ACCURACY ON LOW WAVES

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1934

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RADIO WORLD

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The First and Only National Radio Weekly
623d Consecutive Issue — Twelfth Year

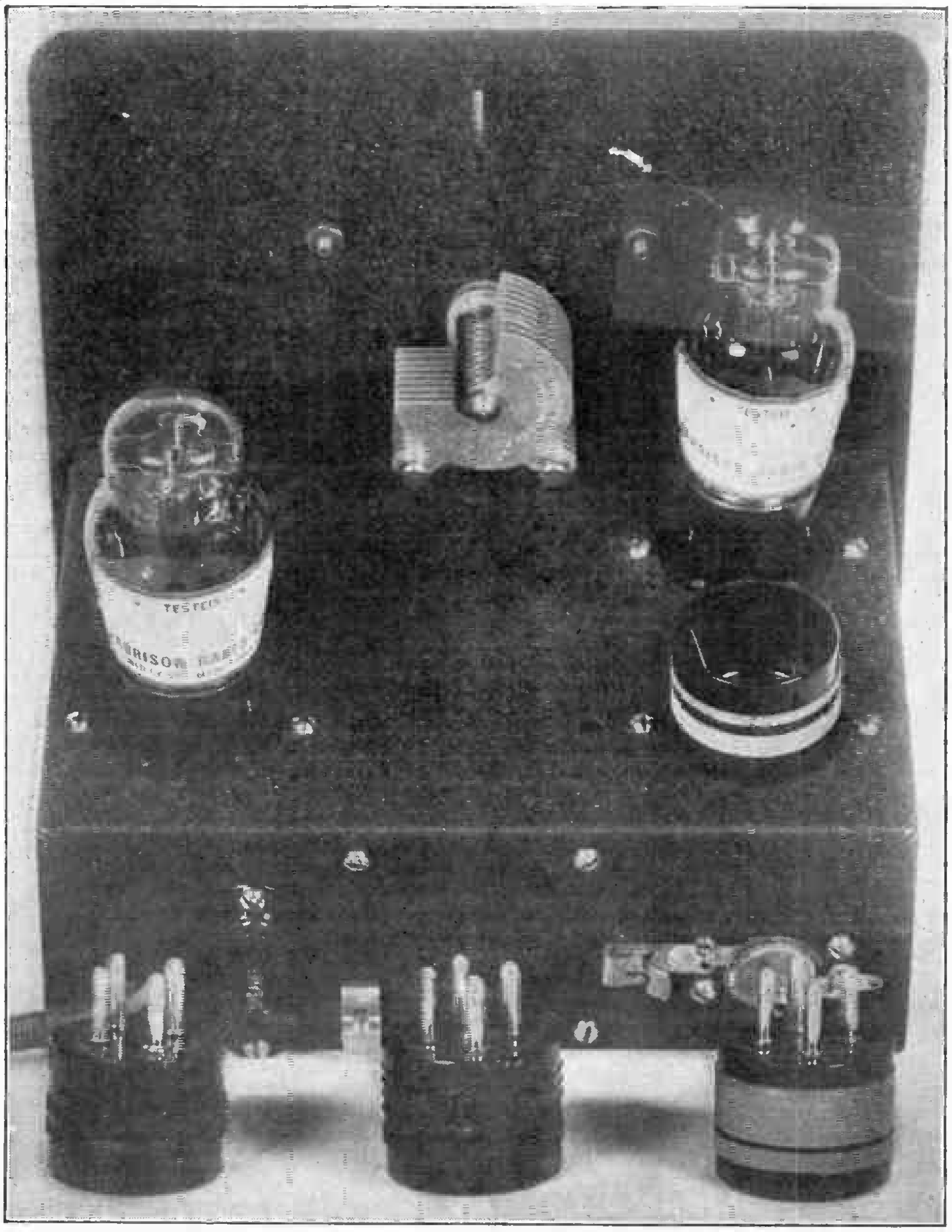
Decibels Explained

A Small Battery Type Vacuum-Tube Voltmeter

30-190-Meter Converter

An I-F Wavemeter

SHORT-WAVE DOERLE RECEIVER



The TWO-TUBE DOERLE

See Article on Pages 12 and 13

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A 30- TO 190-METER CONVERTER

