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RADIO WORLD

REG. U.S. PAT. OFF.

The First National Radio Weekly

654th Consecutive Issue—Thirteenth Year

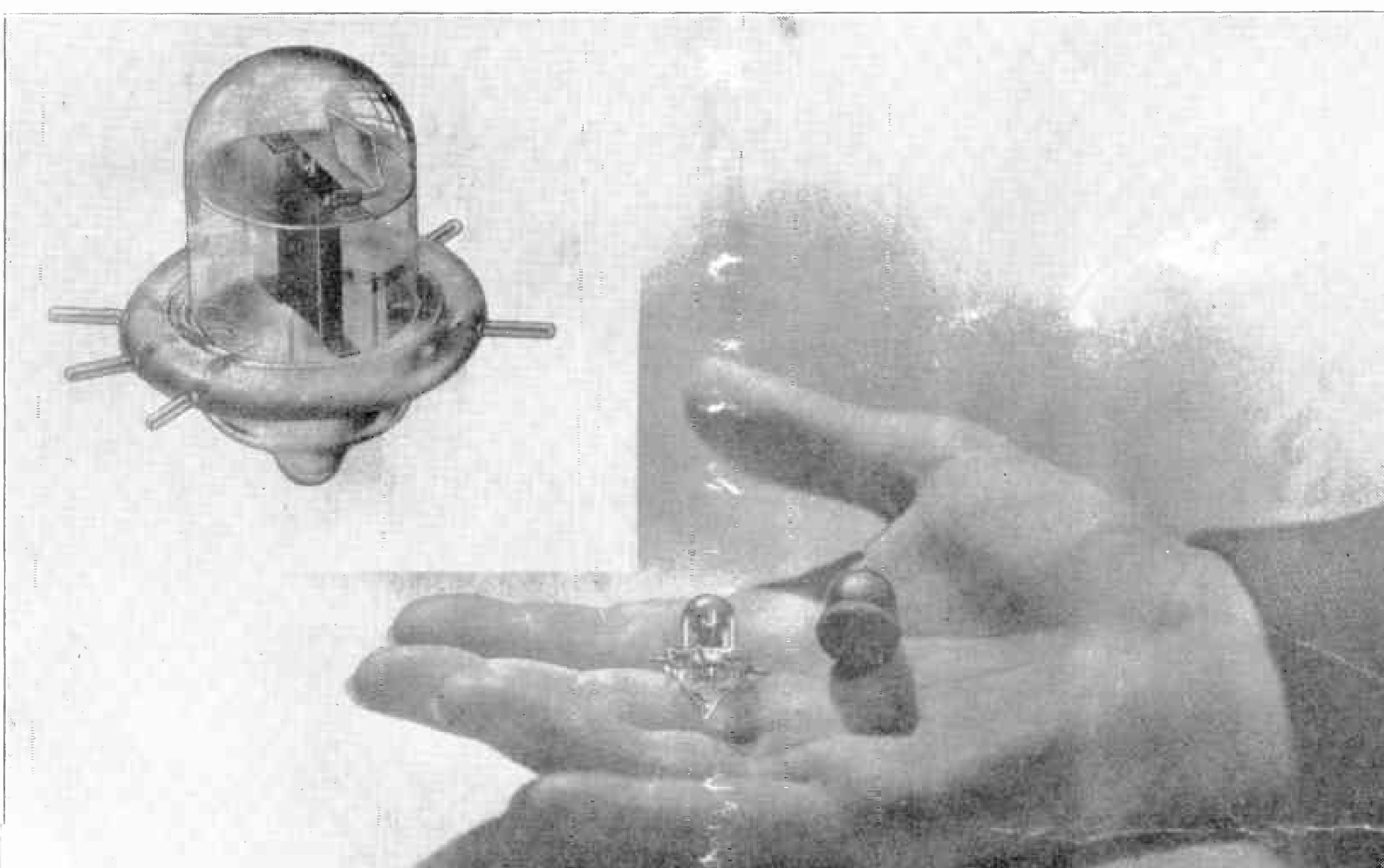
Oct. 6th 1934 15c Per Copy

UP-TO-DATE SHORT-WAVE CONVERTERS

Bridge Measurements

Volt-Ohm-Milliammeter

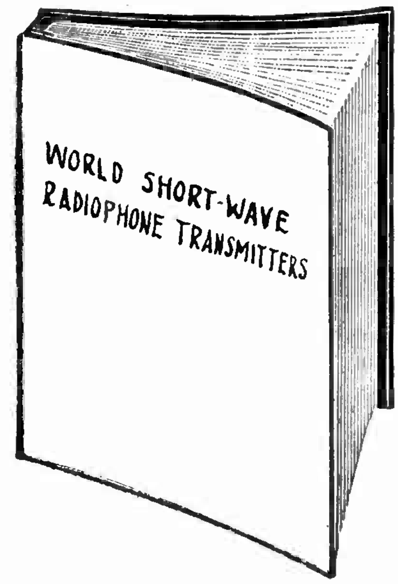
ULTRA-WAVE TUBE ANNOUNCED



955, or "acorn" tube, has just been announced. It is intended for oscillation from 2½ meters down. It is a 6.3-volt model. See page 7.

YOU MUST HAVE—

the World's Outstanding Short-Wave Station List and Time-Zone Map-Chart



INTO ninety-six pages, 8 x 10¼ inches, has been put the very information that all short-wave enthusiasts have been awaiting — *all* the radio phone short-wave transmitters of the world, listed by frequencies, with equivalent wavelength given in every instance, the call letters, the location, and in many instances also the time schedule being given. So complete and accurate a compilation has never before been published. The compilation was made from official publications of the Bureau de l'Union Internationale des Telecommunications, the British Broadcasting Corporation and the U. S. Federal Communications Commission, as well as from unofficial sources of information. There are MORE THAN 2,400 LISTINGS made by the U. S. Department of Commerce.

Nowhere—never—has there been such a massing of the most vital information that radioists want. And remember, this is the most complete work of its kind available anywhere! The list is as comprehensive as human care and ingenuity could make it!

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THE CONTENTS:

Station Identification: List of the most popular short-wave program stations of the world that use characteristic "air signatures," so you can identify the stations by their "signatures."

Foreign Alphabetic Pronunciation: How the letters of the alphabet and numbers 1 to 50 are pronounced in English, French, Spanish, German and Portuguese. Familiarity with these pronunciations aids in station identification, that is, knowing what call letters are being announced, or what frequency or wavelength is mentioned.

Short-Wave Broadcasting and Police Radio Stations by Countries: The calls, location and frequencies are given for the whole world. This is a geographical classification and expedites station-finding and identification. It repeats, geographically classified, data found in the main grouping of the 2,400 stations by frequencies.

Distances to Foreign Cities: A textual explanation of how to determine how far any one city on earth is from some other city. A Department of Commerce map gives direction of shortest distances (measured on great circle). This map is right in the book. Besides, there is a table of distances between key cities of the United States for guiding determinations of world distances, as well as a table of world distances for principal cities.

Short-Wave Radiophone Stations by Frequencies: This is the comprehensive, never-before-available list of the 2,400 or more stations, including all the program stations on earth that send on short waves, using phone (speech and music) but not including amateurs. A treat unparalleled in radio history—the most accurate list of its kind man has ever produced!

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THIRTEENTH YEAR

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Up-to-Date Converters

Tested Methods Applied for Outstanding Results

By Herman Bernard

THOSE who have broadcast sets and want to tune in short waves naturally turn to the converter. Very excellent results have been obtained from some converters, very poor results from others. It is the purpose of this article to set forth some of the reasons for poor results, apply remedies, and also disclose circuits that yield satisfactory performance.

The principle of the short-wave converter is widely known, but there are always some unaware of it. Hence this exposition:

If a short-wave station is sending a program, that program can not be tuned in on a broadcast-band receiver, because the broadcast-band set responds, say, from 540 kc to 1,600 kc, and the short-wave station is using a carrier frequency much higher than 1,600 kc. Some device is needed that will do some work at or near the frequency of the short-wave station.

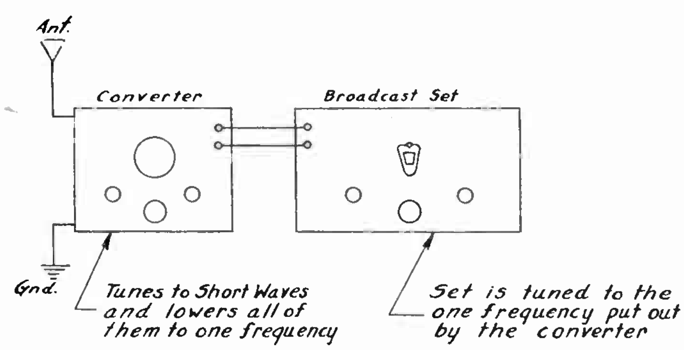

FIG. 1
The theory of the short-wave converter is illustrated. Since the broadcast receiver is tuned to one frequency, the converter lowers incoming short waves to that frequency, for amplification and detection.

Frequencies Examined

Let that device be simply a battery-operated oscillator, as shown in Fig. 1-A. Except for the absence of earphones and any control of oscillation the design would be that of a one-tube regenerative short-wave receiver. But here we are dealing only with radio frequencies, and we want the output of the converter to enable reception of short-wave stations on the receiver's speaker when the converter is connected to the broadcast set.

Now, Fig. 1-A is just an oscillator, let us say, and therefore if we tune it to the frequency of the desired short-wave station, we will have an output equal in frequency to that of the station and of the oscillator, for they are the same frequency, and also we could have an output that is equal to the difference between the oscillator and the station frequency. Of course, this difference is zero, and the reference is just theoretical, but the fact remains that there is or can be an output equal to the difference, and besides, an output equal to the sum. We shall ignore the sum frequency, as it does not figure in converter practice.

It is obvious that so far we have not done anything to enable the reception of this particular short-wave station by using the intended converter in connection with a broadcast receiver.

Now let us assign some frequency values. Suppose the station desired to be tuned in is on 6,000 kc. The oscillator is generating 6,000 kc. Hence, there is no output that is communicated to the broadcast set, in respect to this short-wave station.

Interference Right Away

But the receiver has to be tuned to some frequency, and now let us suppose that the resonant frequency is 600 kc. Also let us suppose that there is a station on the air on 6,600 kc and another at 5,400 kc. Without changing the oscillator frequency, we now have a condition that makes it possible to bring in a short-wave station on the broadcast set, indeed, not only one short-wave station but two short-wave stations, and the two come in at the same time as mutual interference.

The reason we get reception from the 6,600 kc station is that the oscillator is generating 6,000 kc, the station is delivering to the converter a frequency of 6,600 kc, and although the oscillator is lower in frequency than the station carrier, still the difference is 600 kc, and that is the frequency to which the set is tuned, so 6,600 kc is received.

But why do we hear the other station—the one on 5,400 kc? The oscillator still generates 6,000 kc, which is 600 kc higher than the 5,400 kc carrier frequency, so the difference is the same, 600 kc, although in this case the oscillator frequency is higher than the station-carrier frequency by 600 kc, while in the previous example the oscillator frequency was lower than the station-carrier frequency by 600 kc.

Some Questions

Several questions will arise. First, a novice will want to know why it is true that the two stations deliver their carriers to the oscillator tube, although that tube is tuned to a frequency different in each instance from that of the carrier. The reason is that the input to the converter is, in a broad sense, untuned, and all short-wave frequencies are put into the converter. There are two tuning condensers, the main one, 0.00014 mfd. that determines, in conjunction with the secondary inductance L1, the frequency of generation, and the series antenna condenser, which affects the radio-frequency resistance introduced into the tuned circuit, and therefore can be set at a value small enough to keep that resistance low, to support oscillation that otherwise might stop. There is some tuning by this small condenser, but it is of a nature

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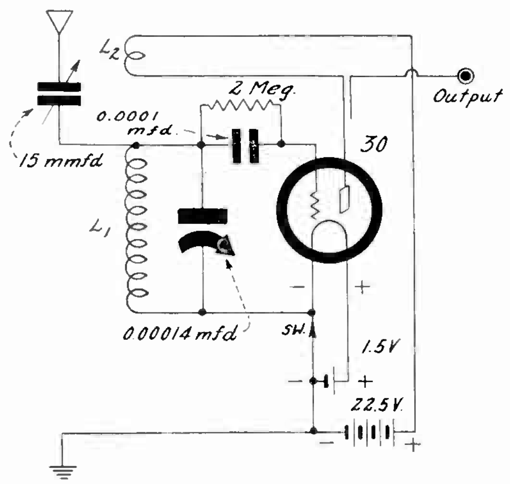

FIG. 1-A

Circuit illustrating the principle of the short-wave converter. This is not intended for actual use, as results are below par

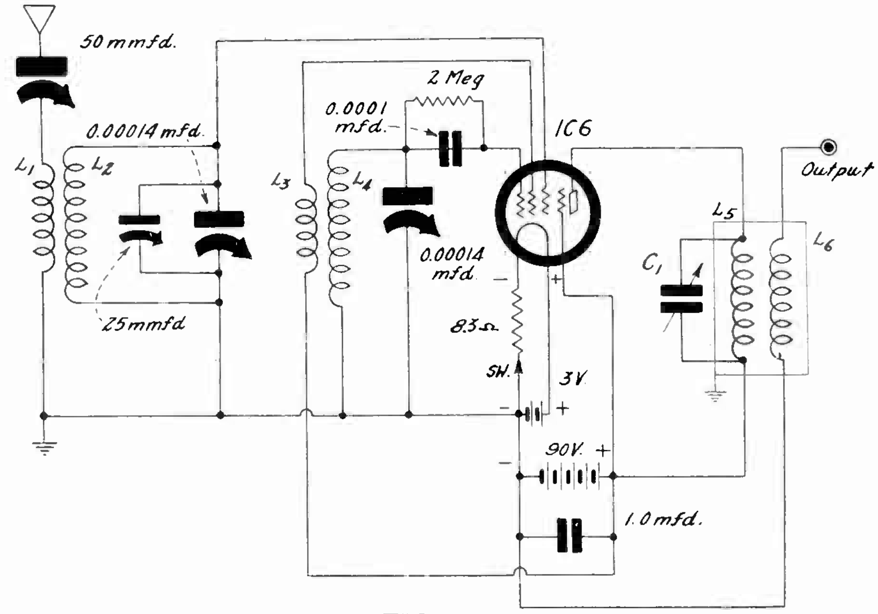

FIG. 2

A practical one-tube converter for battery operation. The new pentagrid converter tube, 1C6, is used. The B voltage may be increased to 135 volts, if desired, for the plate of the pentode. The 90 volts are sufficient even then for the oscillator plate return and for the screen. C1 tunes a broadcast coil's secondary to the intermediate frequency selected, and once set is left thus.

(*Continued from preceding page*)
rather associated with antenna efficiency than with frequency determination.

Another question may be: How does the change in frequency take place? When two frequencies are put into any tube, that tube acts as a frequency changer, and enables taking out the difference between those two frequencies, also the sum of the two frequencies, but we shall forget the sums. The frequency-changing, or conversion, is due to the fact that all tubes distort, even if only a little. A purposeful improvement of the capability of frequency-changing is familiarly known as detection. Hence any detector is a frequency converter. Here we have grid-leak condenser detection, and the conversion is well accomplished.

Image Interference

Another question: Is the device shown in Fig. 1-A any good, since it can bring in at one setting two stations of different frequencies, and provides no means of eliminating one carrier in favor of the other? The answer is that, for practical use, the circuit has no value as a converter, and is shown mainly as an example of the action that takes place, and further to convey the idea that something better than a one-tube device always is required for any sort of satisfactory result. In this sense the duplex tubes would be considered, of course, as two tubes.

Already we have practically found out what all this furor about image interference means. We have noted that two stations, one on 6,600 kc, the other on 5,400 kc, came in at a single setting and interfered, and as we dealt with supposedly real stations, we got strong interference. We also noted perhaps that the condition that brings about this dual reception at a single setting of the converter is that wherein the interfering stations are separated from each other by 1,200 kc, which is twice the receiver frequency. Therefore, we may state that image interference is that form which arises in a superheterodyne when two incoming frequencies are separated from each other by twice the intermediate frequency. From now on we shall call the receiver frequency the intermediate frequency, as it is, for we have constructed something that makes the net result always a superheterodyne; i.f., second detector, and a.f. are in the set; the frequency-changing, and even perhaps some amplification at the intermediate level, is in the converter.

LIST OF PARTS

For Fig. 2.

Coils

Two sets of plug-in coils, four coils to a set, total eight coils; secondary of one of the low-frequency coils to be subjected to turns removal as explained in the text.

