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← **Unique operation in the manufacture of the image-orthicon television camera tube is glass target cutting. After blowing a bubble at the end of a heated glass pipe, the operator uses a fine blow torch to cut a target .0002" thick out of the cleanest wall section of the bubble.**
Courtesy of RCA

CLOSED LOOP SERVOSYSTEMS

Outline of basic principles in the design of servosystems emphasizing the application of servosystem concepts in attacking scientific problems.

By JOHN D. GOODELL

The Minnesota Electronics Corp.

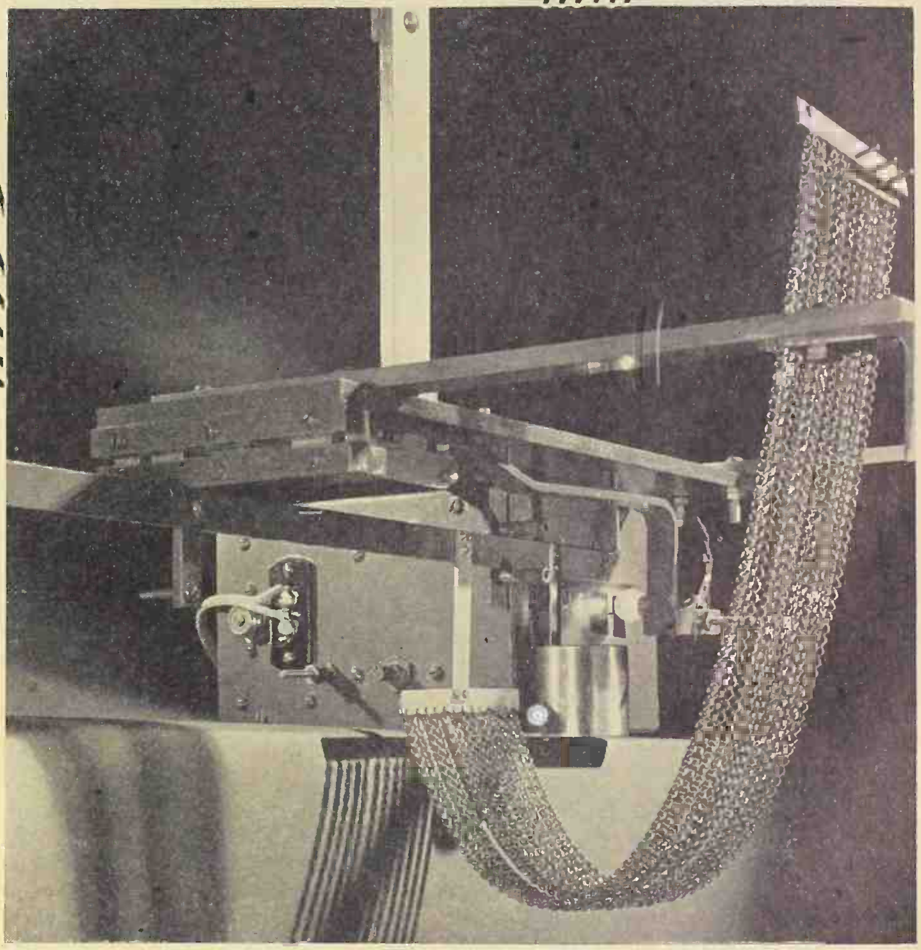


Fig. 1. Balance arm using phosphor bronze springs as a fulcrum operates slit in front of pilot lamp to deflect light beam between two photocells. Output of photocells drives the reversing servo motor to adjust positioning of chains attached to rear end of balanced arm. Weight is added or subtracted by positioning of chains in order to maintain constant dynamic balance.

AT SOME time in his career almost every engineer will be called upon to design, adjust or otherwise deal with a servosystem. As a matter of fact, every engineer deals with systems that might correctly be classed in the servo category, although he perhaps thinks of them in other terms. This is an important point because the ability to think logically and intelligently about any problem is directly related to the ability to consider the problem in terms of a variety of analogies, concepts and viewpoints. The electrical engineer thinks in terms of inductance, capacitance and resistance, and these concepts have been used to advantage in connection with mechanical structures. Conversely it is often helpful in circuit analysis to think of an electrical inductance as having inertia. The development of control devices requires that the designer have an understanding of mechanical elements and that he be capable of relating them intimately to the function and behavior of associated circuitry.

Few audio engineers think of amplifiers containing degenerative feedback as constituting servosystems. Yet all amplifiers fall under the basic definition, for the output tubes constitute a power output mechanism under the control of relatively low power voltage gain stages that drive them. When feedback is introduced the closed loop system is continually striving to maintain the output independent of changes in a number of input variables, or to adjust the input characteristics to the demands of the load. These are basic characteristics of closed loop servosystems.

The word "servo" is derived from "slave." Servomotor is defined as "a relay apparatus; any power driven mechanism which supplements a primary control." This broad definition includes a wide variety of mechanisms with which this article is not particularly concerned. Remote control units of many kinds may be properly defined as servosystems although they depend

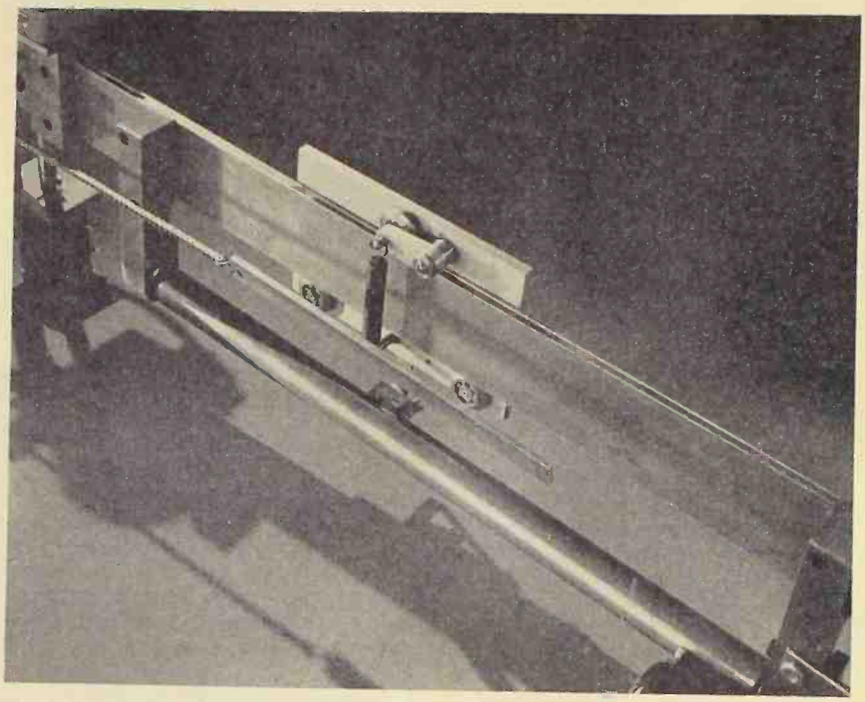
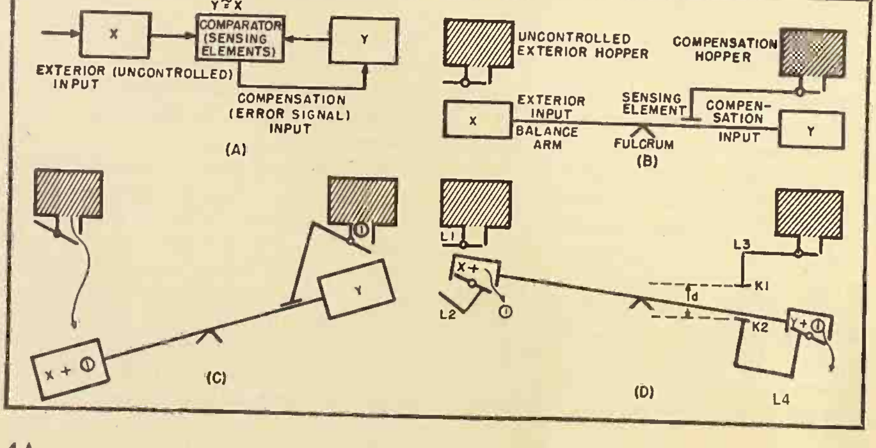


Fig. 2. Rear view of carriage to which is attached free end of chain shown in Fig. 1.

on exterior sources for the calculations necessary to direct their operation. This discussion is limited to servosystems in which certain of the components function within a closed loop in such a manner that the operation of the system is dynamically adjusted by intelligence computed internally and obtained through built-in sensing devices. In this type of system a sensing device "observes" input information that ordinarily represents a change in an input parameter with respect to an output parameter. The system is caused to operate in such a manner as to cancel out the unbalance set up by the changed relationship. In broad terms, these systems may be applied in a group of related variables whenever it is desirable to maintain one or more variables constant with respect to one or more of the others. Actually the constancy is always an approximation but in many structures the error may be made negligible. The simple schematic of such a system is generalized in Fig. 3A and a practical example in simplified form is shown in Figs. 3B, C and D.

In Fig. 3B the quantity X is varied by an exterior input. The comparator observes the quantities X and Y, compares them and generates a compensation input to Y if an unbalanced condition exists. Thus Y is maintained approximately equal to X. In Fig 3C, X and Y are weights at opposite ends of a balance arm. Whenever a unit of weight is added to X as a result of an exterior signal opening the associated hopper, the balance arm is displaced in such a manner that it contacts the sensing element so as to open the compensation hopper and hold it open until an approximately equal unit of weight is added to Y. In Fig. 3D is shown a two-way version of the same system so that whenever either input lever L_1 or L_2 is moved so as to increase or decrease the weight of X, a corresponding lever L_3 or L_4 is appropriately moved to readjust Y.

Fig. 3. (A) Simple schematic of a generalized servosystem. (B), (C), and (D) are practical examples in simplified form in various stages of balance and unbalance.



These may seem like absurdly simple examples, but they define principles and terms as well as indicate the methods used for solving a practical problem described later. It is important to note that during the travel of the balance arm between the limits K_1 and K_2 there is a dead space where no error signal is generated. Thus there may exist at any time a maximum error equal to the weight required to deflect the balance arm through the distance between K_1 and K_2.

Of equal importance is the fact that there is a certain amount of static friction in the bearings and other elements, as well as inertia that resists motion from a rest position. This "stiction" is a limiting factor with respect to sensitivity. Friction as a function of speed of relative motion between close coupled elements is termed "viscous" friction and is a quantity of great importance in servosystem design. Deliberately introduced viscous friction is the commonest solution to anti-hunt design.

In any servosystem there are three basic desirable characteristics related in such a manner that improvement in one is always obtained at the expense of one of the others. An ideal system would respond instantaneously, have absolute accuracy and be completely free of oscillation (hunting) or any form of instability. Bitter experience shows that increased speed of response always reduces accuracy or adds instability. An improvement in stability invariably reduces the response speed or lowers the accuracy. As might be expected, it is equally true that a gain in accuracy inevitably is reflected in a loss of response speed or stability. Unless this fundamental truth is recognized, a design engineer dealing with servosystem problems is likely to be completely frustrated in obtaining optimum conditions. These three parameters must be juggled into an optimum relationship, and it will save many hours of redesigning if each problem is considered carefully in the beginning to determine its relative importance. Sensitivity is another form of the term designated here as response speed.

The apparent impasse presented by this condition may often be greatly reduced in importance, but it can never be eliminated. For example, if the system is intended to measure a dynamic change and the measure may be in terms of an average value, then the factor of stability may become unimportant, the system may be allowed to oscillate and the reading made in terms of a statistical average. (It is possible to be misled in this connection by a system that oscillates unsymmetrically.) Thus the instability is made unimportant as a factor in the problem.

It is worthwhile to consider briefly the relationship between these factors and some of the reasons for their interdependence. Instability in most servosystems is observed as hunting which is essentially synonymous with oscillation. In the system shown in Fig. 3D, assume that the limits K_1 and K_2 are placed extremely close to the balance arm in order to improve accuracy by eliminating the "dead spot" area between them. This means that a smaller unit change in the weight of X will cause the balance arm L_3 to trigger the associated hopper and release a weight to Y that will bring it back to balance. Now when the balancing weight is added to Y, it will swing the balance arm down to normal, and a little beyond normal because of the mass of the various elements, the force involved in dropping the weight on Y and other factors. When it swings downward beyond its normal position L_4 is operated and the added weight is dropped away from Y. Obviously this is a condition of sustained oscillation. In order to eliminate it one might add tension to the bearings, or perhaps introduce a dash pot filled with oil and connected to the balance arm. This addition of viscous friction may be made to damp out the oscillation. The dead spot area is still small and the accuracy is high. But now the speed of response is lowered, and if the cycling of L_1 and L_2 is increased Y will be unable to keep up. This will introduce a large dynamic error. Such variations can go on indefinitely, and juggling of this kind is typical of the struggles that servomechanism designers live with.

These problems can be approached from the standpoint of mathematical analysis and often will yield excellent results with such methods. Inevitably there are certain aspects that are better handled by empiric cut-and-try methods. In common with most design problems, hours of wasted effort can be saved by intelligent planning and careful consideration of the specific requirements of an application.

Servosystems are not uncommonly used to advantage in devices designed for measurements under dynamic conditions. Figs. 1 and 2 are photographs of the basic elements in a system for obtaining accurate dynamic measurements of various types. This system is diagrammed in Fig. 4. A balance arm is arranged so that the input signal may be applied to it. Assume, for example, that it is desired to determine the rate at which liquid components of a chemical emulsion will evaporate under given ambient conditions. A vessel containing the liquid is suspended on the input end of the balance arm and a corresponding weight is added to the other end of the arm so as to produce an initial balanced condition. When the system is placed in operation a certain minimum amount of evaporation will unbalance the arm in such a manner that the slit will deflect the light source to the appropriate photocell. The output from the photocell bridge circuit will be of the proper phase to produce an output from the amplifier that will rotate the motor in the proper direction to drive the lead screw and re-position the chain-carrying carriage. The carriage will move in this instance a sufficient amount to add or remove enough chain to the back end of the balance arm to re-position the slit so that the total light falls between the photocells or is divided between them equally, and the output from the bridge is cancelled. This process continues until the liquid is entirely evaporated and there is no further change at the input to the balance arm. Obviously a recording indicator may be provided to plot a suitable curve that will indicate the instantaneous change under varied ambient conditions, as well as the rate of change. This type of system may be used to measure a wide variety of dynamic input forces varying in either direction with respect to time, or changes in associated conditions, or both.

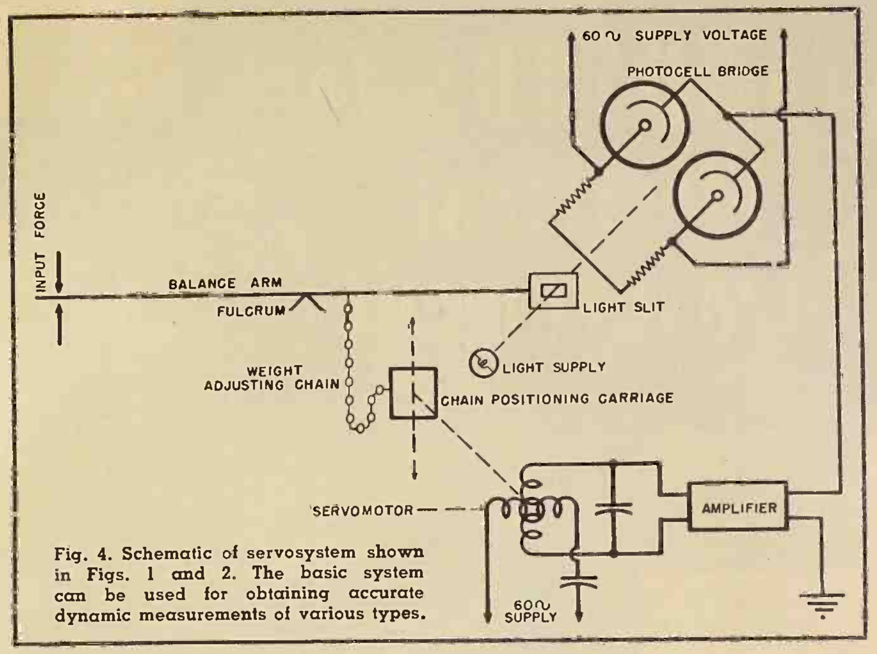


Fig. 4. Schematic of servosystem shown in Figs. 1 and 2. The basic system can be used for obtaining accurate dynamic measurements of various types.