SIMPLE HOME WOUND COIL IN THREE-TUBE DEVICE USING SEPARATE CONDENSERS THAT TRACK APPROXIMATELY

By Jack Tully

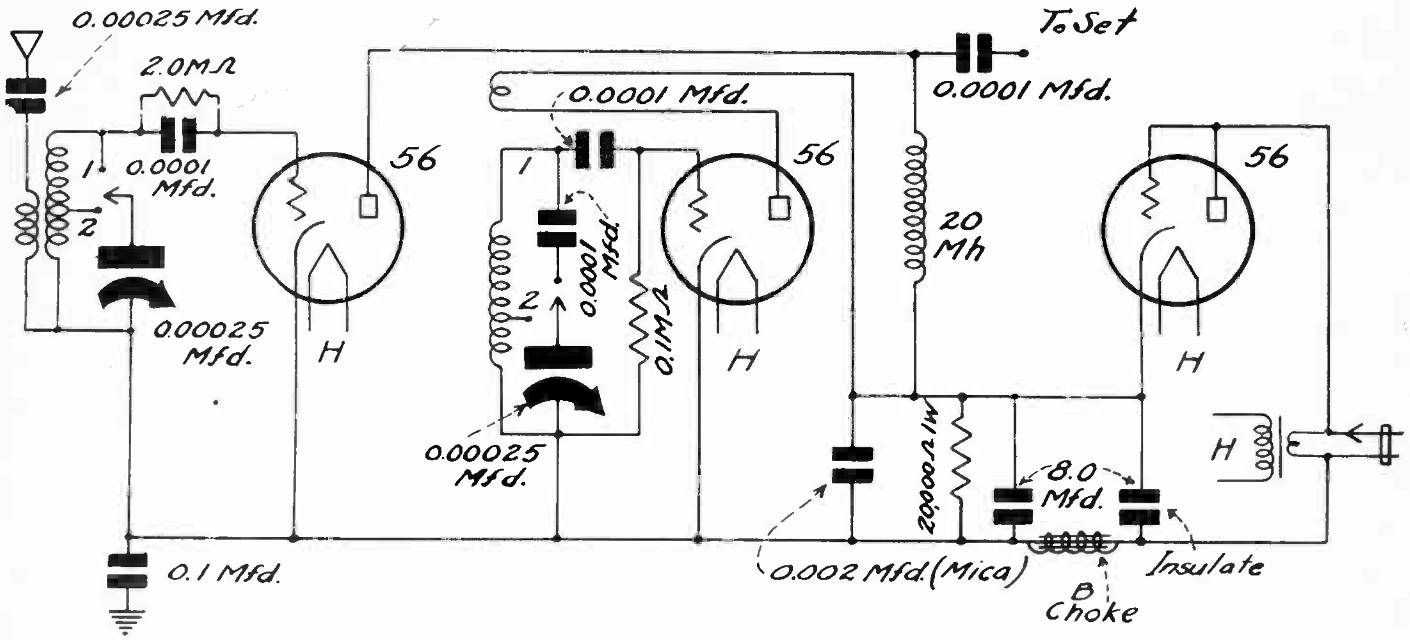


Diagram of a converter to tune from about 30 to 190 meters by switching. A simple rectifier is included.

A short-wave converter that tunes from about 190 to about 30 meters, using a single coil system for the entire range, including only one tickler, wave changing being accomplished by switching, is shown in the diagram. One may easily wind the coils from directions given in the text and shown also in the coil-structure diagram.

Amateur bands, police and airplane calls, and rebroadcasting are receivable, also foreign stations within the frequency range of the converter, and these are considerable. Quite a kick may be obtained from such a device, and yet the parts are few and cost little.

The selection of coil inductances was on the basis of using two separate tuning condensers of 0.00025 mfd. each. The condenser in the modulator or first tuned circuit is used as it is, since the intention is to have the frequency range as great as possible.

First Band Padded

In the oscillator circuit, approximate padding is used, so that the oscillator dial will fairly well track the modulator dial, for the lower frequency band. To accomplish this a series condenser of 0.0001 mfd. is used, to reduce the effective tuning condenser capacity to about 70 mmfd., for a frequency ratio a little greater than 1.8 to 1, which takes into account a minimum capacity of 56 mmfd., due to condenser minimum and the capacity of coil, socket, wiring, etc.

For the higher frequency band of oscillator tuning no padding is attempted, as the frequencies are nearly enough alike to dispense with it, where single condensers are used, as here.

The connections are made from antenna to converter and from converter to set in the usual way, by removing aerial from the receiver, connecting it to converter antenna post, and connecting output wire from converter to vacated antenna post of the receiver. Frequently it is a disadvantage to ground the converter, so ground connection may be omitted after check-up.

The frequencies of response are determined by the oscillator and intermediate frequencies, and not by the modulator, which acts merely as an increaser of selectivity and sensitivity. The intermediate frequency is simply that frequency to which your receiver is tuned.

Use 1,500 kc or Thereabouts

It is assumed that this will be 1,500 kc, but if there is interference on that channel, use another channel not far removed. In general, receivers have greater sensitivity in this region than at the lower frequency end.

Due to the separation of the tuning it will be possible to get a station at two points on the oscillator dial, but you will learn which point is preferable. It is usually the one that provides the higher frequency for the oscillator, rather than the lower. Also, in consideration of the padding, for the first band it will be the dial setting that is closer to that of the modulator. Always there is one setting for the modulator for a given frequency, and the two-spot effect is present only in the oscillator, although because of the inter-relationship the opposite may seem to be true at times.

How Coupling Is Established

Inductive coupling is used between oscillator and modulator, and this is automatically provided by following the diagram for the coil structure. The tickler turns for the oscillator were selected experimentally, on the basis of a 56 tube being used, but if a 27 is substituted, or if the circuit is hooked up for 6-volt tubes as an a-c and d-c model by constructors who like to try out their own modifications, a few more tickler turns may be necessary for insurance of oscillation over the span of frequencies considered. The smaller tickler is justifiable for only a few tubes, of which the 56, one of the best oscillators, is the leader in the small-sized type.

The capacity in circuit is just about right for modulator and oscillator for the low-frequency band, but is somewhat larger than would be selected if there were choice for the next or higher frequency band, hence the tuning for the higher frequencies, when tap is in circuit, is very close, and must be done slowly and carefully to avoid passing over stations.

Layout Discussed

Since the coil can be wound by any one, and since experimenters have sockets, tubes, transformers and the like about the house or shop, no doubt many will desire to construct this converter, which work can be done in a few hours. The layout is not particularly important and the builder may consult his own tastes. Naturally the dials would be at left and right on the front panel, hence condensers likewise, whereas the coil could be between them, with the sockets at rear of the condensers associated with their circuits. The rectifier may be built at rear of the tuning system, as it will be noted that this converter is a-c operated.

LIST OF PARTS

Coils

Modulator and oscillator coil system wound on one piece of tubing, as explained in the text.
One 2.5-volt filament transformer.
One 20-millihenry r-f choke coil.
One B choke, 300 ohms or more d-c resistance, rating 15 henries at 10 ma.