One shielded radio-frequency transformer as used for broadcast purposes with 0.00035 mfd.

Condensers

Two 0.00014 mfd. separate tuning condensers, or one gang of two 0.00014 mfd.

One 50 mmfd. antenna series condenser (variable and panel-mounted).

One 25 mmfd. trimming condenser (variable and panel-mounted).

One variable condenser to tune the larger winding on the broadcast transformer, or a fixed condenser and a smaller variable. See text.

One 0.0001 mfd. grid condenser.

One 1.0 mfd. bypass condenser.

Resistors

One 8.3-ohm filament resistor. (This may be a 10-ohm rheostat adjusted until the filament voltage is 2 volts and left thus).

One 2.0-meg. pigtail grid leak.

Other Requirements

One chassis

One cabinet.

One grid clip.

One dial, or two dials if unganged condensers are used.

One six-hole socket.

One 1C6 tube.

Two No. 6 dry cells, to be connected in series.

Two 45-volt B batteries, to be connected in series.

One filament switch.

One antenna binding post and one output binding post.

Phantom Stations

But suppose there is no station on 6,600 kc, but there is one on 5,400 kc, will there still be interference? Now, the novice would not ask that, I admit. But the experienced radioist knows that there is strong likelihood of interference, because, first, including every licensee, there are about 100,000 in the world, and the possibility exists of interference due to the second carrier frequency even if the station that causes the interference is on the other side of the earth. A squeal is heard and it is annoying. Moreover, even if there is no real station on the possibly interfering frequency, there may be some disturbance in the ether at that frequency, including stray generation or static, and the effect is there just the same. And perhaps it is true that there are reasons for image interference that we do not fully understand yet, although the principle is clear enough. What we do know for a certainty is that there are squeals practically all over the dial, and knowing that, we had better do something about it. The stray radiations that cause these squeals are called phantom stations.

What is a remedy?

The remedy, of course, is to reject the frequencies that could cause interference. They may be rejected automatically, in a sense, by having a tuned circuit for acceptance of the desired frequency always lower than the oscillator frequency by the right amount (the difference being the intermediate frequency), which is called tracking and requires nice and permanent adjustments called padding; or we may have a converter where the interference possibly could come in, but could be eradicated by setting an auxiliary condenser. That auxiliary condenser is in parallel with the tuned circuit that accepts the desired frequency.

One R-F Stage Satisfactory

Next question: Is one tuned circuit enough? For general use, yes. This is true because the intermediate frequency is certain to be pretty high—it will be, of course, in the broadcast band—and the

LIST OF PARTS

For Fig. 3.

Coils

Two sets of plug-in coils, four coils to a set, total eight coils; secondary of one of the low-frequency coils to be subjected to turns-removal as explained in the text.
One shielded radio-frequency transformer as used for broadcast purposes with 0.00035 mfd. tuning.
One 30-henry B supply choke coil.

Condensers

Two 0.00014 mfd. separate tuning condensers, or one gang of two 0.00014 mfd.
One 50 mmfd. antenna series tuning condenser (insulate from any metal panel).
One 25 mmfd. trimming condenser (variable and panel-mounted; need not be Insulated from any grounded metal panel.
One variable condenser to tune the larger winding of the broadcast type r-f transformer, or a fixed condenser and a smaller variable. See text.
One 0.0001 mfd. grid condenser.
Two 8 mfd. electrolytic condensers of the bi-polar type (so no harm results if plug is connected wrong way to the d-c line).
Three 0.05 mfd. bypass condensers.
Two 1.0-mfd. bypass condensers.

Resistors

One 2.0-meg. pigtail grid leak (2,000,000 ohms).
One 175-ohm pigtail resistor.
One 0.01 meg. pigtail resistor (10,000 ohms).
One 5,000-ohm pigtail resistor.
One 0.02-meg. pigtail resistor (20,000 ohms).
One 340-ohm, 50-watt resistor.

Other Requirements

One chassis.
One cabinet.
One grid clip.
One dial (or two dials, if unganged tuning condensers are used).
One seven-hole socket (small size) and one five-hole (UY) socket.
One 6A7 tube and one 37 tube.
One a-c cable and plug.
One a-c switch.
One 1-ampere fuse.
One antenna binding post and one output binding post.

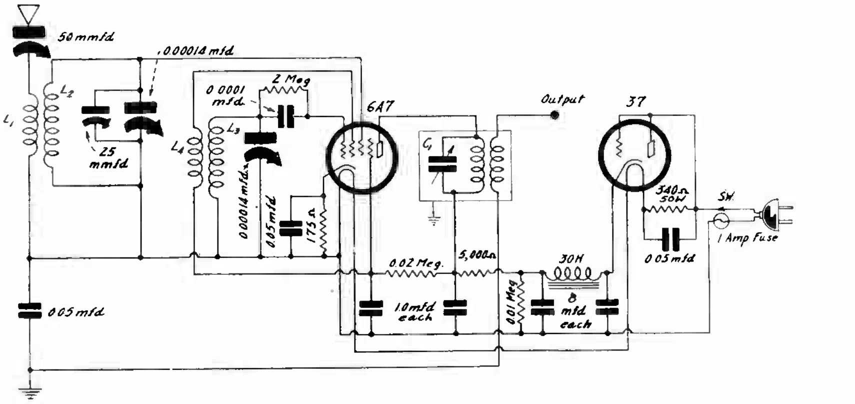

FIG. 3.

The same fundamental radio circuit as in Fig. 2, but this time applied to universal use (90-125 volts, a.c. or d.c.), using two tubes. Note that chassis and ground are insulated from each other. The bypass condenser across the heater limiting resistor is an unusual but valuable precaution. Both Figs. 2 and 3 have a t-r-f stage for aid in image suppression.

higher the intermediate frequency, the less need for extra pre-selection.

A good converter can be built, using one pre-selector stage. This is also called a stage of tuned radio-frequency amplification. For battery operation, the circuit shown in Fig. 2 may be used. This is a practical design. The values of the constants, so far as required, are given on the diagram. The 1C6 pentagrid converter tube is used because it is so much better than its predecessor, the 1A6, but the filament current is twice as great, and therefore the two 1.5-volt cells should be of the No. 6 type. The smallest obtainable B batteries, two of 45-volts each, suffice, as the plate current is small.

The series antenna condenser may be 50 mmfd., since the antenna circuit is removed from the oscillator proper by the high resistance of the oscillating triode part of the duplex tube.

The output of the device is taken from the secondary of a standard broadcast coil, the primary being used for output coupling, the secondary being in the plate circuit. It is necessary to have a good-sized capacity in the plate circuit, to prevent high frequencies from getting by, which would cause trouble, particularly if the receiver proper were itself a superheterodyne. The condenser C1 then would be tuned to any particular frequency to which the set is tuned. It might be advisable, knowing your location, to pick a setting near 600 to 700 kc where there is no local station or any other station that comes in strongly.

The Adjustment of One Coil

Now, the two 0.00014 mfd. condensers may be separate or may be a dual-gang, it makes no difference, as the trimmer condenser of 25 mmfd., which must be front-panel located, takes care of the tracking, after one coil adjustment, and moreover does not change the calibration. In no manner does the response frequency depend on the pre-selector circuit, which performs the function of improving sensitivity and selectivity, but not of establishing the response frequency. That establishment depends solely on the oscillator frequency and the intermediate frequency. Strange as this sounds, it is a fact, and nobody could possibly figure it out differently.

If plug-in coils are used, they might not be intended for converter practice, and it must be said that some of those who have attempted to adjust the inductance for the oscillator have marketed products that hardly could be called successful. An examination was made of four of the principal commercial plug-in coils for receiver intended for receiver use, and a universal factor established that is sufficiently good for general use.

Since the oscillator is intended to generate always a higher frequency than the carrier desired to be tuned in, and since this oscillator frequency is definitely higher than the carrier, being Fc plus Fi, where Fc is the carrier and Fi the intermediate, and since the coils for the lowest band have in general around 70 microhenries inductance, we can compute that the oscillator secondary for this band should have 38 microhenries inductance. Using the factor of 60 turns, often encountered for 70 microhenries, we can strike a general percentage of reduction of turns that works.

Take the lowest-frequency coil, count the number of secondary turns, and reduce these turns until they are 63 per cent of the original number. Example: If the coil had 60 secondary turns, you would use .63x60 or 49.8 turns. The decimal values may be assigned to the nearest whole number. Thus, leave 50 turns. So 50 turns require that 60 minus 50 be removed, or 10 turns off.

This gives you a suitable coil for the low-frequency band. For the other bands, the higher the frequencies tuned in, the smaller the difference need be between the oscillator and station-carrier frequencies, since the absolute difference always is 600 kc, or whatever other receiver frequency is used.

No adjustment of turns need be made for the other coils, because the inductance requirements of the two secondary circuits become progressively more nearly alike, and for the third and fourth bands two identical coils not only suffice, but it would be hard to pad for the difference if one assumed theoretically that they did not suffice when equal. Besides, we have a manual trimmer to take the place of fixed adjustments, and if we ever find that we can not get the t-r-f stage low enough in frequency to give us that state of balance we want, we can use a higher capacity trimmer, say, 50 mmfd.

The sockets used for coil receptacles should not be closer than 6 inches apart, and it is of some advantage to erect a copper or aluminum bracket midway between, something like four inches square.

Unusual Precaution

The universal counterpart of the battery converter of Fig. 2 will be found in Fig. 3, in fact, the two circuits are as nearly the same as they can be, when one considers the fundamental or inherent differences that the tube voltaging requires.

The bypass condenser across the limiting resistor (right-hand side of Fig. 3, under the 37 tube) is something not often found in such sets, but the author's experience has been that the heater circuit is coupled to the r-f circuit inevitably, and the inductance of the limiting resistor sometimes causes dead spots, avoided when the limiting resistor is bypassed. A condenser of 0.05 mfd. is usually sufficient, but the capacity can not be greatly increased beyond that, because if the circuit were then used on a.c. the effective impedance of the limiting circuit would be lowered, and the tubes would get too much heater voltage on a.c., although the right heater voltage on d.c.

Since the capacity across the larger winding of the broadcast-type transformer used for coupling is rather large for frequencies from 600 to 700 kc, it is inconvenient to put in a 0.00035 mfd. variable condenser, so a fixed condenser may be used, of a value less than the required capacity by the capacity of a junior or midget condenser across it. This particular tuning is not very critical, and a 0.00025 mfd. fixed condenser, with a

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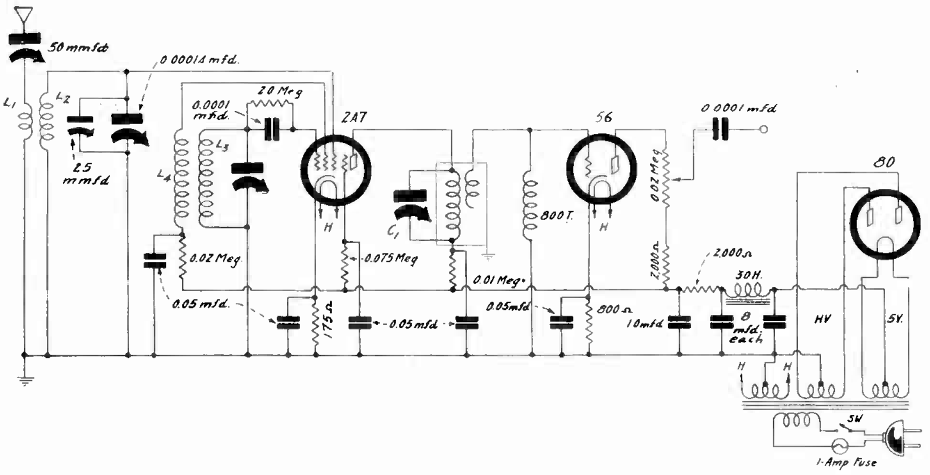


FIG. 4.

This 3-tube converter is a-c operated and has an intermediate-frequency amplifier stage. The coupling transformer has the large winding tuned, the usual primary used for its small capacity, to act as stopping condenser, the grid load being an 800-turn honeycomb coil. Some transformers have such a choke built in, and could be used as found.

(*Continued from preceding page*)
50 mmfd. variable across it usually will do the trick nicely.

If fixed capacity thus resulting is too small the sensitivity will increase as the variable capacity is increased, and if the fixed capacity is too high the sensitivity will increase as the variable condenser across the fixed one is decreased. Accordingly a larger or smaller fixed capacity may be inserted, and the peaking with the variable done on that basis.

Precautions for Fig. 3 Set

The universal model has to be watched in two particulars, First, if uni-polar filter condensers are used for the 8 mfd. values, if the line plug is connected the wrong polarity way, the condensers may be hopelessly damaged. This is true because the leakage through the condenser is small in the right direction and may be exceedingly large in the wrong direction, even causing fluid to emerge from the so-called dry condensers. This trouble does not arise if paper condensers are used, nor if electrolytic condensers are used that are bi-polar, that is, are polarized one way and then the other.

The double polarization results in about half the capacity for a given size, or twice the cost for a given capacity. Of course, paper condensers of relatively high voltage rating and of such high capacity would be very expensive.

Also, in the universal model, chassis and ground are not common. That means one is insulated from the other. It can be seen from Fig. 3 that the chassis is connected to one side of the line. If ground were common to the chassis, and that side of the line were at one d-c potential and ground at the other, a short-circuit of the line would result.

Four-Tube Model

When it is considered that there are four-tube broadcast and short-wave receivers, some of them quite good, one might inquire what is the sense of having a short-wave converter that has that many tubes? Or, to put it differently, is it sensible to have a converter that has as many tubes as the reciever?

There is abundant reason for a four-tube short-wave converter. But it is doubtful if it is quite sensible to work a four-tube converter into a four-tube set. Better have a more sensitive and selective set than that to start with, ye no matter what the set is, if the converter is better, the results are better.

The diagram in Fig. 5 shows a four-tube converter with an intermediate-amplifier stage built in. That is, whatever frequency the set itself is to be tuned to, the two intermediate coils in the converter, that couple to and from the single i-f stage, must be at the same frequency.

The object of the i-f stage is, of course, to increase the selectivity, especially desirable with tuned-radio-frequency receivers, and the sensitivity goes up, also. If broadcast coils for 0.00035 mfd. tuning that have large "primaries"—here used as secondaries—are put into the converter, and the former secondary now used as the primary and tuned, the results will be good.

Change-over Switch

The diagram shows how a panel switch may be used to change over the antenna connection from the receiver to the converter, thus saving the trouble of reaching behind the converter and the set and fastening and unfastening. This method course may be applied to the other converters.

A great deal has been made of the importance of the coupling between the output of the converter and the input of the receiver. It is, of course, true that a suitable coupling should be introduced. In general, if the coupling is direct, as in Figs. 4 and 5, the last tube in the converter should be a low-mu tube, because the impedance of the primary of the antenna coil in the receiver is much more likely to be low. However, whatever tube is used, a proper matching device, meaning correct ratio of transformation, will enable an effective input to the receiver.

The arrangement of the potentiometer at the output of the converter is intended to constitute a volume control effective on the converter only, but if the conditions are not right the receiver itself will be subjected to volume control at the low-resistance settings between arm and B plus. However, the limiting resistor of 2,000 ohms, in series with the potentiometer resistance, is there for the express purpose of avoiding this trouble, and if it is not effective enough the value may be increased even to 5,000 ohms. However, for nearly all receivers the 2,000-ohm value will be found satisfactory.

Output Wire

Besides the transformation or other device associated with this coupling, the output wire itself, run from converter to receiver, is of great importance. It is highly desirable to avoid having this wire serve as an antenna, for then if the receiver proper is quite sensitive there will be a racket due to interference by some station picked up. While detuning the receiver slightlv will help to cure this, if no other station is struck that yields response, of course the i-f amplifier in any converter would have to be readjusted. Yet if the trouble exists it may even persist, despite the detuning, hence it is much better to get rid of pickup.

At once a shielded wire suggests itself, with sheath grounded, but if the sheath is close to the conductor, then the loss due to capacity to ground is tremendous. It might even reduce the input to the receiver by 75 per cent.

Therefore any shielded wire should be of the thick sort, with cotton of ¼ inch radius or more separating the conductor from the outer sheath In fact, besides

LIST OF PARTS

For Fig. 4.

Coils

Two sets of plug-in coils, four coils to a set, total eight coils; secondary of one of the low-frequency coils to be subjected to turns-removal. See text.
One shielded radio-frequency transformer as used for broadcast purposes with 0.00035 mfd. tuning capacity maximum.
One power transformer, with primary and three secondary windings. Secondaries 2.5 volts, 3 amperes; 5 volts, 2 amperes; 350-350 volts a.c. center-tapped. The two other secondaries need not necessarily be center-tapped.
One 30-henry B supply choke.

