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TAMING THE HIGH FREQUENCY SIGNAL GENERATOR
By **J. M. Van Beuren** *and* **Jerry B. Minter**

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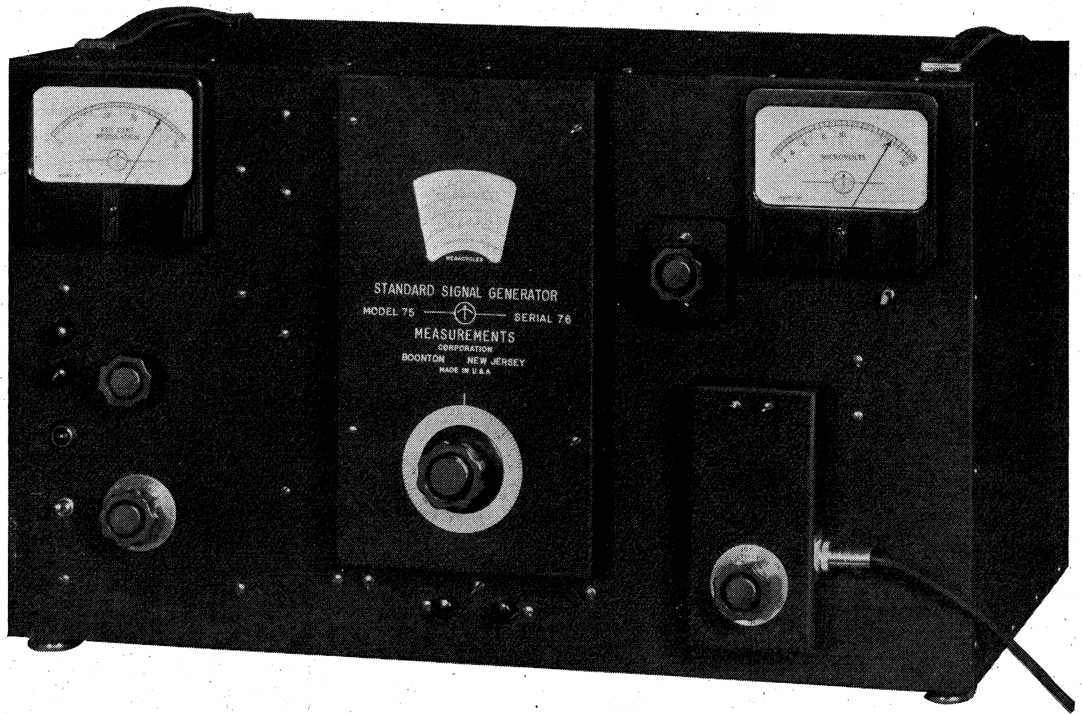

FIG. 16. PRODUCTION MODEL OF THE FINAL HIGH FREQUENCY SIGNAL GENERATOR DESIGN ANALYZED IN THIS PAPER

TAMING THE HIGH FREQUENCY SIGNAL GENERATOR

Analysis of Design Factors Involved in Generators of High Stability and Accuracy

BY JOHN M. VAN BEUREN and JERRY B. MINTER*

ANY signal generator consists basically of three units: 1) the oscillator which generates the RF carrier frequency, 2) the power supply and modulator which supply the necessary operating potential and modulation frequencies, and 3) the attenuator, which serves to reduce the output from the RF oscillator unit to the desired value.

In this discussion we will take up first the design considerations of the RF oscillator. The primary requirements of a good RF oscillator are: high stability of frequency, coverage of a wide range of frequencies, accuracy of frequency calibration, low backlash in the tuning system, and good amplitude modulation capabilities, all combined with a minimum of spurious frequency modulation.

Various difficulties arise in trying to obtain this combination of features, and there are various methods of overcoming some of them. It must be borne in mind, however, that all finished designs consist of a series of compromises between the ideal and what is possible to obtain.

Stability ★ Taking up the first of the considerations involved, that of high stability, good engineering practice dictates the use of a stable oscillator circuit, coil and condenser components that have extremely stable characteristics, rugged mechanical construction, and last but not least, tubes that give off a minimum of heat.

We are able to fulfill most of these requirements with the exception of the last, that of tube heating. While relatively little power is required from the RF oscillator, the dissipation of the tubes and resistors involved cannot be held much below 5 watts in average cases. While this amount of power seems small, it must be remembered that ventilating facilities are necessarily extremely limited, dut to the fact that the oscillator must be entirely enclosed in a metal shield to prevent leakage. Even 5 watts, under these conditions, can cause a considerable rise in temperature of the oscillator unit, with consequent expansion of component parts and frequency shift. The use of negative temperature coefficient compensating condensers naturally suggests itself, but in practice we usually find that due to different rates of heating of different parts and variations in tuning capacity, the ultimate result of trying to compensate usually turns out to be worse than the uncompensated generator.

Frequency Range ★ The second consideration of a wide frequency coverage adds further problems which necessitate still more compromises. Most conventional generators are tuned by means of varying the tank capacity. In order to cover a reasonable range on each tuning coil it is necessary to use a fairly large variable condenser. In a generator covering a total range of 100 kc. to 30 mc., the use of a condenser of around 350 mmfd. gives a reasonably good *LC* ratio in the neighborhood of the broadcast band. However, on the low frequency ranges, around 100 kc., the tuning condenser is considerably smaller than it should be for optimum operation, while at 30 mc. the *LC* ratio becomes considerably overbalanced on the capacity side.

The ideal situation would allow varying of both *L* and *C* in a fixed ratio, but unfortunately this would complicate the mechanical construction to a prohibitive degree.

Accuracy of Calibration ★ The third consideration, accuracy of calibration, brings in many of the difficulties experienced in obtaining high initial stability. The effects of tube aging, gradual changes in the size and shape of component parts, all must be eliminated as far as possible. Special care must be taken in the selection of coil forms, impregnating compounds, and wire insulation to insure that age and constant heat cycling do not cause mechanical changes in the coils. We have experienced considerable difficulty with low frequency coils in using silk insulated wire. Appar-

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ently the silk deteriorates and causes a change in the physical size of the coil which in turn affects its inductance. We have eliminated most of this trouble by the use of glass insulated wire in low frequency coils.

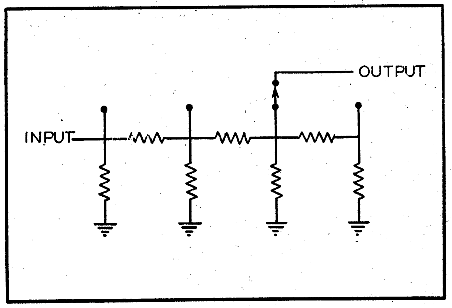

FIG. 1. CONVENTIONAL LADDER-TYPE ATTENUATOR DOES NOT REMAIN PURE RESISTANCE AT HIGH FREQUENCIES

The elimination of backlash from the tuning system of the signal generator is a study in itself. Our experience has been that excellent results can be obtained without the use of prohibitively expensive component parts if care is taken to choose first of all a design which is inherently sturdy mechanically, and then to eliminate all sources of excess friction from the bearings and contact wipers of the variable condenser.