Condensers

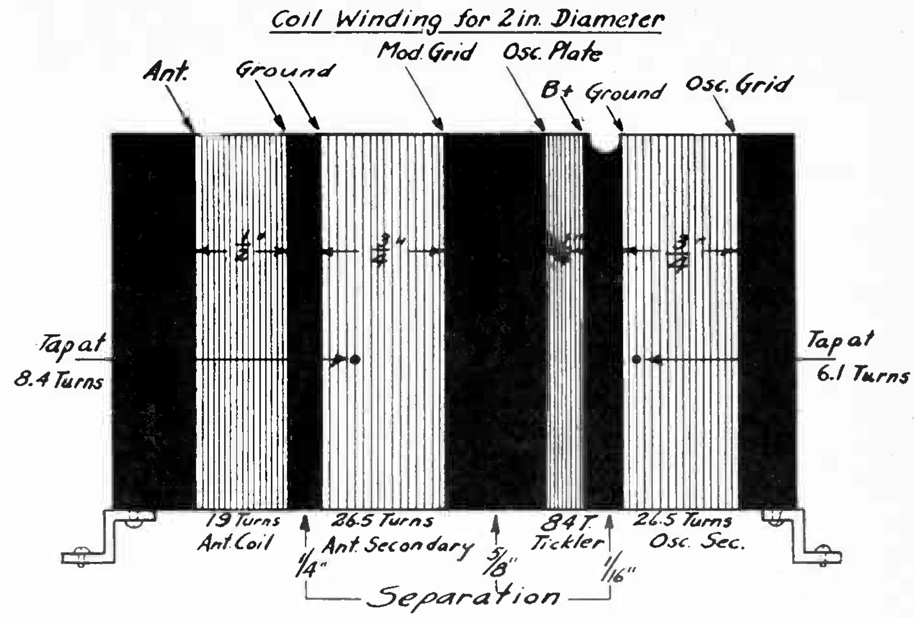
One 0.00025 mfd. mica fixed condenser.
Four 0.0001 mfd. mica fixed condensers.
One 0.002 mfd. mica fixed condenser.
One 0.1 mfd. paper condenser.
Two 8 mfd. electrolytic condensers (one must be insulated from metal chassis, as per warning on circuit diagram).
Two single 0.00025 mfd. tuning condensers.

Resistors

One 2.0-meg. grid leak.
One 0.1 mfd. grid leak.
One 20,000-ohm resistor.

Other Requirements

Three UY tube sockets.
One coil toggle switch (double pole, double throw).
Two dials.
One a-c line toggle switch.
One length of a-c cable.



For a 2-inch diameter tubing the winding data for the converter tuning coil system are as pictured. All windings are in the same direction. The connections are marked on top. Assuming winding is from left to right in the illustration, the modulator and oscillator do not require subtractions to conform to the textual table of turns for taps.

National Union Equips Police Cars With Tubes

Radio cars in the service of the New York City Police Department have been exclusively equipped with National Union radio tubes, under terms of a contract between National Union Radio Corporation of New York and the Police Department.

The selection of National Union tubes as standard equipment in the crime-fighting fleet was made after exhaustive tests which proved the worth of these tubes under the extreme strain inherent in this type of operation.

Data on Winding Coils for 3-Tube Converter

Intermediate Frequency, 1,500 Kc.

Modulator frequencies: (1) 1,600 to 4,160; (2) 4,000 to 10,400 kc.
Oscillator frequencies: (1) 3,100 to 5,660; (2) 5,500 to 11,900 kc.
Modulator full inductive: 40.0 microhenries.
Modulator inductance, tap to ground: 6.2 microhenries.
Oscillator full inductance: 40.0 microhenries.
Oscillator inductance, tap to ground: 3.5 microhenries.
Oscillator tickler: 6.2 microhenries.

Winding Data, No. 20 Enamel Wire

	2-Inch Diameter	*1¾-Inch Diameter*
40.0 microhenries	= 26.5 turns	31.5 turns
6.2 microhenries	= 8.4 turns	9.4 turns
3.5 microhenries	= 6.0 turns	6.6 turns

Antenna winding has 19 turns.

The same antenna winding data apply to both diameters. Wire may be No. 20 enamel.

ACCURATE MEASUREMENT
of Capacity and Inductance

By J. E. Anderson

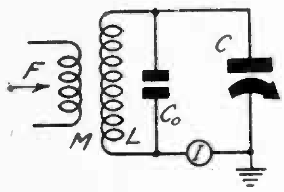


Fig. 1

A simple series tuned circuit which can be used for measuring the self capacity of a coil, or the minimum capacity of a circuit, by the intercept method discussed in the text.

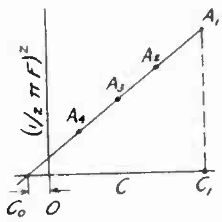


Fig. 2

A graph showing the relation between capacity and the square of frequency of a tuned circuit. The line is straight and the intercept OC_0 measures the self capacity.

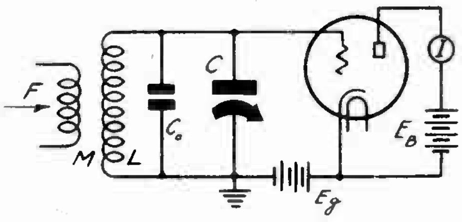


Fig. 3

This shows how the minimum capacity in a coil already in a circuit can be measured by the intercept method. C is the calibrated condenser and the tube is used as detector.

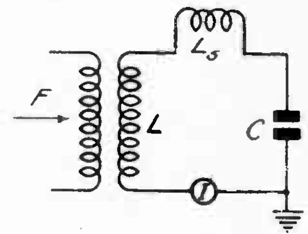


Fig. 4

The inductance of a coil can be measured in terms of a known coil Ls by measuring the frequency of the circuit first with the Ls coil shorted and then with Ls included in series.

WHILE the self capacity of an inductance coil is very small, assuming that it is properly constructed, it frequently happens that it must be taken into account, and therefore some means of measuring it is desirable. Several methods have been devised, some of which are simple enough to be applied by the average radio experimenter.