Condensers

Two 0.00014 mfd. tuning condensers, or one gang of two 0.00014 mfd.
One 50 mmfd. antenna series tuning condenser (insulated from any metal panel).
One 25 mmfd. trimming condenser (variable and panel-mounted; need not be insulated from any metal panel if panel is grounded).
One variable condenser to tune the larger winding of the broadcast-type r-f transformer, or a fixed condenser and a smaller variable. See text.
Two 0.0001 mfd. condensers.
Two 8 mfd. electrolytic condensers.
Five 0.05 mfd. bypass condensers.
One 1.0-mfd. bypass condenser.

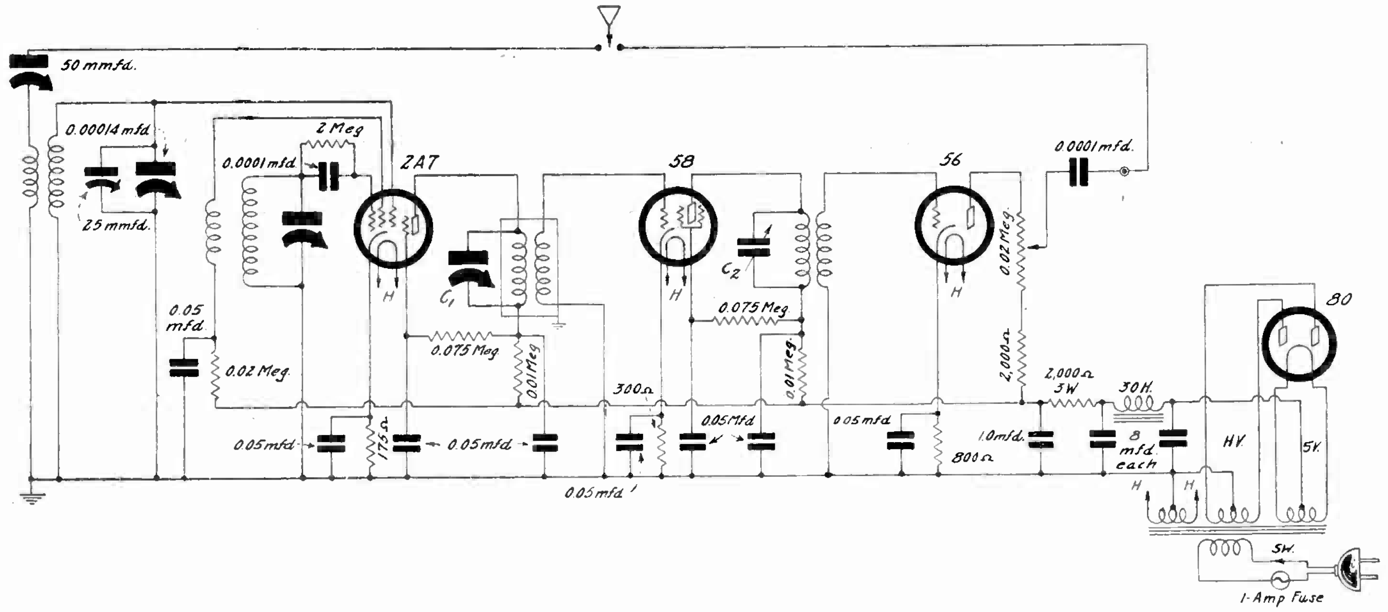
Resistors

One 175-ohm pigtail resistor.
One 800-ohm pigtail resistor.
Two 2,000-ohm pigtail resistors.
One 2.0-meg. grid leak (2,000,000 ohms).
One 0.75-meg. pigtail resistor (75,000 ohms).
One 0.02-meg. pigtail resistor (20,000 ohms).
One 0.02-meg. potentiometer (20,000 ohms); shaft-insulated type, a-c switch attached.

Other Requirements

One chassis.
One cabinet.
One grid clip.
One dial, or if separate tuning condensers are used, two dials.
One seven-hole socket (small size) and one five-hole socket (UY) and one four-hole socket (UX).
One 2A7 tube, one 56 tube and one 80 tube.
One a-c cable and plug.
One 1-ampere fuse.
One antenna binding post and one output binding post.

Note: The list of parts for Fig. 5 is the same as that for Fig. 4, except that these must be added: one broadcast r-f transformer, one 300-ohm pigtail resistor, one 0.075-meg. pigtail resistor, one 0.01-meg. pigtail resistor, one 0.01-meg. pigtail resistor, one six-hole socket, three 0.05 mfd. condensers and one 58 tube.



A converter having a stage of i-f amplification built in, and also provided with a switch to change over the antenna connection from the receiver to the converter and back again, from the front panel. This converter uses four tubes. Since the 2A7 really is two tubes, in one envelope, the effective tube rating is five.

this cotton stuffing there is usually also some rubber insulation on the wire proper, to add to the distance, and this of course is in the right direction.

It is not impractical to use a transposition line, although then a transformer would have to be used in the output—a broadcast coil turned backwards, and not necessarily with primary tuned, although that may be done, also. The secondary, or small-winding coil, then would permit two high-potential points, for takeoff, and of course the receiver would have to be equipped with double input. Then twisted pair may be used, although again there is some loss due to capacity, or a transposition block system introduced, with three or so blocks, some five or six inches apart. At least the shorter this lead connecting converter to set, the better.

The transposition system works also if one side is grounded, thus applying to receiver input methods as still most commonly found.

New 80 Tube Has Corrugated Plates

National Union's engineers have just perfected an 80 tube that is called a marked improvement on the type 80 as previously used in the dome-shaped S-14 envelope.

Since the days of a-c operated radio sets the type 80 has been a very important tube. Its function is to convert alternating current to a form suitable for use by the receiver, namely, to direct current at higher voltage. The more tubes a receiver used obviously the more current the type 80 had to convert until with modern multi-tube sets, the critical point had been reached where the useful life of the 80 had been seriously curtailed.

This problem of useful life and necessary output became further intensified with the introduction of the smaller dome-shaped bulb used to enclose the 80.

In the studies made by National Union engineers to improve the 80, it became apparent that the direct limitation of performance was determined by the degree of back emission existing. Furthermore, back emission was found to be closely associated with the operating temperature. Hence the problem became one of lowering the operating temperature.

Carbonizing was studied in hundreds of cases. Special carbonization was employed but this resulted in only slight improvements. Spacing of elements was studied but even with the optimum, it was obvious that the temperature was still excessive. It was quickly discovered that apparently noticeable improvement could be obtained by increasing the voltage output so that the tube would read higher but the result would be increasing the strain on the transformers and filter condensers in sets that had been designed for a lower output 80, so this was discarded as undesirable.

The only method of lowering temperature without objectionable drawbacks was to increase the area of the plates but the limitation seemed to be the size of the 80 bulb as the elements of the 80 had to be inserted from the bottom and were limited in size by the neck of the bulb. And then the idea of folding or corrugating the plates was hit upon. This gave the increased area that still went through the neck of the bulb. It worked.

The new National Union 80 is a radically different tube both in design and operation. The corrugated plates are noticeable. It will replace any 80 in any set.

Because there is considerably less danger of the new corrugated plate 80 giving way because of shorter life or from line voltage fluctuation, there is less likelihood of burnt-out power packs, hence a safer tube in the radio set.

To give the radio serviceman a comparison of performance the new 80 will give equally as long life at 150 milliampere drain as the old one at 125 milliamperes.

Marked improvement will be noticed in using these new 80's in multitube sets and for any other purpose where long life is required, says National Union.

Micro-Wave Tube Announced

A radically new type of radio tube, resembling an acorn in size and shape, for use by amateurs and experimenters in ultra-high frequency or micro-wave reception and transmission has been announced by the Amateur Radio Division of the RCA Radiotron Company.

Amateur radio experimenters, who have been credited with being the first to open up the practicable possibilities of short waves, are now exploring the possibilities of the extremely short micro-waves which are similar in some ways to light rays because they seem to reach out only as far as the eye can see. Comparatively little is yet known about the micro-waves, and they offer an attractive field for research and experimentation which the new acorn type tube should advance.

In announcing the new device, the RCA Radiotron Company emphasizes that it has been developed for amateur and experimental use, and is in no way to be considered as a substitute for use in conventional types of receivers. The tube, which has been designated by the number RCA-955, is a heater-cathode triode which may be used as an amplifier, detector, or oscillator at frequencies up to 600 megacycles, or about half a meter in wavelength. The new tube is the only triode capable of operating at ultra-high frequencies and it is therefore indispensable for use in the 2½-meter and lower wavelength bands.

Although the 955 is not especially designed to be a transmitting tube, it may be used as such just as other receiving tubes are used in transmitters by amateurs. When used for this purpose, sufficient power output is usually obtainable to cover the line-of-sight transmission distances which are generally reached by micro-wave transmissions.

Because of its extremely small size, the acorn type tube is especially suited for use in portable radio equipment where conservation of space and weight is important.

The essential characteristics of the 955 acorn type tube are:

Heater Voltage	6.3 volts
Heater Current	0.16 amp.
Maximum Plate Voltage	180 volts
Grid Voltage	5 volts
Maximum Plate Current	4.5 milliamps.
Mutual Conductance	2000 micromhos
Amplification Factor	25
Plate Resistance	12,500 ohms

More information on the tube is expected soon.

Bridge Measurements

Capacity, Inductance and Resistance Tested—Some Kinks in Application of Precision Method

By Leslie Forrester

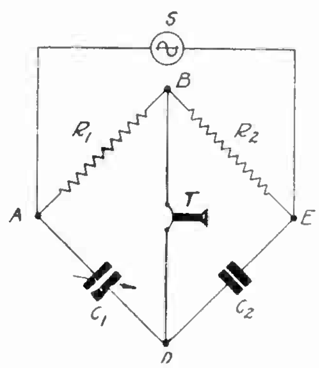


FIG. 1

At left, a capacity bridge, particularly good for large capacities. Immediately to right, a synthetic ground. At exteme right a double bridge also to establish a synthetic ground.

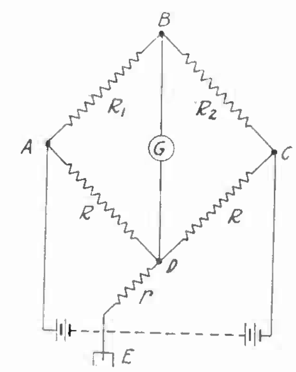


FIG. 2

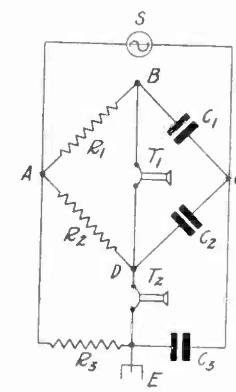


FIG. 3

BRIDGE measurements of capacity, resistance and inductance are commonly made in laboratories, and there are numerous commercial bridges purchasable, but this type of measurement often is dodged by the home experimenter or service man, who may deem it something quite beyond him. However, the bridge method is very simple, and practically every one has the apparatus with which to construct a bridge of some sort.

A bridge, as commonly used, has four arms, divided into pairs, of which one pair consists of equals, the other pair to be equalized for indication. In Fig 1 R1 and R2 are equal resistors (upper ratio arm), C2 is an unknown condenser to be measured and C1 is a calibrated condenser used as the basis of measurement (lower ratio arm). The rule about bridges is that the quotient of the two components of each ratio arm must be equal, whereupon no current will flow in the detecting device. In this instance a pair of phones is the detecting device, but a vibration galvanometer may be used instead. An audio frequency of oscillation, S, is fed to points A and E, but no sound of it is heard in the phones at complete balance.

Reactances Must Be Equal

So $R1/R2 = C2/C1$ expresses the state of balance. The quotients of the equal ratio arms then are equal.

The audio frequency preferably should have a sinusoidal wave form. Also the resistances should be non-inductive, although if they are inductive, the system still works, provided the inductance of each equal ohmic resistance is the same. That is, more closely, the conditions of balance exist if the two reactances are equal.

The fact that phones are used aids sensitivity, as phones are one of the most sensitive instruments used in radio.

It is not absolutely necessary to use equal bridge arms, but it is advisable to do so, to avoid possible confusion of results due to unequal reactances.

The circuit in Fig. 1 is that of the bridge due to DeSauty and shows how capacity of an unknown (C2) is measured in terms of a calibrated condenser (C1). Calibrated condensers are not so common, to be sure, but within the accuracies required, it is possible to calibrate a condenser, and then use this calibration in the bridge. A coil of known inductance, of very small distributed capacity, the condenser to be calibrated, and some frequency-discriminating system whose span is related to the frequencies of the trap circuit are required.

Condenser Calibration

Very small capacity in the inductance exists if the coil is a honeycomb or duolateral of large number of turns and hence of high inductance, and the unknown condenser capacity always is high by comparison to the coil's capacity.

It is common practice to have calibrated condensers of the straight capacity line type, that is, circular plates. In general, the curve will be a straight line, so that equal differences of angular displacement of the dial will represent equal differences in capacity anywhere on the scale. However, some departure from strict straight line is nearly always met, if condensers have supporting bars, conductive or insulating, particularly a central bar of the conductive type, toward and from which the rotor plates must be moved. A small hump then appears in the curve, so especially at such positions must plotting be done carefully. The straight line then can not be assumed.

The condenser, it is assumed, has a maximum capacity of 500 mmfd., and a minimum of 15 mmfd. This is within reason. Also, it may be noted, some of the popular so-called 500 mmfd. condensers have a true maximum nearer 600 mmfd., so if the calibration to be made turns out to deny the rated maximum, do not hesitate to award your faith to the calibration.

The variable condenser is connected across the coil. If the inductance is large, say, as in a given instance, 25.5 millihenries, if the maximum capacity is close to 600 mmfd. the resonant frequency of the trap will be 50 kc, and if the maximum capacity is 500 mmfd. the resonant frequency will be 59 kc, closely.

Inductance Values

To work at the extreme, then, it would be necessary to have some system responsive to 50 to 59 kc, such as a signal generator, and loosely couple the trap circuit to the actual tuned circuit of the generator. With the generator started, and the test calibration circuit off resonance, turn the condenser to be calibrated until the oscillation is stopped by the wave trap effect. Knowing the inductance, the capacity can be computed, or read from a commercial chart. The coil capacity may be neglected, as the percentage accuracy will not be high enough to make the small capacity of the coil matter at all.

If such a low frequency is not attainable, because few signal generators go that low, any generator that takes care of intermediate frequencies may be used, care being taken however to have a suitably-related inductance, say, 3,000 microhenries.

Practically all service oscillators go as low as 135 kc, therefore for such an inductance as stated, a commercial product, 3,000 millihenries, capacities from about 15 mmfd. up to 500 mmfd. may be plotted, taking care of the lower capacities of the condenser, and the curve would have to be assumed as a straight capacity line for the rest of the way, if 500 mmfd. is exceeded. So for use with generators that go to 135 kc or so, or even to 100 kc, the smaller coil is advisable, so that maximum capacity of 600 mmfd. represents around 120 kc and 500 mmfd. is 130 kc, approximately. Information about these precision inductances can be obtained from Trade Editor, RADIO WORLD, 145 West 45th Street, N. Y. City.

The relationship of the frequencies and capacities, in respect to any inductances for radio-frequency use, may be read directly from a large, accurate chart that sells commercially for 25 cents.

Restriction of Use

While the condenser may be calibrated for its entirety, it can not well be used with great reliability for the smaller capacities in making comparisons of unknowns, because of the inherent and stray capacities associated with the generator S and the parts and wiring of the bridge, as well as possibly the container of the bridge.

(*Continued on next page*)

Separate Audio Tone

May Be Taken from this Modulated Signal Generator

By Herman Cosman

Try-Mo Radio Corporation

IN the signal generator diagramed herewith is a separate audio oscillator, albeit this audio oscillation is present in the same envelope as is the radio-frequency oscillation. Output posts are established so that this audio, a tone of about 1,000 cycles, may be taken off for any check on audio amplifiers and the like. For coupling between audio and radio in the generator, the electron action of the 6A7 tube is used principally.