In most servosystems involving motors, various gear trains are involved and it is important to maintain at a minimum the backlash characteristics of each element. Motors are often used to drive potentiometers in bridge circuits where an unbalanced voltage produces a positioning output. Such a system is diagrammed in Fig. 6, and the photograph in Fig. 5 shows one type of gear design for the elimination of backlash. Note that two gears coupled to a single shaft are meshed in common with a single driving gear. The coupled gears are spring-loaded against each other so that backlash is taken up by the opposing pressures of the teeth on the coupled gears against the teeth of the common driving gear. Many other methods of eliminating backlash

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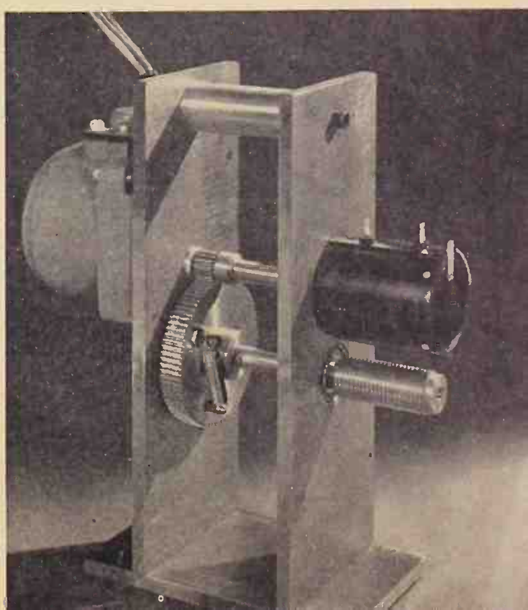
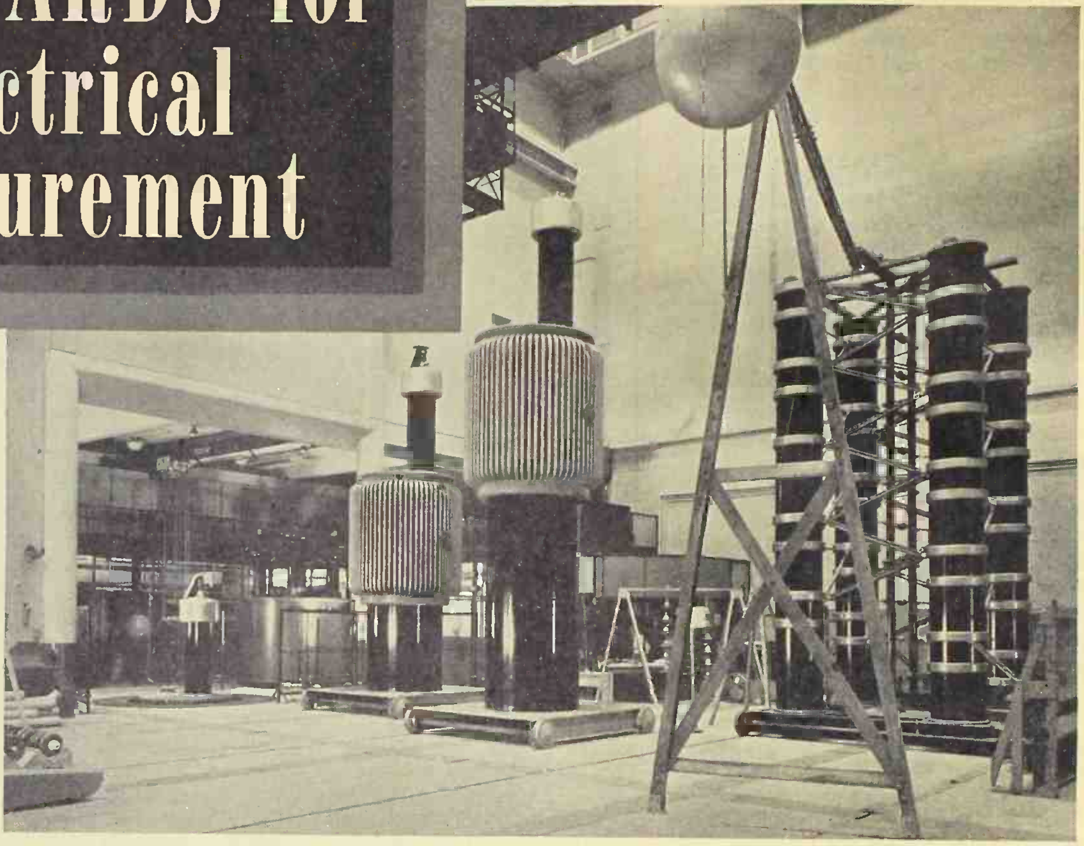
Fig. 5. Spring loaded gear design which is used to eliminate backlash. Motor drives one of the potentiometers shown in Fig. 6.



STANDARDS for Electrical Measurement



Apparatus for the generation of "artificial lightning" at NBS. At right is the two million volt surge generator and in the center are two 350,000 volt transformers.

By FRANCIS B. SILSBEE, Chief
Electrical Div., National Bureau of Standards

Techniques and equipment used at NBS for the precise measurement of electrical quantities.

PRECISE electrical measurements are of fundamental importance to modern science and industry. This is true not only in the communication and power fields but in many other areas where the flexibility and convenience of electrical methods have made them almost indispensable for the measurement of non-electrical quantities. Thus, while in textbooks energy is defined simply in terms of force and length or of mass and velocity, in actual practice the heat energy of fuels and the energy output of prime movers are universally measured to high precision by electrical methods. Likewise, the basic electrical units enter into the determination of nearly all the fundamental atomic constants, as well as into daily measurements of heat, light, color, strain, acceleration, displacement, and chemical properties.

Effective application of electrical equipment and measurement methods requires uniformity to a high degree of precision in the basic electrical units. Some two billion dollars' worth of electrical machinery and apparatus is manufactured annually in this country. Were each manufacturing company to use an even slightly different value for the volt or the ohm, the apparatus made by its subcontractors would fail to function properly as a part of the final product. The result would be an impossibly confused situation, causing large financial losses to the Nation. In the communications industry, the multiplex transmission of intelligence over a relatively small number of circuits is dependent on the precise adjustment of capacitance, inductance, and other circuit components in such a way as to prevent the signals from straying into the wrong channels. This, again, requires precise uniformity in the measurement of the basic electrical units.

Exploded view of a type of "guard-well" capacitor used to provide primary standards from 0.1 to 0.001 micromicrofarads.

As the custodian of the national standards of physical measurement, the National Bureau of Standards has the responsibility of insuring that the units of measurement used in science and industry are constant through the years and uniform throughout the Nation. The Bureau has developed very precise standards of resistance and voltage whose values are established by absolute measurements that fix the relation between the electrical units and the fundamental mechanical units of length, mass, and time.[1] From these basic absolute electrical standards, the Bureau has derived other standards for all electrical quantities in use today.

Because of their technical difficulty,

precise absolute measurements are carried out only in the national standardizing laboratories of a few of the larger countries. Sufficient accuracy in science and industry is obtained through accurate comparison of the secondary or working standards of other laboratories with primary standards thus calibrated. In this country such comparisons constitute the Bureau's calibration service. Each year a stream of about 2000 high-grade electrical instruments, standard cells, and other measuring apparatus flows through the Bureau's electrical laboratories. The services performed range from the comparatively simple measurement of the e.m.f. of a standard cell to the determination of the ratio and phase angle of a multirange current transformer at several frequencies, currents, and loads, which may require 1000 separate measurements. Among the devices submitted are potentiometers, bridges, resistance boxes, volt boxes, capacitors, inductors, multimegohm resistors, instruments and meters of all kinds, precision shunts for large currents, instrument transformers, standard magnetic test bars, magnetic test coils, and standard cells of both the saturated and unsaturated types. They come from manufacturers of electrical equipment, from public utility companies wishing to make sure that their charges are correct, from public service commissions which regulate the utility companies, and from communication laboratories, university laboratories, private commercial testing laboratories, and the many scientific laboratories of the Federal Government.

The demands of modern science and technology have made this work more and more exacting, not only as regards accuracy, but also in the range of values and variety of units in which measurements are made. Thus the Bureau now measures precisely currents, voltages, and resistances having values up to tens of thousands of amperes, hundreds of thousands of volts, and millions of billions of ohms. This is done with direct current, with alternating current of various frequencies up into the thousands of megacycles, and with surges of current lasting only a few millionths of a second.

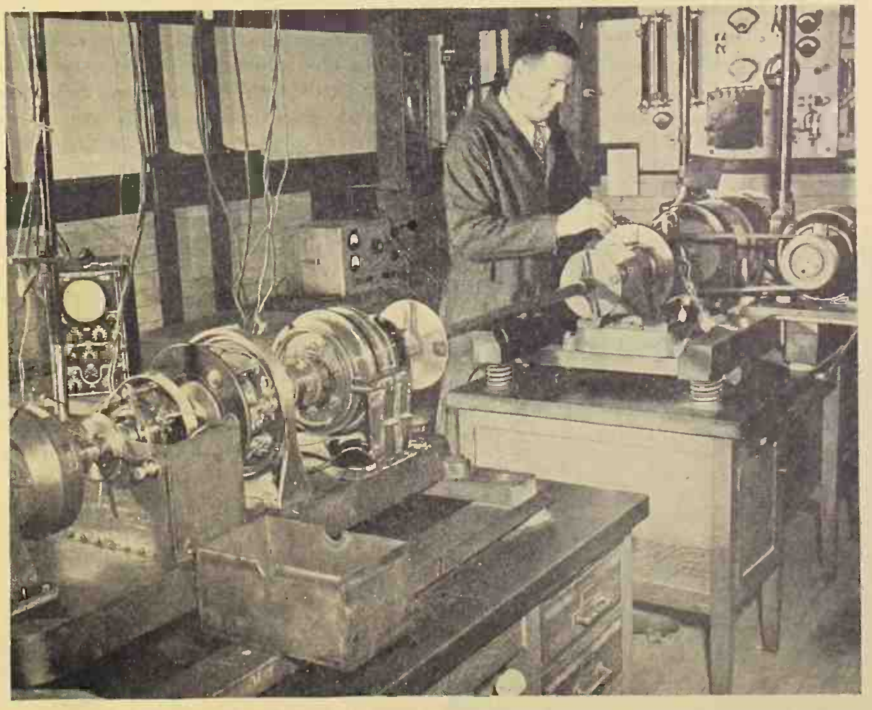
Establishment of Units

The basis of the Bureau's standardization of electrical measurements is the establishment of values for the ohm and the ampere that bear the desired simple theoretical relation to the meter, the kilogram, and the second. However, since an electric current is by its nature evanescent, the volt, derived from the absolute ampere at the time the latter is measured, is embodied in the calibration of a group of standard cells which together with the standard resistors embodying the ohm are kept as permanent primary standards.

The determination of the ohm consists of two steps. The first is the construction of an inductor (either self or mutual) which is so designed that its essential dimensions can be measured mechanically with high accuracy and which is of such a shape that the inductance can be calculated from these measured dimensions. Both self and mutual inductors have been prepared at the Bureau by winding wire in lapped helical grooves on forms of glass, quartz, or porcelain. The second part of the process consists of an electrical experiment in which a bridge or equivalent circuit is used to compare the reactance of the inductor at a known frequency with the resistance to be measured. When the resistance in absolute ohms of the resistors used in the bridge circuit has been determined in this way, the absolute resistance of other standard resistors can be found by comparison.

Laboratory at the National Bureau of Standards for testing all types of ammeters, voltmeters, wattmeters, and other electrical indicating instruments.

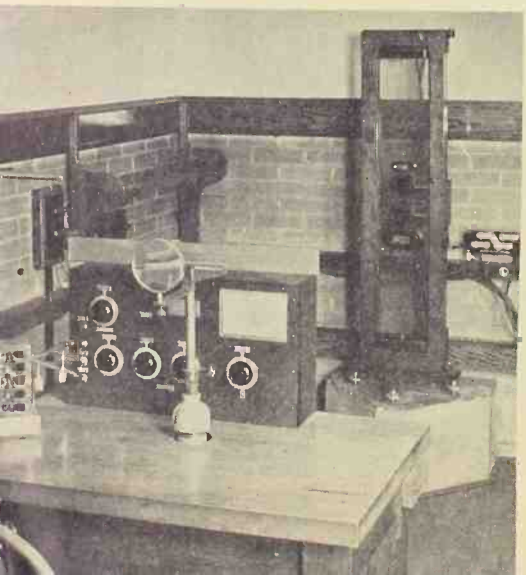
Electrical resistance is measured in terms of length, time, and the permeability of free space by the mutual-inductance, or Werner method using a group of reversing commutators, a reversing generator, and an inductor generator.



Calibration of Mueller bridge. Accuracy of a few parts in a million may be maintained.

A current is measured in absolute amperes by determining the mechanical force between two parts of the circuit in which it flows. In the center of two large fixed coils, a small coil is hung from the arm of a precision balance. All three coils carry the current to be measured, but the current in the fixed coils can be reversed. The small electromagnetic force developed by the current in the coils tends to pull the movable coil downward for one direction of the current in the fixed coils but tends to lift it when this current is reversed. From the change in the force on the balance when the current is reversed and from the measured dimensions of the coils, the value of the current in absolute amperes can be computed.

Standard astatic wattmeter (right background) used at the Nat. Bureau of Stds. to make the transfer from the direct-current standard cell and standard resistors to a.c. measurements of voltage, current, and power.



A second feature of this experiment makes use of the standard current while it is being "weighed" to measure directly the e.m.f. of a standard cell in absolute volts. This is done by arranging the standard cell so that its electromotive force is exactly balanced by the drop of potential produced in a known resistance by the standard current. The e.m.f. of the cell is then computed by Ohm's law.

A group of 25 standard cells and another group of 10 carefully constructed 1-ohm standard resistors serve to preserve the values of the volt and of the ohm from day to day and from month to month. The various members of each group of standards are intercompared at intervals of a few months; and as long as their relative values are constant, it is assumed that the absolute mean value of the group has also remained constant. If an individual standard is found to have drifted relative to the others in its group by a significant amount since the previous intercomparison, it is rejected and replaced by another standard which has a good record of performance. The process or comparing a resistor with the standard mutual inductor is so convenient that it is frequently used as an independent check on the constancy of the group of standard resistors. However, the mechanical measurement of the dimensions of the inductors and of the current balance is so very tedious and time-consuming that this experimental work is carried through only once in a decade as the final check on the constancy of both types of standard.

From the standard ohm and the volt thus maintained at the Bureau, the other electrical and magnetic units are derived by a variety of experimental procedures. The farad is precisely obtained by charging and discharging an air capacitor at a known rate in a Maxwell commutator bridge. The henry is determined by comparison with capacitors and resistors in a Maxwell-Wien bridge. The ampere is re-established, when desired, by measuring with a potentiometer the drop it produces in a known resistance. The ampere and the volt are combined to give the watt, and the joule and kilowatt hour are derived by maintaining a known number of watts in a circuit for a measured length of time. The gilbert and the oersted are computed from the number of ampere-turns used in magnetizing a magnetic test specimen in a permeameter of known geometry. The gauss and maxwell are obtained from the deflections of a ballistic galvanometer which, in turn, is calibrated by reversing a measured current in a known mutual inductor.

Extension of Ranges

The extension of the scale of measurement of any of the electrical quantities to other ranges is based, in large part, upon the establishment of a ten-to-one ratio in a special, highly accurate bridge. By successive application of the ratio, resistances as low as 0.00001 ohm or as high as ten million ohms can be accurately measured. Still higher resistances up to 10^{18} ohms are measured by more complex methods, such as the determination of the rate of accumulation of charge in a known capacitor. Inductance and capacitance measurements are extended over wide ranges by means of ratio arms of known resistance ratio. However, determination of standard capacitances below 1 micro-microfarad is based upon an independent set of measurements involving the construction of air capacitors of such shapes that their capacitance can be computed precisely from their dimensions.

Direct currents as high as 10,000 amperes are measured with a potentiometer and standard resistors of low value so constructed that their temperature and resistance are not affected by the very considerable heat developed when large currents are used in them. Direct voltages up to 1500 volts are measured by means of potential dividers, or volt boxes. The ratios of the dividers are derived by connecting in series groups of resistors whose relative individual values have been found by substitution methods. Specially constructed resistors, shielded to avoid corona discharge, are used in x-ray testing to measure d.c. potentials as high as 1,400,000 volts. In the upper part of this range additional shields separately maintained at appropriate intermediate potentials are required.

The great bulk of the electrical energy generated and utilized throughout the country is distributed as alternating current. The step from the direct-current standard cell to a.c. measurements of voltage, current, and power is therefore of fundamental importance. For 60-cycle work, the transfer is carried out by means of two specially constructed astatic electrodynamic instruments, a wattmeter and a voltmeter. In these instruments the moving coils are supported by taut strip suspensions, and the position of the moving coils is indicated by a spot of light on a scale at a distance equivalent to a pointer 13 feet long. The wattmeter has been carefully compared both with a quadrant electrometer and with the loss in a capacitor which had been tested in a Schering bridge; such measurements have established the accuracy of the two electrodynamic instruments at frequencies up to 3000 cycles. Directly or indirectly, the accuracy of practically all the a.c. instruments used in the transmission of electrical energy depends on these two standard instruments. For tests of ammeters and voltmeters at 400 cycles and above, transfer circuits employing thermocouples are also used.

In commercial practice the range of alternating current is extended upward from five amperes by means of calibrated current transformers. Thus, an important part of the Bureau's calibrating service consists in the calibration of standard current transformers which, in turn, are used by manufacturers and electric utility companies to calibrate their working transformers. Special four-terminal standard resistors, constructed so as to have negligible skin effect and a known computable inductance (hence a known phase angle), are used to measure the ratio and phase angle of transformers up to 2500 amperes with a specialized form of a.c. potentiometer. Beyond this limit, up to 12,000 amperes, the unknown transformer is compared with a multirange standard transformer, which is calibrated on its lower ranges by the use of standard resistors and is then used as a standard on its higher ranges. Careful study of this standard transformer has given assurance that its various ranges bear simple integral ratios to one another.

Similarly, the extension of the a.c. voltage scale above 150 volts is, in practice, based upon the use of voltage transformers. A special shielded resistor, capable of operating at 30,000 volts, is used to measure the effective ratio and phase angle of voltage transformers up to this limit and also to check the performance of standard multirange transformers when they are connected for 25,000 volts. These multirange transformers can then be connected for 50,000 or for 100,000 volts and used as standards at these latter ratings. A still larger standard transformer is calibrated with its coils in parallel at 100,000 volts and used with its coils in series as a standard up to 250,000 volts.

