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DEPARTMENTS

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COVER PHOTO—Courtesy of Stanford Research Institute

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FM in the POWER INDUSTRY

By P. M. OHLINGER
Design Engineer

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Equipment and techniques used in both fixed and mobile installations for communications and control purposes.

The technique of efficient and accurate communications is important in battery power supply conservation.

"THE power is off." This phrase used to mean only the inconvenience of hunting up the old lamp or candle, but now, with the ever widening application of electrical power to daily life, serious problems are presented when service is suddenly interrupted.

Outages are bound to occur and the only thing to do is to cut their duration. Lines and equipment are being constantly improved but Mother Nature can be quite rough at times. It is at these times, when outages occur simultaneously over a widespread area, causing maintenance crews work which seems to be set at them as though by a well-planned diversified attack, that the most efficient use of man power and equipment is urgently needed.

FM two-way radio communication is now being employed by the REA and private power companies as a means of shortening outage time while materially cutting maintenance costs and providing better service.

In this article, the equipment and installations in use by REA and private power companies will be discussed. Illustrations are of the Nishnabotna Valley Rural Electric Cooperative, Harlan Iowa. This REA installation has been in successful operation for over a year. Field experiences, problems, operating procedures, maintenance, licensing, system planning and costs are very similar whether the installation be for the REA or a private power utility. The equipment used in the illustrations of the installation to be described was manufactured by *Motorola, Inc.*

The electrical and operational characteristics of two-way radio equipment of different manufacturers are similar although physically and mechanically the equipment may be different.

Since the opening of this field of communication, sales competition has increased sharply and customer's prices and manufacturer's service have been to the advantage of the customer.

Planning the System

After it has been decided that two-way radio communication is needed for better system operation, there are several things which must be considered in planning the system:

1. *Area to be covered.* The equipment to be installed must be that which will do the job. Equipment size and type, antenna installation, terrain, boundary pattern of the area to be covered and the frequency to be used are all factors to be investigated.

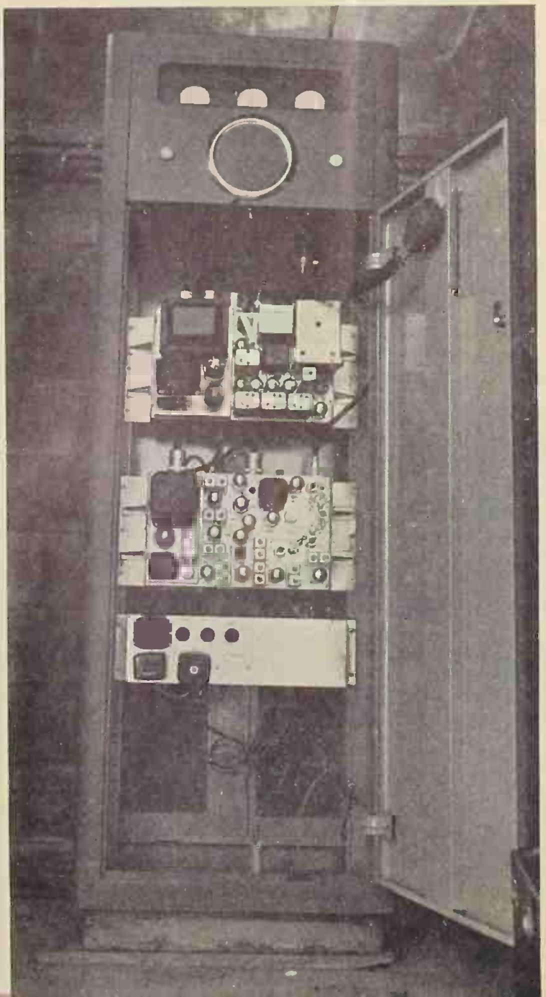
a. Equipment size and type. The area to be covered, the antenna installation to be used, the terrain and the noise levels where the receivers are to be used dictate the size and type equipment which must be used. The installation may be made with equipment having either 30, 60 or 250 watts r.f. power output.

b. Terrain. The power of the transmitter and antenna installation in the Central or Land station is always important, but more so when the type of terrain is such that receiving conditions

Compactness, making for space conservation, features the transmitter-receiver installation in the manager's car.

Antenna, atop a water tower, is fed by coaxial cable from the central station transmitter at the base.

Central station installation has both front and rear cabinet door openings to permit easy access for maintenance.



are spotty. If the sending range of the central station is increased by either a power increase or more efficient antenna installation or both, satisfactory one-way sending may result and then it is possible for mobile units to maneuver into favorable positions for returning calls that ordinarily would not be possible. If there are hills and valleys in the area, the mobile unit moves to the top of a nearby hill where communication can be established.

c. Boundary pattern. If the area to be covered forms a long and narrow pattern, or if the central or land station and antenna installation are at one extreme end of the area, satisfactory coverage is more difficult.

An increase of transmitter power may not be economically feasible, whereas increasing the height of the antenna or a directional antenna installation may be the answer at a less cost than a power increase.

In a situation such as this, noise levels are going to be much higher because of the added receiver sensitivity needed. However, if the boundary forms a long and narrow pattern, it is very probable that additional substations are in operation in these outlying districts to insure satisfactory voltage regulation out on the far ends of the power lines. In this case, pole mounted antennas located at these substations or other well-chosen points can be connected too by the mobile units to maintain communication with the central station. It is sometimes necessary to install remote receivers in locations where noise levels are very low, and then bring their output back over land lines to the central station and office which may be necessarily located in a very high noise level district.

d. Frequency to be used. Frequencies in the 30-40 megacycle and 152-162 megacycle bands are in theory strictly "line of sight" as far as range is concerned. Both bands are being used at the present time. The 30-40 megacycle band is very crowded and considerable sky wave interference is resulting in this band. The 152-162 megacycle band, while more reliable, is slightly shorter in range than the 30-40 megacycle band. The 152-162 megacycle band has been recommended by the FCC as a result of its field tests. If the 30-40 megacycle band is to be used, it will probably be necessary to supply the FCC with data to show that the 152-162 megacycle band cannot be satisfactorily used.

The REA Cooperatives like to have their adjoining neighbors on the same frequency so that they can form a network to be used in an emergency. It is true that transmissions from neighboring two-way radio systems break through that of adjoining systems, but they say that after they become familiar with voices and styles of transmission, they experience little trouble from this factor. Recently, a cyclone swept through an REA district. Very shortly after, the Nishnabotna Valley REA had their trucks and crews down in their neighbor's district helping him restore his lines. Immediate intercommunication between districts paid off in this instance.

2. *First cost, operating costs, and benefits.* In estimating costs of equipment needed in an installation the following items must be considered, although they will not all be required for the average installation:

Central station transmitters and receivers.

Central station remote control console.

Mobile transmitters and receivers.

Antenna systems.

Test equipment and freq. monitor.

Facilities for housing central station equipment.

Heavy duty batteries and oversize automobile generators.

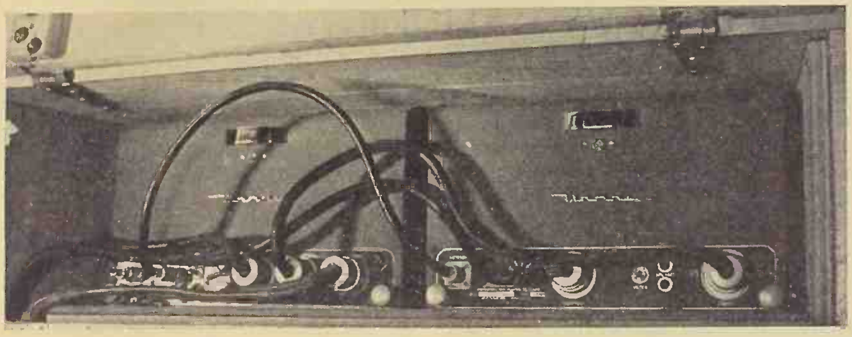
Spare parts and units.

Land lines for remote controlled central station equipment.

← Under chassis view of mobile receiver. Power supply is self contained on a separate removable chassis.

By means of the remote control console, Dean Jorgenson, REA Manager, has his maintenance crews at his fingertips. →

↓ A wood housing is constructed for the transmitter-receiver installation directly back of the cab of the truck.



A.c. power line to remote controlled central station equipment.

An auxiliary power supply.

Purchase, lease, or rental of sites necessary for the remotely operated equipment.

Any taxes that may be applied.

Installation and engineering cost.

If the installation is such that terrain or geography provide an unusual problem the following equipment may become necessary:

Either automatic one-way or two-way repeaters.

Remotely operated receivers.

Additional antenna installations.

The construction, purchase, lease or rental of land lines and necessary sites and power supplies for remotely operated equipment.

In the average size two-way radio system used by the REA, the equipment cost can be estimated at $6000.00 which would include 6 mobile units, one fixed central station, remote control console and the antenna less the antenna tower.

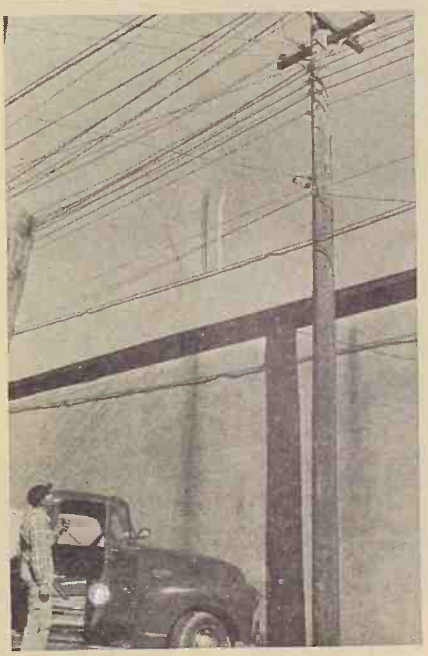
If oversize generators and batteries are required in the trucks, an additional $90.00 will be needed for each installation. The installation cost of a system of this size can be estimated at $25.00 per mobile unit.

In the installations for the larger power systems, the equipment cost and installation should be proportionately greater, about $525.00 per mobile unit.

It is hard to fully evaluate the benefits received from an expenditure such as this in monetary terms because two-way radio is a very important "good will" ambassador. Some examples of savings to be made are:

A maintenance crew may be in some remote corner of the district and a trouble call received from a location near where they are working. To either have the crew in this location make the trip back to the office for instructions or to send another crew out on this call will cost approximately $25.00 per trip. Two-way radio gives the crew in the locality all the information they need, saves another trip and allows more efficient use of manpower. Again, a crew may be out to locate a certain geographic point. When customers' names are similar, it is sometimes difficult to pin down locations exactly, but help from the dispatcher greatly assists in this matter. It has been found that when, as is the custom in some power companies, customers read their own meters and mail them in, a fictitious looking reading can be immediately checked by the maintenance crew in that locality.

One of the largest public power utilities in Iowa is using two-way radio in conductor stringing and sagging. Because of the high construction cost, high voltage transmission lines usually follow a direct line and cut across country over private right of way. This means that to patrol them, the maintenance man must walk the distance. The larger power companies are now using "walkie talkie" type radio for this purpose. The "walkie-talkie" radio is also a great time saver for the surveying crew.



Where joint construction is involved, multi circuits are quickly checked.

3. *Maintenance cost.* The large power companies generally maintain their own radio service departments. REA power companies usually have a service contract with a company or individual calling for a definite time of inspection of the equipment. The maintenance cost is determined by the type and manufacture of the equipment, the amount and severity of the usage and the quality of the maintenance and inspection work. An estimate of the average over-all maintenance cost per month could be approximately $10.00 for each mobile installation and $17.00 for each central or fixed station. However, it is reasonable to expect that in the first 5 years of operation these estimates will not be approached as the normal replacements should be tubes and vibrators during this period. Reports so far bear out this replacement record.

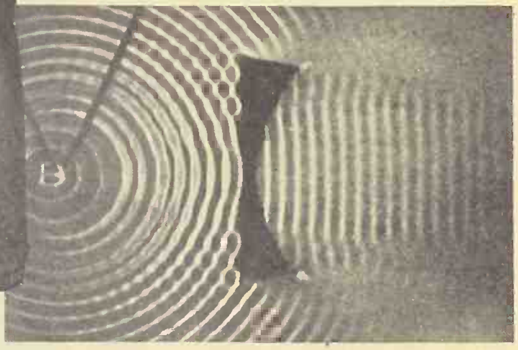
3. *Licensing.* All radio stations in the

(*Continued on page* 28)

Electronically Driven RIPPLE-TANK*

Water ripples and synchronously chopped light may be used for the qualitative and semi-quantitative study of phase fronts near models of antenna structures.

A scientist studies a radar antenna model in the ripple tank.



Wave pattern produced by a wave guide lens with water ripples.

by
ALLEN H. SCHOOLEY
Naval Research Laboratory

IN electronics work it is not unusual to have an antenna aperture across which the phase of radiation should be constant or vary in a particular manner. Often, in scanning systems, the beam tilt and the deviation from phase-front linearity with various placements of the feed point are of interest. Also it is desirable to know how the phase fronts are affected by changes in the excitation frequency. Since the calculation or experimental determination of phase-front patterns is usually a tedious operation, it appears that there is a need for a simple analog device to aid visualization of such patterns.

Since the ripple-tank is a device that has been used extensively to demonstrate most of the two-dimensional phenomena of physical optics,[1] it appeared suited for solving some problems of phase-front visualization met by electronics engineers. New techniques in the operation of the electronically driven ripple-tank were devised and applied to antenna problems, and photographs of phase-front shadow patterns near two-dimensional models of a few familiar antenna configurations were made.

Basic components of the electronically driven ripple-tank include an audio oscillator to drive a synchronous motor which has a slotted (light chopper) disk attached to its rotor. The light from a lamp is projected through the slotted disk and through the glass ripple-tank to a ground glass screen. The oscillator also drives an electromechanical transducer. A probe attached to the transducer touches the surface of the water contained in the tank and excites ripples in synchronism with the pulses of light coming from the lamp. Thus, the ripples, acting like cylindrical lenses, cast stationary light and shadow patterns upon the ground glass screen in accordance with the phase-front pattern set up in the ripple-tank.

The 11-inch square ripple-tank has beveled glass sides high enough to contain about ¼-inch of water. Two electromechanical transducers are used, one of which has a probe vibrator at the focus of a small parabola.

The light consists of a 50 candle-power automobile headlight bulb, beneath the light chopper disk. The disk is usually cut with the required number of slots to show one phase front for each cycle. However, for some demonstrations it may be advantageous to use one-half this number to spread out the pattern by showing every other phase front. On the other hand, twice the normal number of slots may be used to reduce the light flicker. In so doing the number of phase fronts in the pattern is doubled.

Intelligent use of the ripple-tank requires some knowledge of the techniques and limitations of ripple-tank operation. It is usually disturbing to note that the velocity of water-ripple propagation is dependent on wavelength, which is not the case for electromagnetic waves. However, the variation in velocity with wavelength is unimportant in most two-dimensional antenna model work because the basic scaling relationship that should be maintained is:

$$d_m/\lambda_m = d_a/\lambda_a$$

were d_m and d_a are corresponding dimensions of the model and antenna, respectively, and λ_m and λ_a are the wavelengths for the model and the antenna, respectively. Since most work requires the use of only one frequency at a time, it makes no difference what the velocity of propagation may be as long as the relationship in Eqt. (1) is maintained. All the measurements should be made in terms of wavelength and not in terms of frequency. It is interesting to note that the velocity of ripple propagation is less than the velocity of electromagnetic waves by a factor of the order of 10^9.

The increase in the phase velocity of ripples passing through a wave guide may be demonstrated by means of the ripple-tank. This suggests that some aspects of Kocks[2] wave guide antenna may be simulated by the ripple-tank. Such a lens, shown above, was designed for an index of refraction of about 0.55, and was made of ¼-inch thick brass, milled with 32 slots spaced

(*Continued on page* 27)

**Exhibited by the Naval Research Laboratory at the 1950 National Convention of the Institute of Radio Engineers.*

FREQUENCY DIVIDERS

By HAROLD E. BRYAN

The design of circuits which will produce accurate submultiples of a given frequency.

FREQUENCY dividers have not enjoyed the popularity that they deserve, due in part at least to a lack of understanding of their capabilities. To many people the term *frequency divider* means *multivibrator.* The latter is capable of very reliable operation as a frequency divider, but has a bad reputation because of many improperly designed circuits. There are in addition a number of circuits other than multivibrators available for divider service. All of these have individual advantages and disadvantages; which type is to be preferred depends on such factors as waveform, stability requirements, etc.

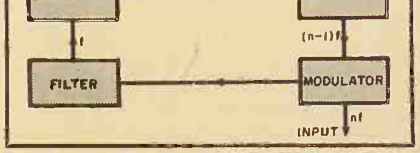
Frequency division has essentially the same applications as multiplication —production of signals controlled by and definitely related to other signals of different frequency. In most applications the output of the divider is harmonically related to the driving frequency, although this is not always true. It is possible to construct dividers which will divide by fractional as well as integral ratios. Equivalent results can usually be obtained otherwise, although probably at greater cost economically and operationally. The use of dividers is essential to the operation of such devices as crystal savers*, which would not be economically feasible without them.

Generally speaking, there are two types of frequency dividers—those that deliver sinusoidal signals without external filters, and those that don't. Aside from the waveform requirements, the divider must be sufficiently stable that tube and voltage changes normally experienced do not change the division ratio. It must also be easy to synchronize so that it is not affected by changes in the driving signal.

Dividers with sinusoidal waveform may be used when it is not necessary to have exact control of the relative phases of the driving and output signals. Since many of the applications which have pushed the development of dividers have been those that require phase control, like radar and television, not much information is available on the sinusoidal type.