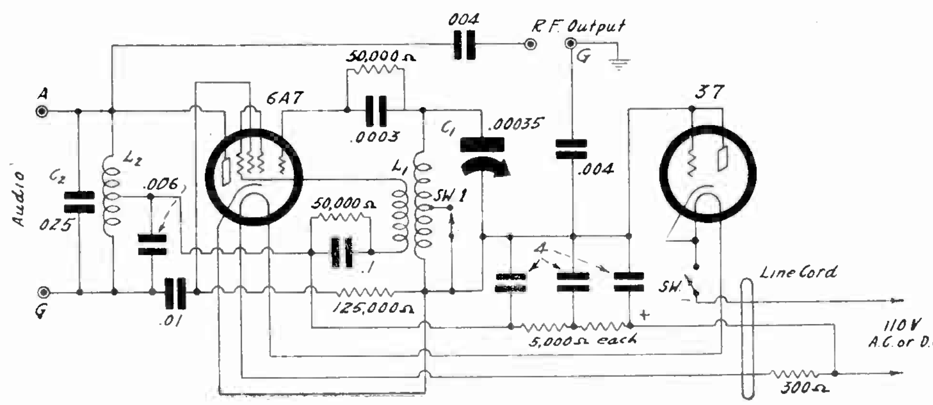
This instrument has a shorting switch for changing the bands. The fundamental range when the switch is open is 100 to 275 kc. This band is used for the fundamental and the second harmonic, which can be done conveniently by consulting a curve-sheet. The instrument has a very fine precision true-vernier dial that can be read to one part in 1,000.

Harmonics Used

Thus the fundamental, 100 to 275 kc, and the second harmonic, 200 to 550 kc, account for intermediate-frequency service to the broadcast band. When the switch is closed the frequencies are 500 to 1,600 kc, covering the broadcast band, and for second harmonic use enable measurements, 1,000 to 3,200 kc.

This instrument is of the universal type, since it works on a.c. or d.c. The line voltage may be 90-125 volts. If a.c. is used the frequency may be 26 to 60 cycles. Thus wide application is assured.

A curve-sheet is furnished that shows the frequencies for the dial settings for both switch positions and for the second harmonic orders of these positions. Therefore the dial is read accurately as to the numerical setting, the number is referred to the curve sheet, where the words "dial divisions" appear on the upright, and at the proper line for the numerical setting the interception with the curve is noted, and the right-angle line is followed to the base to read the frequency.



Separate access to the modulation, a 1,000-cycle note, is provided in this r-f signal generator. The r-f fundamentals are 100 to 275 kc (second harmonics used for 200 to 550 kc), and 500 to 1,600 kc (second harmonics use for 1,000 to 3,200 kc).

The diagram shows the 2A7 tube backwards, compared to the more usual method, but this simplifies the drawing. From right to left, therefore, the first grid is the control grid of the r-f oscillator, the next grid is the positive grid of the oscillator, or its effective plate, which is tied to the screen, while there is capacity coupling to the audio oscillator's plate, for a-f feedback. There is some augmentation of the electron coupling to yield most acceptable percentage modulation. The audio coil is uncored and the drop in L2 is shorted to radio-frequencies, permitting satisfactory output due to remaining resistor load.

The generator uses a 37 tube as the rectifier, has a resistor-capacity filter built in, and has outputs for r-f and a-f separate, as already noted, with the ground potentials for the colored binding posts marked G.

The limiting resistor of 300 ohms should be 50 watts.

This generator has been in successful use in many laboratories and by many service men, and provides smooth control, minimum difficulty of operation, excellent opportunity for accuracy, and is so constructed that it is very easy to install an

Three Types of Bridges for Measurements

(*Continued from preceding page*)

It is practical, of course, to replace the tube-generator S with a buzzer, with A and E connected to the ends of the electro-magnet, which would minimize the capacity to ground, or at least provide a ready means of neutralizing the effect of this capacity. The method used is that shown in Fig. 2. The battery supplying the voltage for the buzzer may be of high enough voltage (for such type buzzers) to enable connecting a resistance from the joint of the two lower arms to a point on the block of dry cells that completely eliminates the signal from the buzzer when the armature ends are connected to A and E.

The trouble with finding the small capacities in terms of the calibrated condenser is that there is some current through the phones, and a null point is difficult to establish, or, if established, may be false. It has been said that trouble is due to stray capacity, which is true, too, of course, but the other factor, not mentioned before, is that the calibrated condenser itself attains an impedance at the small capacities comparable to that of the phones. That is, we have both the difficulty of attaining balance due to the shift in the impedance distribution, and also we may have false indicating points due to the stray capacities.

Resistance Measurement

Of course, the trouble due to the impedance shift may be eliminated, practically, by using for S a radio frequency, and measuring that frequency with a current-meter, either of the a-c type for the sensitive to the frequencies concerned, or of the d-c type, if a series crystal detector is used in series. The trouble with the crystal is that it requires a very sensitive d-c microammeter, unless the output of S, the radio-frequency generator is large, when the sine wave ceases to exist, usually.

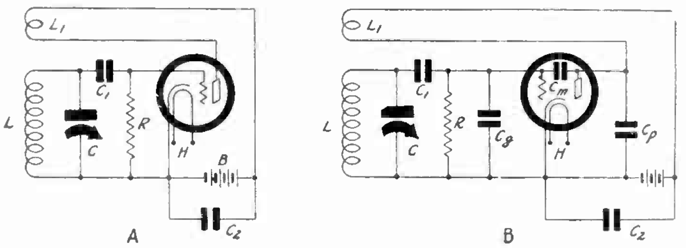
The arms need not consist of a pair of equal resistors and a calibrated condenser and an unknown. They may consist of resistors entirely, where the two in the upper ratio arm would be equal and one of the lower ones would be a calibrated variable, the other lower one the unknown; or, retaining the two equal resistors at top, the lower branch may consist of a known inductance a variable inductance for one side and an unknown inductance for the other. Of course the variables always must be calibrated, and the unknowns must be of values lying within the range of the calibrated variable.

Synthetic Grounds

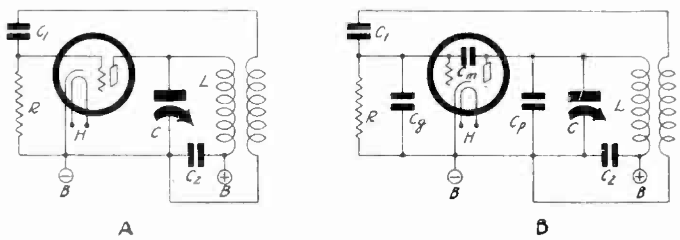
The balance requires equality in any bridge, and false readings sometimes are due to ground capacity. It is desired to have the common point of ratio arms grounded, which is equivalent to grounding a center tap on a transformer. Off-center grounding causes spurious current flow.

In Fig. 2 a resistor r is led to the mid-point of the battery, or other point that eliminates a tone when there should be no tone. That is, sometimes at intended balance there is unbalance that leaves a residual tone. In the double bridge R3 and C3 are balanced to eradicate the spurious tone.

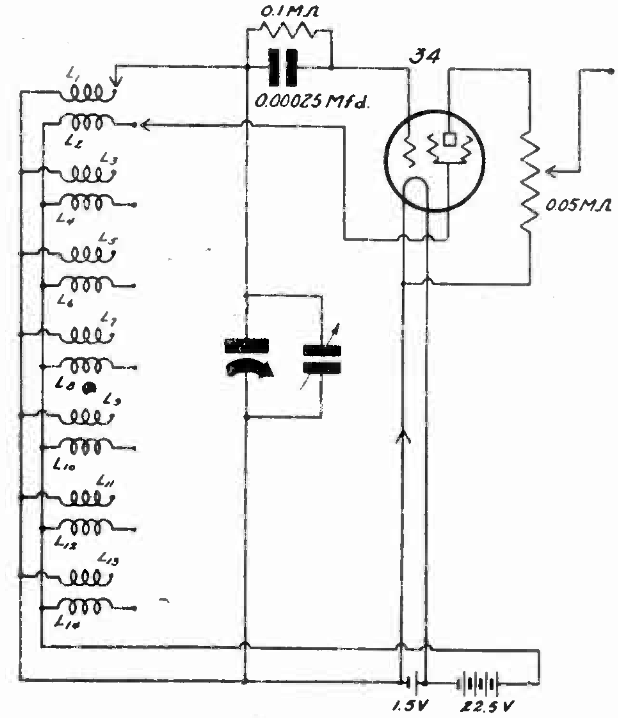
Popular Feedback Circuits



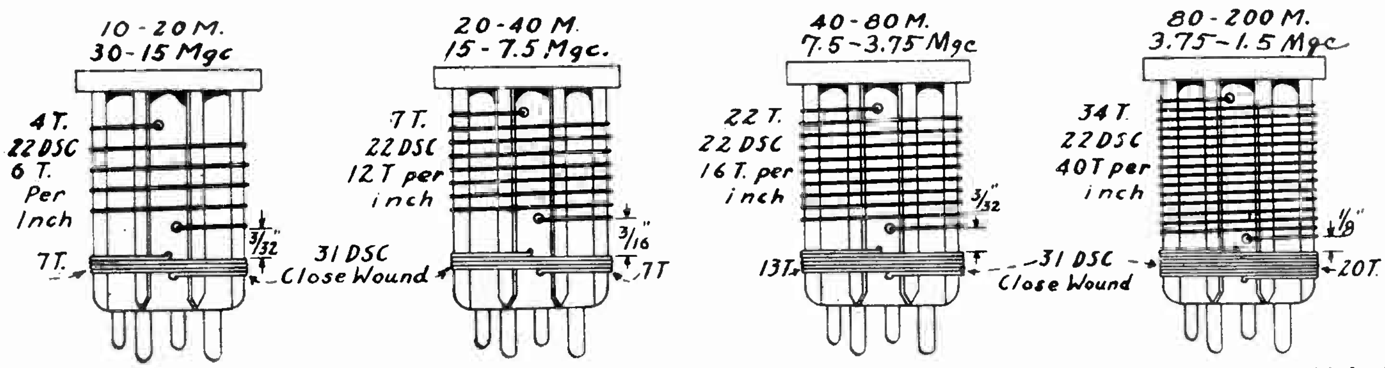
The tuned-grid type of feedback is most popular today. In A is shown the grid-leak type, which is usually fairly stable. Here C1 is the grid stopping condenser, R is the grid leak in parallel with the tuned circuit, C is the tuning condenser, L the tuned secondary and L1 the tickler. C2 bypasses the B batteries and should be 1 mfd. or more. B shows the grid-to-cathode capacity as a fixed condenser, Cg, also the plate-to-cathode capacity, Cp as such, and the grid-plate capacity Cm.



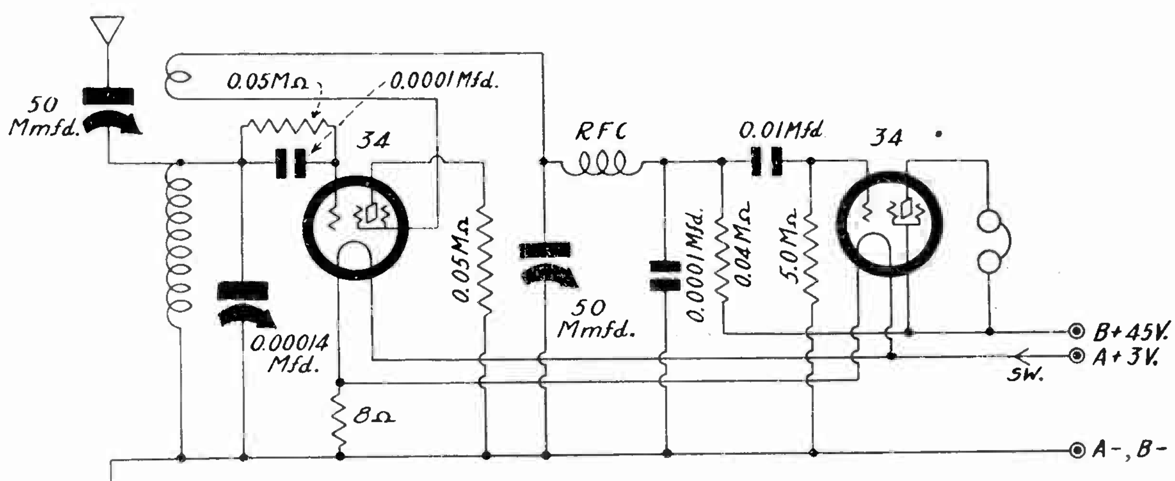
The tuned-plate feedback method is another workable one. In this example there is no direct current through the feedback winding, as the stopping condenser is between the pickup coil and the grid.



The screen as the feedback winding is becoming popular, as it enables the use of the element that would be the plate as a pick-up grid for electron coupling of the output. The intensity of the oscillation may not be so strong as when the more conventional circuiting of a screen-grid tube is used.



For practically any circuit using a two-winding plug-in coil system, the above data may be followed for 1½-inch diameter.

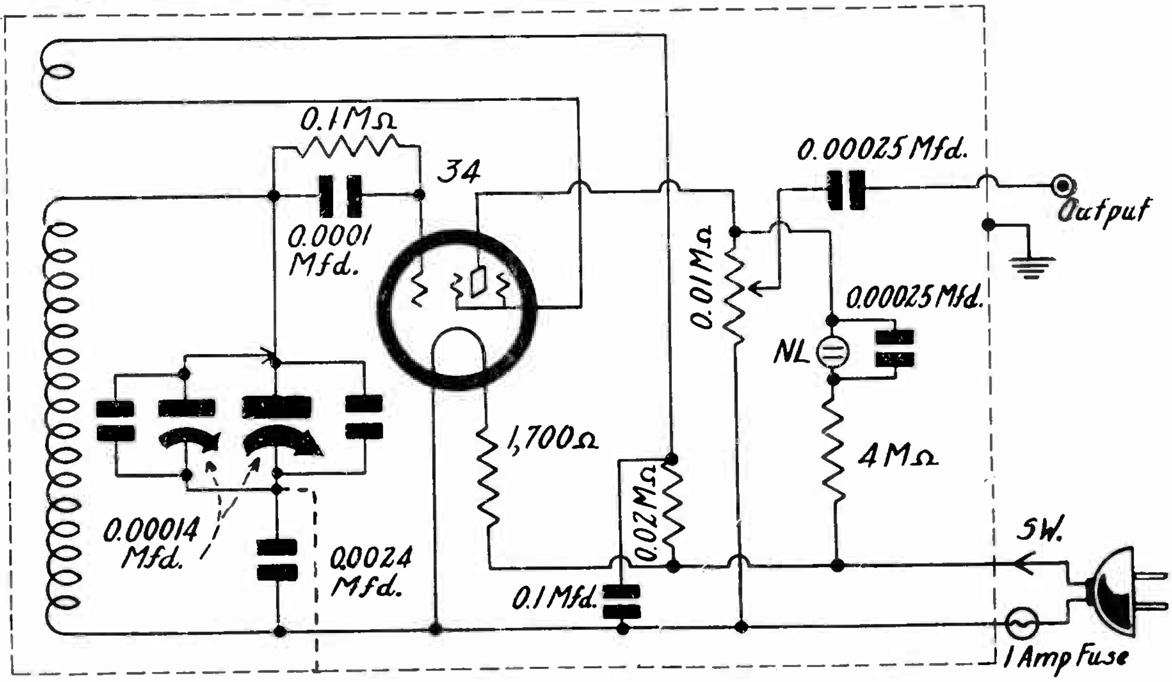


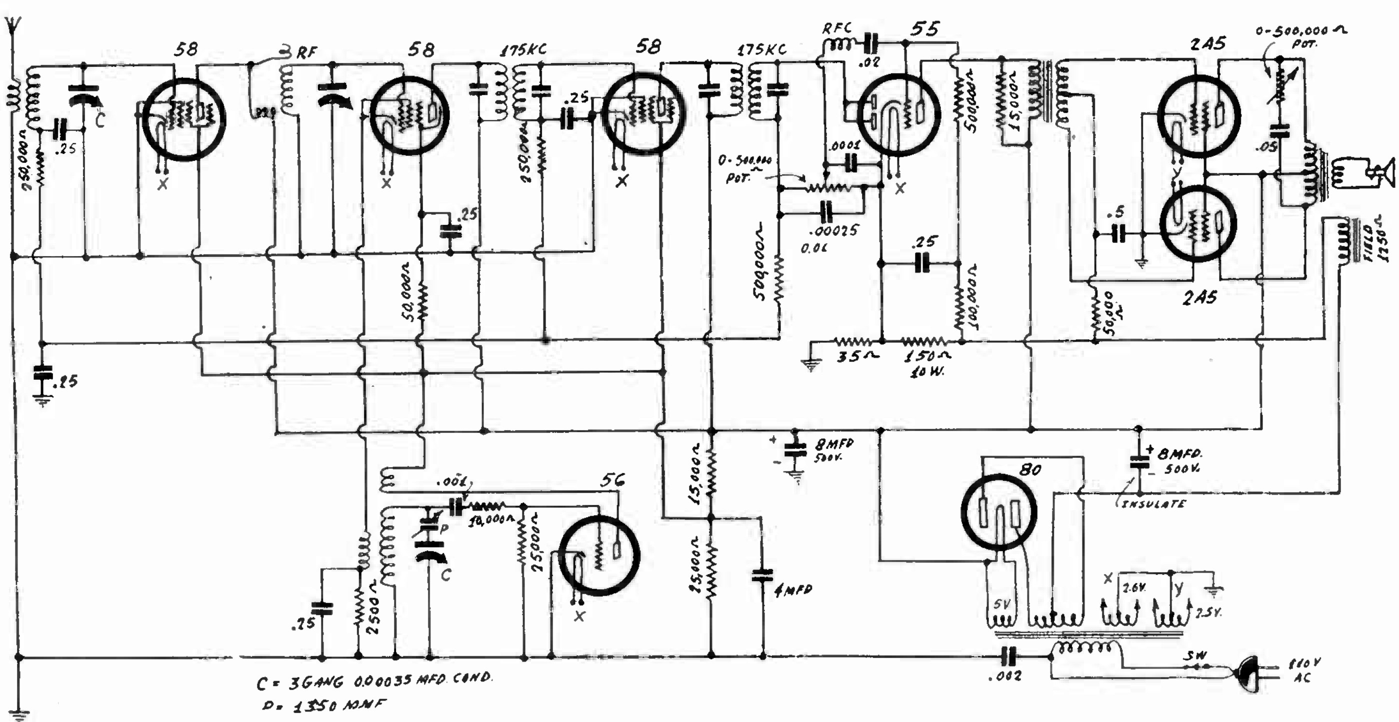
The 34 may be used as a regenerative detector for short waves as shown. Sensitivity is affected by the value of the space-charge load resistor, shown as 0.05 meg. (50,000 ohms). This resistor may be raised until sensitivity declines and a value used that provides maximum sensitivity. Data on the coils on 1½" diameter are given directly above.