Modulation ★ The subject of modulation capability brings us first to the choice of the method of modulation. Grid modulation has been used on a modulated amplifier, but is generally characterized by relatively high envelope distortion. It is not feasible to grid-modulate an oscillator direct. Plate modulation has become generally the accepted method, as it produces the lowest distortion of any workable system. Plate modulation can be applied directly to an oscillator using amplitudes up to 50%.

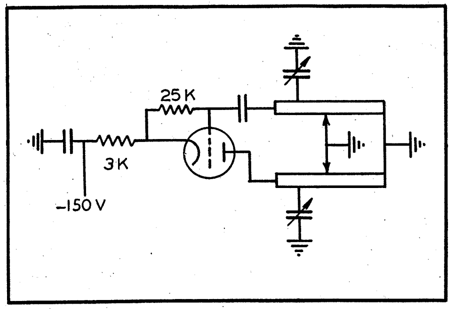

FIG. 4. PARALLEL RODS GANGED WITH VARIABLE CONDENSER FORM RESONANT CIRCUIT

In this case, of course, considerable spurious frequency modulation is produced as a result of the amplitude modulation. Where a master oscillator is used to drive a modulated power amplifier, the depth of modulation can be increased to 100%, while still maintaining low envelope distortion. Since the amplifier must track accurately with the oscillator over a wide frequency range, it is usually preferable to employ a screen grid type tube as a modulated amplifier to avoid neutralizing difficulties. Unfortunately screen grid tubes possess a characteristic "knee" on the modulation curve at the point where the plate voltage approaches zero. Consequently the envelope distortion rises somewhat between 90 and 100% modulation. Another difficulty arises when modulation at high audio frequencies is attempted at low carrier frequencies. The fly-wheel effect of the tuned amplifier tank makes it impossible to obtain considerable depth of modulation at the higher audio frequencies, unless the tuned circuit is heavily loaded with resistance to spoil the *Q* of the circuit. When this is done heavier modulation may be employed, but in turn the RF harmonics rise to a considerable value.

The consideration of spurious frequency modulation is an important one. The direct modulation of an oscillator is ideal from the standpoint of simplicity, but very often it is necessary to modulate at depths greater than 50% and, in certain types of measurements, frequency modulation cannot be tolerated. This leads us to the use of a master oscillator and modulated power amplifier. The MOPA is certainly superior in practically all electrical characteristics but, unfortunately, is many times more complex and difficult to adjust than the simple oscillator. In the case of a UHF signal generator operating at hundreds of megacycles, this problem becomes even more difficult, and a really successful instrument has not yet been developed. The design of ultra-high frequency oscillators involves many different problems from that of medium frequency generator, and a typical example will be discussed later in this paper.

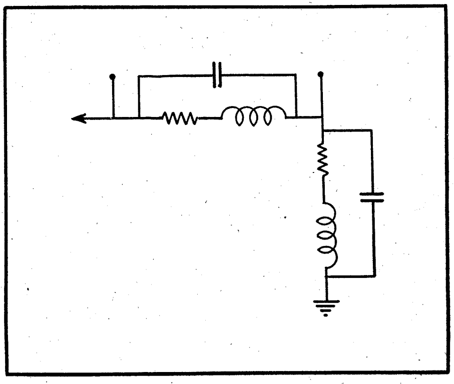

FIG. 2. ELECTRICAL EQUIVALENT OF ONE STEP OF CONVENTIONAL ATTENUATOR

Power Supply ★ The power supply and modulation equipment of most generators are of conventional electrical and mechanical design, and present few unusual problems to the engineer. Consequently we will pass on to the discussion of the attenuator, which might be termed the heart of any signal generator.

Attenuator ★ The most commonly used type of attenuator consists of several resistance pads connected in a ladder arrangement as shown in Fig. 1. This is the conventional picture of an attenuator, with series and shunt resistors connected in the usual manner. If resistances would only remain pure resistances at high frequencies, everything would be well, and the design of attenuators would present no particular problem. Unfortunately, this is almost never the case at frequencies above a few megacycles.

The actual electrical equivalent circuit of a single step of a conventional attenuator is shown in Fig. 2. Here we see that each resistor contains a certain amount of distributed inductance as well as some shunting capacity. At high frequencies, the distributed inductance forms a substantial impedance and can seriously upset the attenuation ratio of the step. This can be corrected by adjusting the amount of inductance in each resistor. For example, if the resistance ratio at DC is 9 to 1, at high frequencies the inductance of the series arm would have to be 9 times that of the shunt arm in order to maintain a correct ratio. This can be done but the process is clumsy, and due to the added inductance, the characteristic impedance of the attenuator will rise considerably. A much more satisfactory method is to eliminate as far as possible the inherent inductance of the resistors.

This can be done by using non-inductive carbon resistors and surrounding them by a close-fitting metal shell, which tends to short-circuit the inherent inductance of the resistor. Much the same situation applies to the shunting effect of the capacity of the resistors. This also can be compensated by adjusting the ratios of shunting capacity, but we have found that by using a low characteristic impedance attenuator, capacity effects even at several hundred megacycles are negligible.

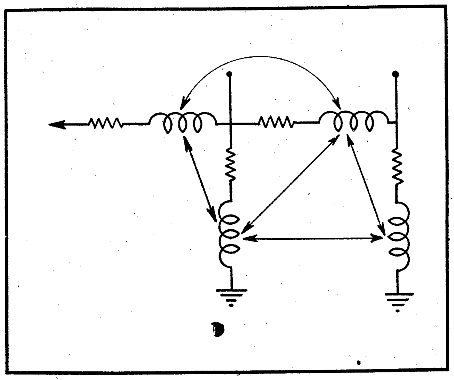

FIG. 3. ILLUSTRATING MUTUAL INDUCTANCE BETWEEN ELEMENTS OF ATTENUATOR

Self-inductive and capacitative effects become a minor consideration, however, when compared to the real stumbling block of most attenuator design, the effect of mutual inductance between the various steps of the attenuator. This situation is shown in Fig. 3. The effect of this mutual coupling between steps of the attenuator