One of the simplest sinusoidal dividers is the synchronized oscillator, illustrated in Fig. 2A. Harmonics in the output of an oscillator produce instability. At the same time, these harmonics are necessary to the synchronization process. Therefore, if the oscillator is quite stable, it is hard to synchronize. Synchronization in this type of circuit occurs due to interaction of an oscillator harmonic with the driving frequency. Since the effective synchronizing signal is the result of modulation in the oscillator itself, the driving signal must usually be quite large in order to obtain the necessary control. The higher the Q of the circuit the harder it will be to drive and therefore the easier it will be for it to drop out of sync without notice. Also, the higher the grid excitation, the greater will be the driving signal needed for control. If excitation is reduced, instability may result due to partial or almost complete loss of modulation action. Thus, although this type of divider has its place, due to its simplicity, it does have serious disadvantages.

Fig. 1. Disadvantages of Fig. 2A are partially overcome in this circuit by separating oscillator and modulator functions.



One way of overcoming some of the disadvantages of the simple circuit is illustrated in Fig. 1. Although this still uses a free running oscillator with its disadvantage of continued operation with loss of signal, the oscillator and modulator functions are separated. The oscillator output feeds a multiplier, generating a frequency at $(n\text{-}1)f$, where f is the synchronized oscillator frequency. The difference frequency in the output of the modulator is f (driving signal $= nf$) and this is selected and used as a synchronizing signal for the oscillator.

Elimination of the major disadvantage of the above (continued operation without controlling signal) is easy—eliminate the oscillator, as shown in Fig. 3. We saw above that the output of the modulator driven by signals of nf and $(n\text{-}1)f$ contains the frequency f, and this is the desired output frequency. The signal at $(n\text{-}1)f$ is supplied from the output itself through a frequency multiplier. If the gain around the loop containing the modulator and frequency multiplier is equal to or greater than one, the circuit will operate just like any regenerative oscillator, provided the driving signal is present. The loop gain is made less than one at all other frequencies to prevent improper operation. High ratios may be obtained with this type circuit, although high selectivity is necessary in the multiplier to prevent change in the ratio.

The discussion so far assumes the use of square-law modulators. Higher orders may be used to obtain different results. By selecting a harmonic in the frequency multiplier as an output frequency, it is theoretically possible to multiply or divide by any rational ratio.

This type of circuit is not all advantage. It is relatively complex and may not be self-starting. Sometimes it is necessary to supply a starting signal by means of thyratrons or similar devices. These dividers are limited in operating frequency only by the limitations of the modulators and frequency multipliers employed, and therefore may be used in many radio frequency applications.

An interesting application of this type of circuit is shown in Fig. 5. Here the input frequency is divided by two and then multiplied, providing outputs at $f/2$ and $nf/2$, where n is an odd integer. This is accomplished with one modulator and one tube.

Dividers With Non-Sinusoidal Output

Of the relaxation types of frequency dividers, the multivibrator is the best known. A free running type may be used if continuous division is desired, although the same disadvantage is ex-

*Bryan, Harold E., "Crystal Savers", RADIO-ELECTRONIC ENGINEERING, March, 1950.

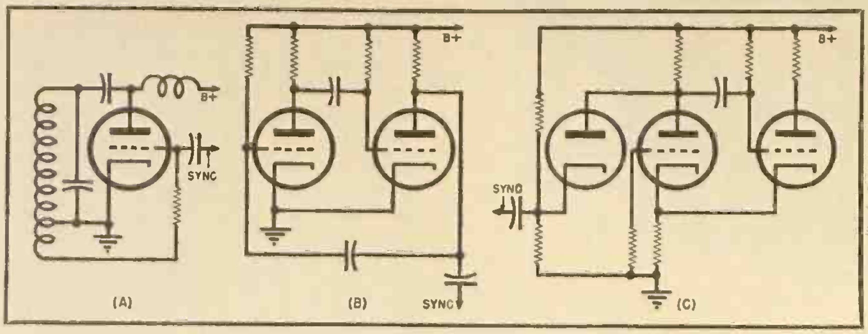


Fig. 2. (A) Synchronized oscillator. (B) Free-running multivibrator frequency divider. (C) Frequency divider which oscillates only when triggered.

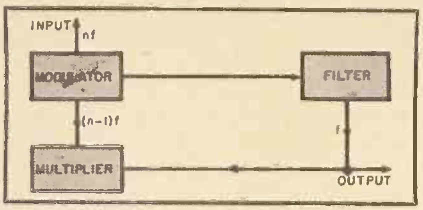


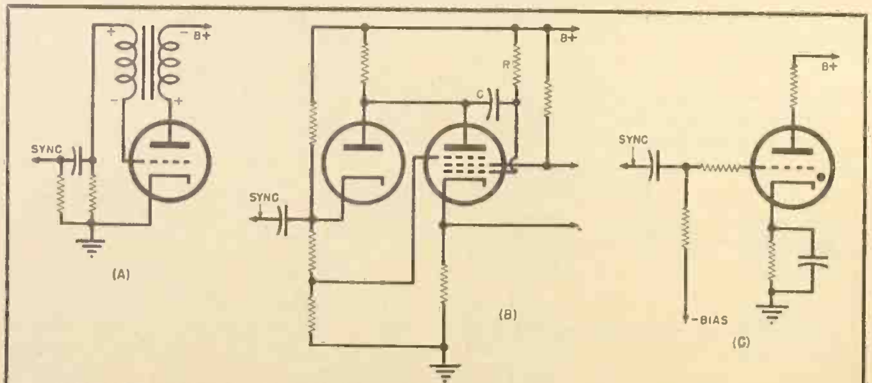
Fig. 3. Circuit resulting from eliminating the oscillator in Fig. 1.

perienced here as in the previous types, since oscillation continues in the absence of synchronizing signal. All of the relaxation types of oscillators are easy to synchronize, however, and simple in construction.

In the free running multivibrator, proper design is important; otherwise unsatisfactory operation is certain. In the preferred design the unsynchronized portion of the period is slightly less than half the total, and the synchronized part thus a little greater than half. Grid resistors should be large, at least one megohm if possible, and plate resistors used should provide large plate swing. If these factors are considered, the divider will be very stable under synchronized conditions, and quite tolerant of driving waveform. Synchronizing signals are applied to the grid or plate of one tube. A multivibrator of this type is illustrated in Fig. 2B.

A more desirable type of multivibrator oscillates only when triggered. It has one stable and one unstable state, and depends for its action on the fact that when it is in its unstable state synchronizing signals have no effect. As seen in Fig. 2C, this type multivibrator is maintained in the stable condition by cut-off bias on one grid, and zero or low bias on the other tube. A trigger signal cuts off the originally conducting tube and opens up the other. Since there is nothing but a time constant to maintain this condition, it returns to the original state when the charge has leaked off the grid enough to allow conduction to again take place. Because the tubes are connected in a regenerative manner, the change from one state to the other is abrupt rather than gradual. The cathode coupled circuit is popular, the cut-off tube being maintained so by the current from the conducting tube through the cathode resistor. This resistor should be relatively large in value. The plate resistor of the cut-off tube should also be large, in order to provide a large plate swing and supply a maximum of signal to the following grid. The negative trigger required is usually fed to the plate of the cut-off tube through a biased diode. The diode insures that no triggering signals are applied during the unstable period, since it is cut off during this time. Satisfactory operation is obtained with almost any kind of triggering signal of sufficient amplitude, and the division ratio will be quite stable with respect to voltage and tube changes.

Fig. 4. (A) Blocking oscillator circuit. (B) The phantastron circuit used as a frequency divider. (C) Thyratron used for frequency division.



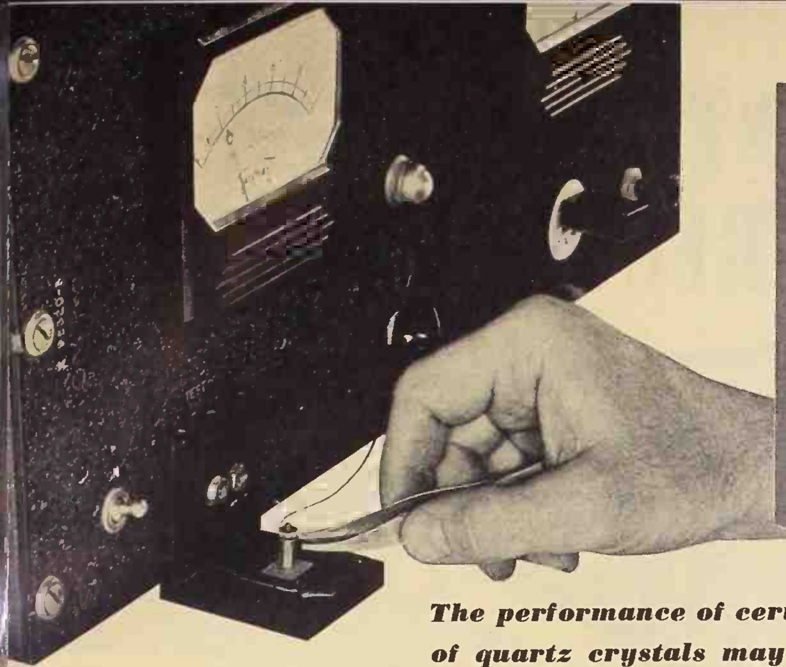
Blocking oscillators may be used as frequency dividers where pulsed output is desired. A typical circuit is shown in Fig. 4A. Since the blocking oscillator presents a very low impedance to the driving signal, it is difficult to synchronize. Triggering from a high impedance source is possible through a shunt feed sort of circuit, but there may be severe reaction on the driver. The blocking oscillator is more sensitive to voltage, tube and signal changes than the other types so far discussed.

Operation is normally such that the free running frequency is slightly lower than the synchronized frequency. A positive signal voltage is applied to the grid, driving the plate in the negative direction. Due to the regenerative connection between the plate and grid, the drop in plate voltage causes a rise in grid voltage, driving it still more positive. When plate saturation is reached, the plate voltage begins to rise and the grid voltage to drop. Again the regenerative action takes hold and the grid is rapidly driven beyond cut-off. After the tube has been cut off, nothing can happen until the grid voltage leaks off to the point where a trigger pulse can start conduction again. The signal pulses are ineffective while the tube is conducting and when the grid bias in the quiet period is greater than the trigger amplitude. The trick is to get the circuit constants and driving signal so adjusted that the tube will fire on the *nth* but not on the $(n\text{-}1)th$ pulse. Any variation in these values will tend to produce a change in the division ratio.

The blocking oscillator has the same major disadvantage, also, as the other types of free running dividers—continued operation without driving signal—and so gives no warning of trouble in previous stages. Its principal use is in the production of very short pulses. These dividers can be stabilized to some extent through the use of resonant circuits in the cathode lead. The voltage developed across this circuit so modifies the timing waveform on the grid that the *nth* trigger pulse is accentuated with respect to the others. Sometimes more than one such circuit is used, each with different resonant frequency. Frequency for the resonant circuits is usually chosen such that it is $(A + \frac{1}{2})$ times the output frequency, where A is an integer.

The phantastron may be used as a divider, and in such service offers a high ratio of utility to cost. This circuit, developed during the late war for use in gate and sweep generators, is very stable and reliable, and requires a minimum of parts. The division ratio is

(*Continued on page* 30)



Experimental arrangement used at NBS to investigate a phenomenon associated with wedge-shaped crystals.

LOADING QUARTZ CRYSTALS

The performance of certain types of quartz crystals may be improved in some instances by loading with inert materials.

THE ERRATIC performance of piezoelectric plates has long been a problem in the production of oscillator units, and many investigations have been undertaken to determine the causes of instability. Experimental results obtained by Leland T. Sogn of NBS over the past few years show that it is possible to improve the performance of certain types of thickness-shear quartz plates by coating their surfaces with some inert material. Two distinct effects have been noted: first, that produced by an amount of the loading material so small that the resultant frequency change is as little as 0.03% of the crystal fundamental; and, second, that produced by a much larger mass of the loading material properly distributed over the central area of the crystal. The latter seems to have the beneficial effects now achieved by contouring, a difficult and expensive process. The potential usefulness of loading thin crystals to improve performance as well as to recover plates ground too thin in the production stage should encourage further research on the various aspects of quartz-crystal loading.

A phenomenon associated with a wedge-shaped 0.5 x 0.6-inch BT oscillator plate (width parallel to the *x*-axis) prompted the present investigations. When the electrodes coupling the oscillator plate to the electronic circuit were placed over the thicker portion of the plate, the frequency was not only lower, as anticipated because frequency is inversely proportional to thickness, but the activity was considerably higher, shown by the magnitude of the grid current. Lower frequency was associated with higher activity or amplitude of vibration, and vice versa.

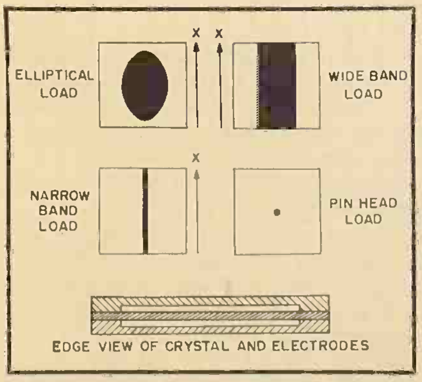
To investigate this phenomenon a small ¼-inch probe electrode was employed. With this electrode, it was possible to confine the energy fed back from the electronic circuit to a small area of the plate and thereby obtain a series of frequencies and activities as the electrode was moved in short steps from the thick to the thin portion of the plate. In "flat" plates the frequency fluctuated about a mean value as the electrode was moved over the plate surface, and it was found that activity measurements as well as frequency measurements can be used to detect minute differences in thickness which were not disclosed even by instruments sensitive to differences of less than 20 microinches. Activity readings were actually used to check and control the contour of plates during the process of hand-grinding.

In most of the hand-finished plates used in these experiments, positions determining a certain frequency were found to be scattered indiscriminately over the surface although some oscillator plates had contour and edge conditions such that only a few, nearly equal frequencies could be obtained. For example, in an 8.7-mc. plate with only two frequencies about 5 kc. apart, the frequencies would alternate from one to the other as the electrode was moved across a line roughly parallel to the *x*-axis, which divided the plate into two approximately equal areas. This plate apparently was composed of two approximately equal flat areas which differed in thickness by the equivalent of a 5 kc. difference in frequency. The balance between the two frequencies was so delicate that a rapid alternation between the two frequencies could be obtained by adjusting the temperature or circuit constants, resulting in an audible "motorboating" effect in the measuring equipment. Changing the length, or *z* dimension, by alternately grinding opposite edges (parallel to the *x*-axis) produced anticipated results. When the edge bounding the thick end of the plate was ground, the higher frequency became dominant because the area of the thin, high-frequency plateau became relatively larger. Subsequent grinding on the other edge reversed the effect: when the thicker area was relatively larger, its lower frequency was dominant. This procedure was repeated several times with identical results.

Experiments were also carried out using machine-lapped convex crystals. Results were similar, but one new fact was disclosed. The lowest frequency, excited when the small electrode was placed at the exact center of the plate,

(*Continued on page* 24)

Schematic representations of the various "load patterns" applied to quartz plates in an investigation of the effects of loading on performance.



AUTOMATIC ANTENNA PATTERN RECORDER

Fig. 1. Components of the automatic antenna pattern recording system. Left to right—logarithmic amplifier, antenna mount, and graphic recorder.

By SAMUEL FREEDMAN

Details of a system for determining antenna radiation patterns rapidly and accurately.

THE efficient transmission and reception of electromagnetic waves in the radio portion of the frequency spectrum is primarily dependent on the utilization of antennas of proper shape and dimension to provide the best radiation patterns.

This has made necessary the development of facilities for checking antennas and equipment performance into antennas. Such checking of performance and radiation patterns is necessary in any phase of the radio art whether it corresponds to basic research, development, prototype or quantity production. It is particularly true for microwave equipment where the smallest dimensional design or manufacturing discrepancy, or a deformation, of the antenna system is appreciable with respect to the operating wavelength.

Consequently, throughout the nation today, hundreds of laboratories, manufacturers and field parties are engaged in antenna radiation pattern studies. Offshoots of this work include checking ship radar antenna behaviour as influenced by ship structural work, checking GCA (Ground Controlled Approach) equipment on runways, the efficiency of surveillance radars, and the beamwidths of microwave relay systems. Invariably, much time and expense is lost in setting up for such measurements with manual recordings and arrangements. Under such conditions, as little as two patterns per day are obtained. When the radar antenna firm of *Dalmo Victor* in San Carlos, California, had the problem of taking hundreds of antenna radiation patterns, quicker and simpler means of setting up for each pattern was imperative. Furthermore, these had to be extremely precise and permanently recorded since one-half of the value of any radar is its ability to get precise angle or directivity information; the other half being the range or distance.

Accordingly, there was developed the "Automatic Antenna Pattern Recording System" for presenting the antenna pattern on a recorded sheet. On this sheet, rectangular coordinates are used with the abscissa representing angle in degrees, and the ordinate the log of the power and the intensity.

Fig. 1 shows the three basic units comprising the entire automatic antenna recording system. From left to right these are:

1. Logarithmic amplifier to amplify the signal picked up from the antenna.
2. Tripod antenna mount to support and change the angle of the antenna under test.
3. Graphic recorder to record the information.

The system is unique in the use of an extremely universal antenna mount, ability to take readings or recordings in three minutes per pattern instead of up to half a day as in the past, ability to reproduce the pattern and provide a permanent record, and the equipment is simple enough to be operated by untrained personnel.

Antenna patterns can be taken in any arbitrary plane through a full rotation of 360 degrees, or any fraction thereof, over a power range of 0-50 db. to an accuracy of plus or minus 1 db. The equipment is connected together by means of cables. A common ground wire connects all the units together.