WHEN the screen is used for feedback in the 34 tube, and the conventional plate is grounded through a resistor, does the value of this resistor have any effect on performance?

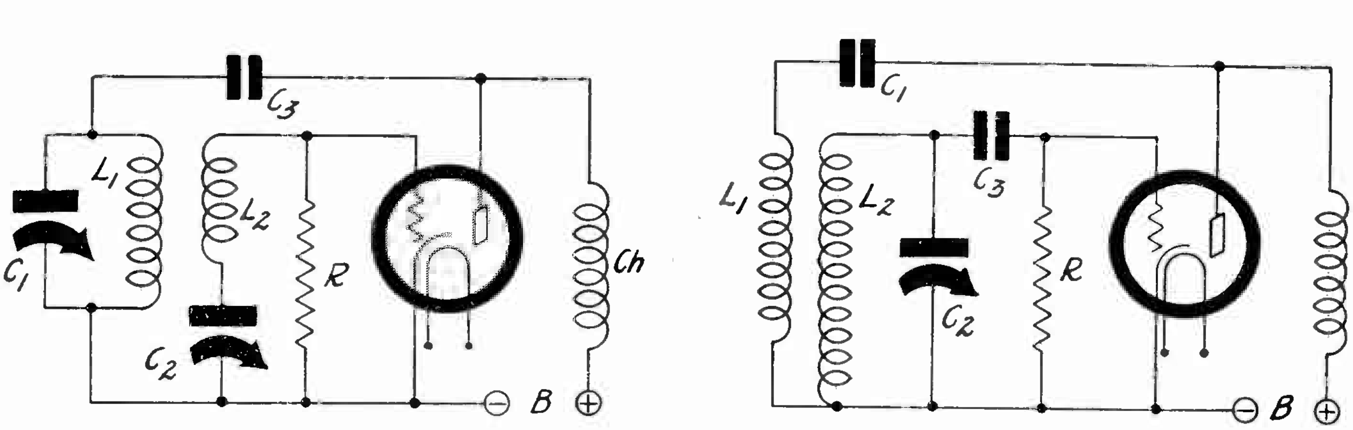
Yes, it does. A value of 0.05 meg. is generally satisfactory. However, higher values may be used, up to the point where the sensitivity of the system is lowered. That is, somewhat more than 0.05 meg. no doubt will improve sensitivity, but a point is reached when sensitivity declines, and it is well then to go back to a value of resistance that affords highest sensitivity. The diagram shows the 34 regenerative detector.

The former example, on opposite page, of screen used for feedback applied to a battery-operated device. In this example the circuit is used on a.c. or d.c., being universal, but there is no change in the feedback on that account. The harmonics will be strong when a.c. is on the plate. This circuit also provides for neon-lamp modulation (an audio tone) when used on d.c. Otherwise the hum is the modulation, on a.c.





Though the tuned-grid type of feedback, with leak and condenser, is fairly stable, many may want to improve the stability, and this may be done by inserting a series resistance between the tuned circuit and the grid. The resistance thus introduced must not be large enough to stop oscillation, but should be large enough to hold the plate current pretty steady as the device is tuned over the smaller capacity part of the spectrum.

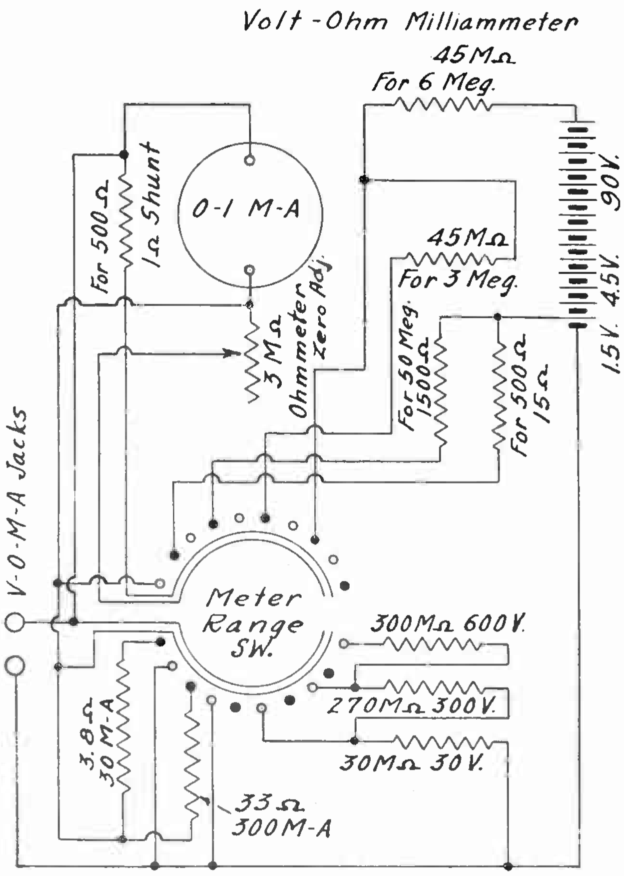


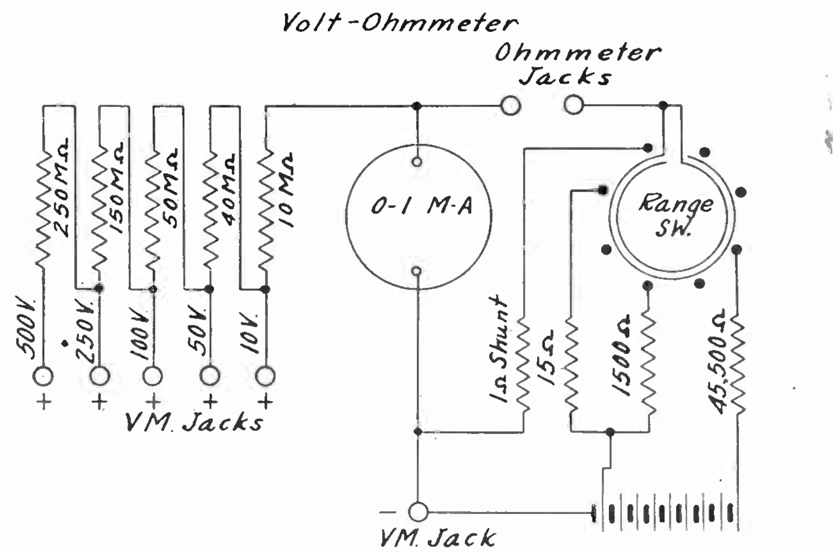
At left is a circuit that has plate effectively parallel-tuned and grid series-tuned. At right the grid is tuned once more, plate untuned, and no d.c. through the plate coil.

SWITCH INSTRUMEN
VOLTS, OHMS AN

General Principles of Circuiting—Provision for A

By Conrad





At left, the circuit for wiring an instrument to read volts, ohms and milliamperes. The words "For 50 Meg." should be read as if "For 50MΩ," that is, for 50,000 ohms. If only voltage and resistance are to be measured, the circuit directly above should be followed. Both of these instruments are of the switch type. The switch should have good contact. The basis of the circuits is a meter of 1 milliampere full range.

THE measurement of voltage, current and resistance is constantly made by radio experimenters and servicemen, and all of them desire to have the best instruments they can afford, but often they find it necessary to use inferior instruments, and know of course that the measurements will not be as accurate.

For measuring current the cheaper instruments do not compare so unfavorably, because current is a thing by itself. Also, in measuring resistance, the comparison is not so unfavorable, either, because the resistance value of the unknown is decided on the basis of current flowing when a known voltage is applied to a circuit consisting of the meter and a series limiting resistor. High resistances can not be measured with low-sensitivity instruments.

When it comes to measuring voltage, the better-grade instrument proves its incomparable worth, because of the large number of circuits in which voltage measurements are made where the current through the device measured is small.

It All Depends On Current

All measurement of voltage, current or resistance, as made with meters used in servicing, depends on current. That is, one may say safely that always current is being measured, nothing else. However, the calibration may be in terms of voltage, or in terms of resistance, besides being in terms of current. Also, the meter may have several scales, so that each calibration is consulted for each particular purpose. Thus the scales might be 0-600 volts, 0-300 volts, 0-30 volts, 0-30 milliamperes, 0-300 milliamperes, and 0-500 ohms, 0-50,000 ohms and 0-3,000,000 ohms, etc.

Since we are always measuring current, and since the needle deflection will be proportionate to the current, the current scale will be linear. Also, since the resistance in the measuring circuit does not change on d. c., the voltage scale will be linear. Therefore it is practical to have a current scale coincide with a voltage scale, that is, 0-30 or 0-300 could serve for milliamperes and for voltage, and also a given resistance scale could be subjected to specific factors of multiplication, by right choice of ascending voltages and limiting resistors.

Thus, some lower-resistance scale (50,000 ohms) could be multipled by 60 (6 meg. maximum reading).

When we are measuring resistance we have a limiting resistor in circuit to start with, and this resistor is such that when the terminals to which the unknown resistor are to be connected are shorted (zero resistance applied), the needle moves to full-scale deflection.

Figuring Out The Limiter

What this resistance should be can be figured out simply, using Ohm's law. The meter's sensitivity must be known. Suppose it is 1 milliampere at full-scale deflection. Then 1 ma must flow. If the voltage applied is 1.5 volts, then the limiting resistor that will cause full-scale deflection of the needle, or 1 ma to flow when the terminals for the unknown are shorted, is 1:5/0.001, or 1,500 ohms. A simple application to all such meters is this: the limiting resistor should equal the number 1 divided by the full-scale current in amperes, the answer multiplied by the voltage. Thus, 1/0.001 equals 1,000. Hence for 1.5 volts use 1,500 ohms. Therefore if the meter is of the 0-1 milliammeter type, the resistance to add per volt is 1,000 ohms. Therefore multiply the voltage by 1,000 and the answer is in ohms. Eg., 1,000x1.5=1,500 ohms.

Since the battery voltage in the cited instance was 1.5 volts, and since the limiting resistor is 1,500 ohms, it is clear that we can not insert a very high value of unknown and get any readable deflection.

Suppose we put 1,000,000 ohms between

NT FOR MEASURING D MILLIAMPERES

-C Tests, Including Relative Output Observations

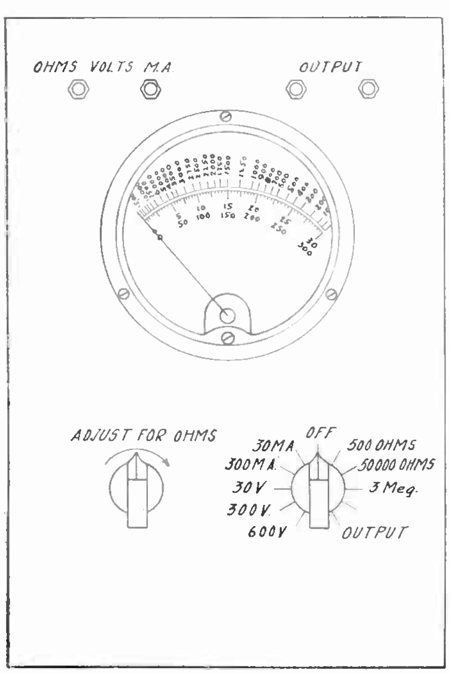
J. Riggles

the terminals for the unknown. The meter resistance is so small it may be neglected, and in this instance the 1,500 ohms of limiting resistance is almost small enough to be neglected. We would get a current "indication" of approximately 1.5/1,000,000, or 1.5 microamperes. Now, this is a current entirely too small to read on a 0-1 milliammeter, and what was stated as an "indication" was a theoretical and not a practical one. In practice the needle may be said to stand still when 1,000,000 ohms are introduced under the circumstances.

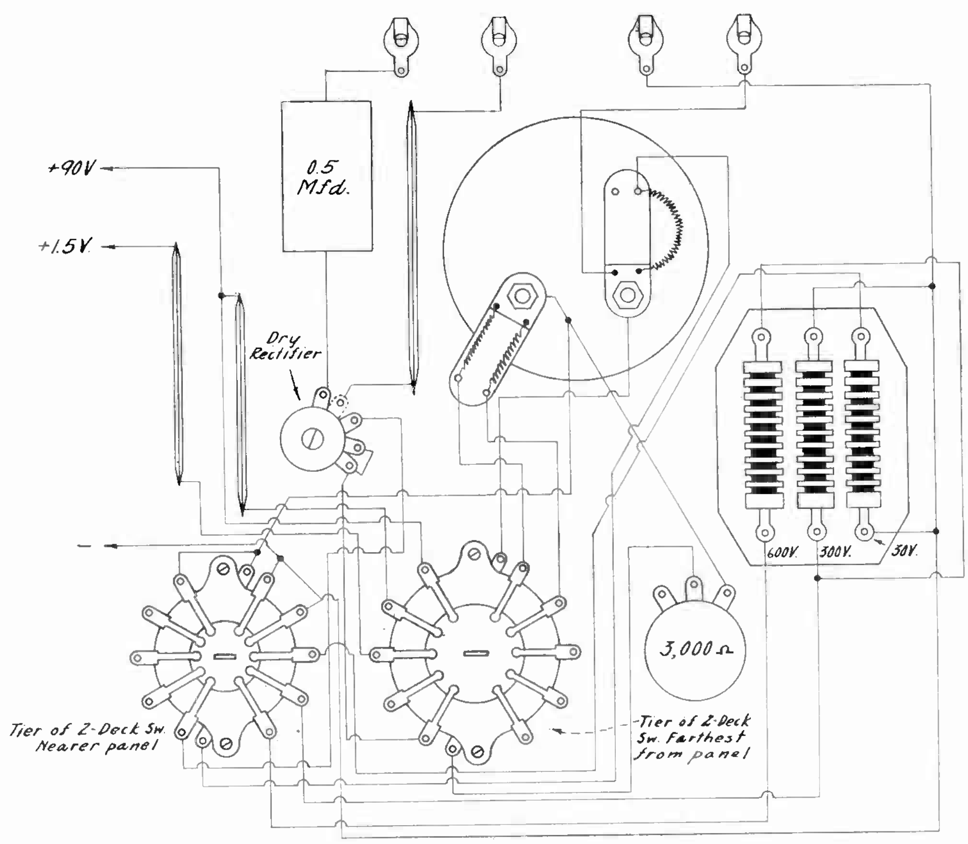
However, we may increase the voltage, and of course increase the limiting resistance accordingly. Suppose we jump the voltage up to 45 volts. Then the limiting resistor will be 45,000 ohms. If we increase the voltage another 45 volts we would have to double the limiting resistance also. Instead of having two resistors, one of 45,000 ohms and the other of 90,000 ohms, we may so arrange the circuit that for 90 volts an extra 45,000 ohms is put in series with the 45,000 ohms used for 45 volts. The sum of the series resistors is 90,000 ohms, and extra expense is avoided because one of the resistors does not have to have so much wire on it.