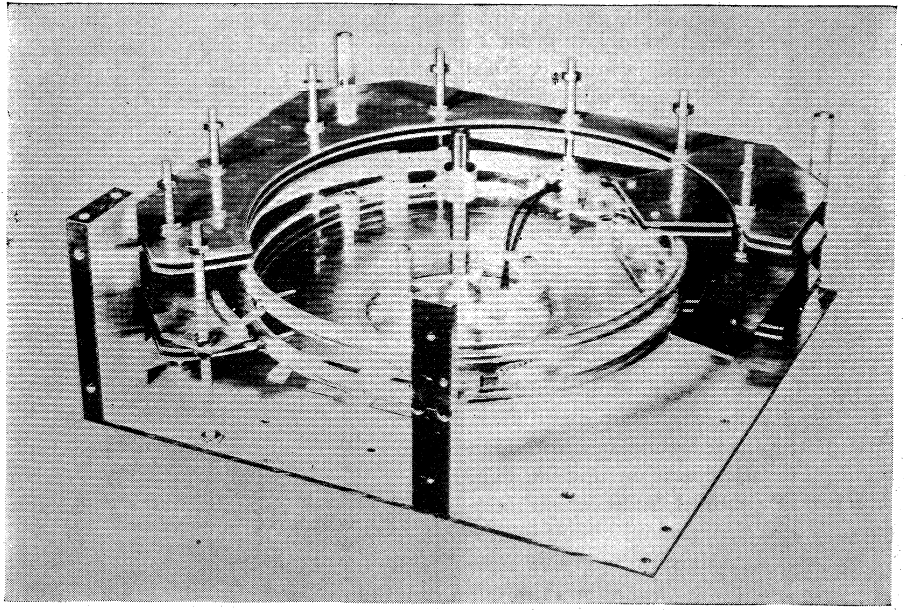

FIG. 6. THE COMPLETE OSCILLATOR ASSEMBLY, WITH ONE SIDE PLATE REMOVED. THE MAIN SHORTING CONTACTS ARE STATIONARY, WHILE THE UNIT IS ROTATED

can be so serious that at a frequency of 50 mc. an unshielded attenuator designed to give an overall attenuation of 120 db may actually give less than 20 db.

Therefore, the greatest care must be taken in the individual shielding of each step in order to prevent such interaction from taking place. It requires considerable study and experience to design an attenuator that is free from mutual inductance effects at frequencies above 100 mc. However, by careful design and placement of parts, it can be accomplished.

Design Details ★ Having discussed some of the basic problems of signal generator design, let us now follow the incorporation of these concepts into the actual design of a high frequency standard signal generator. We undertook the design of this instrument because a considerable need has been felt for an instrument to operate in the neighborhood of 400 mc. and also we were much interested in finding out what could be done toward attaining an accurate voltage source at these frequencies.

We recognized from the start that a great deal of conventional practice and design would probably have to be abandoned. However, we decided to see just what could or could not be retained, and just how much we would have to depart from what might be termed lower-frequency design. As it turned out, many of the things which we thought would present almost insuperable difficulties proved in practice to have very little to do with the successful operation of the instrument, and many things which we thought would present no difficulties formed the basis for most of the headaches.

However, the conclusion to be drawn from all this is that a great deal of conventional engineering design can be used at high frequency, provided that care is taken to think through the effect that higher frequencies have on the various circuit parameters.

Now to take up the design of the generator. The first thing was to set up desirable specifications. They were as follows:

FREQUENCY RANGE: 50 to 400 mc., greater if possible.
OUTPUT VOLTAGE: 1 microvolt to at least 100,000 microvolts.
OUTPUT IMPEDANCE: to be as low as possible.
ATTENUATOR: resistance type, balanced to ground.

The reason for some of these specifications may not be clear at first glance. Considerable discussion has arisen as to what is the optimum output impedance for a signal generator.

Since the ideal voltage source has zero impedance, we felt that the lower the output impedance, the better. While a great deal of work done is on 72-ohm transmission lines, it is extremely useful to be able to feed the output of the generator into the grid of a tube or other capacitative device. In the event that the output impedance of the generator is 70 ohms or more, the capacitative reactance of the grid is often low enough at high frequencies to upset seriously the termination of the output line. As a low impedance output can be used quite readily into a 70-ohm line, we felt that for all-around use the low impedance is the most practical. We chose the resistance type attenuator in preference to others mainly because it is the type with which we have had most experience and, also, we were curious to know whether such an attenuator would work at frequencies as high as 400 mc. As a great deal of work is done on balanced systems, we decided to make it of the balanced type.

Having set up a desirable set of specifications, the next step was to try to put them into an instrument. The first consideration was, of course, to generate the necessary radio frequencies. A number of circuits were considered with the idea of having as stable an oscillator as possible. This pretty much ruled out lump circuit constants, and indicated the use of a resonant transmission line of some sort for the

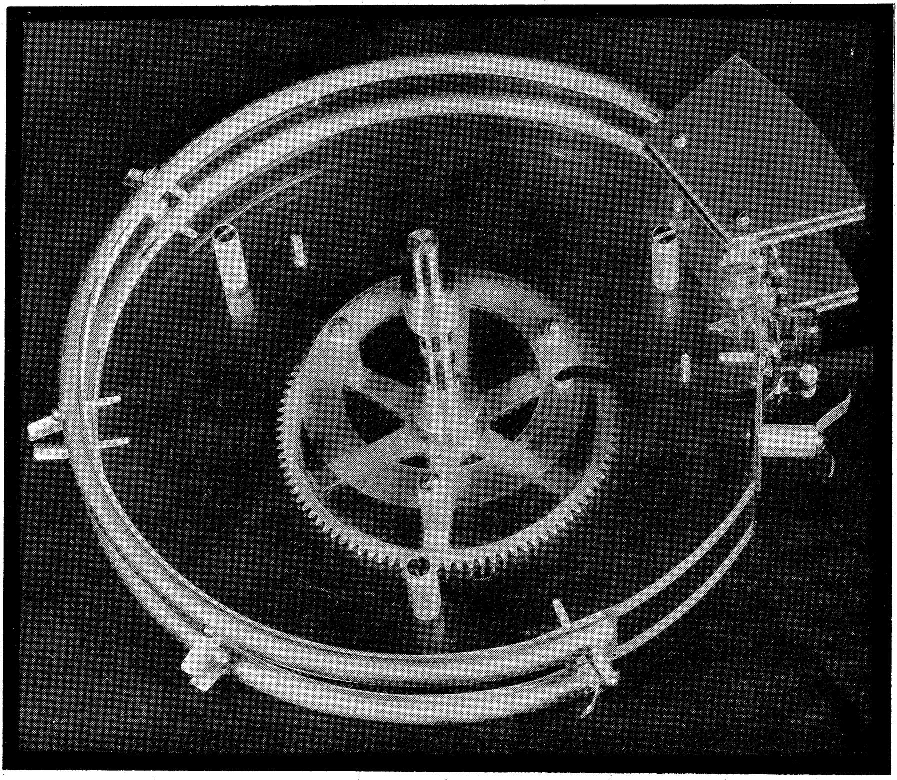

FIG. 5. RESONANT CIRCUIT COMPRISING PARALLEL RODS, CONDENSER PLATES, AND OSCILLATOR TUBE, AT RIGHT, DESIGNED AS A ROTATABLE MECHANICAL ASSEMBLY