For ease in adjustment, an antenna reversing switch is provided at the antenna mount while the on-off switches and the 115 volt a.c. cords are on the graphic milliammeter and the logarithmic amplifier. Antenna position is transmitted to the recorder by means of a selsyn system and it is so adjusted that 10 degrees of rotation causes a movement of 1 division on the graph paper. The antenna patterns are recorded in only one direction. A small throwout gear is provided for disengaging the recorder while the antenna is being adjusted or reversed in direction. This same gear also makes it possible to properly engage the selsyn system so that the zero degree reference point falls upon a given line of the graph paper.

The additional equipment required for pattern measuring work consists of a suitable transmitter and receiver system with a square law detector. Sufficient amplification should be available to present the logarithmic amplifier with 100 volts at the zero db. level.

Antenna Mount

The antenna mount (center of Fig. 1) consists of a tripod stand which is adjustable in height from 42" to 60" and will support a top load of 150 pounds. The antenna may be mounted by means of a suitable bracket to the "T" slots of the rotary head which is fastened to the mounting plate of the tripod. The rotary head is in turn driven by a 115 volt a.c. 1/70th horsepower reversible motor at a rate of 60 degrees per minute. This motor also drives the transmitting selsyn at 60 times the speed of the rotary head or 10 r.p.m. Selsyn inaccuracies resulting from slip torque are thereby reduced since a high selsyn speed to recording speed ratio is maintained by this arrangement. The antenna position can be read directly off a scale placed on the rotary head in degrees of rotation. A vernier is provided by which accuracies to greater than 1/10th degree can be read. By approximation, this can be further read to 1/100th of a degree.

Below the mounting plate are mounted the selsyn, driving motor, reduction and coupling gears, motor reversing switch and the cable connector. The driving power from the motor is transferred to the rotary head by means of a sprocket and chain link.

The control system can be separately used, either by use of the chain link as is, or by using an additional length of chain to the rotary head. This can take care of installations or occasions where it is desired to dispense with the tripod mount in favor of some other particular mounting. Should the installation or occasion require a completely separate antenna mount, an additional selsyn can be provided. It is desirable, however, that the rotary speeds of such systems be limited to a maximum of 60 degrees or one-sixth revolution per minute. This maximum rotational speed is governed by the rate of response of the graphic milliammeter recorder. It has been found that for speeds in excess of 1/6th r.p.m. the recorder will fail to faithfully reproduce quick power changes in the antenna pattern. It is further necessary to maintain the selsyn's speed to the antenna speed at 60-to-1 for proper recording relationship. This is 10 degrees per division on the recording paper.

The total power consumption to motor and selsyn is 48 watts at 115 volts.

Graphic Recorder

The graphic milliammeter employed is the *Esterline Angus* Model AW illustrated to the right in Fig. 1. It has a 0-1 ma. movement and 1250 ohm d.c. resistance. The information records on a strip graph using standard graph paper.

The meter movement results from power obtained at the motor jack of the logarithmic amplifier. The graph paper is driven directly by the receiving selsyn through a 20-3 gear reduction system. By this means, one division on the graph paper represents 10 degrees of rotation of the system under test.

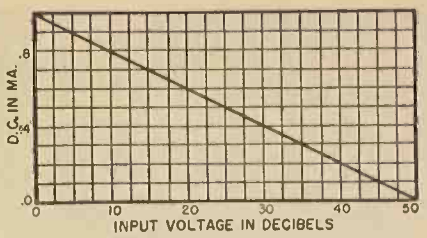


Fig. 2. D.c. output current in ma. vs. input voltage in decibels.

The gear drive for the drum of the graphic recording instrument may be disengaged by means of the lever on the mounting so as to allow the selsyn to turn freely or as required to position the chart strip. It is recommended that the gears be disengaged at all times except when recording. The antenna information can be recorded in one direction only. The unidirectional drive feature allows the chart drum to be driven only in the forward direction.

When turning the equipment on, the receiving selsyn will tend to hunt or rotate if an off-phase position combination of the selsyn link exists as current is applied. In such cases, the current needs to be immediately removed. Such hunting or rotation can then be prevented by damping the movement of the selsyn with one's finger and reapplying the current to the system.

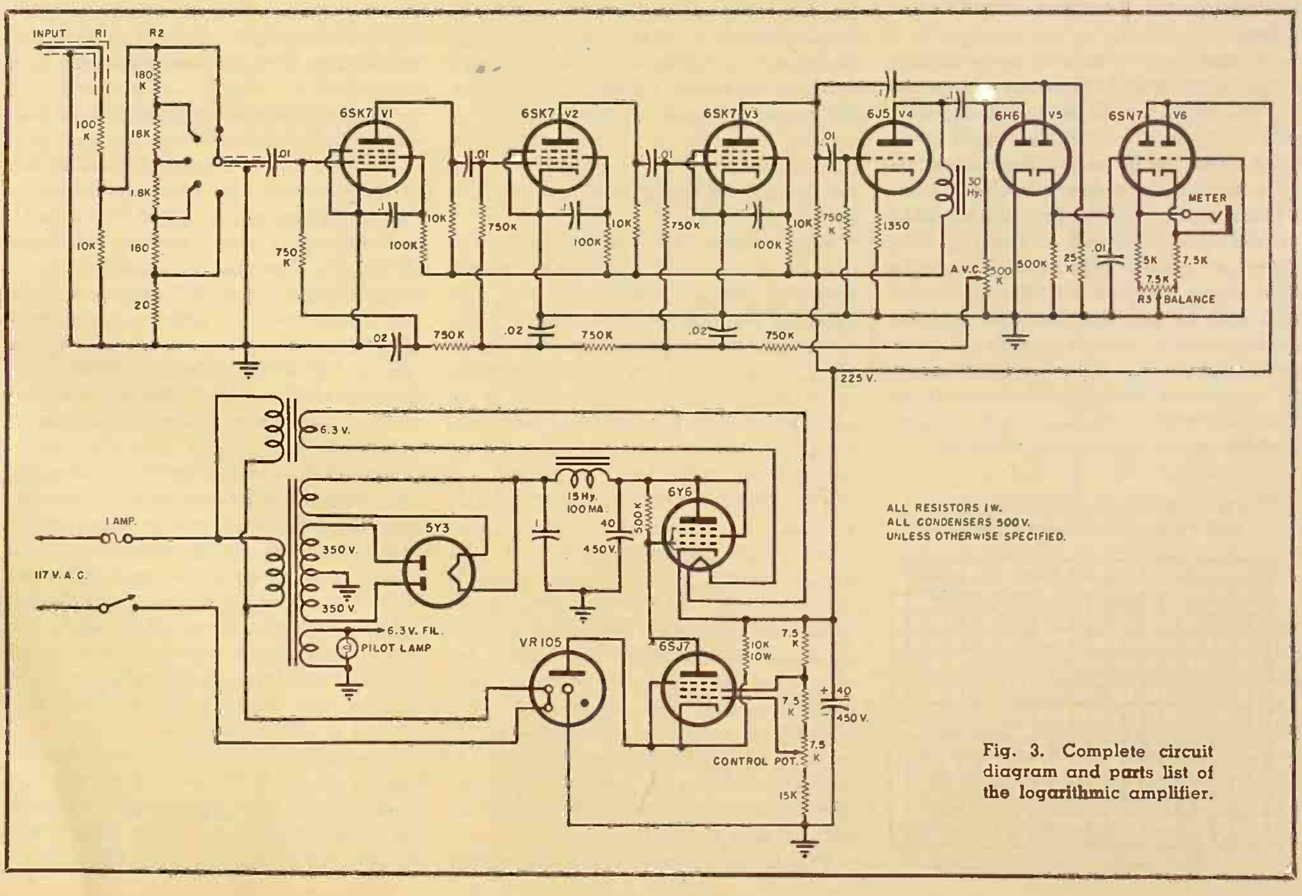


Fig. 3. Complete circuit diagram and parts list of the logarithmic amplifier.

Fig. 4. Antenna pattern penthouse test shacks atop the Dalmo Victor plant.

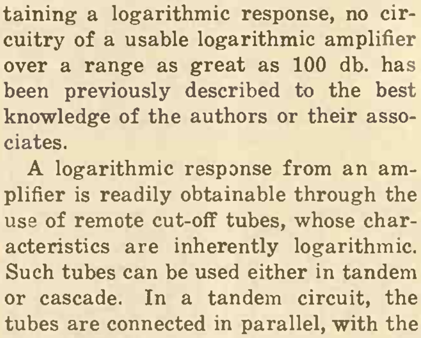
Should noise or other reasons make it necessary in a particular installation to ground the instruments, the grounding of either the tripod or graphic recording milliammeter should suffice since a ground connection between the two sections has already been provided.

Logarithmic Amplifier

The use of a logarithmic, rather than linear, amplifier is desirable where large variations in output are involved as in the case of automatically recorded antenna patterns. While there have been many methods described for obtaining a logarithmic response, no circuitry of a usable logarithmic amplifier over a range as great as 100 db. has been previously described to the best knowledge of the authors or their associates.

A logarithmic response from an amplifier is readily obtainable through the use of remote cut-off tubes, whose characteristics are inherently logarithmic. Such tubes can be used either in tandem or cascade. In a tandem circuit, the tubes are connected in parallel, with the control grid of each successive tube biased at a different level. Each tube then works between cut-off and saturation with its grid voltage-plate current characteristics operating over a given portion of the logarithmic output range. By proper overlapping of the working characteristics of the successive stages, a rather good logarithmic response can be obtained. The cascade amplifier as described in this article consists of several stages of amplification connected in series in a conventional manner. By applying the output of such an amplifier as negative bias voltage to its grids, it is possible to obtain a non-linear amplifier whose output is proportional to the logarithm of the input. This approach has been found preferable even though greater ranges may be obtained from the tandem circuit at a cost of less stability and having its response dependent upon individual tube characteristics.

Fig. 5. D.c. output current vs. d.c. grid voltage to cathode follower.



It can be used over a frequency range of 200 to 20,000 cycles per second between 0-100 db. to an accuracy of plus or minus 1 decibel. The a.v.c. circuit, however, will not faithfully respond to frequencies above 200 cycles per second. As used in practice, with a square law detector such as a bolometer or crystal, the effective range of this amplifier is reduced by a factor of two. Therefore, in antenna recording equipment, it can be thought of as having an effective range of 0-50 db.

Fig. 3 shows the circuit diagram and parts values of the logarithmic amplifier with cascade amplification as successfully employed in this automatic antenna pattern recording system. Tubes V_1, V_2 and V_3 are three 6SK7 amplifiers in cascade. The type 6SK7 tube is an extended cut-off pentode. Its grid voltage-plate current characteristics are approximately logarithmic in nature.

The output of the last stage of 6SK7 cascade amplification (V_3) drives a rectifier circuit (one-half section of type 6H6 tube V_5) which in turn directly drives a 6SN7 d.c. output stage (V_6). A balance circuit has been placed in the cathode circuit of the 6SN7 stage to account for unbalance caused by tube differences and the emission potential of the 6H6 rectifying circuit. The meter is driven directly by the difference in potential existing between the two cathodes of the 6SN7 tube with various input voltages applied.

The a.v.c. voltage needed to obtain logarithmic response over a 100 db. range is approximately 15 times greater than the voltage available from the last 6SK7 tube. This deficiency is taken care of by having the last cascade stage (V_3) drive a 6J5 a.v.c. amplifier (V_4) which has a constant gain exceeding 15. This in turn drives the other section of the 6H6 tube which supplies and rectifies the a.v.c. voltage and feeds it back to the grids of the cascade amplifier.

It can be observed in the graph of Fig. 5 that the d.c. amplifier characteristics tend to level off toward the high end of the scale. This tends to flatten out an opposing characteristic of the 6SK7 cascade amplifier, producing an improved logarithmic response over the entire range.

Best results are obtained from the amplifier in the 10-.001 volt range. Since standard bolometer and crystal amplifiers most used in the field are designed for a maximum output of 100 volts, a 10:1 voltage divider (R_1) has been placed in the input circuit of the amplifier. This voltage divider needs to be changed if the amplifier is used in an application that differs in this respect, so that a maximum signal of 10 volts will be applied to the grid of the first 6SK7 at the 0-db. level.

A calibration switch has been included at the input of the amplifier for R_1. This switch controls a calibrated attenuator having five positions in steps of 20 db. each. When used with a square law detector, it can be considered to be in steps of 10 db. each. It is used for calibration purposes and as a step gain control.

The logarithmic amplifier can be best calibrated as follows:

1. With the calibration switch at the 0 db. position and 100 volts input to the amplifier, adjust the a.v.c. potentiometer until a 1 milliampere movement is noted on the graphic recorder.

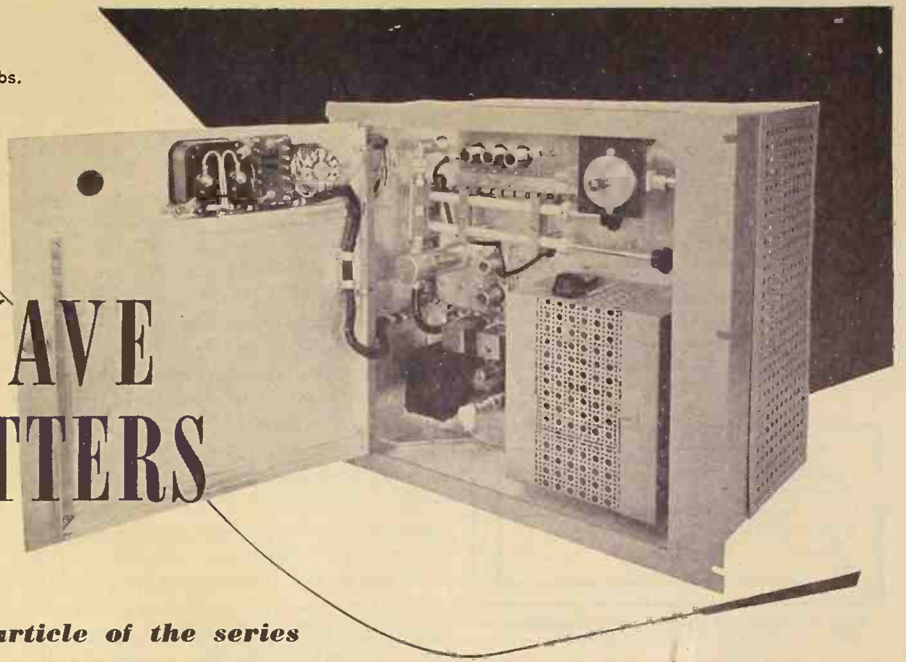
2. Change the calibration switch to its lowest position (80 db. down) and adjust the balance adjustment (R_3) so that a 0.2 ma. movement is noted on the graphic milliammeter. Repeat this procedure until these two positions are in full agreement.

For high stability and low noise, the amplifier is supplied with a low impedance regulated power supply. The voltage of this supply can be regulated for values between 200 and 250 volts and will maintain a given voltage for changes in a.c. voltage from 90 to 135 volts. Its internal resistance is approximately 25 ohms. For best logarithmic results, the voltage should be maintained at 225 volts d.c.

The manufacture of this amplifier requires all of the finery normally encountered in high gain amplifier design, particularly in this case where the

(*Continued on page* 28)

By J. RACKER
Federal Telecommunication Labs.



MICROWAVE TRANSMITTERS

Part 2. The concluding article of the series on microwave transmitters includes a discussion of positive-grid oscillators, klystrons, and magnetrons.

Microwave transmitter operating in the 952 to 960 mc. band. Klystron is located within shield on righthand side of chassis.

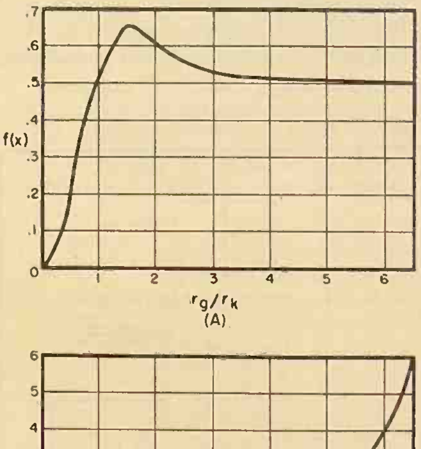
In the first article on Microwave Transmitters[1], it was shown that in order to employ standard negative-grid oscillators at microwave frequencies it was necessary to develop special triodes in which the electron transit time was small compared to a period of oscillation. In this case the effects of electron transit time were considered detrimental to the power output and efficiency of the circuit. In this article we shall consider microwave transmitters which depend upon the finite period required for an electron to travel between plate and cathode to effect oscillation. These oscillators, sometimes referred to as transit time oscillators, include positive grid oscillators, klystrons, magnetrons, traveling wave tubes and resnatrons.

Positive-Grid Oscillators

The simplest and earliest type of transit time oscillator is the positive-grid oscillator. This type of oscillator is not used very often today because of its low power output and efficiency. However, for the purpose of this article, it has more than historic importance since it clearly demonstrates the basic principles upon which all later type oscillators operate. A clear picture of the operation of this circuit would greatly help the reader to understand the principles of the more complicated tubes.

Consider the motion of an electron leaving the cathode of the simple circuit shown in Fig. 3 in which the grid is positive with respect to both cathode and plate (with plate and cathode at same potential). The electron emitted from the cathode is accelerated as it approaches the grid plane. Passing between the grid wires, the electron enters the grid-plate region where it is decelerated. It comes to rest momentarily in the vicinity of the plate, reverses its direction of travel, and is accelerated towards the grid plane, which it then "overshoots" and the process is repeated. The phenomenon is very closely parallel to that of the oscillation of a damped pendulum (damped due to the fact that the electron loses some energy during each cycle). Eventually the electron will strike a grid wire and be absorbed in the grid circuit.