Appropriate Selection

Now, we can not expect linearity on the resistance scale of the meter, because as the values of unknowns become larger and larger, the percentage of current change becomes less and less. This results in a crowded condition of the resistance-calibration scale, that is, if we attempted to use a single scale with a single voltage and single



Front panel of the Triplett Model 175 volt-ohm-ammeter.



Pictorial diagram of a volt-ohm-milliammeter, with provision also for output measurements. A dry rectifier is included, also a series condenser. Otherwise the diagram represents pictorially the circuit wiring shown in the first illustration (extreme left-hand side of this page).

limiting resistor used for wide-range coverage. But we do not attempt to do that. We select some maximum resistance value that we think can be read read well on the scale for the voltage conditions and limiting resistor, and so for 1.5 volts and 1,500 ohms we might say that a satsfactory reading could be obtained up to 500 ohms.

If we want to go higher we use 45 volts and 45,000 ohms, and if we want to read up to 3 meg. or 6 meg. we use 90 volts and 90,000 ohms. Just what the upper limiting of resistance reading should or can be may be disputed, because different persons will disagree as to how closely they can read the scale, or how close the reading should be to the real resistance value.

In the diagram at left is shown the circuit for wiring a Triplett instrument that measures voltage, resistance and current (milliamperes), along the lines discussed. The basis of the circuit is a 0-1 milliammeter. For voltage readings series resistors are used, just as they are used for resistance-measuring purposes, and the relationship is the same. However, instead of the variable quantity being an unknown resistance, the variable quantity is an unknown voltage, so the limiting resistor is made high enough to cause full-scale deflection for the application of the maximum voltage of a given scale, rather than for minimum resistance of the unknown, which applies to the ohmmeter.

The circuit at left measures d-c currents and voltages, and also d-c resistances. Where the designation "Meg" appears the meaning is megohms, or millions of ohms, thus to read to 3 meg. means to read to 3,000,000 ohms, and to read to 6 meg. means to read to 6,000,000 ohms. The Greek letter ω (omega) for ohms, when preceded by M means thousands of ohms, thus, 45Mω=45,000 ohms. In the diagram at left "For 50 Meg." should read "For 50 Mω," meaning for 50,000 ohms.

If the current readings are not desired, then the instrument is a volt-ohmmeter, diagramed in the second circuit.

The pictorial representation of the volt-ohm-milliammeter is shown at extreme right on this page, with the additional provision of a dry rectifier and a series condenser, so that output readings may be taken. As relative values are sufficient, no separate a-c calibration is necessary.

Harmonics Indentified

By a New, Accurate, Triple-Check Method

By Herman Bernard

METHODS of using harmonics of signal generators, with notations on accuracy of determining an unknown frequency, are the basis of the following summation:

1. *Product of two frequencies divided by their difference.*

If a signal generator is lower in frequency than the circuit to be measured, harmonics of the generator may be used for computing the unknown. Use any setting of the generator that supplies a response to the receiver, note the frequency of the generator, turn the generator dial in either direction, note the frequency of the adjoining response position of the generator dial. The unknown frequency is the product of the two frequencies read, divided by the difference between these two frequencies. Example: If the frequencies read are 120 and 128 kc, the product is 15,360, the difference between 128 and 120 is 8, and the unknown is 15,360/8 or 1,920 kc.

This method is useful if the unknowns are not any substantial multiple of the two frequencies read, otherwise the accuracy of the signal generator calibration would have to be far greater than is to be expected, say, 0.05 per cent. The reason is that for measuring high frequencies the difference is an unverified controlling factor, so that if one frequency is just right on the calibration, and some frequency close to it is off 1 per cent., the resultant error becomes enormous.

Possibility of Error

Suppose the frequencies actually generated are 200 and 199 kc. The unknown then is 39.402 mgc. But suppose the generator calibration is accurate at 200 kc, but off 0.5 per cent. at what actually is 199 kc. but which reads 198. Then the unknown would be incorrectly determined as (200 x 198)/2 or 19.9 mgc., almost 50 per cent. off. This is an extreme and unlikely instance. Suppose the calibration is correct at 128 kc, but when 120 kc is generated the reading is 119 kc. which is less than 1 per cent. off. Then the unknown would be wrongly determined as (128 x 119)/9 or 15,232/9 = 1,692 kc, whereas for the true frequencies, 120 and 128, the unknown is 1,920 kc, a difference of 228 kc, or an error of more than 11 per cent. Therefore any determinations requiring use of high harmonic orders is subject to possibilities of serious error, due to the large net effect of dividing by small percentage error differences. The error introduced into the product does not matter so much, but that introduced into the difference, where the absolute error may be 50 per cent. for a 1 per cent. error in the generator calibration, is serious.

Accurate Methods

2. *Determination of Actual Harmonic Orders.*

The formula of product divided by difference is mathematically perfect, but the application is circumscribed by the impossibility of attaining in practice the extremely high degree of accuracy of calibration that would be needed for assurance of scientific results. Therefore it is much better to determine the harmonic order, for when that is known, the frequency read may be multiplied by that order, and the percentage accuracy of the generator is at all times communicated to the measurement of the unknown.

Because the relationships of harmonics and fundamentals are those of numbers related to one another in a definite proportion or ratio, this ratio may be ascertained. Ratios may be developed from the change in capacities necessitated for the consecutive responses, or from the changes in frequencies or equivalent wavelengths. The author has developed a method of determining the harmonic order from the two frequencies read and which can be solved by mental arithmetic. The rule follows:

Where two resonances or responses are obtained in an unmolested receiver due to tuning the generator to two positions yielding consecutive responses, the harmonic orders of these two responses are the summation of consecutive augend and addend producing the sum of the frequencies, divided by the difference.

An augend is a number to which addition is made and an addend is a number added to the augend. For instance, in the case of A + B, A is the augend and B is the addend.

Application of New Method

Take any two consecutive response frequencies as read, say, 128 and 120 kc. The sum is 248. The difference is 8. Divide 248 by 8 and obtain 31. The consecutive augend and addend of 31 are 15 and 16. So the harmonic orders are 15 and 16. The lower harmonic applies to the higher frequencies read, and the higher harmonic to the lower frequency read. Thus, 15 x 128 = 1,920 and 16 x 120 = 1,920. So if the fundamentals are calibrated to an accuracy of 1 per cent. the unknowns are determined to an equal accuracy. As only whole numbers apply in practice, and as the division must produce a whole number that is the sum of consecutive augend and addend, we can get the harmonic order by mental arithmetic, although we might have to use pencil and paper on high harmonic orders to multiply a read frequency by the selected factor.

The identification of the consecutive harmonic orders is very simple, because when the difference obtained between the two read frequencies is divided into the sum the quotient or answer always is an odd number, assuming consecutive responses in these cases. Subtract 1 from this odd number and divide by 2 to get the augend, or one harmonic, and add the borrowed 1 to the quotient to obtain the other harmonic order. In fact, only one harmonic order is needed, and by subtracting 1 from the quotient and dividing by 2 the harmonic order of the higher frequency is obtained. The other or next higher harmonic for the lower frequency fundamental may be used simply as a check.

Further Aid to Accuracy

Incidentally, the ascending order of the quotients is in steps of 2 and as the quotients always are odd numbers, the last fact is useful as a guide to accuracy. Moreover, if any one frequency of generation is known to be accurate, then the accurate frequency value of the other position on the generator scale becomes known, even though the calibration is off.

It is true that here a difference is divided into a sum, whereas in the formula first considered a difference was divided into a product and now small absolute differences as between true generated frequencies and calibrated representations of those frequencies could introduce just as large error as in the first example, were it not for the check on the accuracy, resulting from the necessity of the difference being a whole number resulting from the division of the difference into the sum, and moreover a whole number that is an odd number. And besides there are only two consecutive numbers that when added will yield the odd number first obtained. Hence, there is a double check on the accuracy. As a third check, it is obvious that the difference (8 in the example of 120 and 128) is divisible not only into the sum of 120 and 128, i. e., into 248, but of course also into 120 and 128 individually, as verification of the harmonic orders.

Ratio Method

Another method of obtaining the harmonic orders is to read any two frequencies that consecutively produce a response in the receiver, and establish a ratio for these frequencies, which may be a fraction or a whole number, and either way works, depending on whether the higher is divided into the lower or the lower into the higher. The resultant ratio factors will identify the harmonics. In general, this method requires pencil and paper, but may be used as a check on any determination arrived at by the previous harmonic-identification method.

Dividing the lower frequency into the higher, the resultant ratios are apportioned to the harmonic orders in the following a table for accurate disclosure of the harmonic orders up to the 101st:

Harmonic Order of the Higher Frequency Read Is	*Harmonic Order of the Lower Frequency Read Is*	*When the Higher/Lower F Equals This Ratio*
1	2	2
2	3	1.5
3	4	1.333
4	5	1.25
5	6	1.2
6	7	1.67
7	8	1.143
8	9	1.125
9	10	1.111
10	11	1.1
11	12	1.09
12	13	1.083
13	14	1.0761
14	15	1.071
15	16	1.0667
16	17	1.0625
17	18	1.0588
18	19	1.0555
19	20	1.053
20	21	1.05
21	22	1.048
22	23	1.0455
23	24	1.0434
24	25	1.042
25	26	1.04
26	27	1.0385
27	28	1.037
28	29	1.0357
29	30	1.0345
30	31	1.0333
31	32	1.0322
32	33	1.0319
33	34	1.03
34	35	1.0294
35	36	1.0285
36	37	1.0277
37	38	1.027
38	39	1.0263
39	40	1.0257
40	41	1.025
41	42	1.023
42	43	1.024
43	44	1.0234
44	45	1.0227
45	46	1.0222
46	47	1.0217

Harmonic Order of the Higher Frequency Read Is	*Harmonic Order of the Lower Frequency Read Is*	*When the Higher/Lower F Equals This Ratio*
47	48	1.0213
48	49	1.0208
49	50	1.0204
50	51	1.02
51	52	1.0196
52	53	1.0192
53	54	1.0188
54	55	1.0185
55	56	1.0181
56	57	1.0178
57	58	1.0175
58	59	1.0172
59	60	1.0169
60	61	1.0166
61	62	1.0163
62	63	1.0161
63	64	1.0158
64	65	1.0156
66	67	1.0151
67	68	1.0149
68	69	1.0147
69	70	1.0144
70	71	1.0142
71	72	1.0140
72	73	1.0138
73	74	1.0136
75	76	1.0133
76	77	1.0131
77	78	1.0129
78	79	1.0128
79	80	1.0126
80	81	1.0125
81	82	1.0123
82	83	1.0121
83	84	1.0120
84	85	1.0119
85	86	1.0117
86	87	1.0116
88	89	1.0113
89	90	1.0112
90	91	1.0111
91	92	1.0109
92	93	1.0108
93	94	1.0107
94	95	1.0106
95	96	1.0105
96	97	1.0104
97	98	1.0103
99	100	1.0101
100	101	10.1

3.—*Consecutive settings.*

Since frequency differences are concerned in the computation methods, if the fundamental readings can be obtained conveniently for two positions that are 1 kc apart, to cause adjacent responses also, the operation is simplified. In the case of the product divided by the difference, there need then be only one operation instead of three. Simple multiplication suffices, because the difference is 1 and the divisor is 1, and in both instances do not change the result.

For high frequencies of unknowns, responses are numerous on the dial, but with some idea of the unknown, in terms of megacycle steps, as for use in station-finding, when that aid nearly always is present, the generator fundamentals may be selected for any range having 1 kc separation registered, e. g., 100-200 kc. In other words, some inkling to start with avoids the necessity of skipping all over the dial.

Merged Into One

When the responses fall on even kilocycle bars for the 100-200 kc range, the numbers under "Responses on Generator Fundamental" disclose the measured frequency to be that listed under "Unknown Frequency Then Is in Mgc." As all responses on fundamentals are consecutive in kilocycles, and close together, there is danger only of absolute error, scarcely of relative error, therefore the result will be about within the accuracy of the fundamentals, but may be checked by the using harmonic-order method, that is, determining the harmonic and multiplying the read frequency by that determination. The table for adjacent responses 1 kc apart appeared in the September 22d issue.

The foregoing method, product divided by the difference, is expressed as a formula thus:

$$F_x = \frac{F_2 F_1}{F_2 - F_1}$$

where Fx is the unknown, F_2 is the higher of the two consecutive fundamental frequencies of the generator, and F_1 is the lower of the two response frequencies of the generator.

The formula for the harmonic-counting method is:

$$F_x = F_2 (n) = F_1 (n + 1).$$

where the symbols have the same meaning as before, and in addition n equals the harmonic order.

In the operation we determine n and add 1 to get n + 1, so have both harmonic orders for the two frequencies read. As we are now dealing with frequencies confined to those read on the generator for consecutive responses just 1 kc apart, we have brought the two methods to an identity, or both are exactly the same, because the harmonic order of one frequency read on the generator is equal to the other (consecutive) response-creating frequency read at the next bar. That is, for 10.1 mgc, the 100th harmonic of 101 kc fundamental is used and for 100 kc fundamental the 101st harmonic of 100 is used, and this situation obtains for all frequencies of unknown from 10.1 without limit, although the table terminated at 39.8 mgc.

Just to apply the harmonic-counter method, for 101 and 100 kc fundamentals, the sum of the two numbers is 201, the difference is 1, and since 1 divided into 201 still equals 201, we subtract 1 from 201, get 200, divide 200 by 2, get the harmonic order as the 100th for the higher frequency (101 kc) and 101 for the lower frequency (100 kc). In both instances the answer is 10,100 kc or 10.1 mgc.

Another New Method

So far we have dealt only with consecutive responses, and the bulk of the harmonic technique has been built up in that direction. However, if the frequencies measured are quite high compared to the generator fundamental frequencies, that is, the harmonic orders are high, and there are any misgivings about an incorrect fundamental calibration causing error in the measurement, or some result is obtained that does not check with the methods outlined, while the error results from the application or calibration and not from the method, the peril of error may be minimized by using all the responses obtainable. On this basis a new, accurate method has been developed by the author, as will appear at the end of this article.

Suppose that the generator is set to the lowest frequency that will produce a response in the receiver. If the unknown is high we shall have numerous responses. In previous discussion we dealt with two response points, but only one difference. Now, as we use more response points we must recognize that we are still striking differences. Therefore with a response due to the generator being at or near the low-frequency extreme, say, at 102 kc, we may traverse the dial and count the responses. Only the number of differences counts, therefore, the total responses less 1 is used as the basis. For 10 responses there would be 9 differences, for 11 responses 10 differences, etc. Hence, if we started at 102 and got the last response at 198, total 11 responses, net differences 10, we could use the harmonic-counting formula, or the product-divided-by difference formula, and muitiply the answer by 10.

Using More Responses

Since one desires to make the measurement as easily and readily as possible, for high frequencies, it is well to select some generator fundamental on an even kilocycle bar, and turn the dial, counting the responses, until near what is the expected end of the chain, when a halt is made at another even kilocycle bar.

Example: The lowest frequency to yield a response on an even bar is 100 kc, the highest is 200 kc, the number of responses is 11. What is the frequency? Using the harmonic-counting method, the sum of 100 and 200 is 300, the difference between 200 and 100 is 100, dividing the difference (100) into the sum 300 yields 3, and the harmonic orders therefore are 1 and 2, multiplied by 1 less than the total responses, e. g., 10. So the harmonic orders are not consecutive, but are products of consecutives, i. e., 10 and 20, applied to 200 and 100, and the unknown is 2,000 kc or 2 mgc.

It is not necessary actually to have the responses occur at even-bar positions, as estimating between bars does not mar the accuracy, by the harmonic-counter method.

Same Spreadout for All

4.—*Direct counting of harmonics.*

We now come to the very latest disclosure of importance in harmonic technique, as embodied in a commercial test oscillator of the author's design, the 334-A. It is the simplest system of all, and is applicable particularly to the 2-to-1 frequency range of any generator with a fundamental range of 100 kc, though with less convenient practice could be applied to any generator.

This method is not automatic, for all automatic methods result in crowding of part of the dial, and therefore introduce difficulty of reading, hence mar accuracy for high frequencies; it does not use differences calibrated on a dial, but could be applied to a generator that has no calibration, save for the terminal frequencies (100 and 200 kc); and it communicates to all measurements the percentage accuracy of the generator, and besides contributes the same spreadout for any and all frequencies measured. No other system affords equal spreadout for any and all unknown frequencies, for computations based on product divided by difference, or on sums and differences, or automatic systems using these or similar methods, inevitably are constricted to a smaller span for a higher unknown frequency; indeed, the smallness of the calibrated difference is the only measure of the value of the unknown frequency.