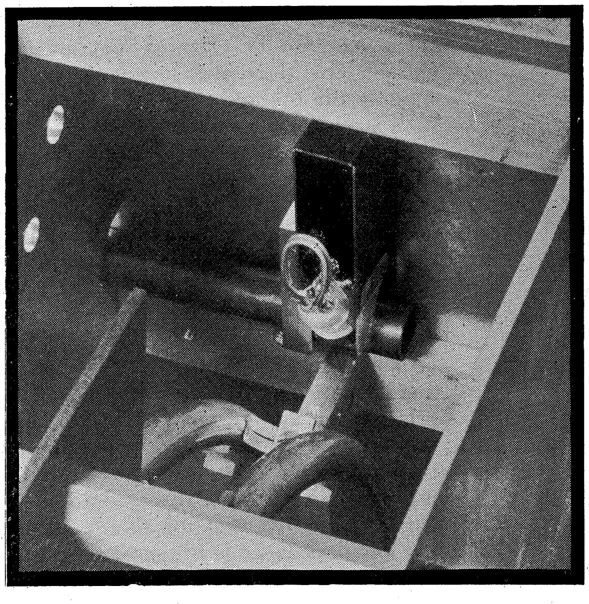

FIG. 7. VARIABLE COUPLING LOOP IS ADJUSTED BY MEANS OF CONTROL GEARED TO THE HOLLOW SHAFT

frequency determining element. The first type considered was a coaxial line which has the advantages of a low radiated field and a high Q. An experimental oscillator was built along these lines. It seemed to operate quite well at the higher frequencies, but in order to reach a reasonable lower frequency limit, the physical size became relatively tremendous, unless capacity loading was added to reduce the low-frequency limit. A great deal of difficulty was experienced in trying to make a satisfactory co-axial type oscillator which could be loaded with capacity. So this type was finally abandoned in preference for the parallel rod (balanced line) type of resonator.

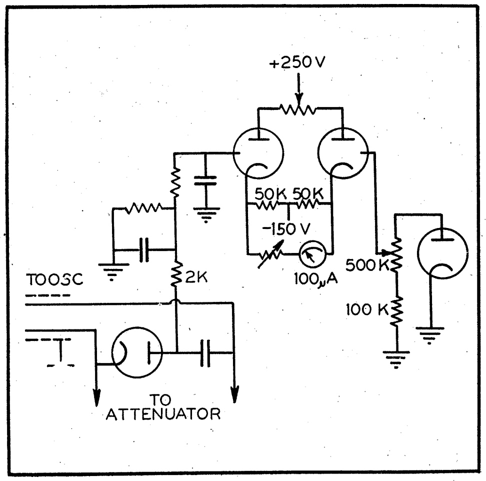

FIG. 8. VOLTMETER COMPRISING UHF DIODE ACROSS BALANCED TRANSMISSION LINE

Upon further experimentation it was found that the parallel rod oscillator seemed to have many advantages for use in a signal generator. The oscillator could easily be loaded with capacity to reach a reasonably low frequency, while keeping physical size well within bounds. A pair of rods about 18 ins. long with approximately 50 mmfd. of capacity would give a low limit somewhere around 50 mc. In order to cover the complete range of 50 to 400 mc., either several ranges of capacity load would have to be employed or a variable condenser would have to be used. In order to maintain a fairly constant output and avoid difficulties in range changing, it was decided to try variable capacity plus a variable length line to cover the whole frequency range without a switching.

The fundamental circuit is shown in Fig. 4. The parallel rods which form the resonant circuit have a shorting slider whose position can be varied. A ganged variable condenser is connected at the open end of the line, which is varied in conjunction with the slider. The grid of the oscillator tube is connected through a blocking condenser to one of the rods. The grid leak is returned to the cathode. For the sake of simplicity it was decided to ground the B +, and connect the plate directly to the other rod. The resistor in the cathode lead was found to improve general operation.

Having determined on a suitable oscillator the next problem was to adapt it to a suitable mechanical design. There are two main actions to be accomplished in varying the frequency. The position of the shorting slider must be varied in combination with the variable loading capacity. It was also found necessary to short the unused portion of the parallel rods at high frequencies, as the section behind the slider would tend to resonate as a half-wave line, causing serious dead spots. The first design considered was a lead screw to vary the position of the slider, connected to a gear train which rotated the variable condenser. The difficulties involved in such a design were vast, as the mechanical complexity assumed nightmarish proportions when we tried to gang together the aforementioned lead screw and gear train to some means for shorting the unused portion of the line. In addition to the mechanical difficulties, the physical size was also rather large. So, in order to conserve space, we tried rolling up the parallel rods in a circular shape and having the shorting slider travel around in an arc.

We finally found that if we used the circular-shaped rods, and moved the rods instead of the slider, all three operations of varying the length, the capacity, and shorting the unused portion of the line could be done very simply with only one moving part. The type of assembly which evolved from this idea is shown in Fig. 5. The parallel rods are bent into three-fourths of a circle and mounted on insulating discs. The oscillator tube is mounted on the discs and rotates with them. A set of condenser plates is attached to the open end of each rod for adding capacity. The clips spaced along the length of the line are used to short the unused portion of the line, as will be explained later.