Fig. 1. Plot of (A) f(x) and (B) g(y) for Eqt. (2).



If no other parameters were introduced in the circuit, many individual electron oscillations would occur in the space between cathode and plate; the exact phase and amplitude of oscillation between any two electrons would depend upon the time at which the electrons were emitted and space charge at that time.

Now assume that an alternating voltage is superimposed on the grid potential whose frequency is double that of the natural oscillation of the electron stream as shown in Fig. 2, and maximum amplitude very much smaller than the d.c. voltage V_o. Let us define the velocity v_o as the velocity of the electron at any point in the cathode-plate space with the grid potential at the d.c. value V_o.

Consider the relative velocities of electrons leaving the cathode during grid a.c. potential of *A*, *B*, and *C* shown in Fig. 2. An electron leaving during time *A*, travels at a velocity less than v_o in the cathode-grid plane because during this time the grid is always at negative a.c. potential. It loses more velocity between grid and plate since during this time the grid is positive. Thus, its over-all velocity is less than v_o.

An electron leaving the cathode with grid at time *B* will travel at about v_o since both during its cathode-grid and grid-plate paths the grid is positive half the time and negative half the time. Finally an electron emitted at time *C*

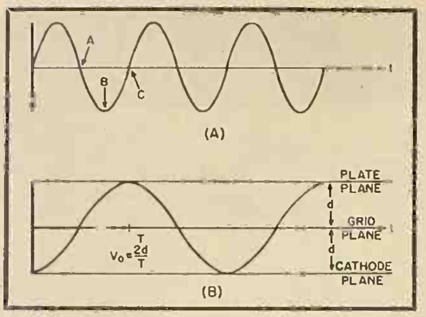


Fig. 2. Graph of (A) grid a.c. voltage and (B) electron transit with frequency double that of the natural frequency of a positive grid oscillator.

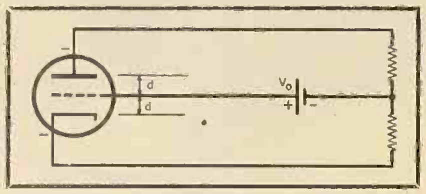


Fig. 3. Simplest positive grid oscillator.

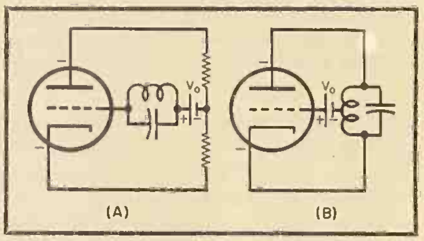


Fig. 4. Schematics diagrams of two different types of positive grid oscillators.

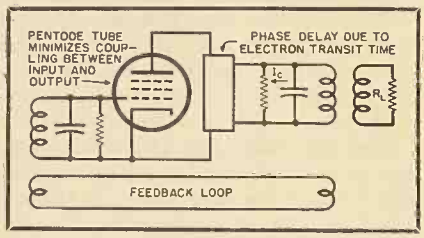


Fig. 5. Equivalent circuit diagram for a double resonator klystron oscillator.

will travel at a velocity greater than v_o, since grid is positive when it is in grid-cathode plane and negative in the grid-plate plane. It is readily seen that electrons emitted at time C tend to catch up to electrons emitted at time A, so that electrons will tend to oscillate in "bunches" instead of completely at random. Of course this analysis is very approximate assuming that no space charge exists to vary the progress of the electron stream and that a.c. variation is very small compared to the d.c. so that an electron leaving the cathode at time A arrives at the grid at time B although grid a.c. potential has been negative.

To obtain the desired a.c. potential on the grid, two circuits may be used as shown in Fig. 4. The tuned circuits shown in this figure would be either a resonant line or cavity depending upon frequency of operation. These circuits operate in the following manner: The oscillating electron space charge induces an alternating component of current in the external circuit. The resulting voltage drop across the load impedance produces an alternating field in the interelectrode space of the tube. Those electrons which oscillate in this field in such a phase as to be retarded by it transfer a portion of their energy to the resonant circuit during each cycle of operation.

The frequency of the circuit shown in Fig. 4A, for V_m (maximum value of a.c. component) much smaller than V_o, is given by the following relationship[5]:

$$f = \frac{148 \times 10^7}{V_o\, d} \qquad (1)$$

where d is in cm.

Eqt. (1) indicates that the frequency of oscillation is completely independent of the resonant frequency of the external circuit and depends only on V_o and the distance between cathode or plate and grid. In practice it has been found that oscillation can exist even though the resonant frequency of the external circuit differs from the fundamental frequency or a harmonic of the frequency of electron oscillation. However, an abrupt change in wavelength and pronounced increase in power output occurs when the external circuit is tuned to the fundamental or a harmonic frequency. A possible explanation for this is that when the external circuit is tuned to the electron oscillating frequency, it absorbs more power. This increases the a.c. potential amplitude V_m—which causes a shift in frequency.

The frequency of the circuit using cylindrical-electrodes shown in Fig. 4B, which acts in much the same manner as far as its external circuit is concerned as the circuit discussed previously, is given by[5]:

$$f = \frac{1.5 \times 10^7 \sqrt{V_o}}{[f\ (x) + g(y)]\ r_g} \qquad (2)$$

The quantities $f(x)$ and $g(y)$ are function of the cathode radius r_k, grid radius r_g, and plate radius r_p. These functions are plotted in Fig. 1.

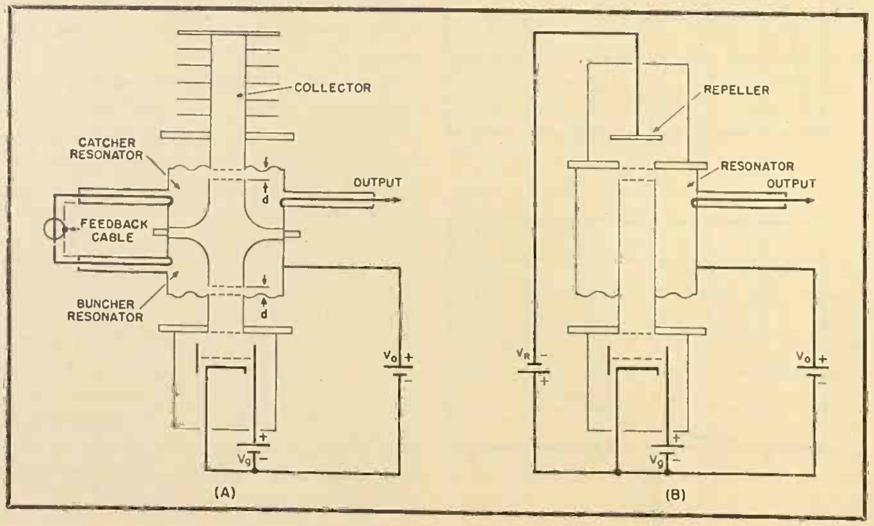
Klystron Oscillators

A tube that utilizes the basic principles of the positive-grid oscillator with greater efficiency and power output is the klystron. It is apparent that the more effectively the electrons are "bunched" the higher the frequency stability, power output and efficiency. Three conditions are necessary to achieve optimum bunching and they are: 1) The velocity of the electrons must be very large compared to the change in velocity caused by the a.c. voltage for reasons previously outlined. 2) The change in velocity due to the a.c. voltage must be great enough for the faster electrons to catch up to the retarded ones, and 3) space charge must be negligible.

The klystron tube is designed to optimize each of these conditions as much as practical. Two types of klystrons, shown in Figs. 6A and B, are available. Consider the klystron shown in Fig. 6A, known as the double-resonator klystron. The cathode and grid of this tube comprise an electron gun which accelerates the electron stream to a very high velocity. This permits condition 1 mentioned above to be satisfied with relatively large a.c. amplitudes.

This electron stream is further accelerated by a "buncher" grid which is at high d.c. potential and—due to the action of the buncher resonator—contains an a.c. component. The frequency of this a.c. component—determined by the cavity resonance frequency—should be the same as the desired "bunching" frequency. This a.c. component will retard or further accelerate the electrons, depending upon its instantaneous value,

Fig. 6. (A) Double resonator klystron, and (B) reflex klystron construction.



and cause bunching as accelerated electrons catch up to retarded ones.

The electron stream, then passes through another grid known as the "catcher" grid. Immediately behind this grid is a collector. Both "catcher" grid and collector are at the same potential as the bunching grid. The catcher grid is tuned to the bunching frequency through another resonator, known as the catcher resonator. The phase of this grid a.c. is such as to retard the beam during the periods that the "bunched" electrons are passing so that energy is transferred from the beam to the resonator circuit. The collector carries off the excess electrons so that the space charge will be minimized.

It should be noted that a traveling wave effect occurs across each grid, i.e., the instantaneous voltage is not constant over the entire grid but varies sinusoidally as a function of distance. If the grid length is large compared to a wavelength, many harmonics will be set up. This is indicated graphically by the Applegate diagram shown in Fig. 7. It is therefore possible to use the klystron as a frequency multiplier by feeding in a signal and tuning the catcher cavity to a harmonic of the input signal. Similarly it is possible for one klystron to operate over a series of harmonically related frequencies—all other parameters remaining constant.

Fig. 5 is a schematic diagram of the equivalent circuit of a klystron oscillator. The multigrid tube emphasizes the isolation of catcher and buncher circuits. The two tuned circuits represent the two resonators. The current I_c is the induced current flowing in the catcher resonator. The output to input coupling represents the feedback circuit. The resistance R_L represents the load.

Using this equivalent circuit and the Applegate diagram shown in Fig. 7 as a basis, it is possible to derive a relationship between the voltage stability of the double resonator klystron and the accelerating voltage, the harmonic at which the klystron is operating, and the Q of the tank circuit. This relationship is

$$\frac{\Delta f}{f} = \frac{N}{2Q} = \frac{dV_o}{V_o} \qquad (3)$$

where N is the harmonic of operation, and Q is the loaded Q of the resonator (catcher).

Two characteristics of the double resonator klystron are apparent from Eqt. (3). One is that the frequency stability is proportional to the voltage stability and the Q of the resonant circuit. The second is that it is possible to frequency modulate or tune a klystron by changing the accelerating voltage.

Another form of klystron oscillator, shown in Fig. 6B, utilizes the reflex principle for obtaining feedback. The

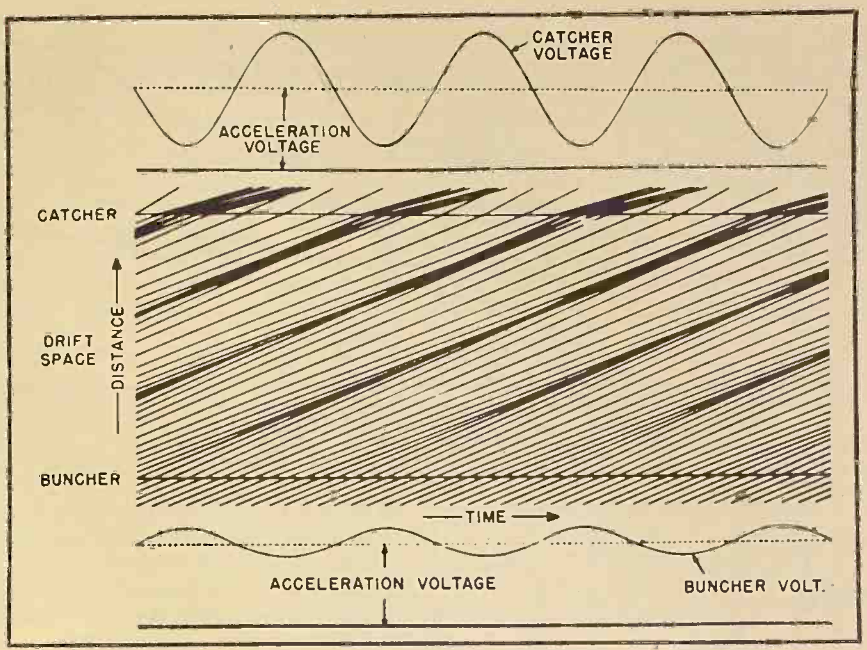


Fig. 7. Applegate diagram showing electron bunching in a klystron.

electron beam is velocity modulated as it passes between the resonator grids. A retarding electric field beyond these grids due to the repeller which is operated at a highly negative voltage causes the beam velocity to decrease to zero and reflects the beam back through the resonator grids. Bunching occurs during the transit interval during reflection. The reflector distance may be much shorter than the drift space in a double resonator klystron because the electrons travel the distance twice and their velocity is nearly zero during a part of the transit time.

The reflex klystrons are used for low power (of the order of up to 10 watts) oscillators. They are more convenient to use because only one resonator must be tuned rather than two. As in the double resonator klystrons harmonics are set up within the tube so that it may be operated at a number of harmonically related frequencies.

The frequency of a reflex klystron is primarily dependent upon the reso-

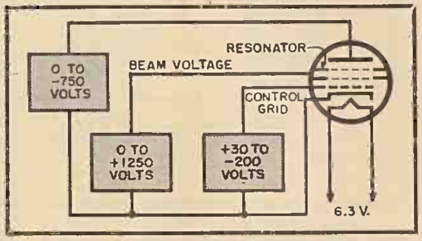


Fig. 8. Block diagram of basic oscillator circuit for a reflex klystron.

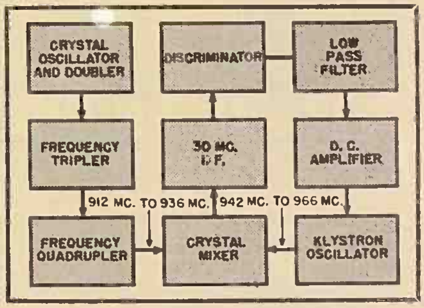
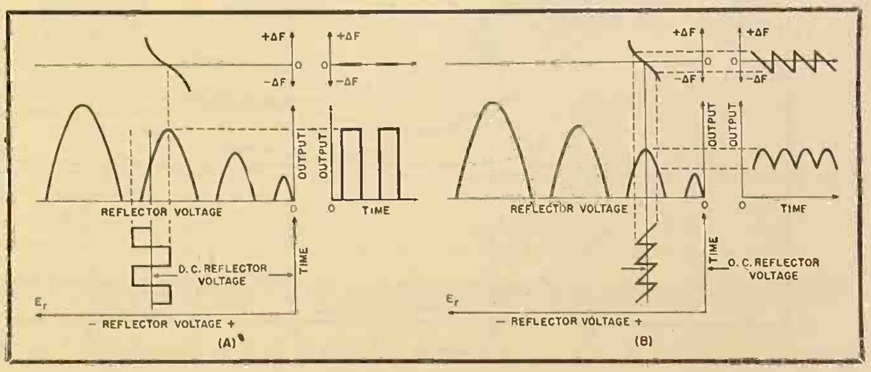


Fig. 9. Typical crystal controlled center frequency stabilization system.

Fig. 10. (A) Typical pulse modulation and (B) typical frequency modulation of a reflex klystron type of oscillator.



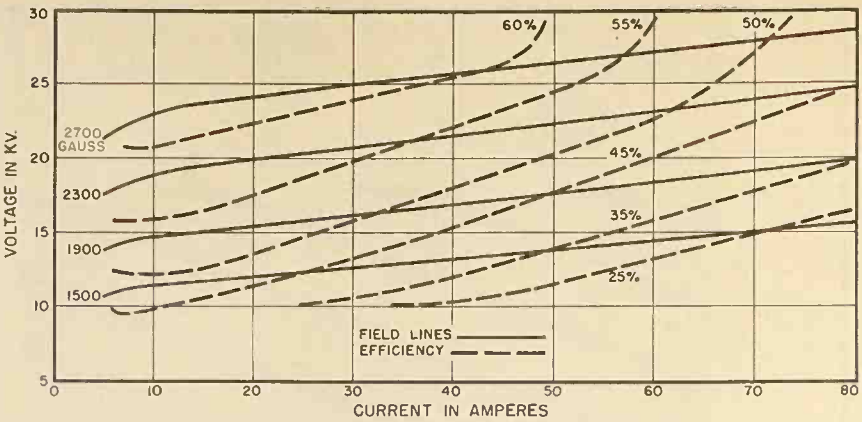


Fig. 11. Typical performance chart of magnetron including plots of voltage, current, magnetic field and efficiency.

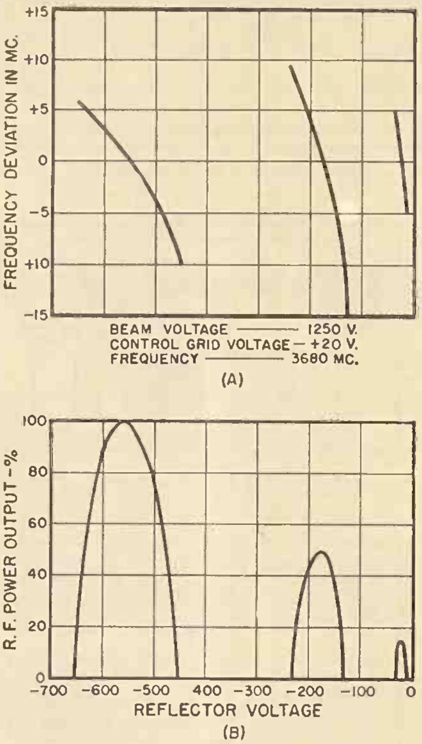


Fig. 12. Typical reflector characteristics for reflex klystron oscillator.

nant frequency, the accelerating voltage, and the repeller voltage. The most sensitive of these parameters is the repeller voltage—i.e., a small change in repeller voltage causes a relatively large change in frequency. Consequently it is this voltage that is usually varied for tuning or frequency modulation purposes.