For all this testing and calibration work, other than that performed for the Federal and State governments, the law requires the Bureau to charge an appropriate fee.[2] These fees are high

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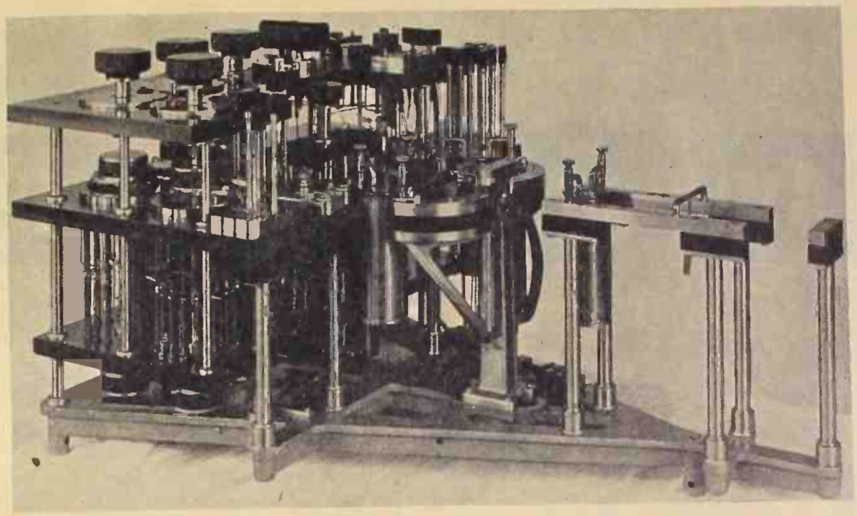
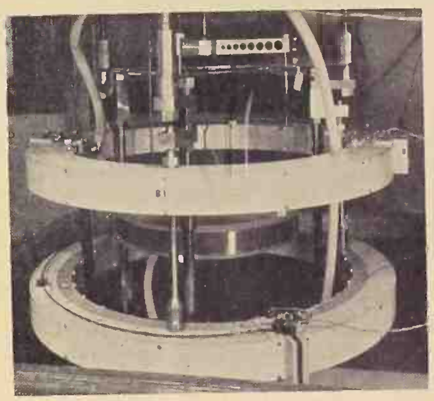
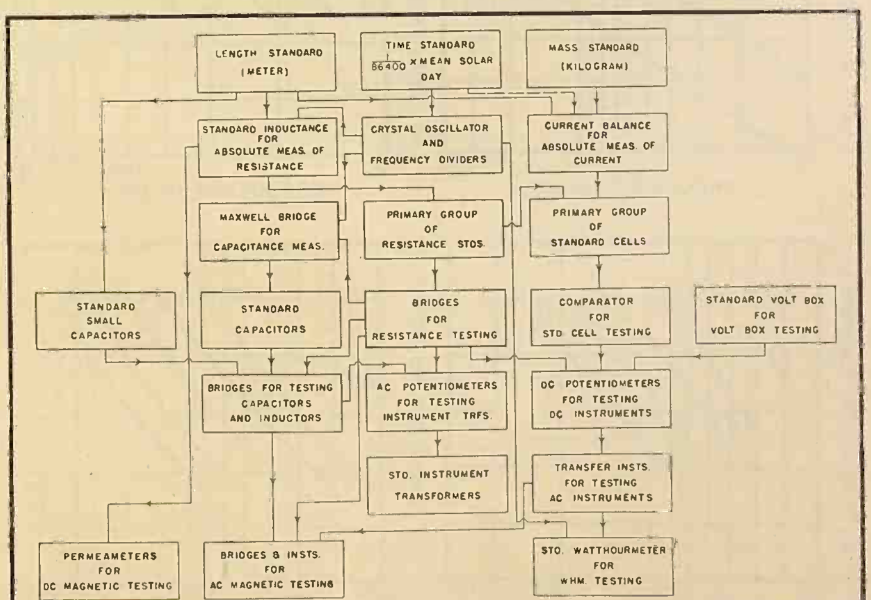


High precision d.c. bridge used at NBS for extending the scale of measurement of electrical resistance from standard units to other ranges.



Coils of the current balance used to "weigh" current for the absolute determination of the ampere. The smaller coil is suspended, coaxial with the two larger coils, from the pan of a sensitive balance.

Block diagram showing steps used in deriving precise values for all the electrical units from the basic mechanical units of length, mass, and time.



Antenna Systems Design

By G. B. DEVEY

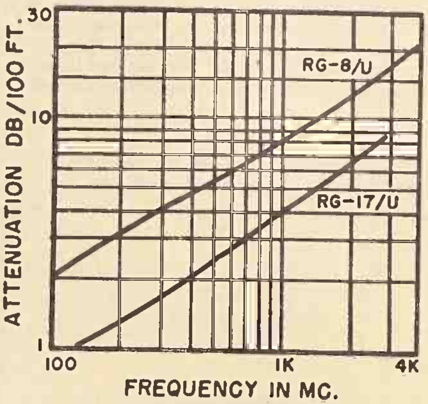
Some considerations in the choice of a transmission line and SWR for v.h.f. and u.h.f. antenna systems.

IN THE design of an antenna, care is taken to maintain a reasonable impedance match with the transmission line over the required frequency range of operation. The Voltage Standing Wave Ratio (VSWR) is ordinarily used as a measure of the impedance match. Antennas in the v.h.f.-u.h.f. range are often designed with the requisite that the VSWR be less than 2:1 in the desired frequency range. The choice of a transmission line often is not so carefully considered and may not be compatible with the stringent VSWR specification for the antenna.

Suppose that an arbitrary power attenuation of 3 db. (50 per-cent) be permitted between a transmitter and its antenna system. Suppose further that the transmitter output provides a perfect impedance match at the transmission line feed point. Reference to the curves of Fig. 1 shows that the commonly used RG-8/U cable (a 50-ohm, polyethylene cable about ⅜" in diameter) is not useful above 185 mc. if 100 feet of line is required.[1] Even 50 feet of RG-8/U fails to meet the 3 db. requirements above 570 mc., and this presupposes a perfectly matched antenna at the termination of the cable. In the case of RG-17/U (a 50-ohm, polyethylene cable about ⅞" in diameter), it is possible to operate with 100 feet of cable up to 670 mc.; 50 feet is within the allowed attenuation up to 1700 mc. Here again the transmission line is considered to be terminated by a perfectly matched antenna.

When a transmission line is terminated by an impedance mismatch, a standing-wave ratio greater than 1:1 is caused to exist on the line. As mentioned above, a VSWR of 2:1 is generally acceptable in v.h.f.-u.h.f. communications equipment. A standing-wave ratio greater than 1:1 increases cable attenuation since higher currents exist in the cable than are present in a matched condition. Figs. 2 and 3, for 50 and 100 feet of cable, respectively, show power attenuation in RG-8/U cable for various degrees of load mismatch. In Figs. 4 and 5 the same information is shown for RG-17/U cable. Calculations are made on the radial arm of a standard Smith transmission line calculator. A table can be prepared indicating the maximum permissible operating frequency of RG-8/U and RG-17/U for several values of VSWR. Iso-db. curves of 3 db. attenuation for 50 and 100 feet of RG-8/U and RG-17/U are contained in Fig. 6.

It is not always possible to meet VSWR requirements in antenna design.



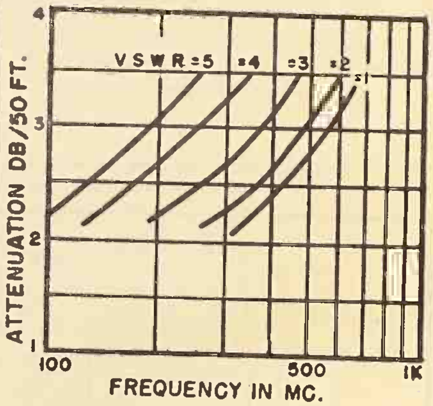
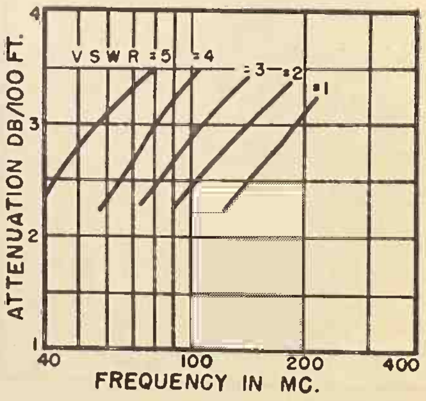
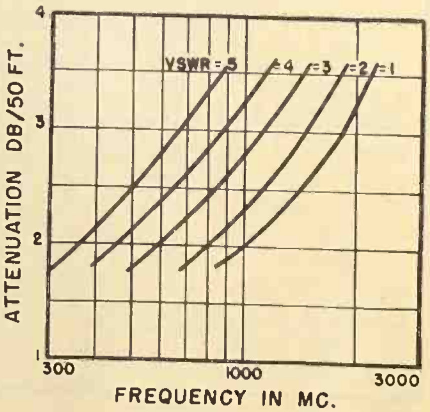
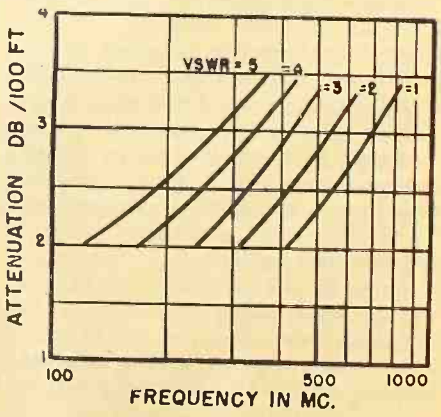


Fig. 1. (Top left). Attenuation of standard r.f. cables. Figs. 2 and 3 (Top right and lower left). Attenuation of RG-8/U cable for various values of frequency and VSWR. Figs. 4 and 5 (Lower center and lower right). Attenuation of RG-17/U cable for various values of frequency and VSWR.







This is particularly so in the design of antennas for ranges of frequency 2:1 or greater. Fig. 8 is the VSWR curve of an antenna designed for v.h.f-u.h.f. communications equipment; call this Antenna "A". Note the rise in VSWR in the frequency range above 340 mc. Fig. 7 is a reversal of the curve in Fig. 8; call this Antenna "B". Here the VSWR is more than 2:1 below 280 mc.

If Antenna "A" were employed with 50 feet of RG-8/U cable, the 3 db. attenuation limitation would be encountered above 360 mc., as shown by Fig. 8. If the antenna characteristics were reversed, however, as per Fig. 7 (Antenna "B"), the 3 db. attenuation point would be at 240 mc., and in no case would it rise over 3.3 db. in the entire frequency range under consideration (see Fig. 9). It is therefore possible, through a judicious choice of impedance characteristics, to employ antenna designs which might otherwise be discarded because of failure to meet specified VSWR and/or attenuation limits. This can be illustrated by another example. Suppose that an antenna were designed with VSWR characteristics that are essentially symmetrical about the middle frequency, as indicated by Fig. 10A. Again, there is a sharp rise in VSWR at the high frequency end. For best efficiency it is desirable to design the antenna to have VSWR characteristics as per Fig. 10B. In this case the VSWR is made to be lower at the high frequency end and to increase at the low frequency end; a shift of middle frequency to a higher value will accomplish this. The result of this maneuver is to place the high values of standing waves at frequencies where cable attenuation is least and attenuation of the system is thereby reduced to an optimum level.

From the foregoing information, it is evident that careful consideration must be given to antenna *systems* design rather than to antenna design alone. Likewise, care must be exercised in the selection of proper transmission line. Whereas RG-8/U cable is adequate for one installation, it may introduce unreasonable attenuation in another system. On the other hand, RG-17/U cable should not be considered as a panacea, for cost and installation difficulties may impose more trouble than the decrease in attenuation is worth.

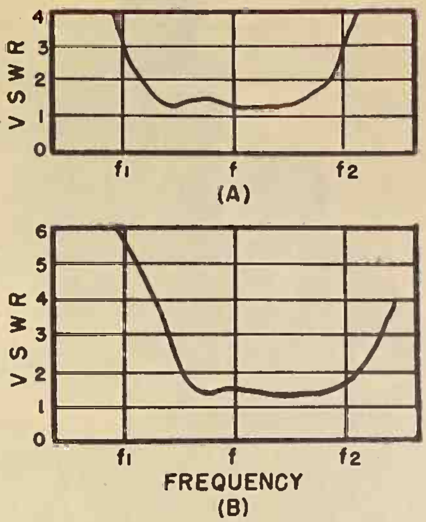
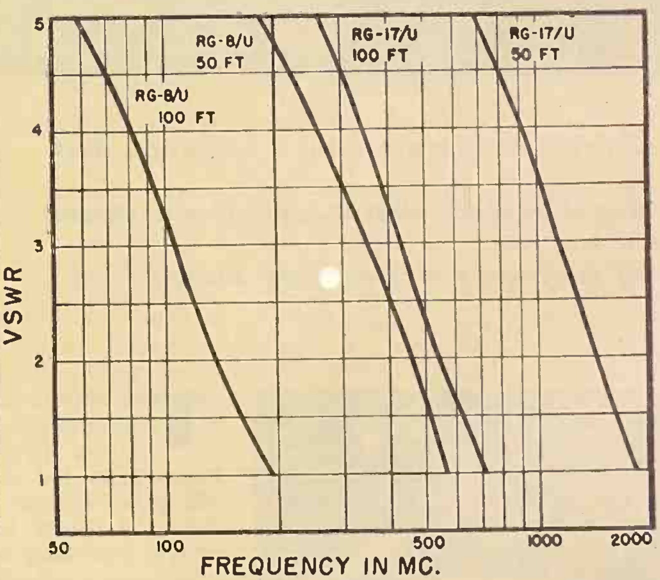


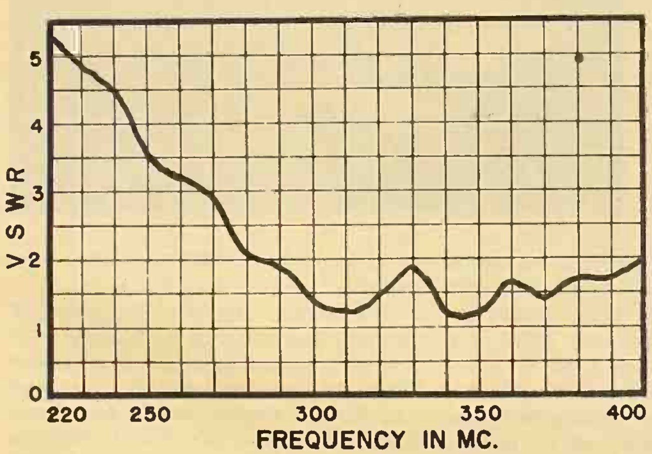
Fig. 10. Illustrating middle frequency shift to effect optimum system efficiency.

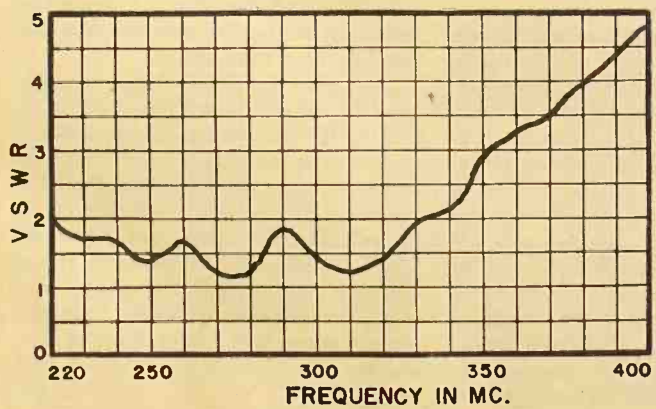
REFERENCE

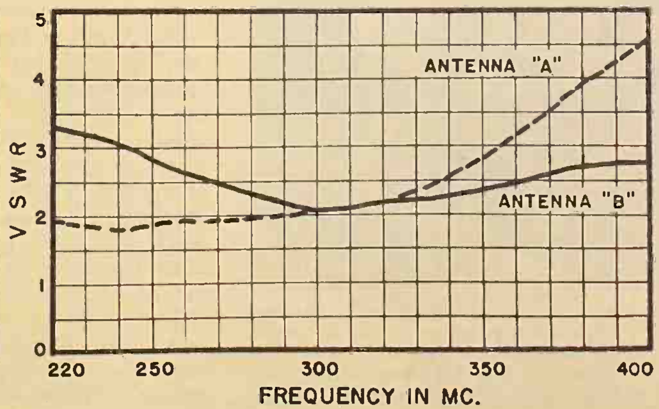
1. *From NAVSHIPS 900,102, Index of Army-Navy R-F. Transmission Lines and Fittings. It should be noted that these curves presuppose perfectly matched terminations, or a VSWR of 1:1.*

Fig. 6. (Top right) Maximum usable frequencies of RG-8/U and RG-17/U for VSWR values of 1 to 5 and a system attenuation of 3 db. Figs. 7, 8, and 9 (upper left, lower left and lower right respectively). VSWR curves for antennas B, A, and C respectively as described in text.





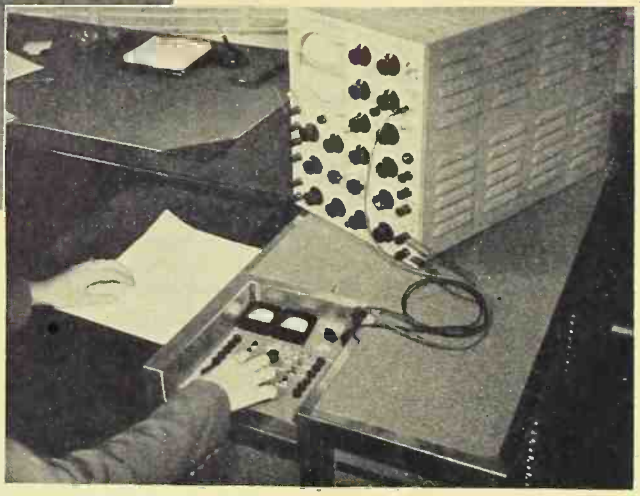




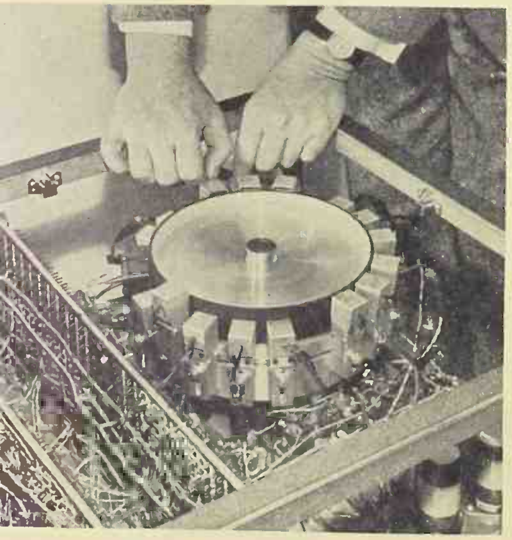
The "MADDIDA" Electronic Computer

Over-all view of the desk size mechanical brain. Its compact size (it weighs only 400 lbs.) and enormous mathematical capacity have resulted from the application of new design techniques. At the left are the intake and output lines which lead to the "eyes" and "ears," auxiliary devices which read information on graphs or tapes.