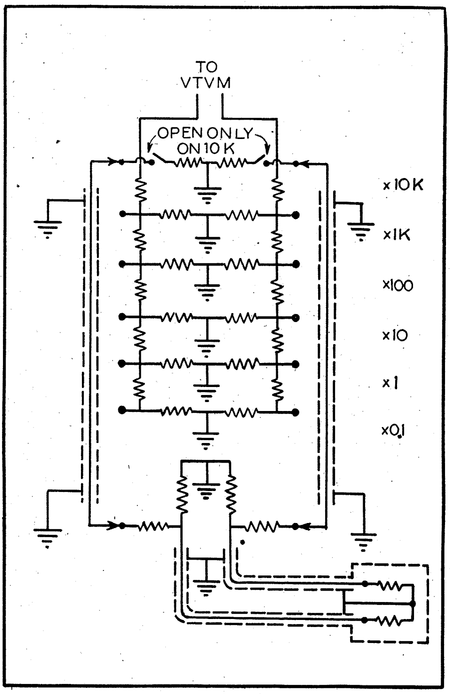

FIG. 9. DIAGRAM OF THE BALANCED LADDER-TYPE ATTENUATOR FINALLY SELECTED

Fig. 6 shows the complete oscillator as-

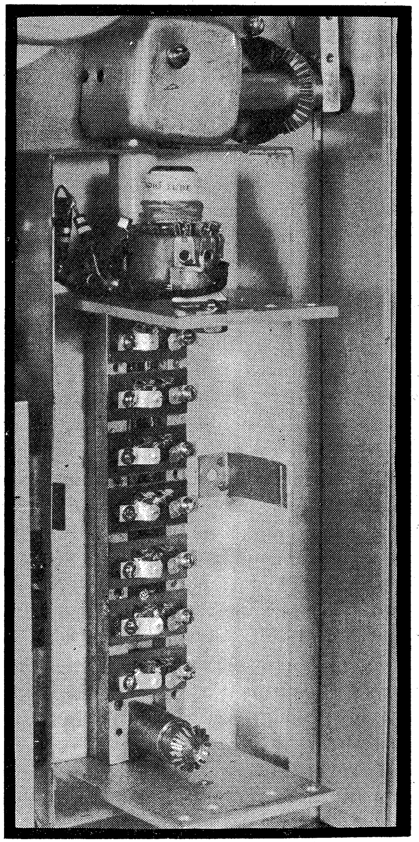

FIG. 10. CLOSE-UP OF ATTENUATOR MOUNTING, VT VOLTMETER, AND DC AMPLIFIER

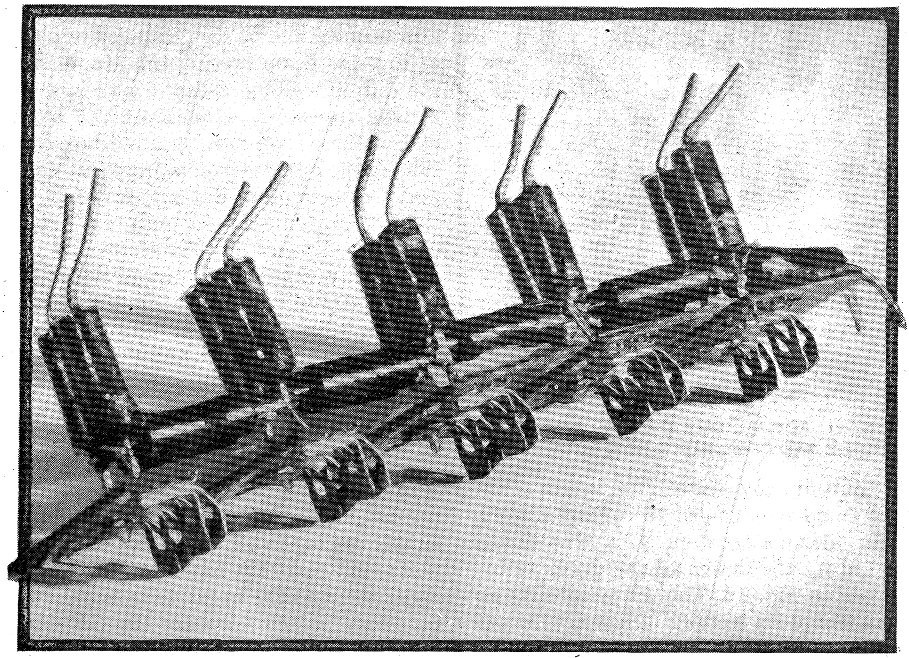

FIG. 11. COMPLETE SET OF SERIES AND SHUNT RESISTORS MOUNTED WITH THEIR SILVER LEAF SPRINGS FOR GROUNDING THE SWITCH DRUM ILLUSTRATED IN FIG. 12

sembly with one side plate removed. The rotor unit turns on its axle, and the main shorting contact, which controls the length of the line, is held stationary. Consequently, as the rotor revolves the length of the line is varied. As the length of the line increases, the condenser plates attached to the rotor mesh with the stator plates which are held on a series of studs. These stator plates are so shaped that, as the length of line increases, the rotor plates mesh deeper and deeper with them, thus adding considerable capacity loading. Now, if we turn the rotor counter-clockwise, the active length of the line decreases and the inactive length increases. As mentioned before, the inactive portion tends to resonate as a closed half-wave length of the line at the higher frequencies, and it is necessary to short it at frequent intervals to prevent dead spots. The clips which are spaced along the line perform this function by shorting on a stationary strip at the proper time. A pair of these clips can be seen just beginning to short in Fig. 5. These clips continue to slide along the stationary shorting strip, keeping the inactive portion broken up into short sections and preventing resonances in the working range. Thus the three operations of varying the length of the line, varying the capacity loading, and shorting the unused portion of the line are all accomplished with the single movement of the rotor.

Having designed the means for generating the required range of radio frequency, the next problem was to get it to the attenuator. This involved some sort of pick-up loop system and a means of controlling the voltage into the attenuator over a 10 to 1 range. A conventional pick-up loop and slide wire were tried and proved very unsatisfactory, because the relatively large inductance of the slide wire caused it to resonate in the working range. We assumed that in order to avoid excessive frequency reaction when the fine output control was varied, a relatively constant load would have to be presented to the oscillating circuit.

Various systems of slide wires, capacity and resistance devices were tried and found sadly wanting; and in desperation we turned to a simple variable coupling loop. Surprisingly enough, this worked very well, and caused less frequency reaction when varied than any of the systems previously tried. A mechanical design was then worked out as shown in Fig. 7. The coupling loop is mounted at the end of a T branch of a hollow copper tube. From the coupling loop leads run inside the tube, spaced by polystyrene beads, to form a balanced transmission line of approximately 150 ohms surge impedance. The beads are slightly smaller than the inside diameter of the copper tube, and the wires forming the transmission line are flexible so that the line can twist freely inside the tube. The tube is supported by mounting blocks, one of which can be seen in the picture, and can be rotated in its mounting. This causes the pick-up coil to approach or move away from the main shorting contact, which is the point of maximum current. In this way, the coupling is varied and the voltage at the end of the line is varied with a minimum of complexity. The coupling at the high frequencies between the tank circuit and the loop increased greatly and we found it necessary to supply a small copper shield for the loop to retire into. Without this shield only approximately a 3 to 1 maximum-to-minimum voltage was obtainable.

