-mile radio relay link was constructed by The Bell Telephone Company of Canada, and at present is a single channel from Buffalo, N. Y., to Toronto. Construction is underway for a further addition to the network from Toronto to Montreal, Canada.

American cities added to the network recently include Youngstown, Wilkes-Barre, Reading and South Bend. Newest member of the fast-growing network is station WKNB-TV in New Britain, Conn., bringing the total to 120 TV stations in 76 cities in the United States.

TV Goes to School

The New Jersey Bell Telephone Company is providing television circuits to the Department of Education for trying TV as an educational medium in public schools of New Jersey. Microwave radio equipment connects a studio at Rutgers University near New Brunswick, with high schools in New Brunswick and nearby Highland Park. Each of these feeds an elementary school over a short wire extension. Daily telecasts from Rutgers to the four schools vary in length and will continue for an indefinite trial period.

Billion Dollar Taxes

Bell System operating taxes for 1952 were $706 million and customers paid telephone excise taxes of $615 million, again pushing total direct taxes on Bell Telephone service well over the billion-dollar mark. This is equal to $2.85 per telephone per month.

Though the telephone is far from being a luxury, excise taxes on toll calls, for example, are much higher than those imposed on any other essential service or product. Furs, jewelry, luggage, cosmetics, and cabaret entertainment are taxed 20 percent; telegrams, and tickets for trains, busses, and planes are all taxed 15 percent; sporting goods and inexpensive watches are taxed 10 percent. Utilities such as electricity, gas, and water have no Federal excise tax at the consumer level. Long distance telephone calls are taxed at 25 percent, the highest of all.

Deal-Holmdel Colloquium

The sixth regular meeting of the Deal-Holmdel Colloquium was held on March 6 at Holmdel. R. L. Wallace, Jr., spoke on *A Junction Transistor Tetrode.* This recent transistor development is of interest since it is the primary element in the tiny repeater described elsewhere in this issue.

Radio Relay Plans

Five additional microwave radio relay routes are in process. One, from New York to Albany, will interconnect with the newly constructed Albany-Buffalo microwave system and provide a second radio relay route westward from New York City.

A joint undertaking of the Southern Bell Telephone and Telegraph Company and Long Lines will provide a microwave radio link between Atlanta, Georgia, and Louisville, Kentucky.

By this fall, two new channels in each direction will be completed between Chicago and St. Louis.

A 423-mile radio relay network is being extended north of Chicago, linking Chicago, Milwaukee and Minneapolis. By mid-summer, plans call for four telephone channels, one in each direction, between Chicago and Milwaukee, and between Chicago and Minneapolis.

Another route will join Pittsburgh and St. Louis, via Indianapolis and Terre Haute, Ind. Equipment buildings are completed, towers are being built and service is scheduled by mid-year. This route will be a telephone channel at the start.

G. E. Peterson to Lecture at the Universtiy of Michigan

G. E. Peterson will take a leave of absence from the Laboratories this summer to give two lecture courses at the University of Michigan. Titles of the courses are *The Science of Speech Improvement* and *Measurement in Speech Science.* Both courses will begin on June 22 and continue through August 14.

More Mobile Telephones

Mobile telephones in service reached a total of 11,480 last year, an increase of nearly 1,500 over 1951. This increasingly important telephone service now serves 159 areas in the United States and 17 areas in Canada. The Bell System also had under contract, at the close of 1952, 470 private mobile systems in the U. S. These are provided for taxicabs, police and fire departments, public utilities, and other industrial concerns.

Operator Toll Dialing In New Orleans

New Orleans, Louisiana, joined eighteen other cities on March 1 as the latest addition to the growing list of operator toll dialing facilities. Approximately 1,800 communities throughout the country may be dialed by New Orleans operators. In addition, calls routed to and through New Orleans from other cities are switched automatically by the new equipment.