Some Examples

Suppose we take concrete examples. The fundamental is 100 to 200 kc, calibrated in steps of 1 kc. We set the pointer at 100 kc. That is what the generator produces—100 kc, plus or minus 1 per cent., if the accuracy is 1 per cent. The 334-A is rated at 1 per cent., but actually has greater accuracy.

Now, we get a response at 100 kc. We turn the dial for the full distance from 100 kc to 200 kc. No other response is heard. Do we know what the unknown frequency is—the frequency of an intermediate amplifier, for instance? If we know it, how do we get that knowledge? We know the unknown is 100 kc, because unknowns of multiples of 100 kc are concerned, and there was a response in the receiver due to generation of 100 kc, and no other response, though we traversed the whole dial to 200 kc. If the frequency of the unknown were less than 100 kc we would not hear any response, or if higher would be a multiple of 100 kc and we would have obtained more than one response.

Suppose the responses are supplied by 100 kc and 200 kc settings. What is the unknown? It is 200 kc, because the second harmonic is 200 kc, and 200 kc itself caused a response in the receiver. No other unknown frequency would satisfy the conditions of two responses for the traverse of 100-200 kc.

Formula is Child's Play

So for 100 kc unknown we got one response when we started at 100 and traversed the dial to 200 kc, for 200 kc unknown we got two responses under the same conditions. As the unknown frequencies increase, the number of responses increase directly. So for 2,000 kc unknown we get 20 responses, for 3,000 kc unknown we get 30 responses, etc.

(*Continued on next page*)

(Continued from preceding page)

Therefore for a 2-to-1 frequency ratio we have this very simple formula:

$$Fx = nF$$

where Fx is the unknown frequency n is the total number of responses heard in the receiver, and F is the generator frequency next lower to the high-frequency terminal of the generator.

The system is most appropriately applicable to high frequencies, since it enables measurements in steps of 100 kc, which at these frequencies would be termed in megacycles: 0.1 mgc. Moreover, the percentage of closeness with which the determination may be made increases with frequency, whereas in all automatic counting systems, including a method devised by the author, known as the Automatic Electric Harmonic Counter, the crowding at the higher frequencies greatly impairs the usefulness, although at relatively low frequencies the application is satisfactory.

No Crowding of Dial

Moreover, any method of attempting to overcome the crowding effect caused by normal tuning characteristics, by using large parallel capacity, reduces the frequency ratio so that the device can be used only as a station finder, and not also as a test oscillator for intermediate frequencies, unless the fundamentals are placed somewhere near the audio range, which is not to be considered.

The answers are in kilocycles, but if instead of multiplying responses for kilocycles, we multiply the responses by 1,000.

Some users will be interested in wavelengths, also, although the general rule is to use the frequency method of designation for the most popular program, amateur, police, airplane and ship channels (1,600 kc to 20 mgc). Also, usually station lists give both frequencies and wavelengths.

Since the dial is calibrated 100-200 kc, the numbers 101, 102, 103, etc., to 199 may be read as if 100 were subtracted. Then, since the pointer is of the double type, positions for corresponding wavelengths could be written on a lower scale (below hub). The number 200 would be read as for 100 responses, due to subtraction by 100, but the other numbers on the top scale are pat for the purpose. The traverse permits the gradation of wavelength values from 3,000 to 30 meters, the metrical differences varying according to the exponential term of wavelength compared to frequency.

Higher Frequencies

The case of one response represents 100 kc, hence 3,000 meters, the case of 100 responses represents 10 mgc., read at 200 kc on the dial, so 30 meters. And for higher frequencies or lower waves the number of responses may be continued to be counted, and the equivalent wavelength determined from a chart relating frequencies and wavelength (such as printed in last week's issue, September 29th), or from the 3,000-1,500 meter wavelength calibration of the fundamental on the 334-A signal generator, by determining the unknown frequency, selecting some frequency on the fundamental related to the high frequency by an easily-handled factor, and reading the equivalent fundamental from the dial, and dividing that wavelength by the factor. Thus, for 15,600 kc as determined by the wide-span decimal counting method, read 156 on the fundamental frequency range, note this goes into 15,600 a hundred times, read the wavelength for 156 kc as 1,922 meters, divide by 100 and the wavelength is determined as 19.22 meters. For responses above 100, one may also use the double index, by simple proportion.

Above 6,000 kc

For frequencies above 6,000 kc (waves below 50 meters) the 0.1 mgc difference is indeed close enough, and, as stated, the higher the unknown in frequency, or the lower in wavelength, the smaller the percentage difference the steps bear to the unknown, so by this method the exponential or crowded condition is not only overcome but reversed. Of course the number of responses must be counted, but it will prove a surprise to practically everybody how quickly and successfully this can be done, and especially those whose chief pursuit in these matters is accuracy will appreciate the value and the soundness of the method.

Multiples of Higher Frequencies

The use of the simple system of direct-counting was applied to 100 kc as starting point because of the scale. A possible objection is that if only this method is applied, unknown frequencies not integral multiples of 100 kc could not be measured this way. But the unknown, for any high frequency, is always a multiple of 100 kc or some frequency a bit higher than 100 kc, so get a response from the lowest frequency of the generator, traverse the dial to twice that frequency, count the responses and multiply by the preceding low frequency.

As stated, for high frequencies, say, above 10 mgc., the 100 kc starting point is entirely suitable, and will yield responses or beats for all unknown frequencies, within the 1% accuracy limit, which for 10 mgc. is equal to the starting frequency of the generator, 100 kc, and for higher than 10 mgc. is a difference smaller than the accuracy factor, and from 10 mgc. up therefore always yields results, wherever the set is tuned.

Automatic Method

5.—*Non-computation methods.*

The methods outlined all deal with computation, even that method whereby the harmonics are directly counted. It has been shown that some computation methods are better than others, that is, the preferable solution is to obtain the harmonic order, read a low frequency and multiply this reading by the harmonic order, to have the resultant measurement as accurate as the calibration of the generator.

It will be noticed that the higher the unknown frequency, the greater the number of responses due to traversing the dial of the generator. It follows therefore that the higher the unknown frequency, the closer together will be any two consecutive positions of the generator dial that create responses. This is confirmed by inspection of the table of ratios, which shows that the higher the frequency to be measured, the smaller the ratio resulting from one frequency creating response being divided into the other (consecutive) frequency creating producing response.

It is therefore obvious that an automatic method can be applied for harmonic counting, calibrated as a measurement of the unknown frequency. Since the generator dial positions are closer together the higher unknown frequency, the difference between the generator frequencies creating responses will be a measure of the unknown frequency, though not a direct measurement.

It is not suggested that the automatic method referred to is excellent, for its scope is limited, nor is it stated some other method can not be better.

Formulas Stated

The first response, say, due to the generator's higher frequency, F2, results from that generator frequency being multiplied by harmonic order n. It is unnecessary to know the value of n. The next dial position of the generator (lower frequency) will produce a response in the detector (receiver) on account of the next higher harmonic F_1 $(n + 1)$. We have found before that

$$Fx = F_2 (n) = F_1 (n + 1)$$

wherewhere Fx is the unknown frequency, F_2 is the higher frequency to which the generator is tuned, n is the harmonic order of F_2, and F_1 is the next lower frequency to which the generator is tuned to repeat the response.

Therefore we can tell where the response will fall, either starting at the higher frequency of the generator, say, selecting 200 kc for the constant starting point, when the formula is as given directly ahead, or starting constantly at the low-frequency end, 100 kc, when the formula is:

$$Fx = F_1 (n) = F_2 (n - 1).$$

Points Established

We used the direct harmonic counting system, starting at the low-frequency extreme, principally to get 100 kc differences rather than 200 kc differences. Let us determine where some of the positions will fall for specified frequencies in the automatic harmonic-counter system, say, 1.8 mgc to 20 mgc, or at least establish a few points to show the theory.

Suppose we start at 100 kc again. If we got two responses, it will be remembered, when direct-counting was applied, the unknown was 200 kc. Where was the second response? At 200 kc. Therefore if we use a double pointer, on a tier below the hub we can mark a bar representing the same pointer position below as is occupied by 200 kc above the hub, and call that 200. We are ascribing positions for second response-creating points for frequencies spaced 0.1 mgc, so we want to find where 300 will fall. We start at 100 kc and, lacking the simple guidance of the first instance, apply the formula.

For 100 kc of the signal generator 300 is represented by the third harmonic. The next higher-frequency position of the generator dial creating response in a receiver still tuned to 300 kc will be of the next lower order, so we divide 300 by 2, getting 150, and inscribe a bar below in line with 150 kc above, and mark it 300.

Sharp Reduction

So the formula for finding the position that marks the frequency separation between fundamentals, starting with the lower generator frequency, and using two fundamentals, responses due to consecutive positions of the generator dial, is:

$$F_2 = \frac{F_1}{(Fk / F_1) - 1.}$$

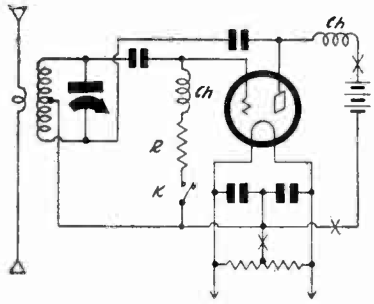
where F_2 is the higher generator frequency, here the unknown, F_1 is the lower generator frequency, and Fk is the frequency now assigned, but in later practice to be the unknown, or frequency to be measured.

So the positions for the second response when the frequency to be measured is 400 kc is 400/3, or 133 kc, and when 500 is to be measured is 500/4, or 125 kc, and when 600 kc is to be measured is 600/5, or 120 kc, etc. Note how sharply the differences reduce.

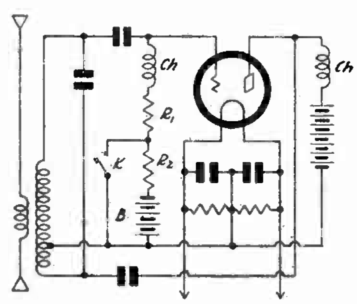
This method, like all other automatic methods that refer to differences on the dial as the measure of the unknown, results in points coming close together eventually, as was found from the fact that from 1.8 to 7 mgc an 0.2 mgc separation was maintained with mechanical ease, from 7 to 10 mgc the separation was necessarily worse, or 0.5 mgc differences, and from 10 to 20 mgc the jumps were in 1 mgc steps. This is what is meant by the exponential nature of the calibration.

Has Some Good Points

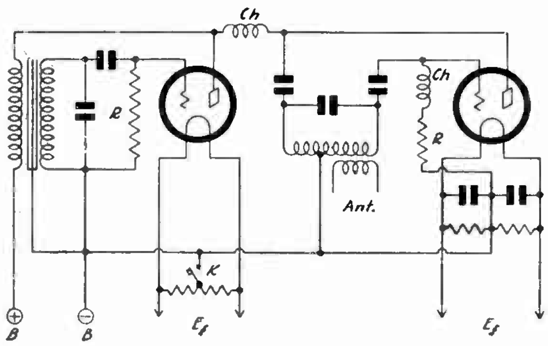
The system applies well enough if the frequencies to be measured are relatively low, compared to the generator, but does not apply well at all when the frequencies to be measured are relatively high, and besides it is a method, like any automatic one must be, has diminishing order of accuracy as the frequency of the unknown is higher, for manipulative reasons. Bars eventually so close together that they are hard to read, or bars separating wide differences of the unknown, are themselves a denial of accuracy.



Keying by opening and closing the grid circuit. A closed key produces an unmodulated wave. Dots and dashes sent out by the above may be received by heterodyne method



This is a similar grid method, though the grid is never open. The bias is too high for oscillation unless the key is closed, when unmodulated carrier results



The tube at right is a Hartley r-f oscillator. The one at left is a tuned-grid audio oscillator. When the key is closed the modulation is put on the carrier. With key open the carrier continues but is unmodulated. Heising modulation is used.

Radio University

Code and Phone Transmitters

WILL YOU PLEASE give me an insight into the keying process for telegraphic transmission, also show some systems of using voice modulation?—L.H.C.

The simplest method is that for telegraphy, where dots and dashes are sent, by stopping and starting oscillation. The grid return may be interrupted by the key, as shown in the first diagram at upper left on this page. When the key is depressed the carrier is sent. When the key is open there is no oscillation. The same condition of presence and absence of oscillation prevails in the diagram second from left, although there the grid never is open. The bias is made so high when the key is open that there is no oscillation, and when the key is closed oscillation takes place. In both these instances the interrupted carrier principle is involved. For reception of this kind of transmission a circuit is necessary that is oscillating near the frequency of the transmission. The difference in frequency between the two determines the frequency of the resultant audio tone. At upper extreme right a separate audio oscillator tube is used, and when th ekey K is depressed the audio tone is introduced into the radio-frequency oscillator, which oscillates continuously. Therefore reception may be had without an oscillating receiver, for the carrier is ever-present. The three circuits so far discussed are telegraphic. The two lower diagrams show phone circuits, at left with Heising modulation, which is a plate-circuit system, and at right a grid-circuit-modulated counterpart of the circuit at left.

* * *

Ultra Frequencies for Fans

IS THERE ANYTHING much that a home constructor can do about the ultra frequencies? These offer very interesting possibilities, but, not being an amateur, what can a fellow do about them?—J. D. C.

A receiver can be built for bringing in stations transmitting on ultra frequencies. Amateurs can be picked up, and they use phone on the 56 mgc band. Besides, on other related frequencies various experimental efforts are being conducted, including television, and you might want to try scanning some of this. The work in this general band is so much of an experimental nature that even official lists of world short-wave stations include none of these ultra-frequency stations, except eight in Hawaii and two in Argentina. As you know, the reception range, in general, is as far as the eye can see, just as a measure of distance, not of conditions of light and darkness. So there is no hope of your tuning in Hawaii and Argentina. A new tube particularly useful for ultra-frequency circuits, the 955, has been announced. Otherwise rather awkward efforts have had to be made to press regular receiver tubes into service for reception and transmission. Of course the 56 mgs band is not so very far down—or up—being in the 5-meter region, but frequencies much higher are used, and the new tube will work on 2.5 meters and below, and inferentially be of service for lower frequencies, if any wide frequency coverage is to be attempted.

* * *

Too Much Volume

PERHAPS YOU NEVER before ran across this one. My receiver is too sensitive and I cannot turn down the volume to a comfortable level on local stations. This must be annoying to neighbors late at night. In fact, it causes me some annoyance. The detector I use is a 55, which has a negative bias for the triode, the diode load resistor being a potentiometer with arm slid across the total resistance to pick off as much voltage as the operator desires—except that he can not pick up as little as he desires! There is indeed a change in volume as the control is manipulated, but the minimum volume is

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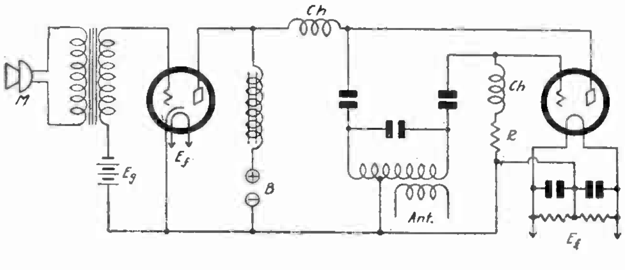
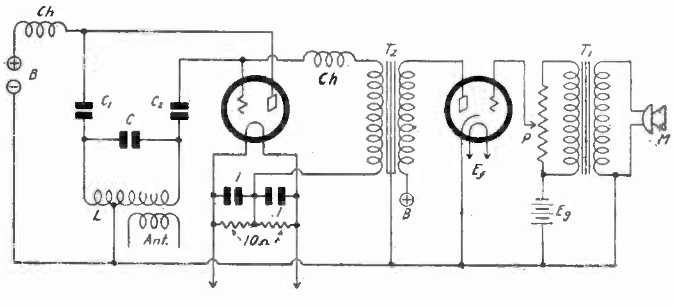
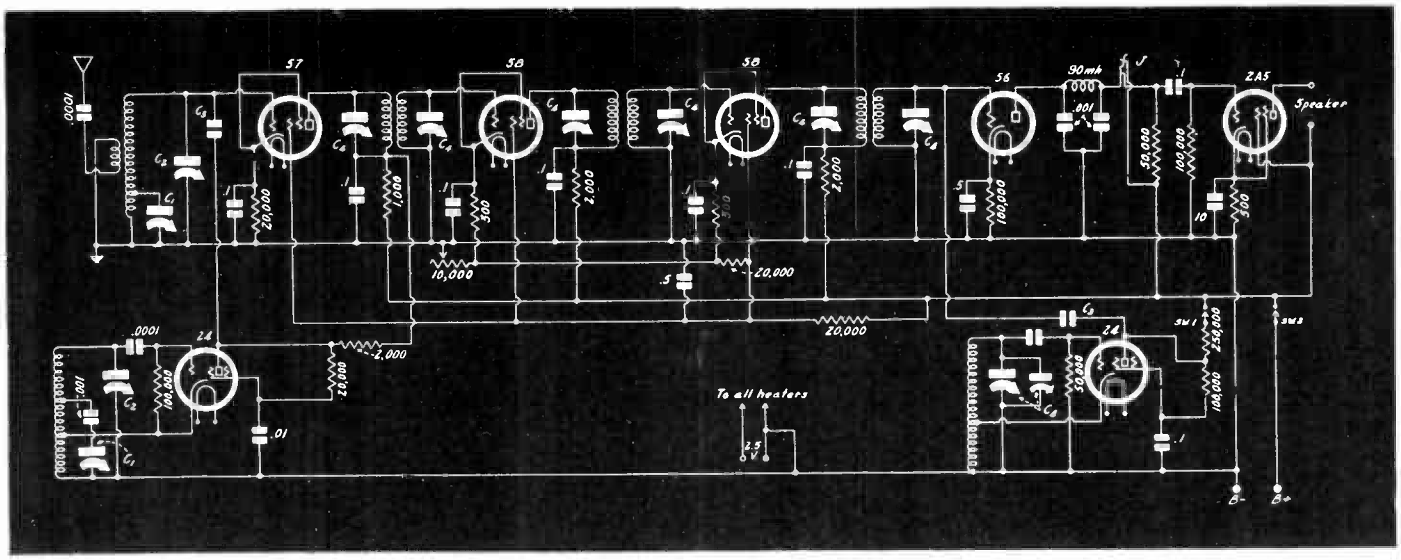


This is a system for phone transmission. The Hartley r-f oscillator at right sends a carrier continuously. Sound modulation results whenever the microphone M is excited



Heising modulation previously shown is a plate-circuit affair. The above circuit uses grid modulation, otherwise is substantially the same as the circuit at left. Above, the tube at left is the r-f oscillator



This seven-tube short-wave superheterodyne has a beat oscillator (lower right) coupled loosely to the input to the 56 second detector, and detuned slightly from the intermediate frequency. For unmodulated, keyed carrier telephony reception this oscillator condenser may be front-panel tuned over a small range, say to 10 kc from zero beat to afford tone selection.