Upon leaving the RF unit, the transmission line from the loop enters the attenuator system proper where the vacuum tube voltmeter is located. The voltmeter consists of a special ultra-high frequency diode connected directly across the balanced transmission line as shown in Fig. 8. The maximum voltage that can be developed across the line over the whole frequency range is approximately 1 volt and, as we wished to vary this over a 10 to 1 range, it was necessary to be able to read accurately on a meter 1/10 volt across the line. If two diodes were used with one plate connected to each side of the line, and the cathodes grounded, this would

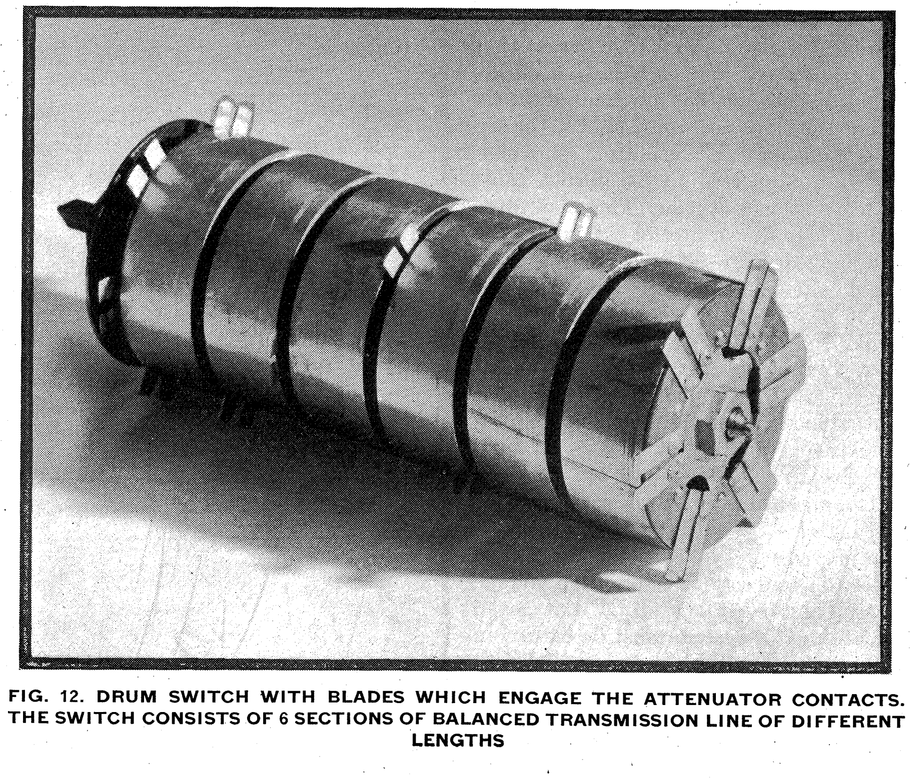

FIG. 12. DRUM SWITCH WITH BLADES WHICH ENGAGE THE ATTENUATOR CONTACTS. THE SWITCH CONSISTS OF 6 SECTIONS OF BALANCED TRANSMISSION LINE OF DIFFERENT LENGTHS

give only .05 volts per diode at the minimum position, and this was found too small for satisfactory indication. Therefore, a special diode with low cathode-to-heater capacity was used and placed directly across the line. This gave very satisfactory indication with the 1/10 point occurring at approximately 4% of full scale on an expanded scale meter. In this case, the diode is used as an essential pure voltage source, the current to operate the meter being supplied by a balanced DC amplifier of high stability. When used as a voltage source only, even these extremely non-uniform experimental diodes are quite satisfactory and follow a predetermined calibration curve very closely.

From the vacuum tube voltmeter the voltage continues into the attenuator, the diagram of which is shown in Fig. 9. The attenuator has six steps of 10-to-1 ratios and is of the balanced ladder type, having a characteristic impedance of 75 ohms per side. The voltage is picked off from the desired attenuator step and transferred to the output cables in a manner which will be described later. A view of the attenuator, vacuum tube voltmeter, and DC amplifier is shown in Fig. 10. The voltage from the RF unit emerges from the transmission line at the upper right hand side, goes through a junction box, and descends into the attenuator shield where it is measured by the diode.

Below the shelf on which the diode is located, the attenuator resistors themselves are arranged. The series resistors run vertically downwards between the two side bars, while the shunts extend through holes in the panel and terminate on the front of the panel. The junctions of the shunt and series arms are connected to the small silver plated clips which are mounted on the bakelite strips. The pairs of series and shunt resistors of the balanced system are placed close together so that stray inductive and capacitative effects tend to cancel out. The junctions of the six attenuator steps are brought out to the top six sets of contacts. The bottom set of contacts are connected to the output cable system on the front panel. The small silver leaf springs shown are for grounding the switching drum which will be described. Fig. 11 shows a complete set of series and shunt resistors soldered to their contact strips. In operation, the resistors are almost completely surrounded by metal which largely eliminates both self and mutual inductance effects, making it possible to operate the attenuator at high frequencies.

The problem of connecting the various attenuator steps to the output cable system proved very difficult. We felt that in order to avoid serious errors from voltage step-up and reflections, all RF voltages in the attenuator system must be carried in properly terminated lines. The difficulty to be overcome was the design of a transmission line of constant impedance so that when the bottom end was connected to the output cable system, the length of the line could be changed to contact the desired attenuator step. This was finally solved by the design of the drum switch shown in Fig. 12. The drum consists essentially of six sections of balanced transmission line of different lengths, arranged in cylindrical form, with the sections of line running parallel to the axis of the cylinder. One end of all the sections of line lies in a plane at the bottom of the drum, and connects to the output cable system in turn. The upper ends of the sections lie at various points along the drum, and by rotating the drum parallel to the attenuator, the various lengths of line are switched in between the output cable contact and the desired attenuator step contact.

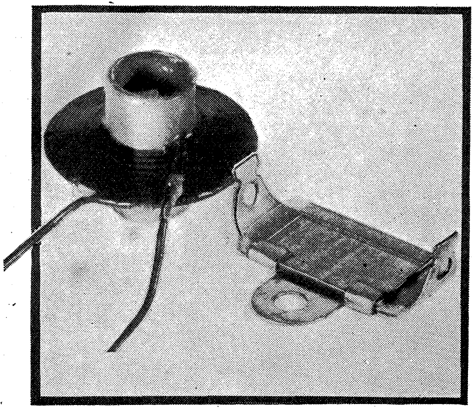

FIG. 14. ACTUAL SIZE OF THE RF FILTER CHOKE AND CONDENSER IN SUPPLY LEADS

In this way the voltage is transferred from each attenuator step to the output cable in a properly terminated line. The arrangement can be seen installed in place in Fig. 13. Upon leaving the attenuator, the output voltage enters a pair of 3-ft. flexible transmission lines. At the outer end of these lines is a terminal box containing the proper terminating resistors to avoid reflections in the output cable. As the entire attenuator and output system is of balanced design, both mechanically and electrically, the ground currents which are often a serious source of trouble in single-ended attenuators cancel. Since all voltages are carried in properly terminated lines, reflection difficulties are avoided and the attenuator system works with remarkable success at 400 mc.