The best known device is the intercept method. It is based on the supposition that the inductance of the coil remains constant as the frequency is increased. A condenser calibrated in micromicrofarads is necessary and also an oscillator capable of supplying any frequency, within a certain range, and the frequency, of course, must be known.

Theory of Measurement

Let L in Fig. 1 be the coil the capacity, C_0, of which is to be measured, and let C be the calibrated condenser. This condenser, in series with a thermomilliammeter is connected across the coil, and a frequency of known value is impressed on the circuit by means of mutual inductance M. If either the frequency or the capacity is varied, there will be at least one combination at which the current, as indicated by the milliammeter, will be a maximum. The circuit containing L and C is then in resonance with the impressed frequency. When this is the case we have the relation $(1/2\pi F)^2 = L(C + C_0)$. If we knew F, L, and C we could obtain the self capacity C_0 of the coil. But we may not know L, for that is the coil on which we are making measurements. If we vary C by a certain amount and then vary F until resonance once more has been established, we have two relations and then L can be eliminated. Then we have sufficient data for determining C_0. If F_1 is the frequency that corresponds with C_1 and F_2 that with C_2, the self capacity of the coil can be computed by the formula

$$C_0 = \frac{F_2^2 C_2 - F_1^2 C_1}{F_1^2 - F_2^2}$$

Special Cases

Two special forms of this formula very useful. Suppose that the output of the oscillator is rich in harmonics so that the second harmonic can be detected on the milliammeter when the calibrated condenser is turned. If F_1 is the fundamental and F_2 the second harmonic, we have $F_2 = 2F_1$. Making this substitution in the formula we obtain

$$C_0 = (C_1 - 4C_2)/3 \quad (2)$$

When this is applied it is not necessary to know what the actual value of the fundamental is, but it is essential to know that the second resonance point is that for the second harmonic. This method is more accurate than the more general method, for there is no change in frequency.

When the second harmonic method is used, the calibrated condenser should be set near maximum for the harmonic, for otherwise it may not be possible to tune the circuit to the second harmonic.

The other special case is similar but it employs the third harmonic instead of the second. The self capacity of the coil then is

$$C_0 = (C_1 - 9C_2)/8 \quad (3)$$

Two difficulties arise when the third harmonic is employed. First, the range of the variable condenser may not be great enough to reach the third harmonic, for it requires that the capacity ratio be at least 9-to-1. The second is that the third harmonic is very weak and it may not be possible to detect it on the milliammeter. This could be overcome by increasing the coupling between the primary and secondary, but this would change the capacity we are measuring. The coupling at all times must be as loose as is consistent with the sensitivity of the meter. Another way of overcoming the difficulty would be to increase the intensity of the oscillation. This would be all right provided that this did not change the frequency of the fundamental. There would be no change if the oscillator were frequency stabilized, but then there would probably be no appreciable harmonics. A stabilized oscillator and a frequency multiplier would be the best arrangement. While the third harmonic method is more accurate than the second harmonic method, if correctly applied, the second harmonic is more practical.

The Intercept Method

When the intercept method is applied for making a determination of the self capacity of a coil several resonance points are found at suitably spaced intervals. Starting with a maximum setting of the calibrated condenser, the corresponding resonance frequency is found by varying the frequency. The value of $(1/2\pi F)^2$ is then computed and this is entered on a sheet of cross section paper against the value of C. The point may be A_1, Fig. 2. The value of C is then reduced a little, say one-fifth of the way from maximum. The corresponding frequency is obtained and $(1/2\pi F)^2$ is found once more and entered on the cross section paper against the new value of C. This may result in the point A_2. The process is continued until four or more points have been obtained. However, too low values of the capacity should not be used.

When all the points have been obtained, and if the measurements have been made accurately, it will be found that all the points lie on a straight line. This line should be drawn, producing it downward until it crosses the axis of abscissas. If not all the points fall on any straight line, draw the line so that the deviation of the points from the line is as small as possible.

It will be found that the straight line crosses the X-axis to the left of the origin, or to the left of the foot of the Y-axis. The distance between the origin and the intersection is called the intercept and that distance is proportional to the self capacity of the coil, or rather to all the capacity in the circuit not included in the calibrated condenser. If the scale along the X-axis has been laid out in micromicrofarads, both on the right and left of the origin, the value of C_0 can be read off directly.

Obtaining Inductance

The intercept method of measuring the self capacity of a coil has the advantage that it is also measured by the inductance of that coil. The inductance is simply the slope of the straight line. The slope is obtained most accurately by taking the highest value of $(1/2\pi F)^2$ on the line, which may be higher than the highest observed value since the line can be produced upward as well as downward. When this value has been selected, the corresponding value of $C + C_0$ should be taken from the curve. The inductance of the coil is then given by

$$L = 1/4\pi^2 F^2 (C + C_0), \quad (4)$$

that is, by the ratio of the vertical distance by the total capacity. If the frequency is expressed in cycles per second and the capacity in farads, the inducance is given in henries.

Immersion Method

Another method of measuring the self capacity of a coil, due to A. Meissner, makes use of the change in capacity when the coil is immersed in oil having a known dielectric constant. Suppose the self capacity is C_0 when the coil is in air. Then if the oil into which it is immersed has a dielectric constant k, the self capacity of the immersed coil will be kC_0. A calibrated condenser and a source of frequency are required. The arrangement in Fig. 1 is used. First the capacity required to bring the circuit in resonance with the given frequency when the coil is in air. Suppose it is C_1. Then the coil is immersed and the circuit is again brought into resonance with the same frequency, by adjusting the condenser C. Suppose the new value is C_2. Since the inductance and the frequency have not changed, we have the relation

$$C_1 + C_0 = (C_2 + kC_0),$$

whence the self capacity of the coil is

$$C_0 = (C_1 - C_2)/(k - 1).$$

Paraffine is a suitable substance into which to plunge the coil, for it has a dielectric constant somewhere between 2 and 2.2. If 2 be taken as the value of k, the self capacity of the coil is simply the difference between the two observed values of the calibrated condenser.