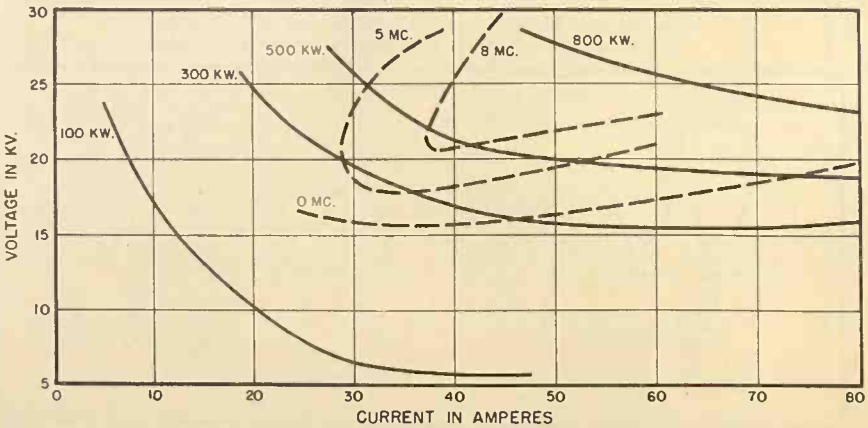
Power Output and Efficiency

The ideal theoretical efficiency of a klystron is 58 per-cent for a double resonator type operating at its primary mode. At higher modes this theoretical maximum decreases, as shown in Table I. The reflex klystron theoretical maximum efficiency is somewhat less than those given for the double resonator type.

Several factors prevent attaining this ideal value of efficiency. The usual beam efficiencies are of the order of magnitude of 50 to 75 per-cent—meaning that the energy of only part of the electrons is available for conversion to r.f. power. Debunching, secondary electrons, resonator losses and other factors reduce the efficiency. Reflex oscillators are usually more efficient than double resonators at low voltages because their starting currents are lower and they oscillate with less power. Increasing the current beyond the starting current—by raising beam voltage—increases the output rapidly at first, then a saturation effect occurs due to over-bunching in the single resonator (space charge effect) and best efficiency may occur with rather low beam current in the reflex klystron. This behavior also explains the inability to obtain an output comparable to that possible with a double resonator klystron when operated at high voltages and high starting currents.

Reflex klystrons now manufactured have a maximum power output rating of the order of 10 watts and an efficiency of about 5 per-cent. The double resonator klystrons operate somewhat more efficiently at rated maximum outputs as high as 200 watts.

Fig. 13. Performance chart of magnetron showing voltage, current, frequency and power.



Practical Problems in Design

When the evaluation of the various methods of microwave generation for an individual application dictate the use of a klystron (the considerations involved will be covered in a later article on "Systems Planning for Microwave Links"—usually klystrons are used in low power frequency modulation systems), the engineer proceeds in the following fashion.

From manufacturer's catalogs, the klystron which most closely meets the requirements of the system, i.e., the power output, frequency range, tuning range, efficiency, frequency stability, etc., is selected. From the characteristic curves given with the klystron selected, the design of the oscillator can be undertaken.

Fig. 12 is the repeller characteristic curve of a typical reflex klystron used in circuit shown in Fig. 8. Curves at left in this figure represent the r.f. power output as a function of repeller voltage and with the resonator set for $f = 3680$ mc., beam voltage at 1250 volts, and control grid at 20 volts. The other curves indicate the frequency of operation for different repeller voltages. For example, with the repeller voltage equal to -600 volts, the frequency of operation will be 3682.5 mc. at 90 per-cent of peak r.f. output for these conditions. It should be noted that these values given assume a matched load. To effect matching, principles discussed in previous articles should be utilized.[2, 3]

The klystron may be frequency or pulse modulated by superimposing a modulation voltage on the d.c. voltage of either the beam control, or repeller sources. The highest degree of sensitivity and linearity can usually be obtained by modulating the repeller voltage. Fig. 10 indicates typical pulse and frequency modulating conditions. When frequency modulating it is important to operate over the linear portion of the repeller voltage versus frequency curve to minimize distortion.

The frequency stability of the oscillator is a function of the three d.c. supplies mentioned above as well as the

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For many years The HELIPOT Corporation has been a leader in the development of advanced types of potentiometers. It pioneered the *helical* potentiometer—the potentiometer now so widely used in computer circuits, radar equipment, aviation devices and other military and industrial applications. It pioneered the DUODIAL*—the turns-indicating dial that greatly simplifies the control of multiple-turn potentiometers and other similar devices. And it has also pioneered in the development of many other unique potentiometric advancements where highest skill coupled with ability to mass-produce to close tolerances have been imperative.

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In this panel are illustrated standard models of HELIPOT multi-turn and single-turn precision potentiometers—available in a wide range of resistances and accuracies to fulfill the needs of nearly any potentiometer application. The Beckman DUODIAL is furnished in two designs and four turns-ratios, to add to the usefulness of the HELIPOT by permitting easy and rapid reading or adjustment.

MODELS A, B, & C HELIPOTS
A—10 turns, 46" coil, 1-13/16" dia., 5 watts—resistances from 10 to 300,000 ohms.
B—15 turns, 140" coil, 3-5/16" dia., 10 watts—resistances from 50 to 500,000 ohms.
C—3 turns, 13-1/2" coil, 1-13/16" dia., 3 watts—resistances from 5 to 50,000 ohms.
—Ask for Bulletin 104—

MODELS D AND E HELIPOTS
Provide extreme accuracy of control and adjustment, with 9,000 and 14,400 degrees of shaft rotation.
D—25 turns, 234" coil, 3-5/16" dia., 15 watts—resistances from 100 to 750,000 ohms.
E—40 turns, 373" coil, 3-5/16" dia., 20 watts—resistances from 200 ohms to one megohm.
—Ask for Bulletin 104—

MODELS F AND G PRECISION SINGLE-TURN POTENTIOMETERS
Feature both continuous and limited mechanical rotation, with maximum effective electrical rotation. Versatility of designs permit a wide variety of special features.
F—3-5/16" dia., 5 watts, electrical rotation 359°—resistances 10 to 100,000 ohms.
G—1-5/16" dia., 2 watts, electrical rotation 356°—resistances 5 to 20,000 ohms.
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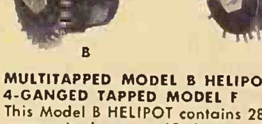
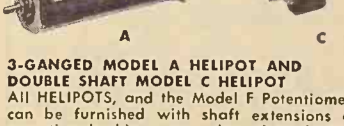
LABORATORY MODEL HELIPOT
The ideal resistance unit for use in laboratory and experimental applications. Also helpful in calibrating and checking test equipment. Combines high accuracy and wide range of 10-turn HELIPOT with precision adjustability of DUODIAL. Available in eight stock resistance values from 100 to 100,000 ohms, and other values on special order.
—Ask for Bulletin 106—

MODELS R AND W DUODIALS
Each model available in standard turns-ratios of 10, 15, 25 and 40 to 1. Inner scale indicates angular position of HELIPOT sliding contact, and outer scale the helical turn on which it is located. Can be driven from knob or shaft end.
R—2" diameter, exclusive of index.
W—4-3/4" diameter, exclusive of index. Features finger hole in knob to speed rotation.
—Ask for Bulletins 104 and 114—

The versatility of the potentiometer designs illustrated above permit a wide variety of modifications and features, including double shaft extensions, ganged assemblies, the addition of a multiplicity of taps, variation of both electrical and mechanical rotation, special shafts and mounting bushings, high and low temperature operation, and close tolerances on both resistance and linearity. Examples of potentiometers modified for unusual applications are pictured at right.



MULTITAPPED MODEL B HELIPOT AND 4-GANGED TAPPED MODEL F
This Model B HELIPOT contains 28 taps, placed as required at specified points on coil. The Four-Gang Model F Potententiometer contains 10 taps on each section. Such taps permit use of padding resistors to create desired non-linear potentiometer functions, with advantage of flexibility, in that curves can be altered as required.



3-GANGED MODEL A HELIPOT AND DOUBLE SHAFT MODEL C HELIPOT
All HELIPOTS, and the Model F Potentiometer, can be furnished with shaft extensions and mounting bushings at each end to facilitate coupling to other equipment.
The Model F, and the A, B, and C HELIPOTS are available in multiple assemblies, ganged at the factory on common shafts, for the control of associated circuits.

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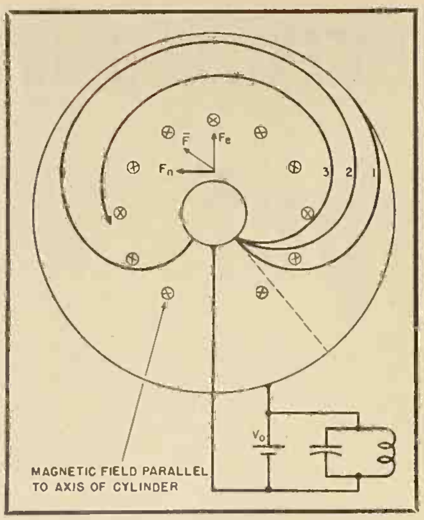

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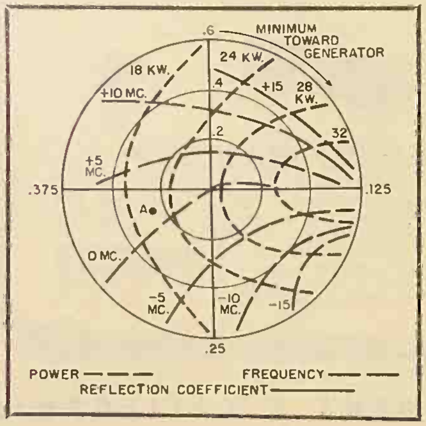

Magnetron Oscillators

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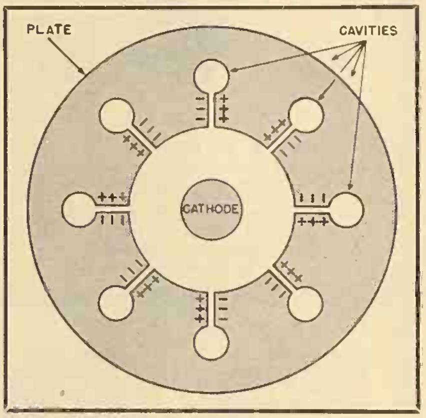

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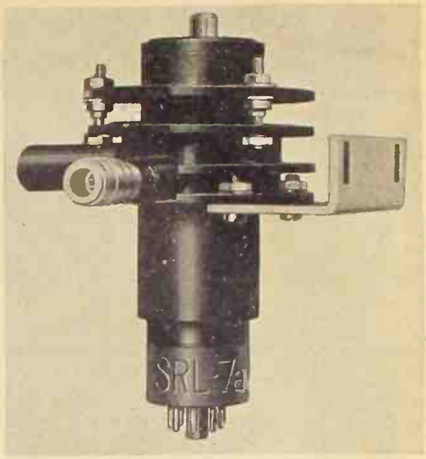

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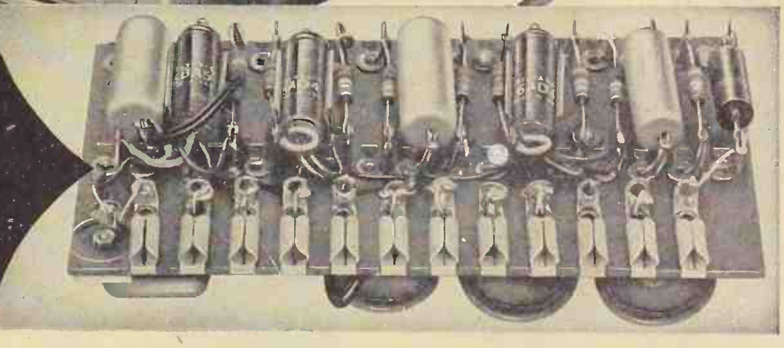

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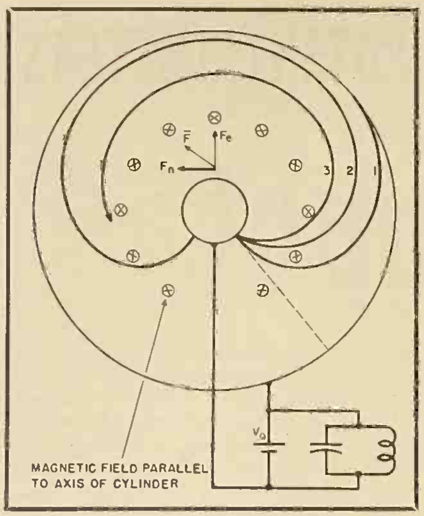

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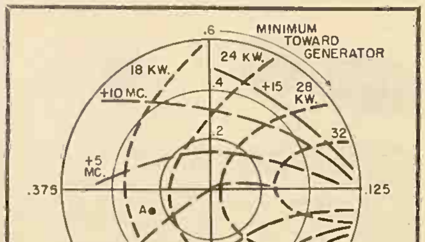

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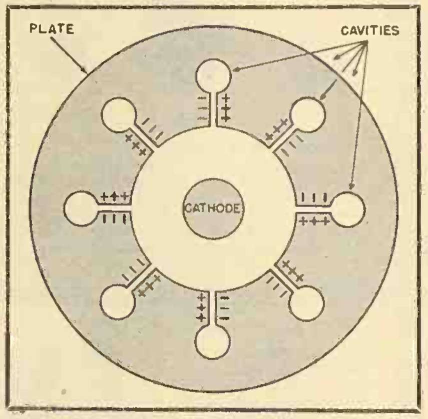

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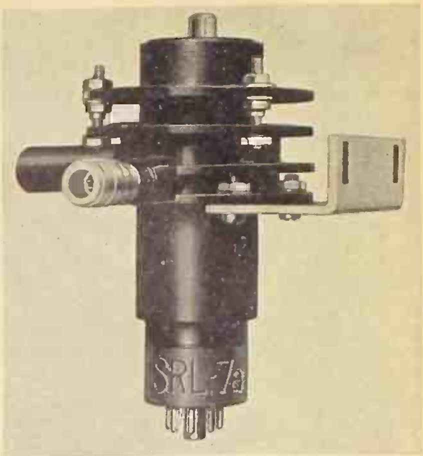

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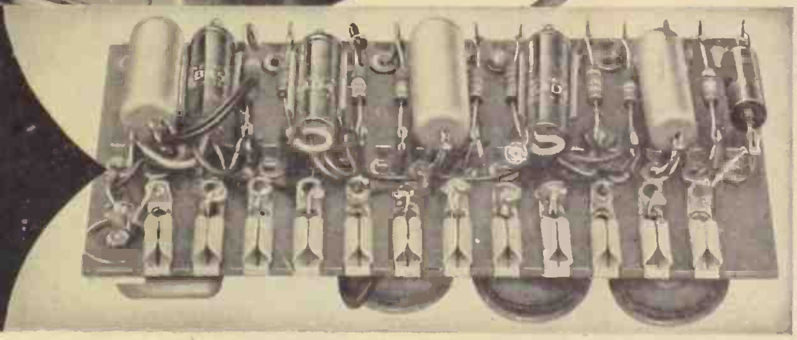

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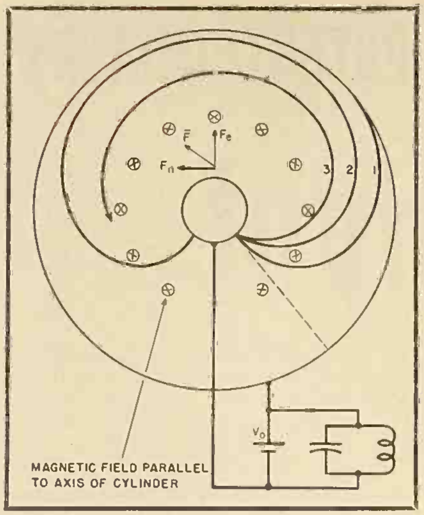

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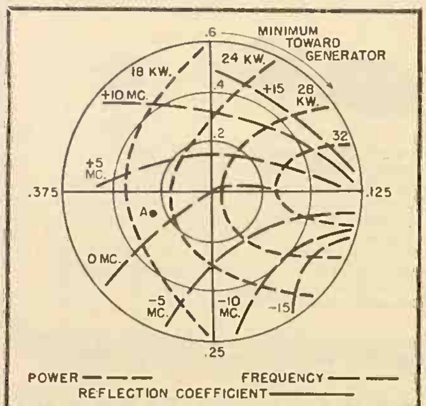

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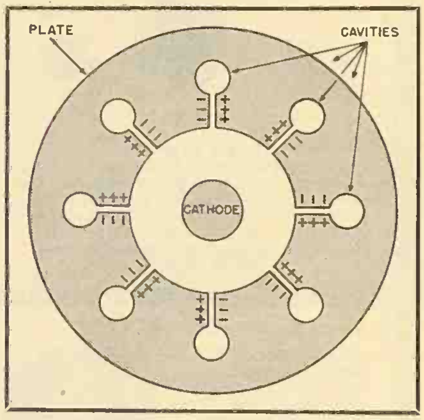

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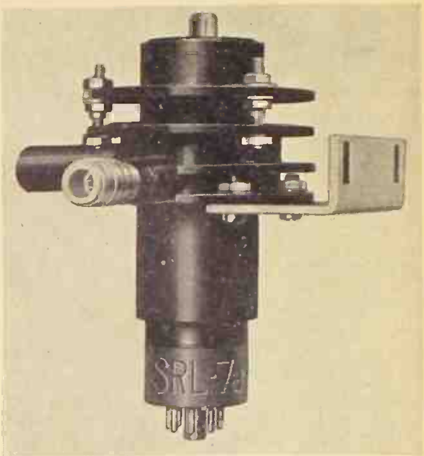