Instructions are fed into the computer by means of a simplified typewriter keyboard on its control panel. The operator is shown utilizing the two binary typewriter keys. The oscilloscope is used to verify figures as they are fed in.



General information on a compact, desk size electronic digital computer designed by engineers of Northrop Aircraft, Inc.



Nerve center of "Maddida" is this rapidly-revolving magnetic storage drum, the only moving part in the unit. The drum can store up about 10,000 numbers which can be used as needed.

THE TERM "Maddida" is a coined word developed from "Magnetic Drum Digital Differential Analyzer," the full descriptive name of a computer recently developed by *Northrop Aircraft, Inc.*, of Hawthorne, Calif. This computer is smaller than the average office desk, yet its mathematical capacity places it in a class with much larger computers.

Maddida is a digital computer which uses less than 100 tubes and has only one moving part—a spinning magnetic drum "memory." Hundreds of germanium crystals in the computer simulate the synapses of the human brain, giving it the ability not only to compute problems, but to make comparisons and make decisions based on these comparisons. It owes its compactness to skillful use of electronic circuity—enabling a single circuit or tube to do multiple tasks—and its use of mathematical short cuts to obtain its answers. It arrives at its answers through a differential equation method adapted from calculus.

The memory circuit of the computer is based on a spinning drum coated with magnetic material. As many as 10,000 digits may be stored on this drum, and any desired number can be found and used in less than one second. Maddida can read twelve graphs or tables simultaneously and can plot six graphs or type out on twelve printers simultaneously as it computes.

This new devise has many applications in industry and research. For example, it can perform automatically many of the vital operations in running a factory, such as a chemical processing plant, by picking up information from instruments and then using the information to control machinery. It can evaluate information and make decisions for controlling valves, thermostats, stokers, tank levels, rates of flow, etc. Its operating accuracy is one part in 100,000,000.

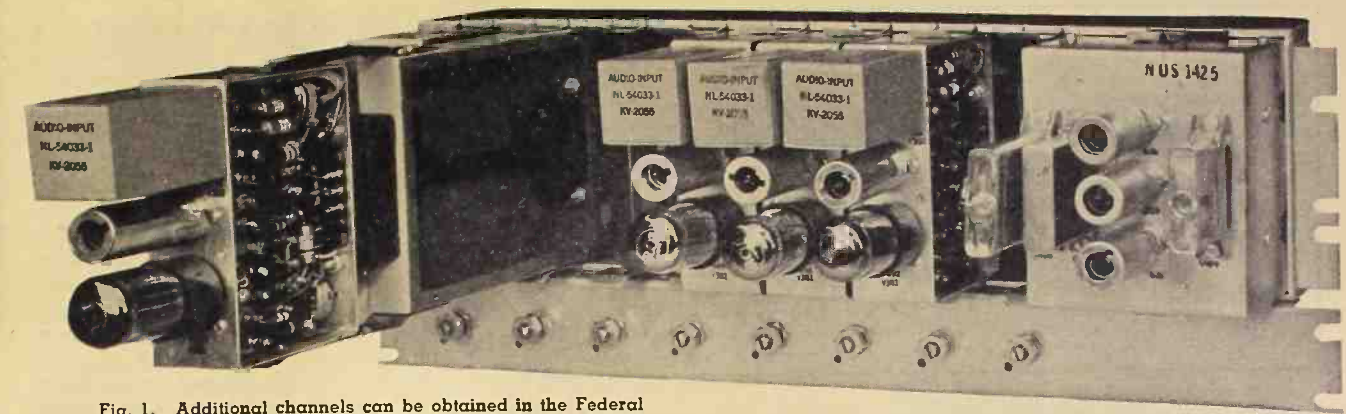


Fig. 1. Additional channels can be obtained in the Federal link by the plug-in unit shown extended in this photograph.

MICROWAVE COMMUNICATION LINKS

By J. RACKER

Co-author, "Pulse Techniques" (Prentice-Hall, Inc.)

Microwave links have certain advantages over wire lines. Equipment is described and types of modulation discussed.

THE SEVERE storms that have swept this country in the last few years causing extensive damage to wire lines served to spotlight the need for communication systems that operate dependably under all weather conditions. It is particularly distressing to many industries, such as railroads, pipe lines, power lines, etc., that the same meteorological factors that result in disruption of their equipment similarly affect wire lines. Hence just when communications were most urgently required, they have been most susceptible to failure.

Microwave communication links represent an excellent solution to this problem. This has been proven in a number of installations where, during a recent storm, all wire lines were torn down but the microwave link continued to provide uninterrupted communication. It is significant that the propagation of microwaves in adverse weather, such as icing conditions, is usually excellent.

In one commercial link comprised of two unattended repeaters and a side circuit, which has been in operation over one year on a continuous 24 hour basis, the outage time logged is about one-third that of wire line performance. This record is especially remarkable when it is realized that in this installation no standby units were installed. When a unit failed, a technician, who had to be located first, was notified. He then had to travel as much as 60 miles to the site and repair the equipment. All of this time was naturally included in the outage time figure. Yet despite this procedure, the outage time was considered too low to justify installation of standby units.

Coupled with the improvement in

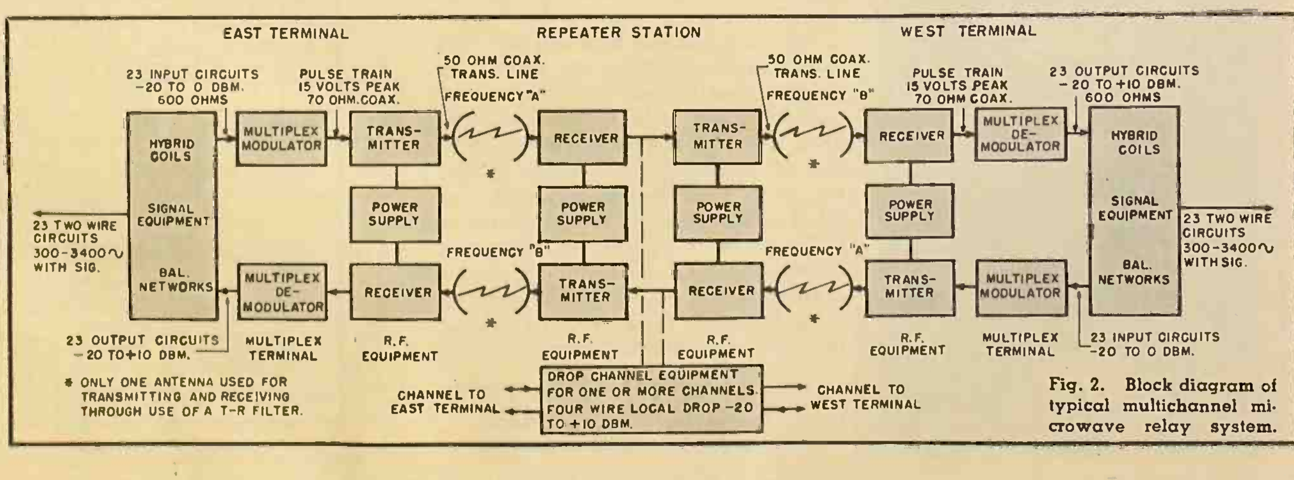


Fig. 2. Block diagram of typical multichannel microwave relay system.

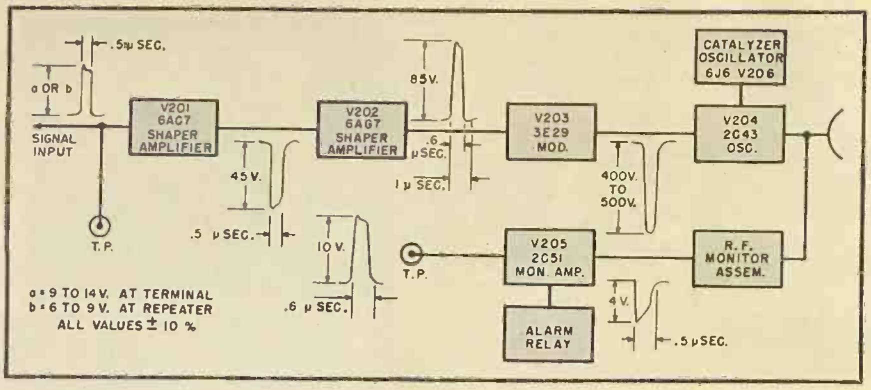


Fig. 3. Block diagram and waveforms for the Federal FTL-10B transmitter.

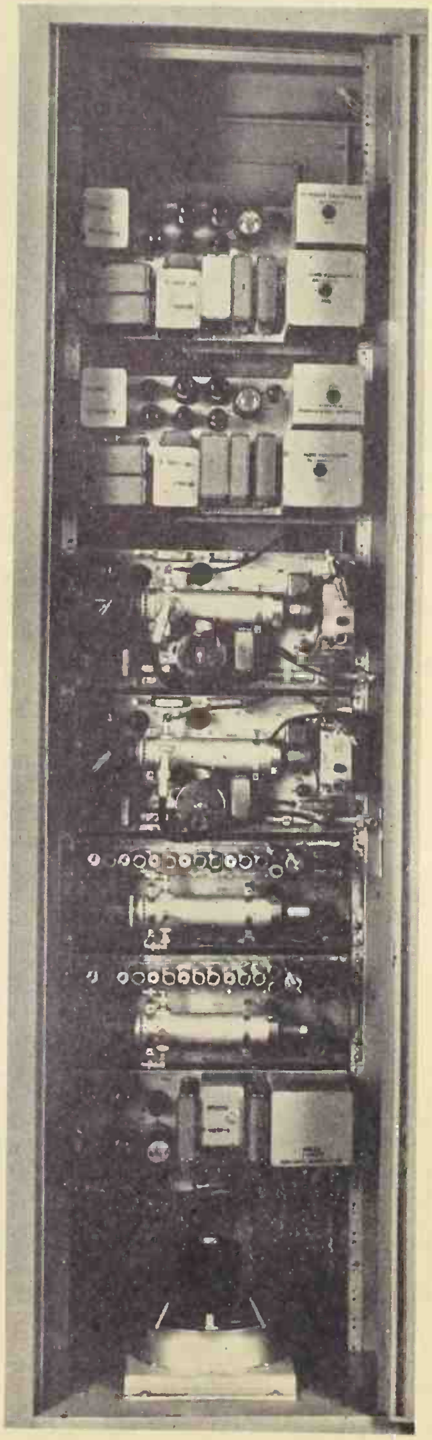


Fig. 4. Rear view of r.f. rack of FTL-10B showing microwave cavity oscillators.

reliability is the fact that it is economical to use microwave links. In applications where the alternative is whether to install a radio link or wire lines, the initial cost of a link runs about 400 to 800 dollars per mile while that of a wire line is estimated at between 800 and 1500 dollars per mile. But even in applications where wire lines have already been installed and it is necessary to expand the communication facilities by addition of four or more audio channels, it is often less expensive to erect a link than multiplex channels on the wire line by means of carrier equipment. Fig. 5 shows the initial cost comparison in one installation between power line carrier and radio links.[1]

Radio links represent a highly flexible mode of communication. In the *Federal* PTM link, for example, it is possible to start with a limited number of channels and add speech band circuits up to a maximum of 23 channels by simple plug-in units shown in Fig. 1. Thus the communication facilities can readily be expanded to provide the multiplicity of services required in present day operations including telephone, teleprinter, facsimile, telemetering, and supervisory controls. Each voice channel of the 23 can, of course, provide its equivalent in telegraph, teletype, and telemetering circuits through the use of carrier.

The PTM link can be integrated with mobile radio telephone to extend the range of mobile operation over the full communication system. In addition, links can be designed to permit drop channel operation (at repeater points) for tie-in to intermediate points, and all of its channels can be terminated on a 2-wire basis suitable for telephone subsets, or PAB switching employing conventional ringing or dialing methods.

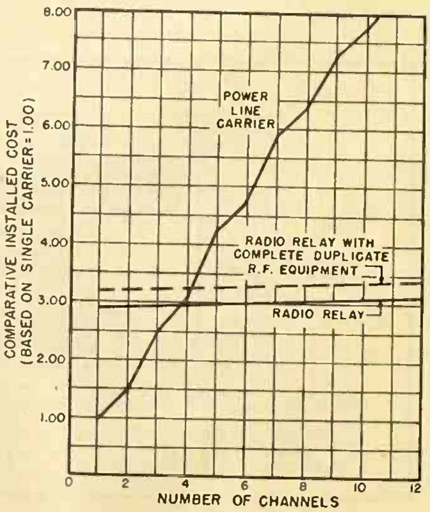
As indicated in a previous article[2], the type of modulation, multiplex method, and carrier power required in a microwave link will be a function of the distance of communication and number of channels to be transmitted. At the present time, with the demand for links still limited, the trend is to design general purpose equipment, *i.e.*, equipment that will be adaptable to a wide variety of applications with particular emphasis on long line, many channel service. However, it is conceivable that, as the utilization of microwaves becomes more extensive, there will be a justification for the design of links that meet more individual requirements. For example, as in carrier equipment, there will be "short" and "long" haul systems capable of transmitting either a small or large number of channels.

The problem of increasing the distance over which the link can operate is primarily one of maintaining distortion and signal-to-noise levels within specified limits. In frequency division systems both distortion and noise accumulate with the number of repeaters used. Therefore in these systems it is not only necessary to utilize higher carrier power outputs, but the linearity of amplifiers at repeaters must meet increasingly rigid requirements as the number of hops increases.

In pulse multiplex systems, other than PCM, only noise is cumulative with number of repeaters (for most practical considerations) providing that sufficient bandwidth is employed. Hence in these systems longer operational distances can essentially be effected by increasing the transmitter power output. In a PCM system neither the noise nor distortion is cumulative (for most practical considerations).

However, it should be noted that there is a difference in complexity and cost of equipment required to obtain the different types of modulation. The

Fig. 5. Approximate cost comparison between microwave radio relay and power line carrier in a typical application.



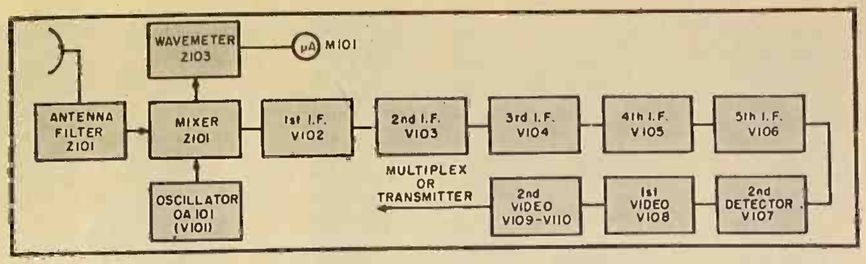


Fig. 7. Block diagram of the Federal FTL-10B receiver.

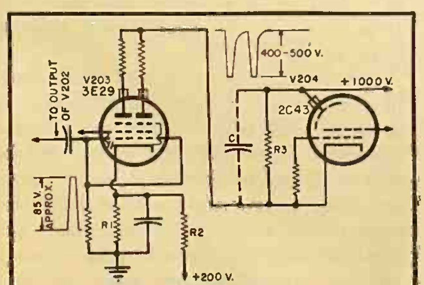
cost of a multiplex terminal in a PCM system at the present time is so high that the use of pulse code modulation is only justified in very long-distance, multi-channel operation. Thus the cost per mile of a PCM link is very high for short distances and very low for long distances (compared to other links), while that of a frequency division link would be relatively low for short distances and high for long distances.

There is a similar consideration for determining the maximum number of channels to be multiplexed. In the 23 channel *Federal* link, for example, a certain amount of multiplex equipment common to all channels must be included in the link even though only four or five channels are to be used. However, it is possible to obtain additional channels by simple plug-in units. Frequency division links, on the other hand, are similar to wire line carrier systems in that, other than providing sufficient bandwidth, they require no common multiplexing equipment to permit expanded service. Thus if one channel is desired, equipment for only one channel is required—for expansion to two channels only channel two equipment is necessary and so on. The cost of these additional units usually increases.

The over-all result is that a one channel frequency division link can be designed to cost less than a one channel (of a 23 channel potential) PTM link. However the cost of adding channels is much greater in frequency division links. Hence, as more channels are used, the price difference between the two links decreases until the relationship is reversed. All other factors being equal, the cost per channel of the PTM system becomes lower at between 4 to 8 channels. Similarly a one channel PCM system is very expensive, but becomes economical when 50 or more channels are to be multiplexed. In designing a general purpose link the object is to try to provide the most economical service for the greatest majority of applications.

A block diagram of the *Federal* 23 channel microwave pulse time multiplex equipment is shown in Fig. 2. As indicated in this figure, a one-way, one-hop FTL-10B consists of a modulator multiplex terminal which converts the individual audio channels obtained from 4-wire terminating sets into a pulse time modulated train of pulses, and a transmitter which transmits a train of PTM r. f. pulses through the antenna. This signal is then picked up by the receiving antenna, and is fed to the receiver which amplifies and detects the pulse train. The PTM pulses are then reconverted into 23 audio channels (if all 23 are used) by the demodulator multiplex unit and fed to 4-wire terminating sets. For a two-way link, this equipment is duplicated except that only one antenna is used for both transmitting and receiving and an appropriate T-R (transmit-receive) filter is incorporated at the input to the receiver antenna.

Fig. 6. Simplified schematic diagram of the modulator-oscillator.



Each channel may be operated on a private or party line basis; dropped off or added at any repeater; and integrated with any signaling or dialing system. Automatic switchover to standby equipment can be utilized to assure virtually 100% reliability, while alarm and fault locator units can be incorporated in the system to aid in rapidly determining a source of trouble when it should occur.