Measuring Minimum Capacity in Circuit

The minimum capacity, as well as the pure inductance, of a resonant circuit installed in a receiver can also be measured by the intercept method. How this may be done is illustrated in Fig. 3. We now have available a detector that is more sensitive than the milliammeter, for the tube following the tuned circuit can be used as detector. If the tube already is a detector, it can be used as it is by only putting a milliammeter in the plate circuit. If it is an amplifier, even then it can be used as it is by adding the meter, but it would be better to change the bias so as to make the detecting efficiency better. The signal can be impressed by the primary that is already on the coil by putting the known frequency in at the grid of the tube preceding.

The condenser that is across the coil L should be set at minimum, and it is the capacity that remains in the circuit at that setting that is to be measured. The calibrated condenser is connected across the coil by as short leads as possible. The process thereafter is exactly the same as that already outlined under the intercept method. As soon as the minimum capacity has been obtained by the intercept, the inductance in the coil can be obtained from the slope.

Effect of Grid Current

The minimum obtained when the tube is changed to a grid bias detector is not necessarily the same as that obtained when grid current flows, because grid current increases the effective capacity. It is possible to measure the effective minimum, but in that case it is better to connect the thermo-milliammeter in series with the calibrated condenser, on the ground side, and to leave the circuit as it is otherwise. The signal impressed should be of the same intensity as that which will be used when the circuit is operating normally.

If there is no grid leak and stopping condenser the effective minimum capacity may be increased several hundred per cent., especially when the tuned circuit is the resonator in an oscillator. This becomes evident when the frequency ratio of an oscillator is measured. Suppose the condenser used for tuning has a certain ratio of maximum to minimum capacity, the circuit distributed capacity being included. That oscillator has a certain frequency ratio, that is, ratio of maximum to minimum frequency. If there is a grid stopping condenser and a grid leak, the ratio might be 2.5-to-1, for example. When the grid condenser is shorted the frequency ratio might go down to less than 2-to-1. Only added minimum capacity would account for this great change. Naturally, the greatest change occurs at the higher frequency end of the condenser. This problem is often met in the design of superheterodyne as well as laboratory condensers. For example, in one superheterodyne oscillator the supposed constants were such that the circuit should have brought in 1,520 kc, but the highest frequency that could be brought in was 1,300 kc. The intermediate frequency in this case was 175 kc, so that the oscillator frequency at 1,520 kc signal should have been 1,695 kc but it was only 1,475 kc. The minimum capacity should have been of the order of 44 mmfd. but was actually 58 mmfd. The actual increase in this case was not very large but it had a very large effect.

Measurement of Inductances

Sometimes it is convenient to measure the inductance of a coil, such as that of the secondary of a radio frequency transformer, by inserting a coil of known inductance in series with the unknown. How this may be done is illustrated in Fig. 4. L is the coil the inductance of which is to be measured, C is any convenient capacity, Ls is a small coil of known inductance, and I is a thermo-milliammeter. The known frequency is impressed on the circuit through the primary. If the resonant frequency of the circuit is first measured with the Ls coil out, or shorted, we get one value, and then if we measure the coil Ls in series we get another. These two relations are sufficient for measuring not only the apparent inductance of the coil L but also the capacity of the condenser C. If F1 is the frequency obtained when the coil Ls is not in the circuit and Fs the frequency when it is in series, we have the two relations,

$L = 1/4\pi^2CF_1^2$ and $L + L_s = 1/4\pi^2CF_s^2$ whence $L = L_sF_s^2/(F_1^2 - F_s^2)$, or if R is the ratio F_1/F_s it is simply $L = L_s/(R^2 - 1)$.

When L has been obtained it can be put in the first formula above for the computation of C. This method of obtaining the inductance of a coil is not so accurate as the intercept method for it does not give the true inductance, but only the apparent inductance with the coil self capacity across it.

Measurement of Mutual Inductance

Mutual inductance of coils can also be measured if a calibrated condenser and a calibrated oscillator are available. Suppose that the two coils the mutual between which is to be measured are connected in series and the capacity found that will cause the circuit to resonate with a given known frequency. Let the inductance of the primary be L1, that of the secondary L2, and let the mutual be M. Then if the two coils are connected in series aiding, the total inductance of the coils is L1+2M+L2. Assume that the capacity necessary to resonate is C1. Now connect the coils in series opposing. The total inductance is now L1 — 2M + L2. Assume that the capacity required to tune this to the same frequency is C2. We have the two equations,

$$4\pi^2(L_1 + 2M + L_2)C_1F^2 = 1$$
$$4\pi^2(L_1 - 2M + L_2)C_2F^2 = 1$$

Solving each equation for 2M and then adding the two together and dividing by 4 we obtain

$$M = \frac{C_2 - C_1}{16\pi^2F^2C_1C_2}$$

Thus by keeping the frequency constant and observing the values of the condensers required to tune the circuit in the two connections, we can obtain the mutual. Of course, the frequency must be known, and it is known if the oscillator used is calibrated. The accuracy of this method depends on the accuracy with which the capacities can be measured and the accuracy with which the frequency is known. There is no difficulty in getting a sufficiently accurate value of F, but more care must be exercised in getting C1 and C2 because of the fact that a difference occurs.

WHAT *IS* THE DECIBEL?