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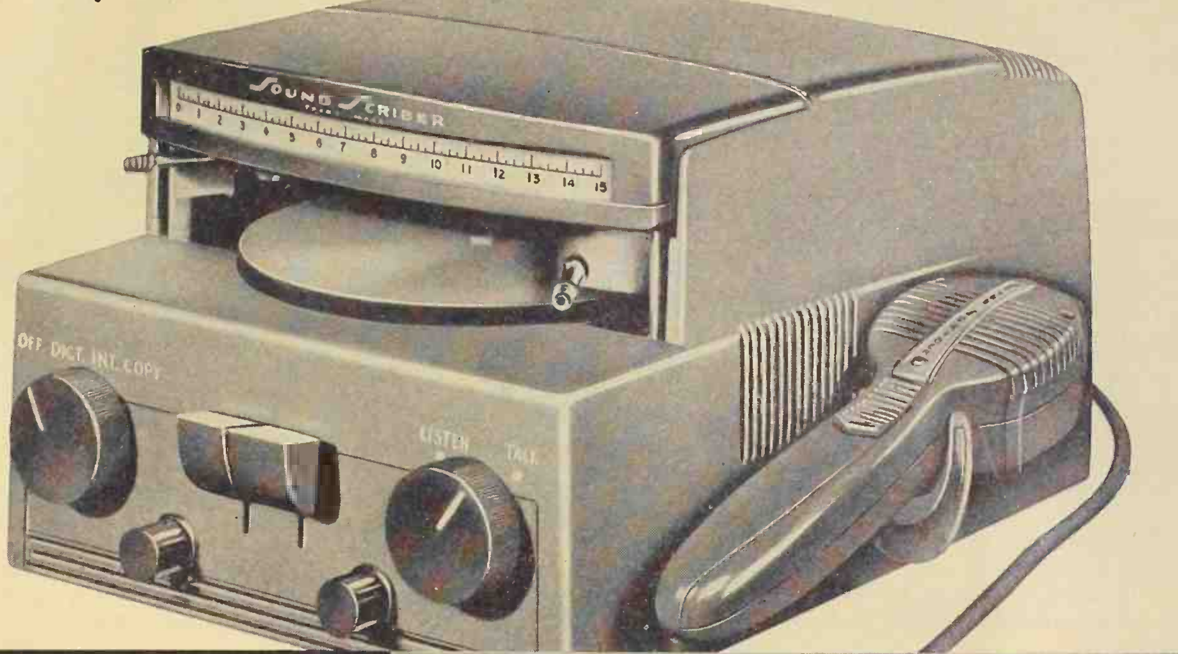

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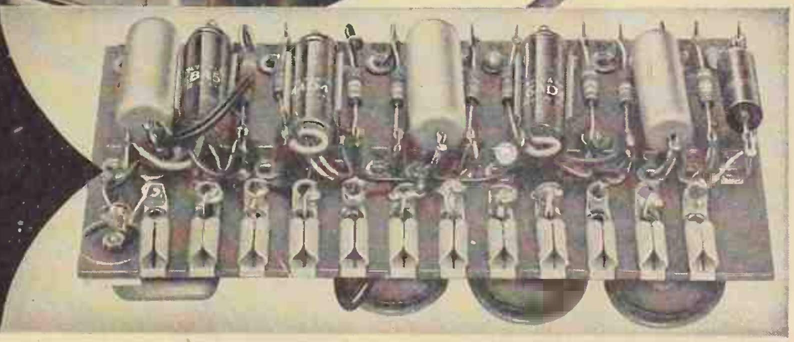

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In electronics, wherever compactness demands minimum size . . . wherever dependability is wedded to economy . . . you'll find Sylvania subminiatures at work, cutting space, cutting costs, cutting servicing requirements and replacement. Write Sylvania Electric Products Inc., Dept. R-2306, Emporium, Pa.

SYLVANIA ELECTRIC

RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT LAMPS, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

NEWS BRIEFS

ATOM SMASHER

Dr. C. C. Suits, vice president and director of research for the *General Electric Company*, has announced that

a machine known as a "non-ferromagnetic synchrotron" is being built under the joint sponsorship of the Office of Naval Research and the *GE* Research Laboratory.

According to Dr. Suits, this atom smasher has been operated thus far up to about a million volts and probably will be in operation at much higher energies before the end of the year. It will be used to study the effects of high-energy radiation, particularly in nuclear research. First erected in one of the old buildings of the *GE* Research Laboratory, the new synchrotron is now being installed in its own building at the laboratory's new quarters at the Knolls, in nearby Niskayuna.

In charge of its design and construction shown from left to right above are Dr. James L. Lawson, and his associates, Drs. H. R. Kratz, W. B. Jones, H. G. Voorhies and G. L. Ragan.

RADAR INTERCEPT

A miniature magnetron radio tube that might be important in radio and radar intercept work has been developed by the Signal Corps Engineering Laboratories.

Compared with the 20,000 to 30,000 volts normally required by commercial type magnetrons, the miniature tube can be operated on less than 100 volts from dry batteries. The tube is approximately the diameter of a lead pencil and is four inches in length.

The basic theory of the new tube was derived from a captured German magnetron used in radar and television, but the design and operation were improved by the Signal Corps.

INSTRUMENT TO MEASURE FARADAY

The National Bureau of Standards has developed an instrument which makes possible measurement of the numerical value of the faraday with exceedingly high precision. Developed by J. A. Hipple, H. Sommer, and H. A. Thomas, the omegatron is basically a miniature cyclotron.

For the first time the faraday is being evaluated directly by physical methods, all previous faraday measurements having been electrochemical. Also, the value of the nuclear magneton may now be determined very precisely so that the ratio of the mass of the electron

to the mass of the proton will be known with greater precision than ever before.

The omegatron with its associated electromagnet, vacuum system, and electrometer amplifier is shown here in use as a mass analyzer. Mr. H. Sommer is checking the position of the omegatron in the magnetic field.

RESEARCH ON GERMANIUM

Speaking at the M.I.T. Conference on Physical Electronics at the Massachusetts Institute of Technology recently, Dr. B. J. Rothlein of The Physics Laboratories of *Sylvania Electric Products Inc.*, described researches he has conducted on the photoresistive properties of germanium previously reported by other research workers during World War II.

Dr. Rothlein showed that a germanium photoswitch may be made to operate a relay for applications such as automatic door openers without the aid of photocells, amplifiers or direct current power supplies.

NEW RCA PLANT

Dedication ceremonies for the new television picture tube plant of the

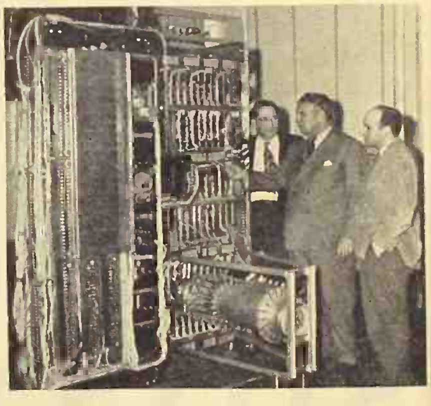
Radio Corporation of America at Marion, Indiana were held recently. Honored guest was Governor Henry F. Schricker of Indiana, who also officiated at groundbreaking for the new plant last year.

Major product of the plant is *RCA*'s recently developed short 16-inch metal picture tube. The new Marion plant is the fourth of the thirteen *RCA* plants to be located in Indiana.

REMINGTON BUYS "UNIVAC"

Announcement of the purchase of more than 95 per-cent of the stock of the *Eckert-Mauchly Computer Company* of Philadelphia, whose founders, Dr. John W. Mauchly and J. Presper Eckert originated the "electronic brain", has been made by James H. Rand, president and board chairman of *Remington Rand, Inc.*

Dr. John W. Mauchly, left, and Prof. J. Presper Eckert, right, inspect the mercury memory assembly of the Univac with Lt. Gen. Leslie R. Groves, U.S.A. (Ret), *Remington Rand's* Vice



President and Director of the company's Laboratory for Advanced Re-

(*Continued on page* 25)

NEW PRODUCTS

RECORDING AND TRANSCRIBING UNIT

The *Permoflux Corporation*, 4900 W. Grand Avenue, Chicago 39, Illinois, is

now introducing a combination recording and transcribing unit under the name of the Tape Riter.

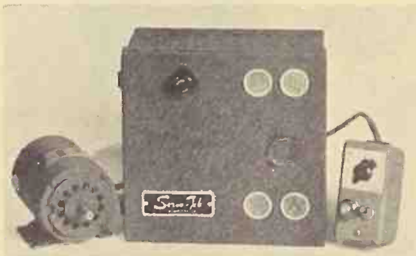
The unit is compact and on the spot recordings can be made with ease. The tape may be used over and over again simply by erasing previous recording with the new message. There is no overtone from the previous recording and correction and deletion of any portion of the message is easily accomplished.

Fast forward and reverse enables the user to find any particular spot on the tape in seconds and accurate indexing is provided.

MOTOR SPEED CONTROL

A simplified thyratron type motor speed control system which operates d.c. motors from the a.c. line has been developed by *Servo-Tek Products Co.*, 4 Godwin Ave., Paterson, N. J. Shunt wound type 115 volt motors of from one thousandth to one tenth horsepower may be controlled over a speed range of better than 50 to 1 with nearly constant speed versus torque regulation.

A physically identical model is avail-



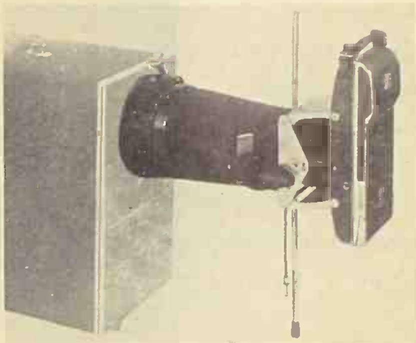
able for operation from the 220 volt line to control d.c. motors of the shunt wound type up to one-sixth horsepower. Speed range is identical for either unit.

The manufacturer believes that applications of this motor speed control system to industrial applications are many and varied, and has offered to assist in application problems.

OSCILLOSCOPE CAMERA

Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y., has announced a new recording camera for photographing the screen of a cathode-ray oscilloscope and producing a print for engineering study within one minute.

Designated as the F-284 *Fairchild*-Polaroid Oscilloscope Camera, this



camera is expected to prove extremely useful to engineers in that it quickly delivers an accurate photographic record of single transients or repetitive phenomena without the need for darkroom processing.

The camera is designed for use with any standard 5" cathode-ray oscilloscope. Writing speeds up to 1 inch per microsecond have been recorded with an accelerating potential of 3000 volts. Print size is 3¼ x 4¼ inches with the two recorded images reduced by a ratio of only 2 to 1 from the original trace.

Further information may be obtained from *Fairchild* by writing to Mr. W. J. Schubert.

MOBILE COMMUNICATIONS UNIT

Type ES-12-A, announced by the *General Electric Company*, Syracuse, N. Y., is a 10-watt mobile radio transmitter-receiver designed for adjacent channel operation in urban and metropolitan areas.

Features of this unit include triple-tuned transformers for extra high selectivity, peak audio putput of 2 watts, adjustable i.f. gain control, and built-in

low pass harmonic filter that reduces interference to other services, including television.

Further information on the ES-12-A mobile communications unit may be obtained from the Commercial Equipment Division.

TIME DELAY RELAYS

Westinghouse Electric Corporation, Pittsburgh, Pa., is now offering type AM pneumatic time delay relays with adjustable delay from 0.2 to 200 seconds. A large graduated dial permits delay adjustment throughout this range for general industrial timing functions.

These type AM relays are available as open or enclosed units, the latter in NEMA type I enclosures with conduit knockouts at top and bottom. Operating coils are designed for satisfactory service down to 85 per-cent of rated voltage. Coils are available in ratings up to 600 volts a.c., 25 to 60 cycles.

Further information may be obtained by writing the company at P. O. Box 2099, Pittsburgh 30, Pa.

MOLDED PLASTIC PARTS

General purpose and low loss dielectric molded phenolic plastic products for the electrical and electronic indus-

tries are now available from the Parts Division, *Sylvania Electric Products*,

(*Continued on page* 26)

Assembly Costs Take a Tumble with Change-over to CLUTCH HEADS

Users Certify 15% to 50% Production Increases for Lower Final Costs

In view of this testimony you may confidently expect these exclusive time and cost-saving CLUTCH HEAD features to deliver a similar ratio of production increases on your assembly line . . . to lower your final costs by producing more for less.

Higher Visibility of the clutch recess eliminates operator hesitation. Even "green" help drives with speed and confidence. No "break-in" needed.

No Damaged Heads . . . Dead-center entry with the Center Pivot Column prevents driver canting, makes straight driving automatic, and checks out delay and expense fixing burred or chewed-up heads.

Now, Non-Tapered Driving that sends skid damage to zero; safeguarding manpower and material. With CLUTCH HEAD's all-square driving engagement there is no need for end pressure to combat "ride-out" (as set up by tapered driving) and the drive home is effortless. This safety factor and elimination of fatigue steps up production.

One-Handed Reaching at "Bottlenecks." Only CLUTCH HEAD provides a frictional Lock-On that joins screw and bit as a unit to permit one-handed reaching into inner spots and driving from any angle.

214,000 Screws Driven Non-Stop. This is the record established by the rugged Type "A" Assembly Bit . . . continuous high torque driving on a main assembly line of one of America's largest automotive plants.

New Bit Life in 60 Seconds. Consider the added tool economy of simplified reconditioning this bit REPEATEDLY . . . by a 60-second application of the end surface to a grinding wheel.

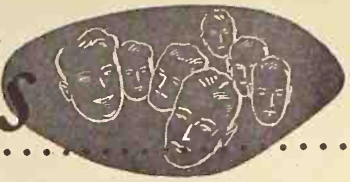
Curing Field Service "Headaches." For simplified field service, CLUTCH HEAD alone has a recess that is basically designed for operation with a common screwdriver or with any flat blade which need only be reasonably accurate in width.

These advantages are fully detailed in the New CLUTCH HEAD Brochure . . . along with technical information your engineers and plant executives will want for reference. Start your investigation of CLUTCH HEAD's potential savings for your assembly by sending for a copy . . . and indicate sizes and types of screws which interest you.

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

Personals



JAMES N. DAVIS, formerly a senior research engineer for the Physics Laboratories of *Sylvania Electric Products Inc.*, Bayside, New York, has been appointed technical representative for the company at Washington, D. C. Before joining the *Sylvania* research staff in 1946, Mr. Davis served as Radar Officer in the Naval Research Laboratory. He graduated from Purdue University with a B.S. degree in general science.

LYNN C. HOLMES has been made associate director of research for *Stromberg-Carlson Company*, Rochester, New York. Senior electrical engineer since he joined the company in 1943, Mr. Holmes is well-known in the field of magnetic sound recording. He is an active committeeman in the AIEE, RMA, the American Standards Association, and is a member of the IRE and the Acoustical Society of America.

DAVID LEO HOWARD, Assistant General Manager of Canadian Pacific Communications, has been appointed President and General Manager of the *Canadian Overseas Telecommunication Corporation*, Ottawa. As representative of Canadian wireline companies, Mr. Howard has appeared many times before Canadian Parliamentary Committees and United States Senate and Congressional hearings in the coordination of telecommunication services.

GEORGE C. JELLIFFE has been named Eastern District Manager for the *Ilg Electric Ventilating Company* of Chicago. Mr. Jelliffe's headquarters will be at 15 Park Row in New York City. A graduate of Stevens Institute of Technology with an M.E. degree, Mr. Jelliffe first became associated with *Ilg Electric* in 1946 as assistant to the vice-president. He was formerly associated with *Western Union Telegraph Company*.

G. PRYOR MOLLOY, formerly associated with *RCA's* Tube Department, has been appointed head of the Field Engineering Department, Industrial & Electronics Division of *American Structural Products Company* with headquarters at Columbus, Ohio. A graduate of Newark College of Engineering, Mr. Molloy is a senior member of the IRE, a member of the AFCA, American Society of Naval Engineers, and an associate member of the U. S. Naval Institute.

HOWARD D. MATTHEWS, consulting engineer for the *W. M. Chace Company*, Detroit, Michigan, passed away recently. Mr. Matthews was widely known for his work in the application of thermostatic bimetal to various problems of temperature-responsive devices. He was a Fellow of the AIAS and a Fellow in the AIEE.

Loading Crystals

(*Continued from page* 9)

did not give greatest activity. Instead the optimum activity, 50 per-cent higher, was obtained by moving the electrode to a different position near the center. Shifting to the thinner edges was accompanied by increasing frequency and decreasing activity; moving from the optimum point toward the center caused both activity and frequency to decrease. The area of the crystal and the frequency range over which this anomalous behavior occurred were small. For example, in a 10 mc. plate which had an edge-to-center frequency variation of 25 kc., the frequency which gave maximum activity was about 5 kc. higher than the lowest frequency obtainable; the electrode position in this case was about one-fifth the distance from the center of the corner of the plate. Typical activity values as indicated by the rectified grid current from the oscillator tube, were 0.5 at the center of the plate, 0.8 at the optimum position and 0.2 at the corner.