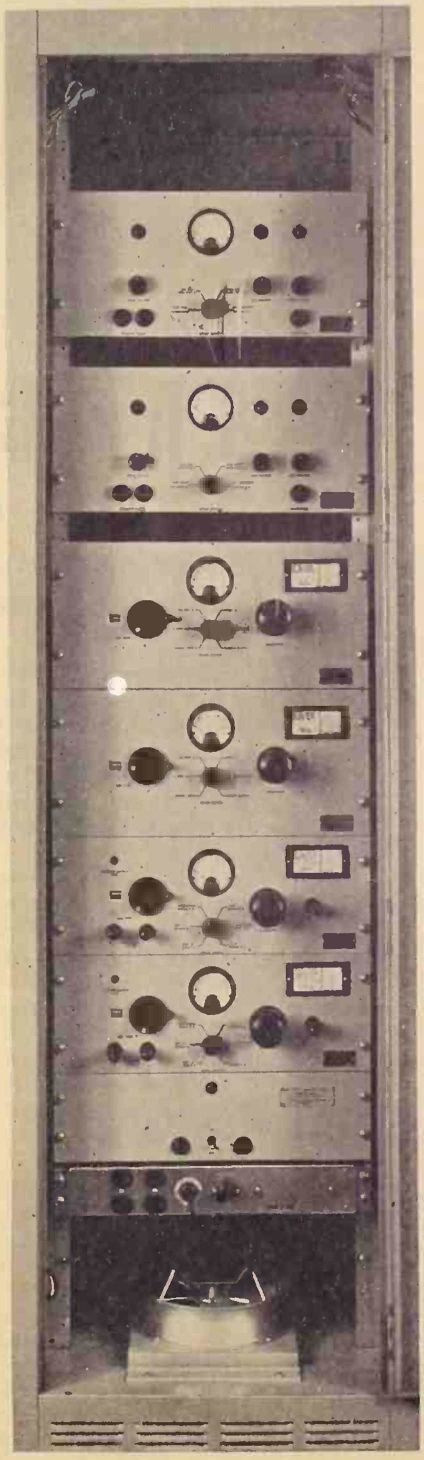
Technical Characteristics

The technical characteristics of this link are as follows:

Carrier Frequency
1650 to 1990 mc.
R. F. Bandwidth
5.6 mc.
Video Bandwidth
2.8 mc.
No. of Audio Channels
23 (maximum)
No. of Signaling Channels
23 (maximum)
Audio Frequency Bandwidth
100 to 3400 cycles
Signaling Bandwidth
D. C. to 20 PPS
Audio Input Level
-20 dbm. (minimum)
Audio Input Impedance
600 ohms
Audio Amplitude Distortion
less than 5%

(*Continued on page* 27A)

Fig. 8. Front view of typical r.f. equipment rack of FTL-10B microwave link.



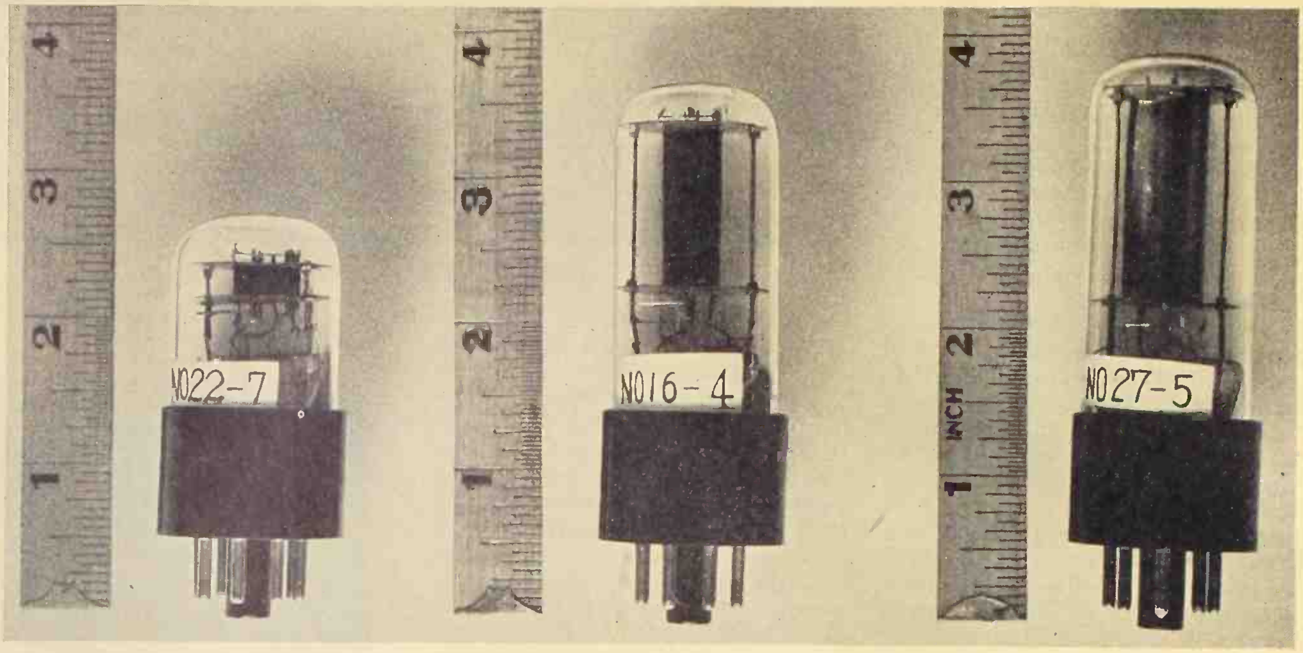


Fig. 1. Photographs of the three different types of tubes that have been developed. No. 22-7 is a voltage amplifier, No. 16-4 is a general purpose model, and No. 27-5 is a power amplifier version.

The BALITRON TUBE

By NORMAN Z. BALLANTYNE

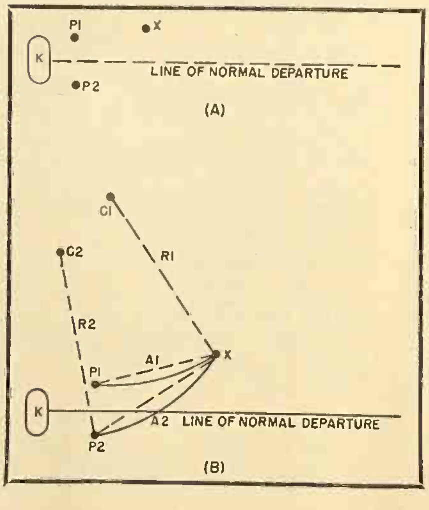
Part 1 of a 2-part article presenting a radically new vacuum tube design having many advantages over conventional design.

THE BALITRON tube is the first deflection controlled tube to develop sufficient plate current and transconductance to be even considered for possible use as a power amplifier. This tube, as a power amplifier, will fit into an envelope not much larger than a cigarette.

This small size tube develops a beam current of up to 43 ma. at a plate potential of 240 volts. It has a single end transconductance of up to 2400 micromhos and an effective signal transconductance of 4800 micromhos. Operated at zero, negative, or positive bias, this tube will produce an output voltage in phase with, or out of phase with, the input signal voltage as desired. Push-pull operation from a single ended input is an accomplished fact. An E_g-I_p curve linear over 85% of its length and a normal degenerative feedback are some of the other surprising features inherent to this strange type of tube.

Many attempts have been made in the past to produce an effective deflection controlled amplifier tube. Most of these attempts have been directed towards symmetrical construction using straight electrostatic deflection of the type used in the ordinary electrostatically controlled cathode-ray tube. But such attempts have floundered on the rocks of the fact that, if the electrons are accelerated off the cathode wall in order to obtain any appreciable beam current, then the velocity imparted to the electrons became so high as to make the deflection sensitivity low and the resulting transconductance had to be low. This factor alone placed a mathematical upper limit upon the deflection sensitivity which could be realized.

Fig. 2. (A) illustrates the layout problems for the arc-lens system. The "line of normal departure" is the path the electrons would follow if influenced only by the field between P_1 and P_2. (B) the basis of the arc-lens system with the curves A_1 and A_2 forming the extremes of the system.



In the Balitron tube the conventional deflection formula does not hold, except in a minor way. This formula is for the deflection of an entire beam of electrons by plates parallel to the path of electron acceleration. In the Balitron only a small portion of the beam is deflected by electrostatic means and the deflection plates are not parallel to the path of electron acceleration. Thus, the conditions of the formula are avoided and new factors must enter the equation. How this is accomplished will become clear as we progress.

Other attempts have been made, both in the United States and abroad, to produce lens tubes where an electrostatically controlled lens would change the focal length of the electron paths and thus produce a greater deflection sensitivity than possible with the straight deflection type of tube. Almost all such attempts have been confined to rectilinear lens types without any great improvement being noted.

The Balitron is a lens type tube employing a lens system which, to the best of my knowledge, has never been employed before. A radical departure from the rectilinear lens system, this system provides a new approach to electron optics which treats the electron as possessing its own unique properties and, therefore, is subject to optical considerations not found in light optics. Of course, such a consideration has long existed but it has never been carried as far as in this system.

The basis of this lens system is not the straight line being refracted through a lens as in normal optics. Instead, in this system arcs are utilized to form what might well be called an arc lens system. Referring to Fig. 2, electrons are emitted from the cathode K and accelerated to the points P_1 and P_2 placed an equal distance from the edge of the cathode. If, from the points P_1 and P_2, we wish to focus electrons upon the point X, we must deflect the beam from the line of normal departure towards the point X while at the same time providing focusing action. In Fig. 2B suppose we erect an arc of one radian or less (just to prevent the use of excessively large angles of arc) from the point P_1 to the point X with the center upon which the arc is swung determined by erecting a perpendicular at the bisection of a straight line drawn from P_1 to X. This gives us the point of C_1 as a center upon which the arc segment A_1 is swung with a radius length R_1. If we treat the point P_2 and X in the same manner, erecting the arc segment A_2 swung upon the center C_2, then both arcs pass through the point X.

By erecting the arcs A_1 and A_2 of electron beams we would provide a focal point for the electrons at the point X and such arcs would provide a lens system which would be formed of arcs. Of course, the arcs A_1 and A_2 would be the extremes of our system with the electron paths between P_1 and P_2 being exposed to different arcs, gradually decreasing in sharpness of curvature with respect to the line of normal departure as the intermediate arcs are erected between A_2 and A_1.

In the practical system, the above outlined system of erecting an arc lens has been carried out in the simplest possible form. How simple this is can be seen by referring to Fig. 3. This shows a plan view of one of the experimental tubes constructed using this system. The circuit shows the potentials present upon the various elements of the tube.

In this system, electrons are emitted from the cathode K and are formed into a beam by the focusing structure G_1. Acceleration is provided by the positive potentials applied to the accelerating anode A on one side of the opening in the focusing structure and to the positive deflection plate Pd on the other side of the opening. The accelerated electrons pass between these accelerating members into the deflection area of the tube. Those electrons entering this deflection area near the positive deflection plate Pd are attracted by the positive potential of that member as it lays along their path but, since these electrons have already attained a high velocity from the initial acceleration, these electrons can only be curved a small amount, passing through the focal point.

Those electrons entering the deflection area of the tube near the accelerating anode A move outward towards the negative deflection plate Nd. Since this member is operated at ground potential, the electrons approaching it rapidly lose the initial linear velocity applied to them and, attracted by the positive potentials applied to the positive deflection plate Pd, the target anode Ta, and the target plate Tp, they curve away from plate Nd and pass through the focal point, thus intercepting the curve of the other electrons.

We have, therefore, erected the same basic system of lens action as originally outlined with the path of the electrons near Pd being similar in form to the curve A_1 of Fig. 2 while the path of those electrons near Nd is similar to the curve A_2, of that illustration. Again, these two curves are the extremes of our system with the intermediate electron paths being thrown into intermediate curves between these two extremes.

That this theory of operation is substantiated in fact is easily proven in the laboratory by using an electrolytic trough model to erect equipotential lines and carrying out the mathematical calculations to derive the electron paths leading to the focal point. It is also easily proven by gassing a tube and actually seeing the formation of the beam. Both methods have been successfully employed.

The above described formation of the beam is without any control applied, excepting beam formation. Consideration of how this lens system produces substantial electron beam control to produce the values of transconductance that it does, must bear further study. We have brought the electron paths to the focal point and now we must consider what happens thereafter.

At the steady state focal point, we are concentrating all the electrons within the beam. Since we have substantial beam current, the electron density per unit of space will become extremely high as these paths approach the focal point. The electron beams approaching

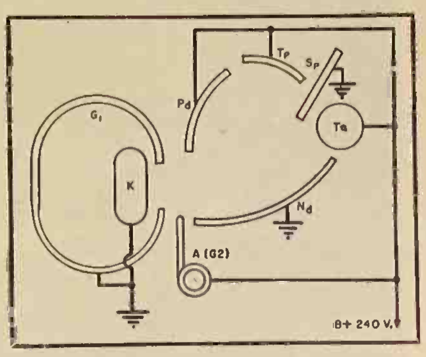
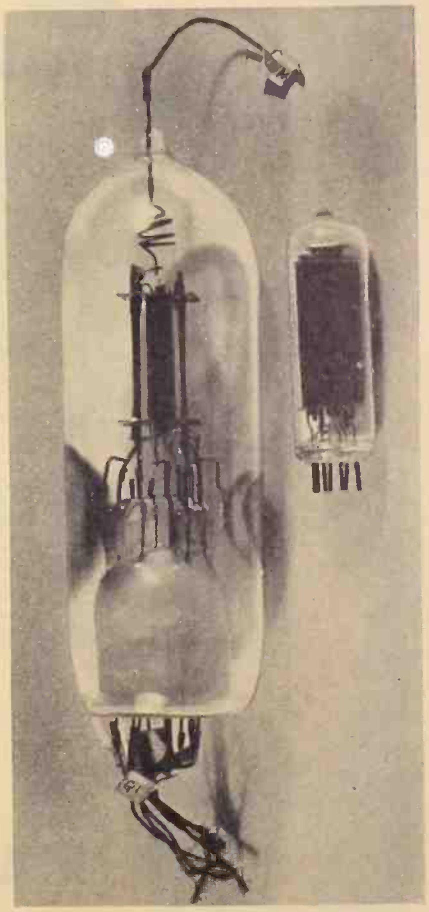


Fig. 3. Plan view of one of the experimental models of the Balitron showing position of the parts and the applied potentials for steady state testing.

this point will be subject to an increasing repulsion to the other electron paths approaching the common point, with the result that the converging force of the electron beams, provided by their different angles of acceleration, will be overcome and the electron paths will become parallel as shown in Fig. 5. This action produces a common vector of the electron paths.

In the control operation of this tube, complete control of the electron beam is exercised by the negative deflection

Fig. 4. An early experimental model of the Balitron (left) compared with a conventional miniature tube (right).



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mpa
METAL POWDER ASSOCIATION

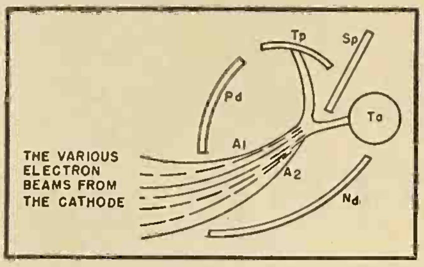


Fig. 5. The vectoring action of the beams in the deflection area of the tube as the electron density is increased in approaching the focal point.

plate Nd, which is equivalent to the control grid of the ordinary tube. This member exercises a control action which is much more complicated than mere deflection or the blocking action of the ordinary control grid. This action is, initially, the change in deflection angle of a small number of the electron beams in the area of the negative deflection plate. By changing the potential of this member either positive or negative, the paths of the electron beams near this member will be changed and control will result.

The operation of Nd in producing control action is shown in Fig. 6. The potential on Nd is shown as a sine wave developed from the signal source S and fed across the capacitor C to the top of Nd load resistor R. This control voltage, shown in Fig. 6A, controls the beam in the various conditions of the circuit shown in parts B, C, and D of Fig. 6. This circuit is a push-pull circuit fed from a single end input.

With zero potential on Nd, the beam (shown by the dashed lines) approaches the point of focus near the separator plate Sp and vectors into parallel beams with equal amounts of current flowing to Ta and Tp. This is the condition of the beam in the steady state condition, shown in Fig. 6B. Since the beam splits and flows equally to Ta and Tp, the currents flowing away from Ta and Tp to the center tap will be equal, the voltage drops will be equal, and the effective current producing magnetizing flux to cut the secondary will be zero.

As the potential of Nd moves towards the positive peak, the position of the beam will be as shown in Fig. 6C. The positive potential of Nd pulls the electrons passing near that structure into a much closer path which results in a much flatter curve. Since the curve A_2 is not as sharp, it will not intercept the electrons in curve A_1 until after these electrons have passed through the steady state focal point. When interception is made, the electrons of curve A_1 and curve A_2 vector into Ta. This causes the current flowing to Ta to increase with an increase in the current flowing away from Ta to the center tap. At the same time, the current to Tp has been decreased and this decrease in current has the same effect as a flow of current from the center tap to Tp insofar as the effective magnetizing flux in the secondary is concerned. The increase in I_{Ta} produces a greater voltage drop across the coil L_2, driving Ta negative with respect to its steady state value. Meanwhile, the decrease in I_{Tp} has caused less voltage drop across the coil L_1, causing Tp to be positive with respect to its steady state value. The effective current producing magnetizing flux on the secondary is the increase in I_{Ta} plus the decrease in I_{Tp}.

As the potential of Nd goes to the negative peak of the cycle, the beam will change to the positive shown in Fig. 6D. The negative potential of Nd causes the electrons entering the deflection area of the tube near Nd to curve away from this member more sharply than in the steady state condition. This sharp curve of A_2 causes it to intercept the electrons in the curve A_1 before these electrons reach the steady state focal point. Thus, the point of focus has been moved towards the cathode and the resulting vectoring action of the electron beams causes them to vector into Tp. With the electron paths vectored into Tp, I_{Tp} will rise and the resulting voltage drop across the coil L_1 will drive Tp negative with respect to its steady state value. In the meantime, the rise in I_{Tp} has reduced I_{Ta} and a smaller voltage drop is produced across the coil L_2 so that Ta becomes positive with respect to its steady state value. The effective current producing magnetizing flux to cut the secondary is the increase in I_{Tp} plus the decrease in I_{Ta}.