RATIO OF POWERS OR CURRENTS RELATED APPROXIMATELY TO THE RESPONSE OF THE EAR

By Morris N. Beitman

Engineer, Supreme Sound Systems

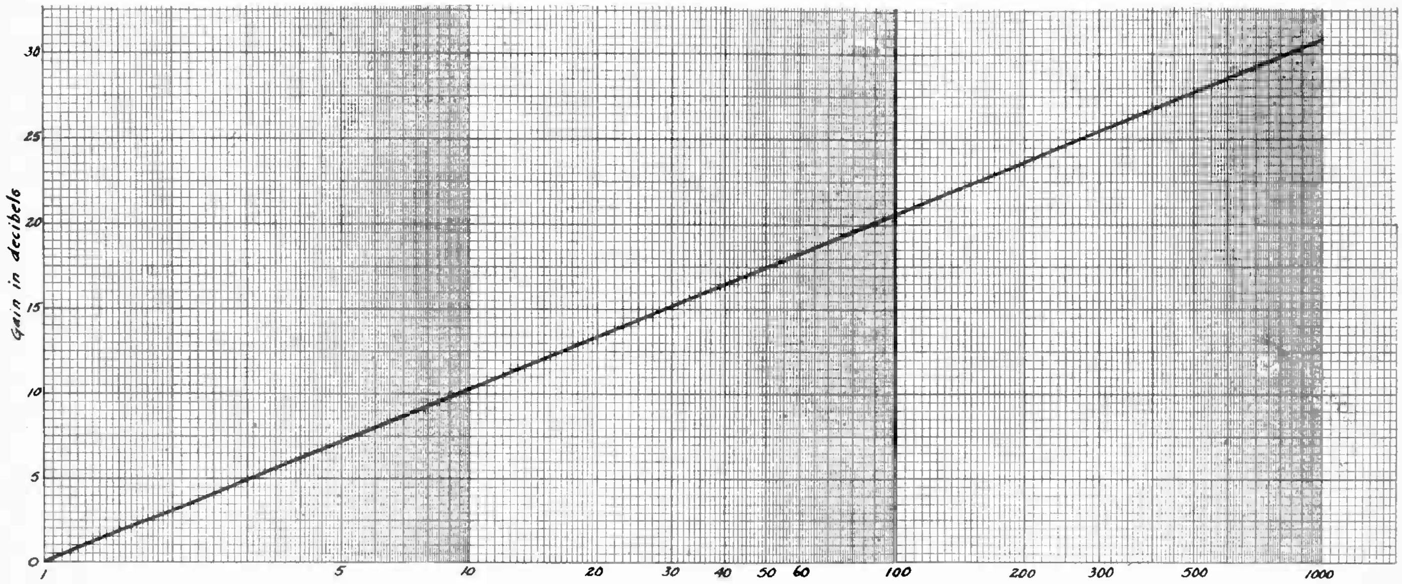


FIG. 1

A graph showing the relation between decibels and power ratios. By definition of the decibel, the line is straight when plotted on logarithmic cross section paper.

OF all radio units the least understood and most often misused is the decibel. The decibel, abbreviated as DB, is a unit of comparison of two powers and under proper consideration may be used to compare currents and voltages. It is the transmission unit measuring power related in some way to the auditory sense.

It is well known that the human ear does not respond to small changes in power, and even doubling the power of a fundamental tone will be just noticeable by an average listener.

The Power Formula

The DB is a logarithmic unit in so much as it varies as the log of the ratio of the two powers in comparison. Mathematically it is expressed as:

$$DB = 10 \log_{10} \frac{P_1}{P_2}$$

This formula states the relation that the log to the base ten of the ratio of the two powers multiplied by ten will give the difference in decibels.

For example: A certain radio is playing at a certain volume and by means of an output meter the power at that volume is found to be equal to 0.3 watts. The volume is somewhat increased and again measured, it is then found to be 4.5 watts. What was the gain in decibels? Using the formula above and substituting the values for:

$$P_1 = 4.5 \qquad \frac{P_1}{P_2} = \frac{4.5}{0.3} = 15$$
$$P_2 = 0.3$$

we get the following expression which is solved by means of simple four place log tables:

$$DB = 10 \log_{10} 15 = 10 \times 1{,}1761$$

The gain is equal to 11.8 DB.

A handy table giving the gain in decibels for various power ratios may be used where accuracy is not very essential. Or a graph may be applied for the same purpose.

The Current Formula

If two currents are to be compared and they pass through the same or equal resistances, the formula below may be used:

$$DB = 20 \log_{10} \frac{I_1}{I_2}$$

Note that for power the multiplication is by 10 and for current the multiplier is 20.

Since DB is always a ratio, when we speak of an amplifier as having so many decibels, we usually assign an arbitrary level of comparison. Usually all amplifiers are compared to 0.006 watts which is supposed to be 40 DB above the noise of the line used in transmission. If one amplifier has 75 decibels in comparison with some arbitrary level, while another has 60 decibels in comparison to the same level, the first has (75-60) or 15 DB more gain.

The degree of equality of reproduction of the different audio frequencies in an amplifier may be illustrated by stating the DB gain of each frequency in ratio to some common level. The ideal amplifier of course would have equal gain for all frequencies and when plotted gain against frequency, it will be a straight line. Such an amplifier does not exist, but variations of a few DB between wide limits of frequency are not noticeable.

Shown on Graph

For example, a public address system varies its output at different frequencies as illustrated in Graph 2. It is seen that the greatest change occurs between 16 and 350 cycles. The change of four decibels at this frequency is permissible and is not noticed by the human ear. One may judge therefore that this is a good amplifier.

Summary

The practical attainment therefore is considered well served when the change is not substantial.

To summarize, the transmission unit is used to express any ratio of power, mechanical loss or gain, etc. related in some sense to the auditory sense. The circuit losses in power, and under proper consideration voltage and current may be expressed in DB. The flatness of the frequency response of an amplifier, loud speaker, or a transmission line may be expressed in DB by plotting a curve in which zero level is the amplification or power output at some arbitrarily chosen frequency.