Temperature runs (-60° to + 90°C) were made on several ½-inch-square 10 mc. plates which had centers about 0.00005 inch concave. All had activities which varied constantly between 0 and 0.2 milliampere over the temperature range, and frequencies which were correspondingly unstable. These oscillator blanks were etched slightly to raise their frequencies 3 to 5 kc., and then were loaded to their original frequency, thereby reestablishing the original relationship between the fundamental and other secondary modes. The loading material was woods metal, applied lightly in a ¼-inch diameter circle concentric with the center of the plate. The effect was a more than threefold increase in the activity (0.2 to 0.7 ma. or more). Subsequent temperature runs revealed that the increased activity was associated with a general improvement in operating characteristics over the entire temperature range. Also, the resistance at series resonance, R_s, decreased several fold while the Q increased correspondingly. Since the same frequency-dimension relationships were maintained, factors other than the usually ascribed coupling phenomena are responsible in some measure for the erratic behavior; perhaps the most important of these is the frequency at which the plate is being driven. In general, it appears that plates whose central active areas have a frequency that is too high for the plate as a whole tend to have poor frequency stability and activity. Elimination of this condition can very easily be effected through a lowering of the frequency by placing a small mass of material upon the central areas.

Loading certain areas of lower-frequency plates very heavily has also been found to be beneficial. It has long been known that giving a slight convexity to some types of oscillator plates results in improved performance. Recent experiments indicate that if this contouring takes the form of a plateau at the center with tapering edges, the performance is improved even more. It appears that heavily loading the central portion of the plate produces effects very similar to those produced by the plateau with tapering edges. It is believed that in both cases the thickness-shear vibration is mainly confined to the central area because the surrounding area is so far off frequency that it remains relatively inert. A difficulty commonly found in mounting low-frequency plates is their failure to oscillate when pressure is applied to the corners,—e.g., when a plate is pressure-mounted between electrodes with raised areas at the corners. Although the active portion of very thin plates in thickness-shear is mostly restricted to the central area, the flexural vibrations which may also be present become quite active at lower frequencies (thicker plates). This may be corrected either by contouring or by properly loading the plates, which may then be securely clamped at the corners with no great reduction in activity.

Several loading materials, both metallic and non-metallic, have been used effectively. Woods metal has certain advantages in hand application because it is soft, adheres well to the quartz, and can easily be removed. The amount of metal for satisfactory results varies with the percentage of the area coated as well as with the shape of the coated area. An elliptical pattern with the long axis parallel to the x-axis has good effect, and a band across the plate in the x-axis direction, covering about 1/3 the area of the plate, is also effective. A narrower band parallel to the x-axis is less effective while similar patterns rotated 90° (long dimensions perpendicular to the x-axis) are still less effective: a narrow band perpendicular to the x-axis appears to have a deleterious effect. In most of the experiments, an equal amount of woods metal was applied to both faces of a plate. (When the coated area was the size of a pinhead, an interesting effect occurs: the frequency decreases at first, as expected, but further application of metal causes the frequency to jump to a point many kilocycles higher than the original frequency).

A better understanding of the theories involved in quartz-crystal loading and how the most beneficial effects may be produced must await more comprehensive study. A considerable improvement over the hand-loading technique could no doubt be effected through evaporation processes similar to those used for coating mirrors.

News Briefs

(*Continued from page* 20)

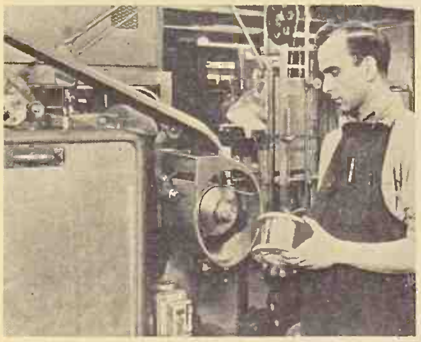
search, South Norwalk, Connecticut.

According to Mr. Rand, plans were begun immediately for developing the amazing new mathematical marvels for use by business concerns requiring large amounts of computing and recording. Manufacture and distribution of the "Univac" will be coordinated with *Remington Rand's* complete line of business equipment.

COPPER WIRES

Nickel-clad copper wires for aircraft, industrial and laboratory equipments, and many other applications where product fabrication or end use is in high temperature or corrosive atmospheres is being produced by *Sylvania Electric Products Inc.*

Mr. Howard M. Boyd, sales manager, said that Sylvania is specializing in diameters ranging from .010″ to .005″ which are particularly well suited for stranding and for lead wire applications where high temperature working of hard glass frequently renders solid copper wires brittle and unworkable.



Production of nickel-clad copper wire is controlled so that a practically uniform ratio of nickel to copper is maintained through a series of cold drawing operations in which the nickel-cladding ranges from 27% to 29%. This material is being marketed under the brand name "Kulgrid".

WEATHER FORECASTING TECHNIQUES

Scientists of the Geophysical Research Directorate, a branch of the Air Force Cambridge Research Laboratory, are conducting studies of new weather forecasting techniques with an analytical mass spectrometer.

The high-sensitivity range of the mass spectrometer, which was designed and built in the *General Electric Company's* General Engineering and Consulting Laboratory at Schenectady, N. Y., is expected to be of aid in the study of reactions which meteorologists believe take place among constituents of the atmosphere as a result of absorption of radiant solar energy. Because it separates molecules of different weights, or masses, the instrument is useful in

recording presence of isotopes, particles which react chemically in the same way as the original, but differ from them in mass and atomic structure.

GE Engineer J. G. Neuland is shown seated before the control panel of the instrument as he watches the chart on which weights of molecules in gas being analyzed are automatically recorded. At the right is the electronic tube rack into which gases are introduced for analysis.

NEW LITERATURE

Measurement of Resistance

The first definitive results of a new and satisfactory method devised for independently checking the stability of the standard of electrical resistance in terms of length, time, and the permeability of free space, are described in detail in a new paper, An Absolute Measurement of Resistance by the Wenner Method.

Published by the National Bureau of Standards, this method can detect a change of a few parts in a million in the standards used to maintain the unit.

This paper may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. at a price of 30c a copy.

Mass Spectrometer Leak Detector

Vacuum-Electronic Engineering Co., 316 37th St., Brooklyn 32, N. Y. has issued a new 4-page bulletin titled Veeco Mass Spectrometer Leak Detector.

Contents of this bulletin describe typical applications, wherever a vacuum, fixed pressure or special atmosphere must be maintained for extended periods of time; principle of operation, features, and pertinent data pertaining to vacuum testing and pressure testing with explanatory illustrations.

A copy of this bulletin may be obtained by writing the company and requesting a copy of Bulletin LD-95.

New Products

(*Continued from page* 22)

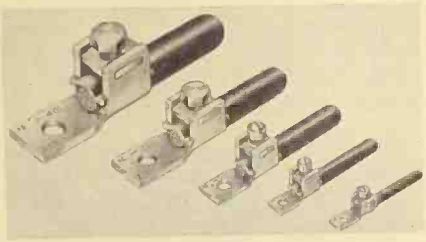
Incorporated, Warren, Pennsylvania.

Available in black, white or colors for specific product identification, parts can be fabricated to close specifications at low unit cost. Facilities include product design and the design and production of required molds for use with modern automatic high-speed rotary and multiple flat-press equipments.

Plastic parts may be supplied as molded pieces, as subassemblies with staked, eyeletted or stitched metal parts, or as complete assemblies of molded plastic and small metal parts.

PRESSURE CONNECTORS

Five lug models comprise the "Wide Range" line of medium-priced pressure connectors for use with copper, aluminum or steel wire in sizes from 14 AWG to 500 MCM, announced by *National Electric Products Corp.*, Chamber of



Commerce Building, Pittsburgh 19, Pa.

These pressure connectors are complete assemblies and each connector is said to be capable of handling a wide range of wire and cable sizes. The three smaller sizes, NE 35, 60 and 100 can be installed with a screwdriver; the larger sizes, NE 200 and 400, with a wrench. All sizes were made with minimum over-all dimensions to expedite installation in small gutters. The entire unit is cadmium plated for corrosion protection.

SAFETY DEVICE

A new kind of electrical control designed as a safety device to protect water-cooled, electrically-operated equipment, such as air compressors, vacuum pumps and the like, against damage through water failure is announced by *The Electro Chemical Supply & Engineering Co.*, 750 Broad St., Emmaus, Pa.

The Esto Water Control can be adjusted to operate at any water flow the equipment requires. If the water supply fails, a weighted lever falls which opens the circuit and the relay stops the equipment or sounds an alarm or both. Also, an Esto-controlled compressor will not start until the water has been turned on.

VOLTAGE SUPPLY

Sola Electric Company, 4633 W. 16th St., Chicago 50, Illinois, is manufacturing an adjustable, regulated, a.c. voltage supply designed for use with equipment that requires an adjustable source of constant a.c. voltage from 0 volts to 130 volts of undistorted wave shape.

The "Solavolt" type CVL provides all of the voltage stabilizing characteristics

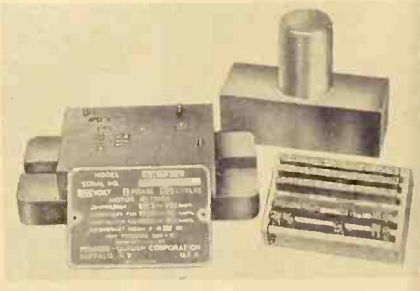
of the standard SOLA constant voltage transformer; ± 1% regulation for line input changes from 95-125 volts with less than 3% harmonic distortion of the input voltage wave. The voltage regulation is automatic and substantially instantaneous.

Each unit is provided with attached input cord and plug; line on-off switch; one standard receptacle for a fixed, regulated 115 volts; one standard receptacle for a variable, regulated output of 0-130 volts; and a pair of jacks with regulated, variable output of 0-130 volts for connecting instruments with plugs or wire type leads.

Technical Bulletin P96 CVL-140 gives full mechanical and electrical specifications and is available on request.

MARKING DEVICE

The *M. E. Cunningham Company*, 192 East Carson St., Pittsburgh 19, Pa., has developed a special stamping fixture for marking metal name plates in mass



production operations. Model PSF-10 is designed for use in a small power press.

screw press, kick press or similar device.

This marking device is composed of a chase block which contains the steel marking letters and a striking block which is held in the throat of the press by set screws. Slots for containing the letters are machined out of the solid tool steel chase block to suit the setup of the name place layout and logotypes are supplied when the same style plate is used for several different models.

Data sheets and additional information may be obtained by writing the company.

POTENTIOMETER

Technology Instrument Corporation, 1058 Main Street, Waltham 54, Mass., has announced a new type precision potentiometer now being manufactured.

Type RVC2 features a crank arm and drive pin assembly which transmits shaft rotation. At the point of contact between crank arm and drive pin the crank arm is spring loaded to eliminate back lash. Use of this method makes it possible to remove a single potentiometer from a ganged assembly by simply loosening the clamp ring and slipping potentiometer out of the assembly.

RVC2 potentiometers are available in a wide range of resistance values and can be furnished with linear or non-linear windings. Full details are available upon request from the manufacturer.

D.C. AMPLIFIER

A wide-band d.c. amplifier designed specifically to increase the sensitivity of cathode-ray oscilloscopes with extended

low frequency response is now being manufactured by *Furst Electronics*, 12 S. Jefferson St., Chicago 6, Illinois.

Model 120 is also suitable to extend the range of vacuum-tube voltmeters, frequency analyzers and other instruments. The amplifier uses push-pull amplification throughout and a special cross-coupled circuit is used to achieve stability and low drift.

Two sets of input terminals are provided, one marked "DC" and connected directly to the input attenuators, the other marked "AC" and connected through a pair of coupling condensers to the d.c. input terminals. The maximum gain of the amplifier is adjusted to approximately 100 and the input attenuators reduce this gain to approximately 10 and 1 (40 db., 20 db., and 0 db. resp.).

SCREEN ROOMS

Pre-built screen rooms for laboratory and production line use which offer maximum radio interference screening efficiency are now available from *Ace Engineering and Machine Company, Inc.*, 3644 N. Lawrence St., Philadelphia 40, Pa.

Available in "cell units", these screen rooms are built to provide a minimum of 100 db. attenuation from 0.15 to 1000 megacycles. Of sectional, double-mesh construction the units require no soldering between sections.

Background radio interference is held to an absolute minimum to facilitate accurate radio interference measurements, r.f. calibrations, inspection tests, fractional voltage measurements, and other research where background noise must be eliminated to assure real accuracy.

Literature giving complete details will be sent on request to the manufacturer.

Ripple-Tank

(Continued from page 6)

1/16 in. on centers. The slots were 0.040 in. wide and 3/32 in. deep; and the concave side had a radius of 1¼ in. Since there is no possibility of interference between the back radiation of the primary pattern and the secondary pattern in the case of the wave guide lens, the side lobe structure due to this cause is absent. Appreciable reflection from the first surface of the lens is evident. It should be possible to simulate some aspects of Kock's[3] path-length delay microwave lenses by using somewhat wider, "zig-zag" slots and a convex model.

Conclusion

It has been the purpose of this condensed report to bring to the attention of electronic engineers some of the virtues and some of the limitations of the ripple-tank as an aid to antenna phase-front visualization. It is believed that this device will be of value to the electronics teacher as well as to the research engineer.

REFERENCES

1. *Sutton, R. M., "Demonstration Experiments in Physics," pp. 149-154, New York: McGraw-Hill.*
2. *Kock, W. E., "Metal-Lens Antennas," Proc. IRE 34: 828-836, November 1949.*
3. *Kock, W. E., "Path-Length Microwave Lenses," Proc. IRE 37: 852-855, August 1949.*

TECHNICAL BOOKS

"ELECTRONIC PRINCIPLES AND APPLICATIONS" by Ralph R. Wright, Associate Professor of Electrical Engineering, Virginia Polytechnic Institute. Published by *The Ronald Press Co.*, 15 E. 26th St., New York 10, N. Y. 387 pages. $5.50.

This textbook presents in a clear and coherent manner the basic electronic principles slanted to meet the requirements of nonelectrical students. By no means limited to the nonelectrical student, the author has also used this material in instructing electrical engineering students and physics majors.

In order to keep the text both flexible and suited to the many different curricula now offered in engineering colleges, more material is offered than will usually be covered in the average one-quarter or even one-semester course. This allows the instructor to choose those topics which he believes most valuable for the class at hand.

The first three chapters present basic electronic principles. Chapter 4, containing a brief review of d.c. and a.c. circuits, may be omitted in cases where the student does not require such a review without affecting the continuity of the text. The remaining eight chapters are devoted to electronic circuits and basic applications of electron tubes.

Only basic equations have been included and these are simply stated with the terms in each equation explained sufficiently to enable the student to use them intelligently.

"PULSES AND TRANSIENTS IN COMMUNICATION CIRCUITS" by Colin Cherry. Published by *Dover Publications, Inc.*, 1780 Broadway, New York 19, N. Y. 317 pages. $3.95.

An introduction to network transient analysis for television and radio engineers, this volume introduces circuit analysis, bridging the gap between simple alternating current theory and operational methods of analysis.

For those who have attempted to supplement their knowledge of transients and have been at a loss to know where to start, this book will be of valuable help. It provides the essential groundwork, using in most instances rigorous physical arguments and only elementary mathematics. Electric waveforms are dealt with rather than analytical functions.

References to published books and papers are given throughout the text, thus enabling the reader to continue beyond the limits of the volume itself.

Antenna Pattern

(*Continued from page 12*)

range exceeds 100 db. This includes excellent shielding of the various stages, common point to point grounds for individual stages and an excellent d.c. regulated power supply. The power drain is approximately 62 watts.

The only critical portion is in the wiring of the first stage of amplification. All grounds of the first stage of amplification including those of the input jack and calibration switch should be grounded to the chassis at only one point. Shielding of individual stages or particular components has not been found to be necessary.

Fig. 4 shows the two antenna pattern testing shacks on the roof of the *Dalmo Victor* building where this automatic antenna pattern recording system has been successfully used. Transmissions from one of these penthouse shacks is received in the other penthouse shack and fed into the automatic antenna pattern recording system.

FM in Power Ind.

(*Continued from page 5*)

United States and its possessions must be licensed. A construction permit is needed and the first step taken is to make application to the Federal Communications Commission on FCC Form 401-C made out in duplicate, and FCC Form 401-A when it is necessary. If the height of the antenna is in excess of 150 feet or within 3 miles of an airport, FCC Form 401-A is to be filled out and sent in in quadruplicate. The frequency desired is sent in with the application. The applications should be signed by an officer or official of the organization rather than by an employee.

When the construction permit is granted, call letters are assigned; equipment can then be purchased and construction completed within 8 months.

Following the construction of the station, a 30-day test period is allowed, providing the radio inspector in charge in the district is notified two days in advance.

When construction and testing are completed, an application for station license is filed on FCC Form 403. This is done well in advance of the expiration of the construction permit. A separate license is required for the land station and one for the mobile units.

The manufacturer's representative usually helps the customer with the license application procedures.

A restricted radio telephone operator's permit is required by persons operating the land or central station. No operator's license is required for mobile units operating on frequencies above 25 megacycles.

Any person making adjustments, taking frequency readings, or doing any maintenance work on either land station or mobile units must have a first or second class radio telephone operator's license.

The Federal Communications Commission also requires that an accurate log be kept of the station's operation.

Equipment Description and Installation

The manufacturer's representative usually supervises the installation work performed by technicians from the factory or from some independent company.

1. *Antennas.* If the area to be covered is from 12 to 20 miles airline, an antenna installation made on the top of the town's water tower or other high point generally gives satisfactory results. If the distance is greater than this, a special tower can be used. In the REA antenna installation illustrated, the antenna is mounted on the top of the water tower which is 125 feet in height.

The central transmitter used has an r.f. output of 30 watts. The farthest point in the system to be reached is 32 airline miles distant. Over the past year of operation, excellent coverage has been obtained. The antenna is fed by coaxial cable from the central transmitter located at the base of the tower in the housing provided for it.

The antenna should be located on a high hill if it is possible to keep it within 10-15 miles of the remote control unit.