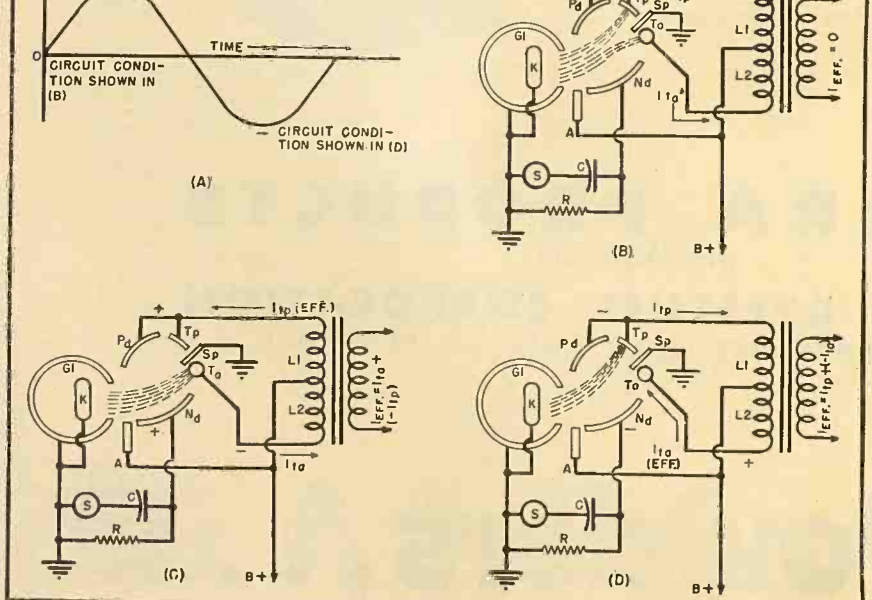
Thus, the means of control is clearly shown to be the change in the arc of curvature of a small number of electron paths in the immediate area of Nd with the resulting vectoring action of the several electron paths producing the actual control of the total beam. It is evident that no attempt is made to swing the entire beam by electrostatic control. A small fraction of the total beam is subject to effective electrostatic control and the rest of the beam is swung by the change in angular velocity produced upon this small fraction. It is by this means that the limitations upon electrostatic deflection as given in the deflection formula are avoided.

The control of the beam and the phasing action can be made more clear by reference to Fig. 7 which shows the graph of this tube. This strange graph is this tube's equivalent of the E_g-I_p curve of the ordinary tube and Fig. 7 is the actual graph of one of the experimental power amplifier models.

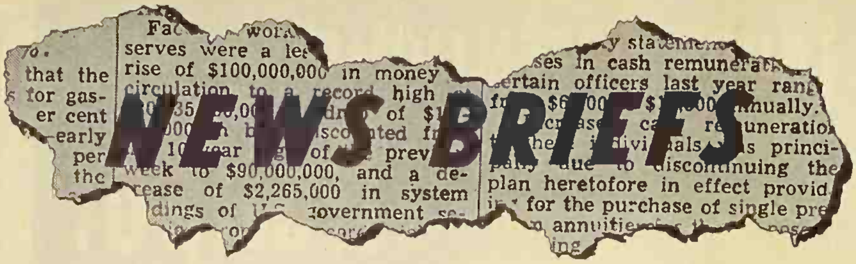
In this graph the current drawn by the target anode, I_{Ta}, is graphed against the Nd voltage. The line for I_{Tp-Pd}*, which is the combined current drawn by the target plate and the positive deflection plate, crosses the I_{Ta} line but is graphed against the same Nd voltage.

(*Continued on page* 30A)

Fig. 6. (A) A sine wave of voltage applied to electrode Nd. (B), (C), and (D) show the conditions in the tube for three points of the sine wave indicated in (A).



**Note: The target plate and the positive deflection plate are tied together here. They may be operated together or separately as desired or may be combined into a single plate.*



H.F. GENERATOR

A high-frequency generator which, when provided with an external, standard 100 kc. frequency source, will fur-

nish up to five watts of driving power at any desired frequency between one and seven megacycles has been developed by *Westinghouse Electric Corporation* for a U. S. Navy application.

The equipment employs a synthesizer-type frequency generator and has a built-in monitor for self-checking frequency accuracy. The unit is capable of providing both A-1 (on-off) emission and F (frequency modulation) emission. The accuracy and stability of the equipment is equal to that of the primary source and the frequency is shown down to the last cycle on a direct reading instrument.

URSI-IRE SPRING MEETING

The regular spring meeting of the U. S. A. National Committee of the International Scientific Radio Union and the Professional Group on Antennas and Wave Propagation of the Institute of Radio Engineers will be held in Washington, D. C., on April 16, 17, and 18th at the National Bureau of Standards.

Administrative meetings will be held the first day and the technical sessions on the two following days. An inspection trip of NBS has been arranged for the afternoon of April 16, and an informal social evening is planned for April 17 when a summary of the Zurich General Assembly of the URSI will be presented.

Technical sessions, sponsored by four URSI Commissions, to be held are as follows: "Tropospheric Radio Propagation," Chairman, Dr. C. R. Burrows, Cornell University; "Ionospheric Radio Propagation," Chairman, Dr. Newbern Smith, Chief, Central Radio Propagation Laboratory, NBS; "Terrestrial Radio Noise," Chairman, Mr. J. C. Schelleng, *Bell Telephone Laboratories*; and "Radio Waves and Circuits, including General Theory and Antennas," Chairman, Dr. L. C. Van Atta, *Hughes Aircraft Company*.

RADAR TUBE RESEARCH

The results of studies on the recovery time of gases of potential value in gas-filled TR and ATR switching tubes used in close-in radar and microwave systems operating at frequencies of 3000 megacycles was the subject of a recent paper by Dr. Lawrence J. Varnerin, Jr., delivered to the American Physical Society.

The research work was performed by the Electronics Division of *Sylvania Electric Products Inc.*, in conjunction with the Evans Signal Laboratory at Belmar, N. J. Dr. Varnerin reported the studies utilized "a shorted length of waveguide with a quarter wavelength section of quartz next to the short. Between the quartz block and a glass vacuum window a quarterwave section of the guide holds the gas under investigation."

Since the quick recovery of switching tubes in short range radar is of primary importance, it is expected that this research may result in greater utilization of these microwave regions.

DR. BUSH TO RECEIVE AWARD

The John Fritz Medal has been awarded to Dr. Vannevar Bush, President of the Carnegie Institute of Washington, D. C. Presentation of the Medal was made during the annual Winter General Meeting of the AIEE held recently in New York.

The latest of numerous honors bestowed on Dr. Bush is for "outstanding scientific contributions to his country and to his fellow men," and was awarded jointly by the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, and the American Society of Mechanical Engineers.

Dr. Bush has played important roles in both World Wars. In World War I he carried on research work in connection with submarine detection for a special Navy Board. In 1940 he was named chairman of the National Defense Research Committee, and a year later was named director of the Office of Scientific Research and Development. As chairman of the National Defense Research Committee and as director of the OSRD, Dr. Bush was a central figure in the development of nuclear fission, culminating in the atomic bomb.

SOUND TAPE IN RADIO STATIONS

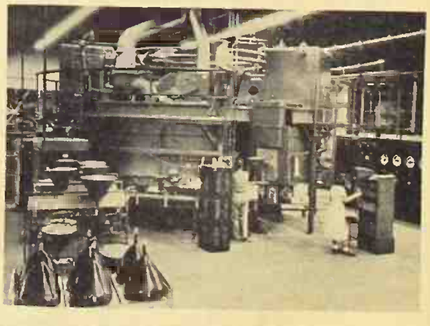
A recent survey of chief engineers of 2000 commercial radio stations in the United States indicates that sound recording tape may eventually be used for radio commercials, open-end shows, and transcription libraries. According to the survey, 95% of the stations now have tape recording equipment, and 86% of the remaining stations plan to acquire such equipment.

Ninety per-cent of the chief engineers questioned said they could handle open-end shows on tape by using two playback units and leader and timing tape. Eighty per-cent indicated that commercials could be handled on tape with the same equipment, and seventy-eight per-cent agreed that a transcription library could be handled on the same basis.

R. J. Gavin of *Minnesota Mining and Manufacturing Company*, sales manager for "Scotch" brand sound recording tape, pointed out that sound tape has already been adopted for a wide variety of jobs and that it is possible that sound tape may eventually be adopted for these additional jobs.

AUTOMATIC TV TUBE MACHINE

Sylvania Electric Products Inc.,'s TV picture tube plant at Seneca Falls, N. Y., is using new rotary machines



more than thirty feet in diameter in daily production of the larger sizes of TV picture tubes.

These machines, designed and built by *Sylvania*, are used to exhaust as many as twenty four 24" tubes in a step by step process, and are believed to be the largest in use by any TV picture tube manufacturer.

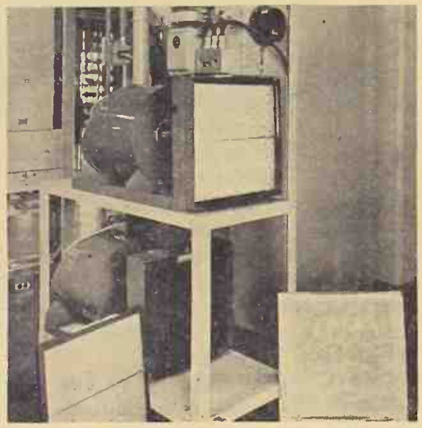
Mr. H. D. Broker, manager of the company's TV picture tube plant at Seneca Falls, said that each machine costs upwards to $200,000 and was designed to increase production efficiency and reduce cost of the largest picture tubes in current demand.

AIR SANITATION

The successful solution to the air sanitation problem encountered in microwave radio repeater stations was revealed recently by the *W. B. Connor Engineering Corporation* of Danbury, Conn.

Certain vacuum tubes, either in "cavities" or exposed in each equipment frame require a steady stream of cooling air for best operating efficiency.

Large deposits of dirt discovered in the air passageways and on the vac-



uum tubes, which threatened continued operation of the equipment, were found to be a coagulation of microscopic particles. An analysis also showed that sulphides in the air were combining with the silver plating of the inner cavity surfaces to produce silver sulphide. The total result was a flaky layer composed of dirt and silver sulphide.

To solve the problem of dirt, a barrier type of filter material known as "Filter Down" was obtained from the *American Air Filter Corporation* for use immediately after the impingement filter. This material has produced results in this application much the same as that of electrostatic filters. The second problem appeared to be one of supplying air free from sulphides.

The *W. B. Connor Engineering Corporation* devised a filter which removed the sulphides from the air before being distributed to the various vacuum tubes. The filter consisted of a bed of activated carbon 1½" thick, held between two meshed screens and supported in a frame of such size that it could be directly substituted for one of the two impingement type filters originally used in the blowers.

NEW LITERATURE

Mica and Mica Substitutes

A transcript of an industry-military round-table discussion on the subject of mica and mica substitutes has been released by the Office of Technical Service.

The round-table discussion, held under an arrangement between the Department of Navy and the National Security Industrial Association, included a number of experts of federal and industrial technical organizations. Subjects covered include solid state synthetic mica, World War II mica research, miniature capacitors, cellulose esters, glass and vitreous enamel insulating materials, dimensionally stable ceramics, the use of block talc, integrated mica, and new uses for mica.

Copies of PB 101 142, Mica and Mica Substitutes—Attendance and Transcript of Proceedings, are available at 50¢ a copy from the Office of Technical Services, U. S. Department of Com-

(*Continued on page* 31A)

NEW PRODUCTS

LINEAR AMPLIFIER

Nuclear Instrument and Chemical Corporation, 223 West Erie St., Chicago 10, Illinois, has announced a new

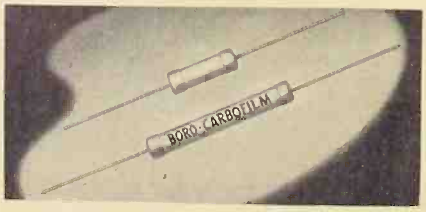
model linear amplifier for adapting *Nuclear* Geiger-Mueller scalers to proportional counting.

The Model 1061 linear amplifier is connected between the detector and a *Nuclear* scaler, and provides convenient sensitivity adjustment, calibrated in millivolts, with a choice of 1 or 10 millivolt maximum sensitivity. The instrument has a flat frequency response from 10,000 cycles to 1.5 megacycles. A set of oscilloscope terminals is located on the front panel, while all other connections are on the rear.

CARBON RESISTORS

Wilkor Products, Inc., 2882 Detroit Avenue, Cleveland 13, Ohio, has announced the use of boron in the making of deposited carbon resistors.

The new Boro-Carbofilm resistors are reported to have an increased range of resistance as well as a lower temperature coefficient. They also possess greater stability with a lower noise level. With their small aging and low temperature coefficient of 20 parts per



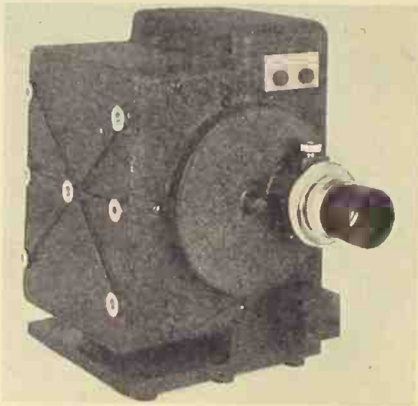
million per degree C, the Boro-Carbofilm resistors are advantageous for high frequency communications, and electronic applications.

These resistors are manufactured under license arrangement with *Western Electric* and are available in ¼, ⅓, ½, 1, and 2 watt sizes. Additional information may be obtained direct from the company.

SYNCHRONOUS CAMERAS

Flight Research Engineering Corp. P. O. Box 1-F, Richmond, Virginia, now has available 35 mm. synchronous motion picture cameras for use in parallel wired gangs of two or more cameras for synchronous data recording.

The Model IV cameras, which may be used for single-frame or continuous exposures and were originally designed for flight testing, missile tracking, and fire control applications, are suitable for many other applications including



process control analysis and wide-base stereographic photography.

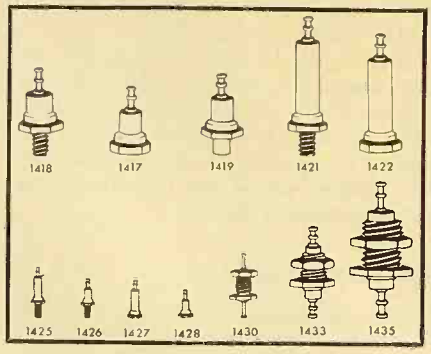
Special features include incandescent and argon coding and timing marker lamps, change gears for speeds of 5, 10 and 20, or 4, 8, 16 and 32 frames per second, a thermostatically controlled film chamber heater, and an auxiliary pulse circuit for indicating externally the instant of maximum shutter opening.

These cameras are interchangeable on mounts for either vertical or side mounting, and may be operated in parallel with the Model III 16 mm. synchronous cameras supplied by the manufacturer.

TERMINAL PLUGS

U. S. Engineering Company, 521 Commercial St., Glendale 3, Calif., is now manufacturing the "1400" series of molded insulated miniature terminal lugs.

Stand-off types are offered with either molded LTSMG31 melamine or molded type MTS-E1 phenolic to JAN P14 specifications. Use of the molded



construction instead of preformed tubular plastic eliminates internal air gaps which act as moisture traps. In addition, the method gives more positive holding and units stay solid and tight under normal heat and vibration.

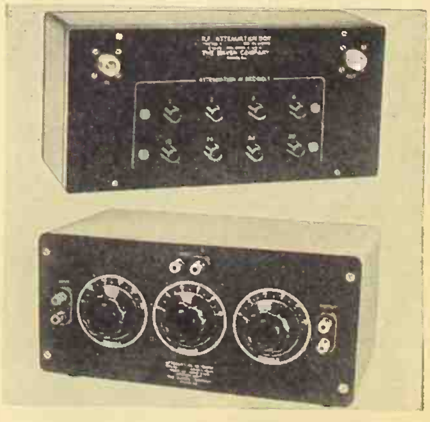
Engineering data describing the "1400" series is available on request.

ATTENUATOR UNITS

The Daven Company, 191 Central Avenue, Newark 4, N. J., now has available two new attenuator units, the RF Attenuation Network and the Carrier Frequency Decade Attenuator.

The RF Attenuation Network, Model 650, has a flat frequency response from d.c. to 225 megacycles and insertion loss is zero over the entire frequency range. This model has a total attenuation of 100 db. in 1 db. steps. Resistors are calibrated to an accuracy of ± 2% at d.c. Impedances of 50 or 73 ohms are standard, and units are available with type N or BNC connectors.

The Carrier Frequency Decade Attenuator, Model 795, is particularly applicable to extremely accurate measurements from d.c. to 200 kc. and can be used up to the lower radio frequencies. A total of 110 db. attenuation is available in 1 db. steps or 111 db. is available



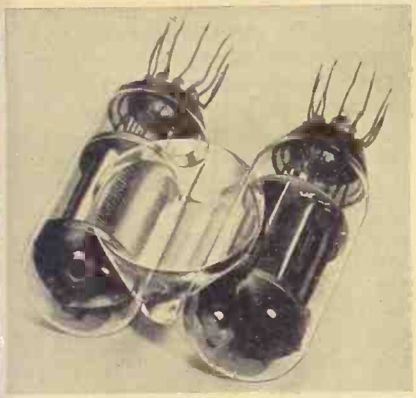
in 0.1 db. steps. Each individual resistor is adjusted within ± 0.25% of its correct value.

Both these models are available in either a balanced H or an unbalanced T network. Further information, including complete catalog data, may be obtained from the manufacturer.

PHOSPHORESCENT MATERIALS

Tracerlab Inc., 130 High St., Boston 10, Mass., now has available a hydrocarbon crystal known as Stilbene and a solid plastic phosphor for use in scintillation detector units.

It is reported that precisely formed phosphors of up to one inch in any dimension are readily machined from the colorless, optically clear, single crystal masses of Stilbene. The plastic phos-



phor can be molded so as to embed two 1P21 photomultiplier tubes operating in coincidence to reduce multiplier noise background, as is shown in the photograph. This phosphor is essentially a solution of Terphenyl in a styrene monomer, the whole mass being polymerized into a solid state.

PORTABLE GEIGER COUNTER

The *Victoreen Instrument Co.*, 5806 Hough Ave., Cleveland 3, Ohio, is now manufacturing a compact, lightweight, waterproof Geiger counter.