(Continued from preceding page)
above ear comfort for local reception. What do you suggest?—O. P. L.

Quite a large number of causes may produce the effect you describe. One that suggests itself readily is that the potentiometer has a limiting resistance built in, so that in fact the arm that is supposed to permit practically shutting off of the signal does not get below some thousands of ohms even when at minimum. Check up on this with an ohmmeter. Another possible cause of the failure of the control to work satisfactorily is that the wiring in and about the second detector is such that there is large stray capacity coupling, enough to cause much input to skip over the diode entirely and strike the triode, where rectification takes place. This of course would be detection independent of the diode and the manual control would affect only so much of the rectified voltage that is due to the diode. This may be only half the total rectified voltage that gets into the audio channel. Besides, in the tube itself there will be some little capacity to augment this effect. You might try using diode-biasing, that is, remove the biasing resistor of the 55 cathode leg, which leg now becomes grounded to B minus, and remove the leak and stopping condenser, connecting potentiometer pointer directly to grid. If grounding the arm then does not shut off the reception, put a limiting resistor between the high side of the potentiometer and the return of the coil feeding the diode, so the potentiometer never can take off the full voltage. Say the limiting resistor is made one-fifth or one-quarter the total potentiometer resistance. Since the whole problem is a relative one, this will surely help considerably. You no doubt have automatic volume control, and if you have a time delay circuit in association with it, omit this delay, as it would be omitted if the previous-diode-biasing suggestion is followed. A. v. c. tends to equalize the volume no matter where such a manual control as you have is set, if the station is a strong one, therefore strong stations are cut down in volume more than medium-strong stations, hence as an aid to your trouble the control should be plentiful, and no lessening of a. v. c. introduced (as it is introduced by time delay action).

* * *

Coupling Beat Oscillator

HOW SHALL the beat oscillator at the intermediate level be coupled to the i-f circuit of a short-wave receiver?—I. K. C.

The coupling must be very loose, otherwise the beat oscillator may drive the intermediate amplifier into oscillation, particularly if the two frequencies, that of the i-f channel and of the beat oscillator, are very nearly alike. It is advisable to have the beat oscillator at least slightly detuned from the i-f frequency, to be sure that when a station is tuned in that there will not be zero beat, but some note that can be identified. A very small condenser from plate of the beat oscillator to grid of the second detector tube will provide coupling. This condenser can be improvised by twisting together two pieces of insulated wire, about 3 inches long, taking care that the ends do not touch. One extreme of one wire goes to plate, other extreme of the other wire to grid. This enables the length to be used for the actual wiring between the two points. The diagram shows the condenser connection, also the complete receiver.

* * *

Focusing Micro Waves

I RECENTLY READ in your magazine about an attempt to standardize the classification of high frequencies. Has the standard been adopted? Are these waves easy to focus?—P. O.

Standardization is still under discussion. Meanwhile it is hard to follow technical writings sometimes because of lack of such a standard, although due to the general context or the statement of regions in meters or centimeters or megacycles the mystery becomes clarified. Some standardization should be adopted, as the micro waves are becoming more and more important. We refer to waves of 1 meter or less. It is very easy to focus these waves in a narrow beam by means of properly-shaped reflectors. These radio-optical waves naturally lend themselves to such reflection, and the shorter they are in wavelength the easier the reflection, but the harder to get satisfactory oscillation. However, new tubes will take care of the problem of generating the frequencies, in due course.

* * *

Current at High Frequencies

IS IT POSSIBLE to measure current conveniently at frequencies above 20 mgc?—L. M.

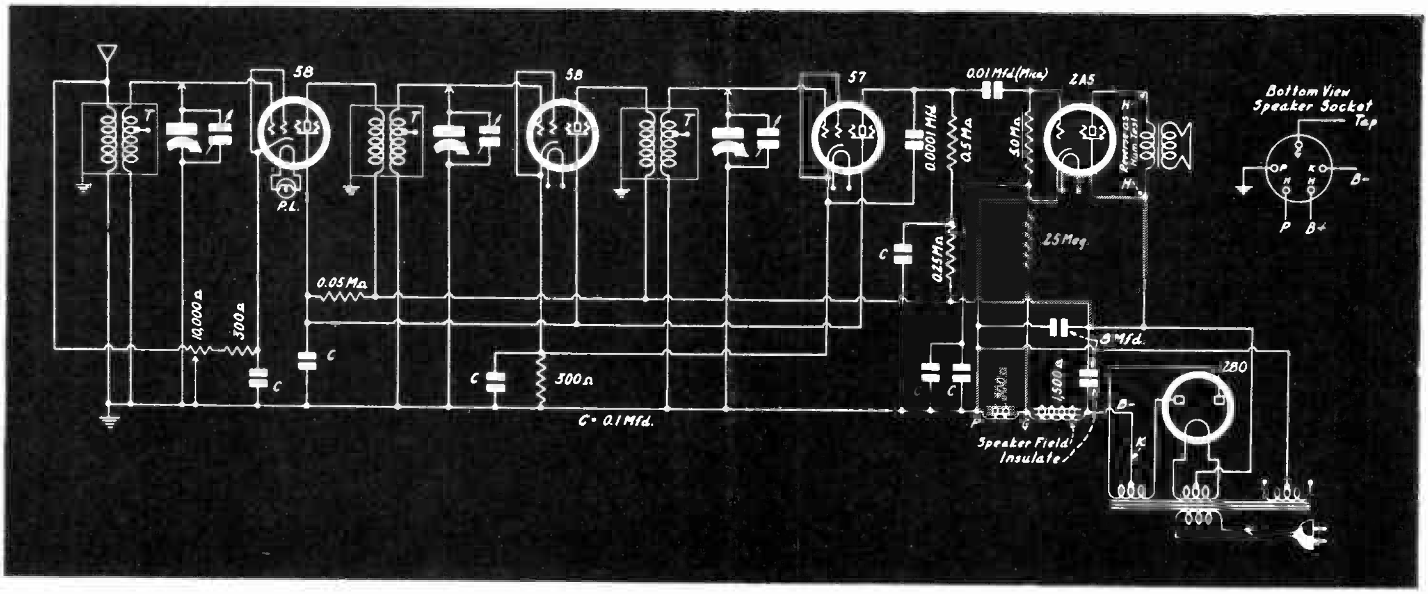
That depends on what you mean by convenience. Of course such measurements can be taken, but they require somewhat more care than just measuring the voltage of a dry cell. One method, due to H. M. Turner and P. C. Michel, of Yale University, comprises a closed ring freely suspended in the field of an exciter coil. The exciter current is calculated from the physical dimensions of the instrument and the observed period of the torsional vibration of the ring. The smallness of the physical dimensions minimizes the capacity effects. The impedance of the instrument is independent of the current amplitude. The power consumed is relatively small.

* * *

The Super-regenerator

CAN THE SUPER-REGENERATIVE circuit be stabilized? Why is not super-regeneration a good thing for the broadcast band? What is the effect of the second oscilation frequency, and is it just as well to generate the two oscillations in the one tube, or should a separate tube be used?—K. S.

There is no reason why the super-regenerative circuit can not be stabilized, so far as we know, particularly as it is simply a regenerative circuit subjected to a special modulation. The super-regenerator is useful for high frequencies above 30 mgc, or below 10 meters—and is used particularly for waves around 5 meters or less. It is practically the standard for reception by amateurs in the 56 mgc band. It is very effective there and besides tends to correct for the frequency drift of the high-frequency transmitters themselves. It is well known the 5-to-10 meter band is not characterized by much transmitter stability, although improvements are being made fast. The super-regenerator is not selective—one reason for inadequacy on the boadcast band—and therefore the effect of the drift is somewhat overcome. It must be admitted that super-regenerative sets are noisy. This would follow from the fact that they are intensely sensitive. Noise is another reason why this type of receiver is not satisfactory for the broadcast band. An added cause of noise is the second frequency introduced, as this is usually of an audio nature, because the improvement of sensitivity and general operation is greater the lower the second frequency. It makes small difference whether the same tube is used for production of the two frequencies, or two different tubes. If one method is more sensitive than another, a point to consider is that the less-sensitive method is, if anything, nearly too sensitive itself. The theory of operation of a super-regenerator, by the way, is as follows: A tube is made to oscillate at a high frequency, say, in the 5-to-10 meter band. Instead of permitting the oscillation to reach its saturation amplitude, a control is introduced. If the tube were allowed to maintain its maximum amplitude the plate current will be



This is practically a standard five-tube t-r-f-set. The speaker field is used as B supply choke and semi-fixed C bias supply for the 2A5. Five leads from the speaker terminate in a UY plug, the socket connections for which are shown at upper right.

practically cut off, with leak-condenser detection used, and the terrible squeal of spillover for such high frequencies would be heard, also operation extremely critical. To get away from these conditions, and besides improve sensitivity, the second frequency is generated, which is known as the quench frequency, introduced into the detector tube (or both frequencies may arise from the same tube) so that at the high frequency the amplitude is interrupted at the frequency of the second generation. By driving and limiting the amplitude of the high-frequency circuit this way the spillover is avoided, also oscillation at the h. f., and the most sensitive point on the characteristic (represented by the condition of just-below-oscillation) is moved away up. Spillover should not be able to take place.

* * *

Measurement of Loss

HAS THE POWER LOSS of oscillators at high frequencies been measured, and if so, by whom?—K. C.

Yes, F. P. Cowan, of Harvard University, has developed a thermal method. When a tube is oscillating it is generating a certain amount of heat. When it is not oscillating it is generating less heat. If the power input to the tube as used during oscillation is increased during no oscillation until the thermal measurement is the same as it was when the tube was oscillating, the difference equals the power loss. Various indicators have been used, including an air chamber with temperature-controlled outer jacket and a thermopile. A filter used in conjunction with the thermopile removes the heat coming from the glass and leaves only the heat coming from the plate. Accuracies of from 1 to 2 per cent. at 20 to 30 mgc have been attained.

* * *

Trouble with Neon Lamp

I HAVE BEEN USING the neon tube as an audio oscillator, as you suggest, and it works fine in my low-frequency oscillator. As you stated, the oscillation at audio frequencies is stronger if the condenser is put across the limiting resistor, instead of across the lamp. But now that I have put a switch in the oscillator, to cover higher frequencies, I do not get the same results. Sometimes there is oscillation at audio frequencies, sometimes not, and I might add that radio-frequency oscillation at the higher frequencies quits on me once in a while. Any ideas, please?—J W. C.

What makes the audio oscillation possible in the neon lamp is the fact that there is a difference between the striking voltage and the extinguishing voltage. Besides, the maintenance current has to be of a certain minimum value to support oscillation, which perhaps is only another way of saying that the striking voltage has to be reached before there can be oscillation. The lamp illumination may border on invisibility under certain circumstances, but the voltage must be there, nevertheless. Therefore if you couple the audio oscillation to the r-f generator through the plate circuit, any one of several causes could stop audio oscillation. First, if there is a resistor between the coupling point and some lower potential, switching to another band might cause higher oscillation amplitude, greater drop in this resistor, hence reduction in the effective voltage on the neon lamp. Second, if the coupling is such that the r-f voltage in the plate winding aided the d-c voltage, if a succeeding band resulted in lower r-f oscillation amplitude, the contribution to the total voltage would be reduced and audio oscillations extinguished. Third, if any current through the neon lamp affects the r-f plate voltage, then too great a current might cause the voltage drop in the lamp to be excessive, and though the neon lamp would produce audio oscillations, the r-f oscillator would not get enough plate voltage. Suggest you put a bypassed current meter in the plate leg of the r-f oscillator and adjust tickler turns for all bands until the current through the meter is the same for the same setting of the tuning condenser. This tends to equalize the amplitude and get rid of troubles in audio oscillation due to d-c voltage changes.

* * *

Volume Control

IS THERE ANY advantage in reducing the input to a tuned-radio-frequency set, as well as reducing the amplification, for volume control? Do not the super-control tubes render reduction of the input unnecessary?—B. C.

It is advantageous to reduce the input, although, as you intimate, the super-control tubes are of such a nature as to render such reduction less necessary. Nevertheless, often complete control of volume is lacking by simple bias alteration. Therefore the scheme may be used a shown in the diagram herewith of a practically standard five-tube tuned-radio-frequency set. The 300-ohm resistor at lower right is the limiting resistor for biasing the first 58 tube. In series with this 300-ohm resistor is the total 10,000-ohm resistance of a potentiometer, the other extreme of which connects to antenna. The arm of the potentiometer is grounded. Therefore as the arm is moved toward the cathode of the first 58 the sensitivity is increased and the input is not decreased, because the bias is lowered and the primary of the antenna coil is left practically unmolested. As the arm is moved to the left the antenna is brought closer and closer to ground potential, that is, the input is reduced, and at the same time the bias is increased, because instead of the minimum of 300 ohms of the limiting resistor supplying the bias, the total biasing resistance may become, at extreme, 10,300 ohms.

* * *

Maximum Undistorted Power

HOW IS THE MAXIMUM undistorted power output of a triod determined? Please state simplest method.—U. F.

Assuming a constant plate voltage, the maximum undistorted power output of a triode is experimentally determined as follows: A value of load resistance equal to twice the estimated plate resistance is chosen, this load being approximately the optimum value when the percentage harmonics is 5. A sinusoidal alternating voltage of peak value E, and a steady grid bias, Ec, are applied to the grid of the tube and increased together until the percentage of harmonics in the output equals 5 per cent. If the plate resistance at this value of bias differs from the estimated plate resistance, the value of plate load resistance is readjusted to approximate more closely twice the actual plate resistance and a second variation of E and Ec is made. The final values of rp and Ec are reached by successive approximations of this sort, the process being continued to obtain the accuracy desired. If the grid bias is specified, the maximum output is found by repeating measurements with different load resistances. An alternating voltage having a maximum value equal to the grid bias is impressed on the grid circuit and successive measurements of output are made with increasing values of load resistance until the percentage of harmonics is reduced to 5. The output at this point is then the maximum for the given conditions. The load resistance for the maximum output will never be less than the plate resistance, and will be greater or less than twice the plate resistance, depending on whether the specified grid biases are greater or less, respectively, than the bias found for maximum output when there are no restrictions except plate voltage. Limitation on plate power dissipation or in direct plate current may be expressed in terms of a specified grid bias and the measurement made as just described.