A power gain antenna may be used at the central station to make more efficient use of the transmitted signal.

In practice, communications are being carried on over much greater distances than theory seems to indicate should be possible.

2. *Central or Land station.* The central or land station is located as near as possible to the antenna installation. When satisfactory conditions exist and the antenna installation may be made at the location where the dispatching is to be carried on, equipment is being manufactured which has all of the units self contained in a cabinet somewhat similar to the remote control console pictured. Where the r.f. power output does not have to exceed 30 or 60 watts and the antenna installation permits, this type equipment then eliminates the remote control unit, land lines, central station installation and housing facilities.

In the central station housing facilities, some means of even temperature control must be provided as these houses are heated during the winter months. A thermostatic type control is usually used.

3. *Remote control console.* The console in the illustration consists of a standard receiver and preamplifier-line amplifier

chassis to remotely monitor and control a single frequency transmitter and receiver over one pair or two pair of control lines.

The unit is supplied with a control panel which is provided with meters, switches and controls for complete control of the station such as:

a. D.b. meter for modulation and line level indications.
b. Microammeter for signal and frequency checks of transmitter.
c. Speaker selector switch.
d. Modulation control.
e. Clock.
f. Intercom. and send switch.
g. Tone-signal switch.
h. Call letter holder.
j. Pilot lights for carrier indication, transmitter-on and speaker indicators.

The remote control console may be supplied with an additional line amplifier, a frequency monitor or both. The frequency monitor works in conjunction with the monitor receiver and is useful for monitoring r.f. carrier and frequency and indicating modulation. It is also possible to get consoles which will control a two frequency transmitter and two receiver system plus the features mentioned above.

The following functions can be accomplished over one twin conductor cable:

a. Turn transmitter on and off.
b. Modulate transmitter.
c. Amplify audio from receiver from remote central station.
d. Intercommunicate with paralleled remote units on same control line.

The following functions may be added later if new system requirements arise in the future:

e. Turn transmitter on and off for a second frequency.
f. To amplify audio from a second remote receiver.
g. Turn on and off a second receiver or monitor at a remote location.

The console is operated with a dynamic microphone with push-to-talk control or foot switch control. When the output of the console is fed into a matched line, it is possible to operate this unit over very great distances. However, it does not appear economical to operate over a land line over 15 miles in length. It has been estimated that land line service can be had from telephone companies for a rental of about $4.00 per mile per month.

If the power company constructs its own line, a cost of about $300.00 per mile can be expected, depending on labor and material costs and the number of circuits used.

When land line construction is not possible, radio remote control circuits can be used when equipment is adapted for this purpose.

4. *Mobile units.* These installations are divided into two different types, one in the trucks and the other in the passenger car, usually that of the manager, official or superintendent.

Units for truck operation employ a transmitter having 30 watts r.f. output from a 6 volt d.c. battery power input. The plate supply is furnished by a dynamotor—420 volts, 250 ma. Modulation is 30-3000 cycles, 20 kc. deviation each side of carrier. Testing is accomplished by a rotary switch which meters all circuits. A one quarter wave roof top antenna is used. The driver and final tubes of the transmitter use no current until the microphone is removed from the hang-up box. This turns on the tube filaments and brings them up to operating temperature in the short space of time required to lift the microphone from the instrument panel to the operating position. Replacing the microphone on the hang-up box again turns the filaments off.

The mobile receiver has a battery drain of 6.0 amperes at 6.0 volts d.c. input using a synchronous vibrator power supply. In testing, all circuits are metered with a selector switch.

After a little practice, smooth system operation can be especially noted by the absence of useless chatter, and the direct and to the point communications being used. At the time the two-way radio of the Nishnabotna Valley Rural Cooperative was put into operation, the truck batteries and generators used were standard equipment. Trouble was experienced in keeping truck batteries charged. However, the crews soon learned the technique of operating so that oversize batteries and generators were not needed and no further trouble has ever arisen in this respect. Some power companies use code words to convey messages, thus shortening their transmissions and allowing some privacy. One of the methods used by maintenance crews to pin point the location of power line trouble is: Two maintenance crews go out, one proceeding on ahead. This crew disconnects line taps and the crew in the rear then calls in to have the line energized. This crew, in a location where they can observe to see if the oil circuit reclosers hold in, know that if the reclosers do not reopen, the trouble is on one of the disconnected taps. The first crew then reconnects these taps until the defective branch circuit is located. Communication between the two trucks makes this method speedy and sure.

In this swiftly growing field, employment should be gained by many licensed operators needed for the necessary checking and maintenance work on the equipment.

This form of communication is allowing customer service to keep in step with customer power consumption, and is rapidly paying its way through better service, economy in operation and better public relations. Yes, this formerly undreamed of convenience now fathers the so often used, "I don't know what we would do without it".

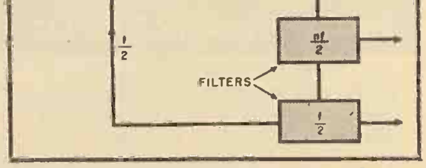
Frequency Dividers

(*Continued from page* 8)

almost independent of tube characteristics—practically speaking at least.

A typical circuit is shown in Fig. 4B. A tube which has two grids capable of controlling the plate current is required, such as the 6SA7 and the 6AS6. The 6AS6 is especially suitable. In its stable state, a high cathode current flows, due to the low bias on the first grid. There is no plate current, the suppressor (or second control grid) being biased beyond cut-off. Consequently, the screen current is high. The plate is held at its initial level by the current through the diode. A negative trigger is fed to the plate through the diode, and the reduction in plate voltage is passed on to the control grid. The resulting drop in screen current drops the cathode voltage, reducing the suppressor bias by an amount sufficient to allow the flow of plate current. This causes a further reduction in plate voltage, and the regenerative connection between the plate and grid continues the action. This goes on until the plate voltage is essentially zero and the control grid at or near cut-off. At this point the grid starts to rise on the time constant RC and the cathode follows. Through regeneration, again the process is continued until the cathode potential is high enough to cut off the plate current and the circuit is ready for another trigger. With all voltages fixed, the delay time is proportional to the time constant RC. Since the distance (voltage-wise) the plate has to fall is determined by its initial level, the delay time can be varied by varying the diode bias, and thus the initial plate voltage. During the time the plate voltage is falling the circuit is unaffected by trigger signals, because the diode is cut off. The output is rectangular and may be taken from either the cathode or the screen. Control may be established with almost any triggering waveform, as long as it has a negative portion of sufficient amplitude.

Fig. 5. Circuit for dividing input frequency by 2 and then multifying it to give various outputs as indicated.



Design is for a given output frequency and it will divide to that from any of its harmonics. Since all voltages maintain a given ratio regardless of the plate supply voltage, the latter may be varied over wide limits without causing a change in dividing ratio or failure to operate. No output is obtained without triggering signals. The total delay time may be calculated from the time constant as follows:

$$T = \frac{E_p - E_c}{E_b - E_c} RC$$

where E_p and E_c are the initial plate and control grid voltages and E_b is the plate supply voltage. The resistance R should be relatively large, to keep grid current down. The frequency of operation is limited only by the stray capacities of the circuit and by the tube capabilities. The phantastron is one of the most satisfactory and reliable of circuits for use in frequency division.

Thyratrons can be used—see Fig. 4C—for frequency division much the same as other relaxation oscillators. The major disadvantages are due to changes in triggering level resulting from temperature and emission changes, and the upper frequency is limited to some twenty or thirty kilocycles by the deionization time. The timing circuit may be either in the plate or cathode circuits, but the cathode type is favored since the timing wave has more effect there due to the amplification factor of the grid. Gas diodes can be used, but the firing and extinction potentials are relatively close together and stability is usually poor.

Any of the dividers discussed may of course be operated in chains in order to obtain stable high order ratios. By the use of feedback complex fractional ratios may be obtained. The feedback voltage is fed back from one stage to an earlier one such that the early one is triggered a little before it would ordinarily be. The duration of that stage's operation is therefore reduced slightly from normal and so of course the overall ratio of the chain is altered slightly, resulting in a complex but stable ratio of input to output frequencies.

While no attempt has been made in this article to give detailed design information, it is believed that sufficient information has been given to enable the user to determine what type he should or would prefer. In some, notably the synchronized and blocking oscillators, design is by experiment anyway to a considerable extent; and in others, design can probably be effected through a combination of the information herein presented and experiment in as short a time as would be required for detailed design preliminary to construction. A bibliography is included for those who wish further and more detailed information on the subject.

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Microwave Trans.

(*Continued from page* 18)

past and several kinds of operation have been employed. The type of tube that is now almost universally employed is the multicavity magnetron, shown in Fig. 15, in which the anode is broken up into a number of segments, each of which contains a cavity resonator. In the simplest mode, called the π mode, alternate segments are in phase with each other, while adjacent segments have opposite polarity.

All electron trajectories are bent in the same way and they travel around the cathode as a cloud rotating at some average rotational velocity. Electrons moving across the gaps between cavities have their rotational velocity increased or decreased depending upon their phase. A bunching action occurs, similar to that in the klystron, which amplifies r.f. power across a later gap. A probe or a slot couples one of the cavities to an output circuit using either coaxial or waveguide transmission lines. In this type of magnetron, the conditions for oscillation are given by the following relationship[5]:

$$f = \frac{4\pi n V}{r_a^2 B^2} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where n is the number of pairs of segments.

The starting voltage at which oscillations occur is given by[6]:

$$V = \frac{\pi f}{nc}\left(r_a^2 - r_c^2\right)\left(B - \frac{2\pi n f}{nc} r_a^2\right) \quad (6)$$

This voltage is known as the Hartee voltage after Hartee who developed the theory.

Magnetron Design Information

As in the case of the klystron oscillator, the engineer can usually select a commercially available magnetron to meet most requirements. For interpretation of magnetron performance it is necessary to make a number of observations that are not made at lower frequencies using conventional type tubes. In addition to the fact that different modes of operation exist and multiple cavities are involved, the magnetron employs a magnetic field, instead of the usual grid voltage, as the controlling parameter.

Two types of charts are normally presented with commercial magnetrons. One type, known as the performance charts, describes the operation of the magnetron in terms of its input circuits. The other type, called the Rieke diagram, describes the operation of the magnetron in terms of its output circuits. A typical set of performance charts are shown in Figs. 11 and 13. Consider the chart shown in Fig. 11. In this chart four parameters are shown, i.e. plate voltage, plate current, magnetic field, and power output. Knowing any two of these parameters, the other two can be determined from this chart. For example, if a plate voltage of 20 kv. and a magnetic field of 2300 gauss are employed, the plate current will be 20 amperes and the power output approximately 225 kw. It should be noted that these charts assume a matched load impedance.

The second performance chart (usually 11 and 13 are combined in one chart—however the author separated them to clarify their use) plots plate voltage, plate current, efficiency and frequency deviation. Hence for the example cited above with plate voltage at 20 kv. and plate current at 20 amperes the efficiency would be approximately 58 per-cent and the frequency deviation about 2 megacycles.

A Rieke diagram, (Fig. 16 shows a typical one) expresses the performance of a magnetron in terms of the r.f. loading for a given input operation. To use this diagram, the standing wave ratio η_v and distance d from magnetron output to voltage minimum are measured. These parameters are then expressed in terms of reflection coefficient K and phase angle β_1 by the following equations:

$$K = \frac{1 - \eta_v}{1 + \eta_v} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\beta_1 = \frac{d}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The point corresponding to these values is then found on the Rieke diagram and the power output and frequency deviation determined. For example, assume that a standing-wave ratio of 2 is measured with a voltage minimum 1 cm. from a magnetron operating at a frequency of 10,000 mc. The reflection coefficient, K, is therefore equal to 0.25 and the phase angle 0.33. This corresponds to the point marked A on the Rieke diagram and indicates an output of approximately 30 kw. at a frequency deviation of about 4 mc.

There are a number of terms that have been developed to express the performance of magnetrons. One of these is the "pulling figure" which is defined as the maximum change in frequency as the load phase is changed over all values while the voltage standing-wave ratio is held at 1.5—expressed in megacycles. Another is the "pushing figure" defined as the rate of change of frequency as the current is varied with constant magnetic field and load, expressed as megacycles per ampere. "Temperature coefficient of frequency" is the change in frequency due to change in temperature. These terms are frequently used in describing the over-all performance of magnetrons.

The degree of frequency stability of a magnetron oscillator is a function of these three parameters. To increase the frequency stability an external high Q cavity is placed between magnetron and load. This decreases the pulling figure. Automatic frequency control circuits such as the ones described in the previous article[1] can be used to further improve frequency stability. In general, mechanical tuning systems are used for the same reason that they are used in lighthouse oscillators.

The magnetron is normally used in pulsed systems, though recently a number of frequency modulated microwave links have been developed which employ magnetrons. There are a number of ways in which a magnetron may be frequency modulated. An external reactance tube, which varies the r.f. loading, can be used to vary frequency. Another method involves placing a thin filamentary type wire across the axis of one cavity in the magnetrons. It has been found that amplitude modulating the current flowing through this wire frequency modulates the magnetron output.

Conclusion

The lighthouse, klystron, and magnetron oscillators are used in virtually all microwave transmitters developed thus far. Other tubes such as the resnatron and the traveling wave tube show great promise and will probably be more widely used in the future. Use of these tubes as oscillators, however, usually entails the design of the tube itself and this subject is far beyond the scope of this series of articles. The traveling wave tube will be discussed when the r.f. amplifiers are considered, since at the present time this tube seems to have its widest application as a wideband amplifier.

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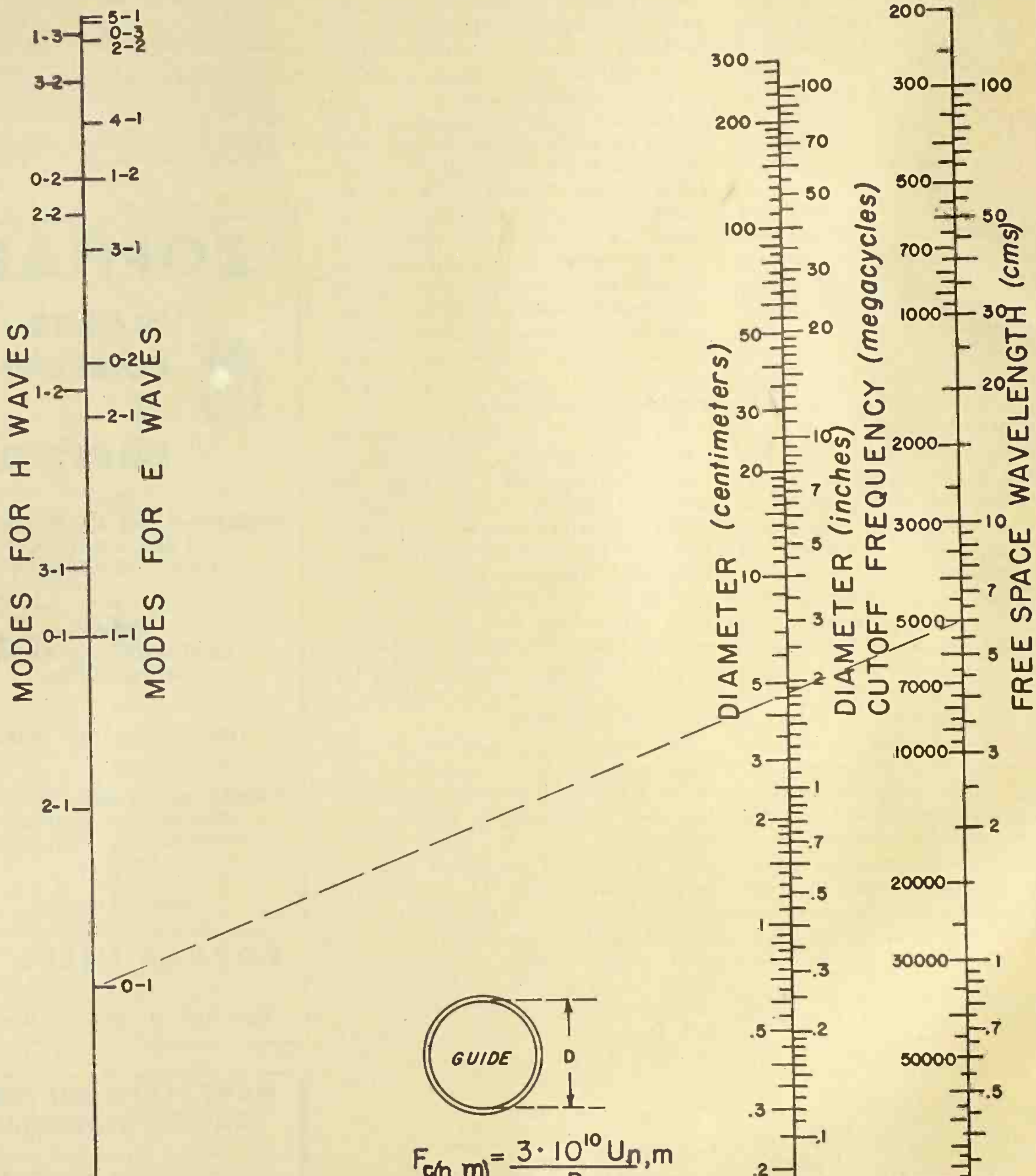
CIRCULAR WAVE GUIDE CUT-OFF FREQUENCIES

The cut-off frequency scale at right is aligned with the particular type of wave and mode selected on the scale at left, and the diameter determined from scale in center.



$$F_{c(n,m)} = \frac{3 \cdot 10^{10} U_{n,m}}{\pi D_{(cms)}}$$

where $U_{n,m}$ is the root of the Bessel for the wave and mode considered, and n is the order of the Bessel function and m is order of the root.