Designated Model 389 Thyac, this Geiger counter is reported to have a long-life, low current vibrator power supply which provides regulated high voltage and plate voltage for reliable instrument operation. The standard 1B85 beta-gamma counter tube may be replaced by the 1B106 mica window counter tube, the 1B124 gamma ray tube, the 1B125 cosmic ray tube, or any other tube having the RMA type 1A-82 coaxial plug-in base.

Beta and gamma radiation is distinguished by slide button control of the beta shield mounted on the watertight probe, and convenient "Fingertip" range control affords ease of operation.

THYRATRON TUBE

The Tube Division of *General Electric Company*, Syracuse, N. Y., has announced a thyratron tube, designed mainly for general control-circuit applications, which has a quick-heating cathode taking only a minute to reach operating temperature.

Designated as the GL-5855, the three-

electrode inert-gas-filled thyratron has a commutation factor rating of 200. Maximum ratings include: maximum peak anode voltage, 1500 volts; maximum cathode current, peak 150 amperes, average, 12.5 amperes; maximum negative control-grid voltage, 250 volts before conduction and 10 volts during conduction.

ELECTRONIC VIDEO RECORDER

A video recorder with electronic instead of mechanical control has been developed by *General Precision Laboratory, Inc.*, Pleasantville, New York. The development will make possible recorded TV programs with picture quality equal to the original "live" telecast.

Basically, the new unit is a TV receiver combined with a 16 mm. motion picture camera, but the electronic design of the GPL recorder eliminates double exposures and under exposures, film fuzziness, garbled sound, and vibration.

A completely electronic system to synchronize the TV image of 30 pictures a second with the motion picture camera speed of 24 exposures per second was designed by the company's engineers. In this recorder, an electric counter is set up to monitor the TV images. A frame of film is pulled into place; the electronic controls turn on the cathode-ray tube of the receiver, count the 525 lines of light which make up one image, then turns off the tube. The procedure is repeated and each frame of film, a separate photograph in itself, gets exactly a full exposure.

The recorder can be set up right in the studios where a program is being produced, or it can pull programs out of the air even in fringe areas. Tests have been conducted for over six months with recordings made 40 miles away, and the report is that the projected results on a 6' x 8' screen are better than the original reception.

Personals

DR. DANIEL ALPERT, formerly head of the inter-atomic physics section of the *Westinghouse* Research Laboratories, has succeeded the late Dr. R. C. Mason as manager of the Physics Department. During the war, Dr. Alpert helped develop the famous T-R switch and also shared in design of the standard frequency cavity. Dr. Alpert received his Doctor of Philosophy degree in physics from Stanford University and joined *Westinghouse* in 1941.

DR. ROBERT G. BRECKENRIDGE has been named Chief of the Physical Electronics Section of the Atomic and Radiation Physics Division of the National Bureau of Standards. Formerly Assistant Professor of Electrical Insulation and assistant to the director of the Laboratory for Insulation Research at MIT, Dr. Breckenridge is a fellow of the APS, a member of the ACS, and of the Washington Academy of Sciences.

LESTER W. CALKINS has been appointed Associate Research Engineer in the Planning Department of *Burroughs Adding Machine Company's* Research Division in Philadelphia. Formerly associated with the *Philadelphia Electric Company* and the *Tinius Olsen Testing Machine Company,* Mr. Calkins received his B.S. degree in electrical engineering from Cornell University and an M.S. degree from the University of Pennsylvania.

JOHN B. MERRILL, general manager of the Tungsten and Chemical Division of *Sylvania Electric Products Inc.,* has been appointed vice president. Mr. Merrill has been with *Sylvania* since 1941. In 1943, he was appointed plant manager at Towanda and the activity was expanded to include the manufacture of tungsten in many forms. When the Tungsten and Chemical Division was created in October, 1945, Mr. Merrill was appointed general manager.

J. GILMAN REID, JR. has been appointed Chief of the Electronics Division at the National Bureau of Standards to succeed Dr. R. D. Huntoon. Mr. Reid joined the NBS staff in 1937 and became an engineer for the uranium project at the Bureau. A member of the APS, the AIEE, and the IRE, Mr. Reid has represented the Bureau on a number of society committees concerned with various phases of electronics and instrumentation.

HULBERT C. TITTLE has been appointed assistant chief engineer for the Radio and Television Division of *Sylvania Electric Products Inc.* Formerly engineering service manager, Mr. Tittle joined Colonial Radio Corporation, a *Sylvania* subsidiary, in 1935. He received his B.S. degree in electrical engineering from the South Dakota State School of Mines and is a member of the IRE, the Radio Club of America, and the ASA.

Servosystems

(Continued from page 5A)

in gear trains are available and the servo engineer should become familiar with them. It is almost axiomatic that irreversible gear trains should never be used if it is possible to avoid them.

With the advent of degenerative feedback circuits in audio amplifiers there came a period during which many designers were misled into the conviction that enough feedback would cure all ills, and they became careless in handling straightforward design problems. It is true that feedback properly applied to *any* system will produce seemingly miraculous improvements in performance characteristics. It is also true that feedback circuits in electronic amplifiers are servosystems. They function as a result of observing an error voltage. This statement is an important one in all feedback concepts. Feedback is triggered, controlled or generated in terms of an existing error. It cannot help the performance of a system unless there is some error present, however small it may be. This means that no feedback circuit can ever do a perfect job. It immediately implies that the feedback circuits should be added only as a means of improving performance after all other methods have been exhausted. It should always be added if the system lacks the desired degree of perfection (and what system does not?), but it should never be thrown in as a panacea for all troubles.

In most servosystems various types of devices and circuits are used to inhibit oscillation. These are generally called anti-hunt circuits and they are usually degenerative feedback arrangements. Well designed anti-hunt arrangements are extremely valuable and will contribute a great deal of stability to almost any system, but they should be used as a final means of cleaning up all the undesirable factors that have not been reduced to a minimum with straightforward improvements in design. There is another important reason for adding degenerative feedback last in the design of an audio amplifier, and anti-hunt circuits last in the design of servomechanisms. Degenerative feedback circuits and anti-hunt systems are designed specifically to work toward an optimum adjustment that reduces troubles. Many faults in design parameters may only be reduced by such methods to borderline conditions where they cause too much trouble to pass them by, but the symptoms of the trouble are so obscured that observation is difficult, intermittent and clouded. Thus the designer who resorts to these procedures too soon in the development stages may waste time end-

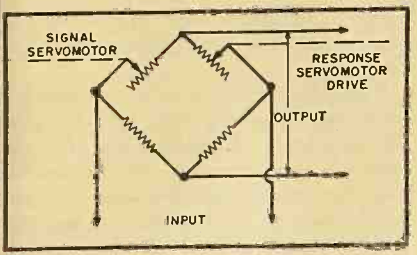


Fig. 6. Basic schematic of a potentiometer bridge which may be used in a servomechanism circuit.

lessly trying to diagnose malfunctions that would be immediately obvious if he would attack them before inserting the stabilizing circuit. A corollary of this is the fact that in troubleshooting existing systems it is almost always desirable to eliminate corrective feedback loops in order to make the symptoms more prominent and more easily diagnosed.

One of the principal difficulties facing the servosystem engineer is the fact that he is often dealing with a closed loop feedback structure that functions only when it is connected in a complete loop. Other types of mechanisms and circuits will yield to analysis of individual components and stages. In tracing the source of hum in an audio amplifier, the common approach is to remove tubes successively, starting from the input end, to disable various portions of the circuit and thus localize the trouble. With a closed loop servosystem each element is so intimately related to the operation of all the others that it literally will not operate with one section disabled. It is usually a matter of almost pure random luck (often influenced unconsciously by a great deal of experience) when the initial diagnosis is correct. A desirable by-product of this is that the designer often makes more accurate adjustments of parameters that actually have nothing to do with the trouble he is tracing and that he would have otherwise considered adequate.

Servosystems are neither new nor are they the unique product of human invention. There are many gigantic servosystems to be found in the structure of the universe. Man himself contains innumerable such mechanisms and uses them continually in daily activities. It is easy to relate servosystem principles to the activities involved in playing games. A tennis player is continually controlling his muscular activities in terms of the input signal fed through his eyes in the form of light. A tight-rope walker has a highly developed servosystem, using the input signal from specialized nerve fibers to control with great accuracy and speed the muscle systems that serve to prevent a fall. This type of system is particularly interesting because it involves the deliberate development of high dynamic sensitivity and response speed at the expense of static stability. Maintaining physical balance is often aided by deliberately oscillating around the point of absolute balance, thus keeping the "motors" running to eliminate inertia effects, and vitiating extremely small and uncontrollable factors by introducing controllable constants of relatively large magnitude.

It is indeed instructive to think in such terms, to recognize that when you drive a car, adjust the controls of your television receiver, play a musical instrument, you yourself are a part of a closed loop servosystem with feedback paths that extend from the outside world through your own remarkable sensing mechanisms to the motor control centers of your brain and back into the outside world via the action of your muscles. It is possible to learn a great deal about the best way to handle widely varying problems by studying servosystems, and to learn a great deal about servosystem design by observing some of the beautifully designed mechanisms contained in you.

Microwave Links

(*Continued from page* 15A)

Signal-to-Noise Ratio
Better than 50 db. (10 hops)
Adjacent Channel Crosstalk
60 db. down
Video Pulse Width
0.5 μsec. (approx.)
Video Pulse Buildup and Decay
Times 0.15 μsec. (approx.)
Primary Power Source
115 or 230 volts, single phase, 47.5 to 63 cycles

A block diagram of the transmitter is shown in Fig. 3. As indicated on this diagram, the video signal from the modulator terminal is applied across the input of the transmitter, amplified and shaped in the r.f. modulator, and the output of the latter applied to the r.f. oscillator. The oscillator employs a planar electrode (lighthouse) triode, a 2C43, operating in a reentrant cavity. The oscillator can be set to any frequency in the 1650 to 1990 megacycle band and has a frequency stability of 0.05 per-cent under the worst combination of humidity, temperature, and line voltage variations.

The first two stages in the modulator are simple resistance coupled clipper amplifiers which through clipping remove any amplitude variations and re-

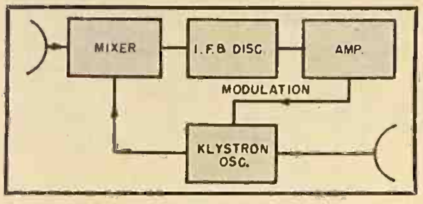


Fig. 9. Feedback principle used in the Philco CLR-6 microwave link.

shape the pulses. The output of the second stage is applied to the grids of a 3E29 beam-power amplifier tube which employs a shunt peaking coil to provide a wideband amplifier response sufficiently large to pass the pulse train without serious frequency distortion.

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Resistor R_3, shown in Fig. 6, is placed in parallel with the plate to cathode circuit of the 2C43. The shunt capacitance C, shown by the dashed lines, is the effective capacitance across the modulator output circuit and consists of the sum of the output capacitance of the 3E29, plate to ground capacitance of the 2C43, the filamentary capacitance to ground, and the stray capacitance associated with this circuit. This capacitance is charged during the "pulse on" period to the same voltage that exists across the 2C43 tube, and must discharge quickly in the "pulse off" period. The function of R_3 is to provide a low resistance path for the voltage across the capacitance to discharge in the pulse off period.

An output of 40 watts peak into a 50 ohm line is obtained from the 2C43 and is fed to the antenna system.

A superheterodyne receiver is used, as shown in Fig. 7, employing a triode type lighthouse tube and reentrant cavity oscillator similar to that utilized in the transmitter; a coaxial cavity crystal mixer; a 30 megacycle i.f. amplifier; and a video output stage. A cavity wavemeter is also incorporated into the equipment for measuring local oscillator frequency.

The cavity oscillator uses the same lighthouse triode as that used in the transmitter and the cavity is almost identical, although the design is simplified since a maximum output of only 100 milliwatts is required. Tuning over a ± 40 megacycle range (by varying plunger in reentrant cavity) can be made from the front panel. Coupling between oscillator and crystal mixer can be adjusted for optimum performance.

The mixer consists of a capacitively tuned coaxial cavity with built-in crystal mounting. The bandwidth at 3 db. down is approximately 12 megacycles and the image rejection ratio is approximately 18 db. Additional image and interference rejection is effected through the use of a bandpass antenna filter connected between antenna (or T—R filter if antenna is used for both transmitting and receiving) and mixer input. This filter consists of two coaxial cavities coupled inductively to produce a bandwidth of about 10 megacycles between 3 db. points with an insertion loss of about 1 db. This results in added image rejection of 45 db.

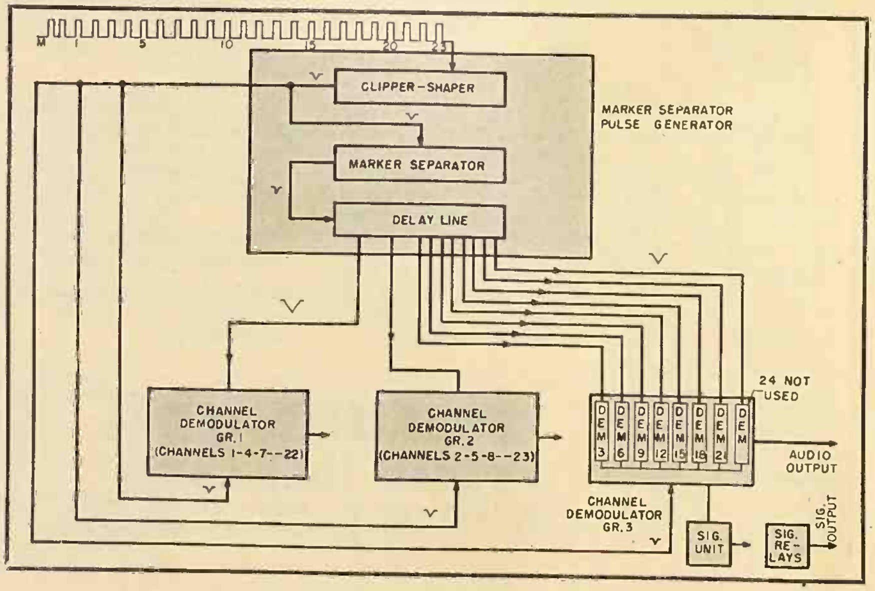
The modulator consists of a pulse generator, delay line commutator, modulator, mixer line amplifier, and marker generator. It is beyond the scope of this article to go into the details of the operation of these stages. This information may be obtained from previously published articles[11, 12]. Suffice to note that the final result is a 24 channel pulse train including one marker pulse (actually two closely spaced pulses) and 23 time modulated audio channels (if 23 channels are used). In order to minimize the introduction of crosstalk, the pulses are modulated in groups of 8, each being separated from the succeeding one by a time spacing of three channels. Thus the first unit modulates channels 1, 4, 7, . . . 22; the second unit 2, 5, 8, . . . 23; and the third unit 3, 6, 8, . . . 24. The three groups are then interleaved.

The audio input to the modulators is obtained from telephone lines through a 4-wire terminating set, which matches the 2-wire telephone line to the 4-wire link. A link is considered a "4 wire" system because a separate path is used for each direction, whereas in a 2-wire telephone system the same pair is used for both directions in two way conversations. The 4-wire terminating set consists of a hybrid coil, blocking capacitor, and a compromise network for each circuit to be terminated for telephone service.

A block diagram of the demodulator is shown in Fig. 10. The received pulses are first limited to remove noise and then separated into individual channels and demodulated. Demodulators are also arranged in groups of 8, this time for flexibility purposes. The audio output is fed through a 4-wire terminating set to the appropriate telephone line.

The audio bandwidth of each channel is 300 to 3400 cycles. However it is possible to increase this bandwidth by combining two channels into one—thereby doubling the bandwidth by in-

Fig. 10. System block diagram and waveforms of the multiplex demodulator.



creasing the pulse sampling rate from 8 kc. to 16 kc. In this way, and with other minor modifications, a wideband channel can be provided whose frequency response is essentially flat from 60 to 6800 cycles. For wider bandwidth more channels can be combined.

Signaling and Dialing

The PTM equipment is inherently designed to transmit d.c. signals. Since voice frequency channels do not require frequencies below 300 cycles, there are 23 low frequency (d.c. to 20 cycles) channels available for signaling and dialing purposes. These low frequency signals are superimposed on the individual channel modulation at the transmitting end. At the receiving end they are filtered out and fed to a separate amplifier operating on a.c. or high speed d.c. relay. The contacts of this relay may be used to control local signaling, ringing, dialing, or supervisory circuits.

When signaling is desired on a channel, the normal (out of service) position of the channel pulse is permanently shifted to the left edge of the channel interval. During the period that the channel is in use—but without voice or other a.c. applied—the channel pulse is positioned in the center. To signal again the pulse is moved to the left again. By this means the equivalent of a d.c. loop is obtained in each transmission direction. "On hook" and "off hook" signals are transmitted for supervision and an equivalent loop for dial impulses is thus made available.

The signaling converter at the transmitter operates from any specified signal and shifts the center position of the pulse from left to the center of the channel interval. It consists of one simple relay. The signaling amplifier at the receiving station amplifies the d.c. from the multiplexed signaling channel to a power level suitable for the operation of drop signaling relays or the dialing apparatus.

Antenna System

The antenna system for both transmitting and receiving purposes consists of a half wave dipole located at the focal point of a parabolic reflector. The line feeding the dipole, which also acts as its support, is a rigid ⅞ inch air dielectric line with an external stiffener sleeve to prevent excessive vibrations.

The size of the parabolic reflector used is determined by the required signal at the receiver and involves such factors as transmission path lengths, expected propagation variations, and nature of the terrain. In general the system is designed to allow at least 20 db. fading over the transmission path. For maximum safety or for longer paths, a 10 foot reflector (34 db. gain) is used, while under more favorable conditions 6 foot reflectors (29 db. gain) may be satisfactory.

Philco CLR-6 Link

Another link that has found commercial application is the *Philco* CLR-6 Microwave Communications Relay Equipment. This link employs reflex klystrons, operating in the 5925 to 7425 megacycle range, in both transmitter and receiver. While the multiplex equipment normally associated with this relay uses PAM, any method of multiplexing—including frequency division—may be used as long as the modulation bandwidth does not exceed 300 kc. The multiplexed signal is then used to frequency modulate the reflex klystron.