TABLE COMPARING GAIN IN DB WITH CORRESPONDING POWER RATIOS

Gain in DB	*Power ratio* P_1/P_2
0	1
1	1.3
2	1.6
3	2
4	2.5
5	3.2
6	4
7	5
8	6.3
9	8
10	10
15	32
20	100
23	200
26	400
29	800
30	1000

ACCURACY ON LOW WAVES

Harmonics of a Stable Standard Used

By Conrad Elskling

THE production of ultra-high radio frequencies of constant frequency presents somewhat of a problem for oscillators working directly on high frequencies are not stable. The problem is usually solved by multiplying the frequency of a stable oscillator, such as one that is crystal controlled, until the desired frequency is obtained. This may involve, in many instances, several stages of multiplication. The process employed is usually that of frequency doubling.

Suppose we have a radio frequency amplifier and impress on the grid of it a signal of stable frequency. If this signal is strong so that the tube is overloaded, there will be harmonics in the output, and they will be relatively strong, especially if the tube is biased to the steady plate current cut-off, or beyond. If we put a parallel tuned circuit in the output of the tube and tune this to a given harmonic, the load impedance at that harmonic will be large and that on any other harmonic, including the fundamental, will be negligibly small. Practically all of the output energy then will be concentrated in the harmonic to which the parallel circuit is tuned.

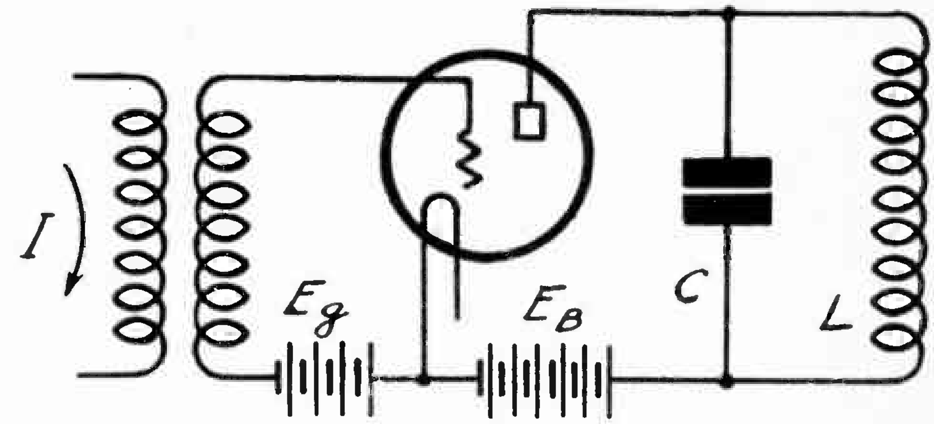


FIG. 1

The circuit of a frequency multiplier by means of which the frequency of a constant value can be doubled or trebled. The LC circuit is tuned to one of the harmonics of the signal put in on the grid.

Doubling

If it is a question of doubling the frequency, it is only necessary to tune the parallel circuit, or tank circuit as it is called, to the second harmonic. The second harmonic will then be selected out of the complex output of the tube and there will be a strong current in the tank at that frequency and a high voltage across the tank. This current, or voltage, can then be used as input to another doubler and the output of this will be four times as high in frequency as the original frequency. This process can be continued indefinitely until the desired frequency is obtained.

As an example, suppose that the original frequency is that of a quartz crystal oscillator having a frequency of 1,000 kc. The first doubling would yield 2,000 kc, the second 4,000 kc, and so on. If we are to produce a stable frequency of 64 megacycles, we would have to have six frequency doublers.

Trebling

In principle it is also possible to treble the frequency at each step, for the third harmonic is also present in the output of the overloaded amplifier. However, the output of the amplifier on the third harmonic is not nearly as strong as that on the second, and for that reason it might be necessary to introduce amplification to obtain a given output. Thus trebling may require just as many tubes as doubling.

By trebling each step the frequency would increase at a much more rapid rate. If the fundamental is 1,000 kc, the third harmonic would be 3,000 kc, the third of this 9,000 kc, and the third of this in turn would be 27,000 kc. The next would make the frequency 81 megacycles. Thus, in four steps, we would go up from 1 to 81 megacycles.

It is even possible to multiply the frequency by four at each step, but the fourth harmonic is much weaker than the third.

Explanation of Circuit

I in Fig. 1 represents the current in the coil of the tank circuit of the frequency multiplier preceding the one that is shown, or the plate signal current in the oscillator that supplies the fundamental. LC is the tank circuit in the multiplier shown. Eg is the grid bias on the tube shown while Eb is the plate supply voltage. Eg should have such a high value that when no signal is impressed there should be no plate current, or it should be considerably higher than the cut-off.