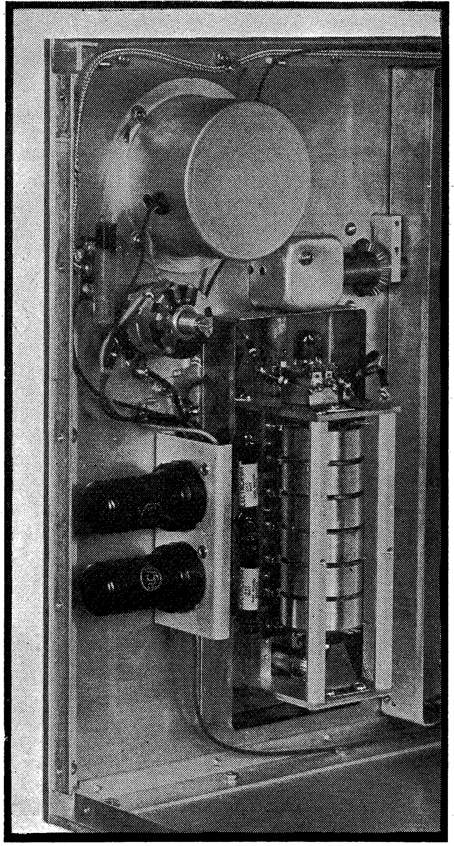

FIG. 13. ASSEMBLY OF ATTENUATOR AND SWITCH ELEMENTS SHOWN IN FIGS. 11 AND 12

The modulation and power supply unit is of conventional mechanical and electrical design. Both a positive and negative supply are needed, the positive to furnish plate voltage for the modulator and audio oscillator, and the negative to supply the necessary − 150 volts for the RF oscillator. A small rectifier and filter system provide 6 volts DC for the heater of the RF oscillator tube. This largely eliminates hum modulation at the high frequencies and makes for a clean note at 400 mc. A primary line voltage regulator maintains constant AC input voltage to the generator at all times.

In the design of the signal generator, leakage is an important factor, and filters must be provided to eliminate stray RF from the voltage supply leads. The component parts of the filter system are shown in Fig. 14. The choke is wound edgewise on a paper tube form. This construction was chosen to reduce capacity between the input and output leads. The associated condenser is of the strap type, having extremely low inductance to ground. In this condenser the "hot" plate runs directly through the surrounding grounded plate, making an extremely effective by-pass at high frequencies.

The oscillator unit and attenuator are carefully shielded by means of copper shields which completely surround the respective units. The overall shielding is accomplished by the metal case. Shafts exposed to RF fields are carefully insulated and grounded to prevent their carrying stray voltages outside the case.

A general back view of the experimental model of this generator is shown in Fig. 15. The power supply and modulation equipment are located on the right hand side and above them can be seen the back of the percentage modulation meter. Between the power supply and the RF unit are located the filters. The chokes are located in aluminum shield cans and the filter condensers are tied down directly on the front panel. The tuning motor is located on the side of the RF unit. Since the main tuning dial of the generator makes some 60 revolutions, the tuning motor saves a good deal of work for the operator. To the left of the RF unit can be seen the pick-up loop support, the tube

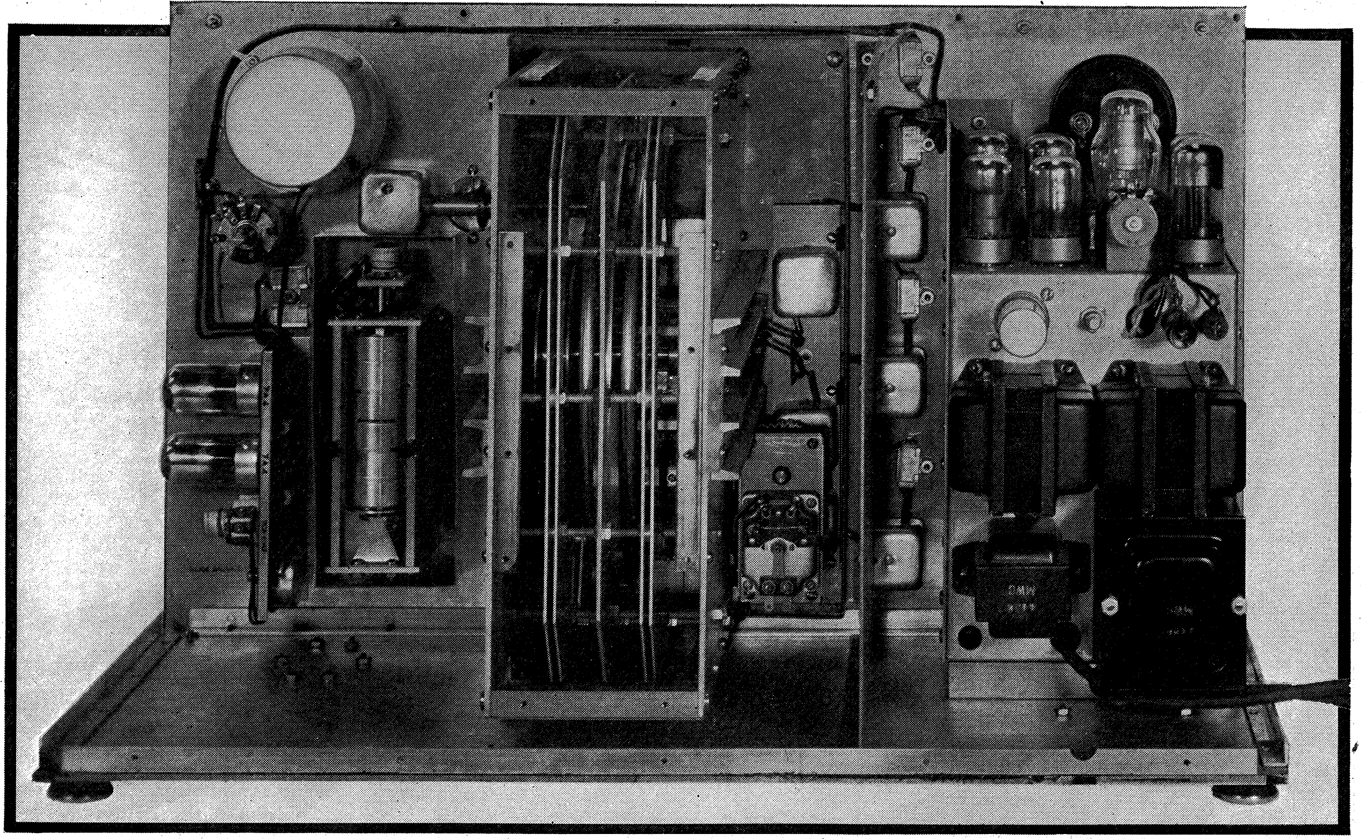

FIG. 15. REAR VIEW OF THE DEVELOPMENT MODEL. POWER SUPPLY AND MODULATOR ARE MOUNTED ON A SEPARATE CHASSIS AT THE RIGHT, WITH THE MODULATION METER ABOVE. MOTOR DRIVE FOR TUNING IS AT RIGHT OF THE ROTOR

which carries the RF from the oscillator to the attenuator. The bevel gear, controlling the position of the pick-up loop, is just to the left of the RF unit. The attenuator and DC amplifier have been described before. A shield is supplied around the output meter to prevent any stray leakage from it.