An interesting phase of this equipment is the use of a single reflex klystron for both reception and transmission at repeater points. This is done through the use of the feedback principle shown in Fig. 9. The operation is essentially as follows:

An incoming frequency modulated signal is mixed with the signal from a local oscillator klystron which operates at a frequency 90 megacycles removed from the center frequency of the incoming signal. The resulting 90 megacycle i.f. signal is detected, amplified and fed back to the reflector of the klystron in such a way that the klystron will track the frequency modulation of the incoming signal. The output of the klystron is fed to the antenna and radiated in the direction of the next repeater station.

Consequently the transmitting frequencies of the entire relay are normally controlled by the frequency of each terminal transmitter. At the terminals the transmitters are held on frequency by a.f.c. referenced to a two cavity r.f. discriminator. All repeaters are equipped with similar r.f. discriminators which are automatically switched into operation if the incoming signal from the previous repeater should fall below a predetermined level. The repeater then operates as a frequency controlling terminal until the signal is restored at which time it will automatically switch back to repeater operation. All r.f. circuits of both repeater and terminal equipments are enclosed in a temperature stabilized housing.

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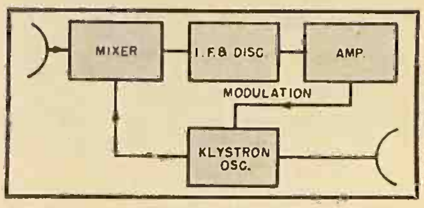
Frequency of Operation
5925 to 7425 mc.
Type of Modulation
FM
Deviation
6 mc. peak to peak
Channel Spacing at Repeater
90 mc.
R. F. Power Output—1 watt



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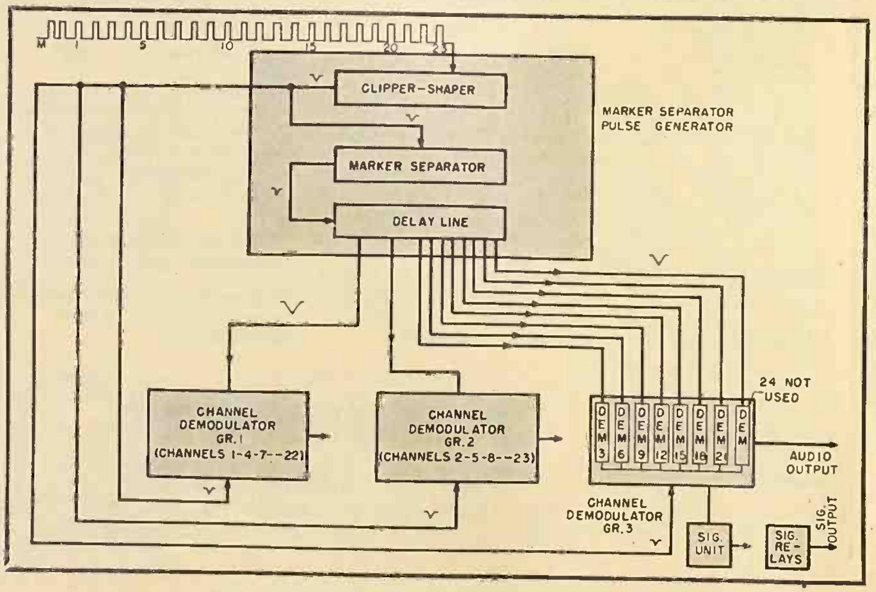

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The characteristics of this link are:

Frequency of Operation
5925 to 7425 mc.
Type of Modulation
FM
Deviation
6 mc. peak to peak
Channel Spacing at Repeater
90 mc.
R. F. Power Output—1 watt

Input Impedance to Modulator
600 ohms
Input Band Pass
300 cycles to 300 kc.
Input Level Required
—6 dbm. nominal
Frequency Tolerance—0.05%
Type of Frequency Control
R. F. Discriminator
Receiver I. F. Band Pass (3 db. down) 8 mc.
Receiver Output Impedance
600 ohms
Receiver Output Level
0 nominal, 10 dbm. max.

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12. *Grieg and Racker, "Microwave Radio Links", Signals, Nov.-Dec., 1947.*

Electrical Meas.

(*Continued from page* 9A)

enough to avoid subsidized competition with private testing laboratories but are low enough to make it possible for all industrial laboratories to attain high accuracy where desirable in their work. In any event, the cost to both government and industry of the Bureau's electrical standardization services is slight in comparison with the savings to the nation which result from the program. For example, the electrical power industry has now grown to the point where the annual bill for electrical energy is approximately four billion dollars. If there were a consistent error of 1 per-cent in the standards used at the Bureau to calibrate the electric meters with which the industry calibrates its customer meters, either the power companies or the consumers would lose 40 million dollars each year. Yet the cost of maintaining the Bureau's service in this field is much less than 1 per-cent of the discrepancy.

The Bureau is currently making efforts to meet the demand for ever-increasing volume and complexity in electrical standardization work. Techniques are being developed for the more accurate measurement of man-made lightning—very short-duration surges of high current—which are coming to be used by electrical manufacturers to test high-voltage equipment. Methods are also being worked out for the more rapid and economical checking of watt-hour meters, and the testing of the very high resistances now used in measuring ion currents and other radiation effects.

REFERENCES

1. *National Bureau of Standards Circular 475, "Establishment and Maintenance of The Electrical Units," by F. B. Silsbee, available from the U. S. Government Printing Office at 25 cents a copy.*
2. *For fees and other information on the testing and calibration program, see National Bureau of Standards Circular 483, "Testing at the National Bureau of Standards," available from the U. S. Government Printing Office at 25 cents a copy.*

The Balitron

(*Continued from page* 20A)

Remember, we are changing the beam current from one plate to the other so a decrease in the current drawn by one plate will result in an increase in the current drawn by the other plate. Thus, this graph is a natural resultant of this change. The cross-over point, the point where the two current lines cross each other, is the point where the currents to each of the plates are equal.

Since the currents to the target anode and the target plate (plus the *Pd* current) are equal at cross-over, it follows that the total beam current is twice the cross-over current of either plate. By adding the currents of *Tp* and *Ta* together along the same *Nd* voltage line it becomes evident that the total current, at any time, is very nearly constant. This means the load placed upon the power supply is constant, regardless of the input signal.

Reference to both Figs. 6 and 7 shows that push-pull operation from a single ended input is an accomplished fact. Obviously, if a single ended input makes push-pull operation possible, in phase and out of phase voltages are produced in the output. Thus, an output voltage in phase with the input voltage is possible.

The cross-over point on the graph of Fig. 7 falls near the zero *Nd* voltage line. Since the cross-over point is midway along the linear part of both I_{Tp} and I_{Ta} curves, this is the bias point for Class A operation. Under these conditions, it is obvious that this tube will require no bias voltage for Class A operation. Note that no *Nd* current is drawn even with a positive voltage upon this structure. This shows that the beam is tightly constructed. One model of this tube was constructed which required a bias of 80 volts *positive* to reach cross-over and no appreciable *Nd* current was drawn until the *Nd* was driven above 100 volts positive with respect to the cathode. Other models have been constructed using negative bias to reach cross-over.

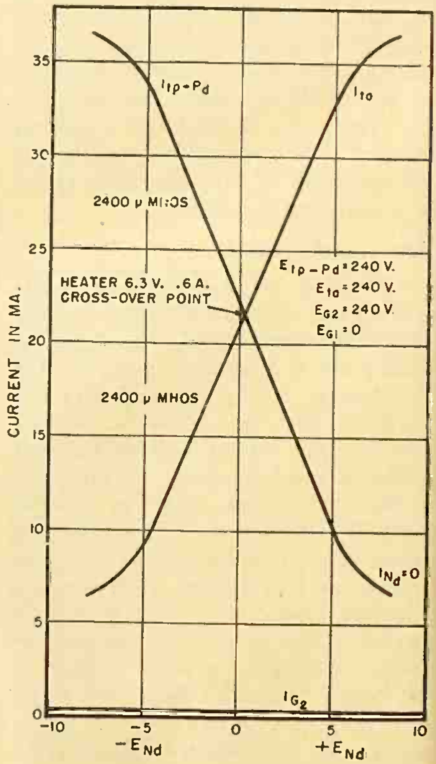
Note how much of the characteristic curve is linear. Only the extreme ends are non-linear. Taking the total length of the curve, the linear section extends over approximately 85% of it. This is considerably greater than the linear section of the best grid amplifier curves.

One thing of enormous interest as shown by the graph in Fig. 7 is the total accelerating anode *A*, or G_2, current. This current is constant for any signal voltage and, while the beam current is 43 ma., the total current drawn by the accelerating structure is *500 microamps*. Thus, the ratio of beam current to accelerating anode current is 86 to 1 in this tube while in the ordinary pentode tube the ratio of plate current to screen current is roughly 4 to 1 and in the ordinary beam power tube the ratio is roughly 10 to 1. But the current shown by the graph for the accelerating anode of the Balitron is at low accelerating anode voltages. One model of this tube was operated with a potential of 240 volts upon *Pd*, *Tp*, and *Ta* while the accelerating anode voltage was increased to 395 volts. Under these conditions, the accelerating anode drew no current whatever.

In normal practice, it is extremely poor design to operate a tube without a load and bypass capacitor upon the accelerating anode. In the Balitron, neither one is required since the accelerating anode current is constant. Being constant, no filtering is required even if a load is inserted.

(*To be continued*)

Fig. 7. The Eg-Ip curve of the Balitron. Note the wide range of linearity.



News Briefs

(*Continued from page 23A*)

merce, Washington 25, D. C. Check or money order should be made payable to the Treasurer of the United States.

Report on Telecommunications and Equipment in Germany

A technical report on telecommunications and equipment in Germany during the years 1939 to 1945 is now available from the British Information Services.

The report covers various aspects of the industry, including research, transmission, instrument design and test equipment. Copies of this report are available from British Information Service, 30 Rockefeller Plaza, New York 20, N. Y., at 40¢ each.

Acoustic Measurements

Two new and one revised standard for laboratory standard pressure microphones and for earphones have been developed under the procedure of the American Standards Association, with 30 national organizations and others under the sponsorship of the Acoustical Society of America.

The first, Z24.4-1949, covers the reciprocity technique for Pressure Calibration of Laboratory Standard Pressure Microphones. The second, Z24.8-1949, gives specifications for these microphones. The third, Z24.9-1949, gives a method for Coupler Calibration of Earphones.

Single copies of the three standards are available from American Standards Association, 70 E. 45th St., New York 17, N. Y., as follows: Z24.4-1949, 20 pages, 75c; Z24.8-1949, 12 pages, 50c; and Z24.9-1949, 20 pages, 75c.

PHOTO CREDITS

6A, 7A, 8A, 9A . . . National Bureau of Standards

12A . . . . Northrop Aircraft, Inc.

13A, 14A, 15A . . . . Federal Telecommunication Laboratories

TECHNICAL BOOKS

"RADIO LABORATORY HANDBOOK" by M. G. Scroggie. Published by *Iliffe and Sons Limited,* Dorset House, Stamford Street, London, S.E. 1., England. 430 pages. $3.50. Available from *The British Book Centre, Inc.,* 122 E. 55th St., New York 22, N. Y.

In this handbook the author describes the methods available for carrying out tests and measurements, using either commercial instruments or improvised equipment. This volume, published for "Wireless World," is the fifth edition which has been revised and new material added, including the more recent developments in vacuum tube oscillator design.

Subjects include the principal sources of power and signals, the various types of measuring and acoustic instruments, methods of comparison and their application to receivers and amplifiers, and the plotting and interpretation of results.

C.G.S. magnetic units have been retained in this book, but in view of the advantages of the rationalized M.K.S. system the main features of it are shown in an appendix.

A special chapter on laboratory technique for v.h.f. work, constructional details of capacitance and resistance and inductance bridges is also included. Useful general information on such varied subjects as musical scales, decibels, wire gauges, filters, etc., makes this volume an all-around handbook for the radio laboratory.

"A. S. T. M. STANDARDS ON ELECTRICAL INSULATING MATERIAL," published by the American Society For Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 670 pages. $4.85.

All the standard and tentative test methods and specifications pertaining to electrical insulating materials which have been issued largely through the work of the Society's Committee D-9 on Electrical Insulating Materials are included in this book.

Subjects covered include: Insulating Shellac and Varnish, Mineral Oils for Electrical Insulation, Ceramic Products, Solid Filling and Treating Compounds, Insulating Fabrics and Textile Materials for Electrical Insulation, Mica Products, and many others together with a number of standards applicable.

Many of the specifications and tests have been revised recently by the Society.

CONSTANT K TYPE HIGH-PASS FILTER DESIGN

By SEIZO YAMASITA

The constants of a "T" or "pi" type constant K high-pass filter may be determined rapidly with acceptable accuracy with the aid of this chart.

DUE TO an unfortunate error, the wrong chart appeared on page 32A of the February, 1951 issue. The chart appearing below applies to high-pass filters and the chart in the February issue applies to low-pass filters. The text material below applies to the chart in the February issue.

Two types of the constant *K* type low-pass filter are shown in Fig. 1. The equations for determining the constants of either type of filter are as follows:

$$L = R/\pi f_0$$
$$C = 1/\pi R f_0$$

where f_0 is the cutoff frequency in c.p.s. and R is the image impedance in ohms.

The chart shown in Fig. 2, page 32A of the February issue, may be used to determine the constants to an acceptable degree of accuracy. If the desired cutoff frequency is above 100 kc., the chart may still be used. The desired value of f_0 is divided by some multiple of ten to give a value which can be read on the chart. The values of L and C determined from the chart are then divided by the same multiple of 10 to give the correct values of L and C. For example, if the f_0 is 500 kc., the constants are determined from the chart for a value of 50 kc. and then the values of L and C are divided by 10.

If any two of the four variables L, C, f_0 and R are known, the chart may be used to determine the other two.

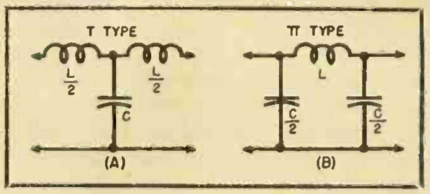
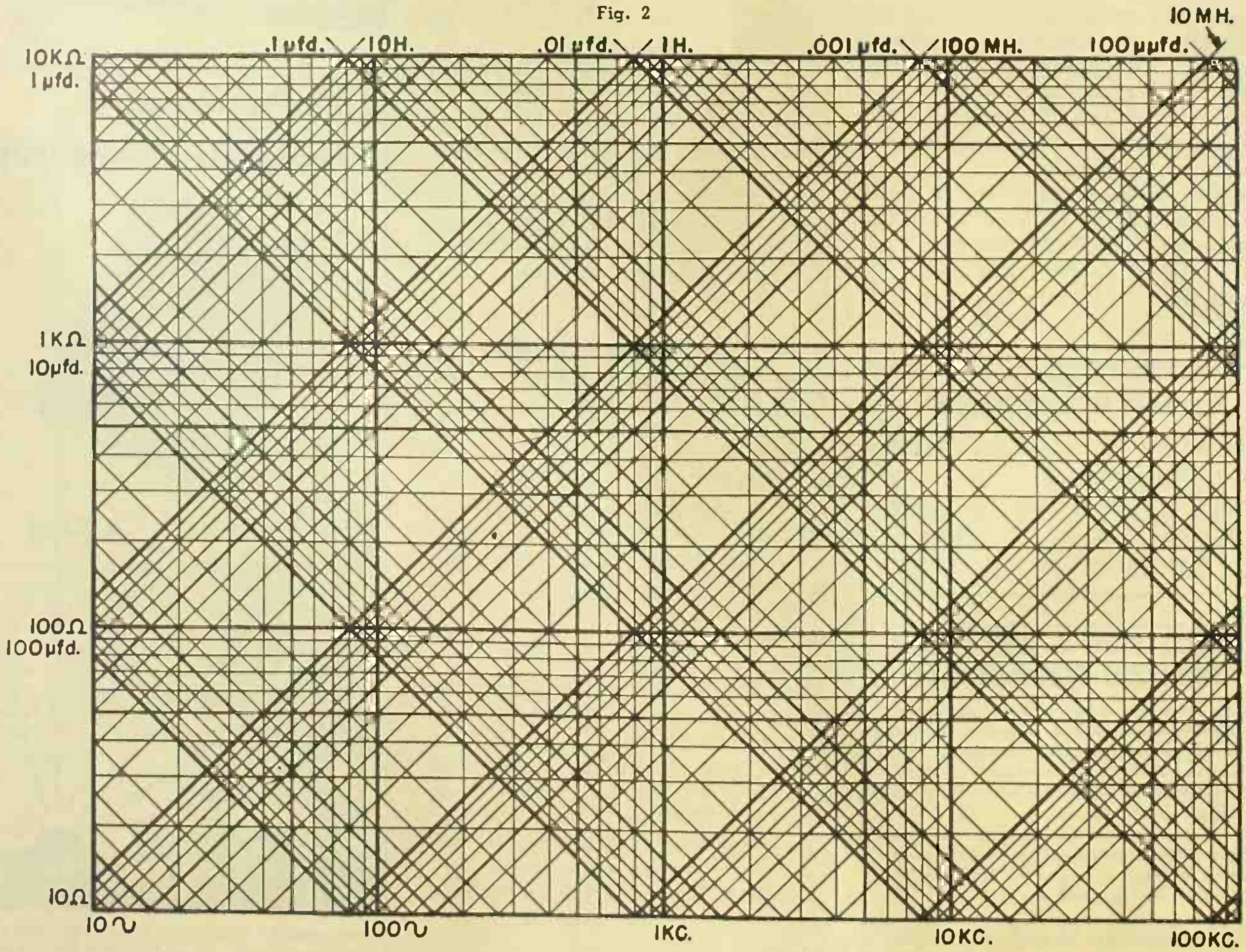


Fig. 1. (A) "T" type and (B) "pi" type constant K low-pass filter to be used with chart on page 32A of the February 1951 issue. See note above.

Fig. 2

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