A front view of the instrument is shown in Fig. 16. The modulation controls, line switch, pilot light, and binding posts for external modulation are at the left. In the center is the main tuning dial and above it the calibration dial. The two push buttons below the dial cover control the tuning motor. To the right of the dial cover is the fine output adjustment knob. Control of this varies the reading of the output meter, the reading of which is multiplied by the indicated factor of the attenuator dial. The output cables plug into the side of the attenuator cover and can be removed for convenience.

A few words as to the methods of testing this instrument may be of interest. The attenuator ratios are, of course, one of the most important features of the generator. They are checked as follows: The output is turned up full and a vacuum tube voltmeter is placed across the output terminals and the calibration of the output meter adjusted until 1/10 volt appears from each output terminal to ground. Then a receiver whose second detector output voltage has been calibrated in a 10-to-1 ratio is attached to the generator. The attenuator multiplier is then reduced from × 10K to × 1K and the output of the latter voltage is checked. Then the gain of the receiver is increased until the second detector output voltage is again .1 volt, upon which the generator attenuator is moved down another step and the output voltage again checked. This procedure is followed for each step on each side of the attenuator at 50, 100, 200, 300, and 400 mc., to make sure that no serious frequency errors occur, and that proper balance between the two sides of the output system is maintained. After the attenuator checks have been completed, the generator is checked to make sure that no excessive leakage is present. Finally, the generator is calibrated against harmonics of a crystal oscillator.

The design of this generator offers the following features:

Modulation to 50% from the internal 400- or 1000-cycle oscillator, or from an external source covering the audio range. The frequency range is 50 to 400 mc.

Calibration accuracy, due to the high stability of the oscillator, can be maintained to better than ½% over long periods. The output voltage is continuously variable from 0.2 volt to 0.2 microvolt. Leakage below 300 mc. is not measurable on a sensitive receiver. Recent experimentation has enabled us to maintain leakage even at 400 mc. at less than 1 microvolt. This instrument supplies a much needed tool to the engineer working in this range, for it is capable of making measurements with an accuracy heretofore unattainable at these frequencies.

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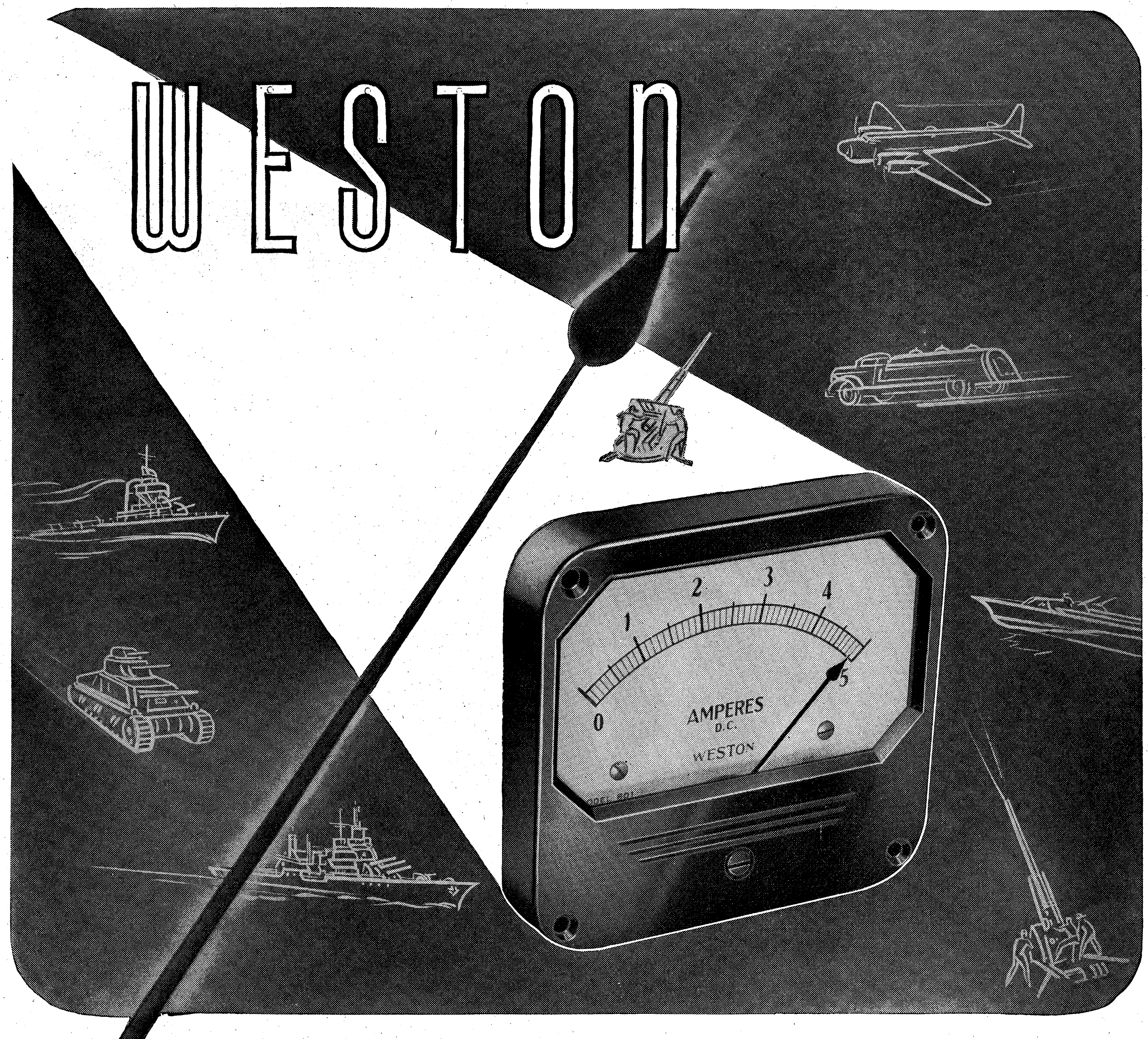

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