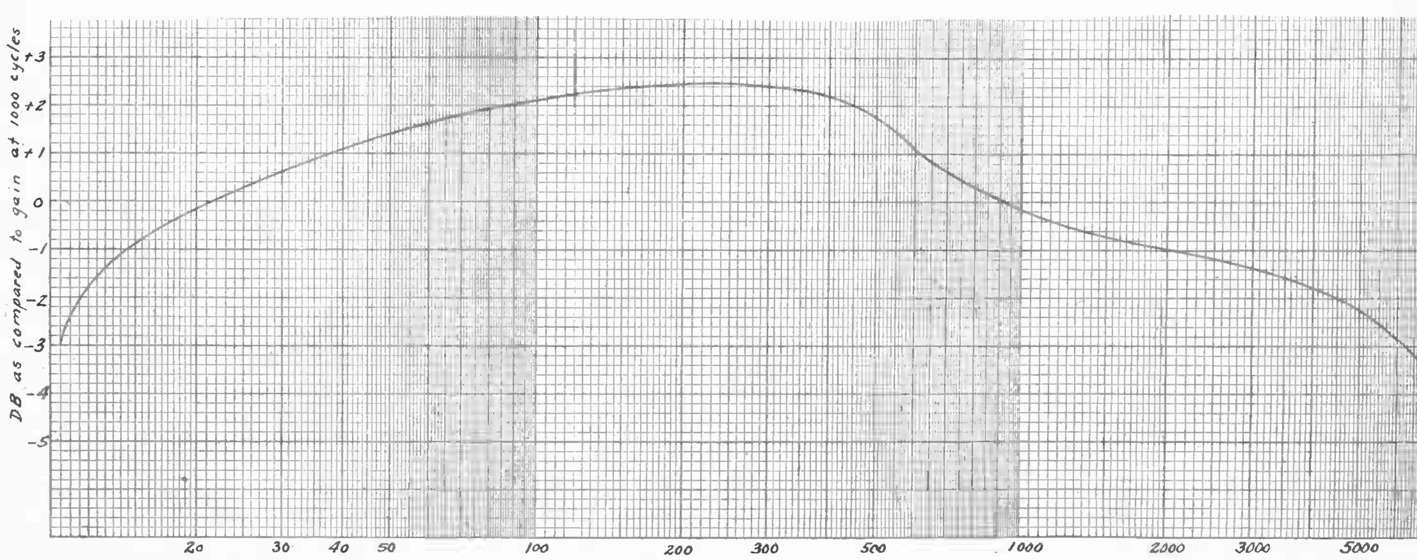


FIG. 2

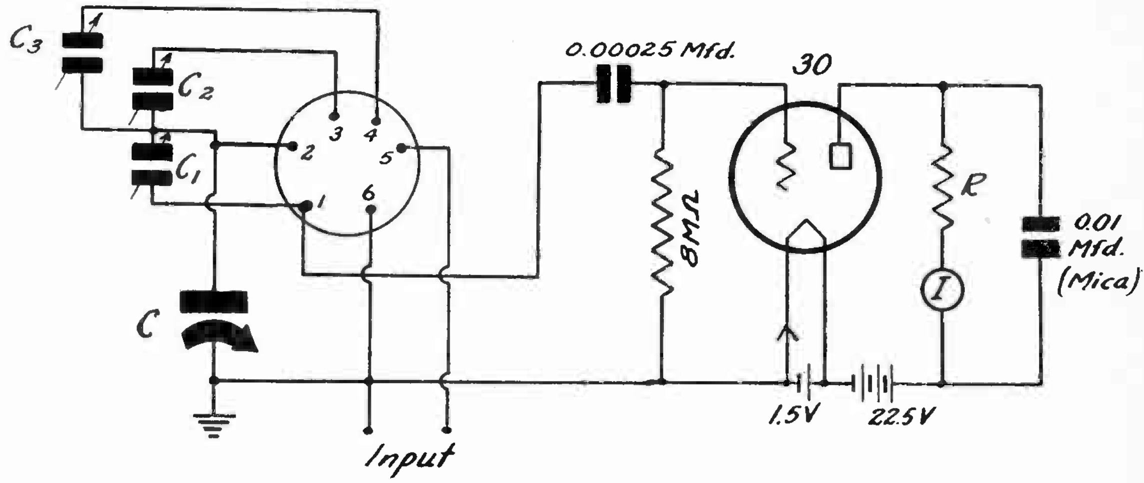
A curve illustrating the decibel gain of a public address amplifier as compared with the gain at 1,000 cycles per second. At 10 cycles there is a relative loss of 3 db and about the same at 9,000 cycles. At 300 cycles there is a relative gain of nearly 3 db.

A BANDSPREAD WAVEMETER

WITH PLUG-IN COIL FORMS USED FOR SERIES CAPACITY SELECTION

By Collin Rainbault

Diagram of the wavemeter. I is indicating meter. Bottom view of coil socket is shown.



ANY one who does considerable calibrating knows perfectly well that a test oscillator itself is not quite the thing for determination of actual values of frequency. The principal reason is the presence of harmonics. These become confusing when one has no knowledge of the region in which one is working, at least not to a closeness equal to the difference between two successive harmonics, or a fundamental and its second harmonic. However, a wavemeter solves the problem.

Such a meter may be built in a manner that precludes harmonics, as with a thermo-galvanometer resonance indicator, but it is assumed that the experimenter wants to keep the proposed meter within the confines of his existing meter equipment, say, using a 0-1 milliammeter as indicating device, or, if handy, a 0-0.5 milliammeter. While the detector tube in the wavemeter itself will generate harmonics, the meter in the plate circuit is far more sensitive than aural observation in determination of whether the fundamental or the second harmonic is being used. These are the two frequency quantities that usually create the confusion.

Needle Swing Differs

The reason why the meter method of indication is better in this respect than the earphone method is that the fundamental of a frequency fed from the unknown to the input of the wavemeter produces a much greater needle swing than does the energy of the second harmonic. For any given range of tuning, therefore, by the extent of the needle deflection, with which the experimenter will become quickly familiar, the time-wasting effort of groping for the frequency identity, and running laborious curves only to find them misplaced by a harmonic multiple, are avoided.

In any device like this it is well to respect the fact that the frequencies must be satisfactorily far apart, that is, the readings should be easily taken, and eye-splitting observations rendered unnecessary for determining a result. The requirement is that the frequency ratio be reduced from band to band.

Some sort of switching arrangement is necessary, and the plan selected is a simple and inexpensive one. Plug-in coils are used. However, so are series condensers in three instances. Hence there are four positions, one for the full tuning capacity, the three others for diminishing values of maximum tuning capacity, established by the series condensers. These condensers should be of the air dielectric type.

Band Distribution

No matter what band one works in, the most acceptable separation would be to have a uniform frequency separation for each total band, but in practice this could not well be carried out for numerous bands of frequencies, unless the coils were exceedingly numerous. However, for a wavemeter that is intended primarily for low frequencies, including all the intermediate frequencies in all the super-

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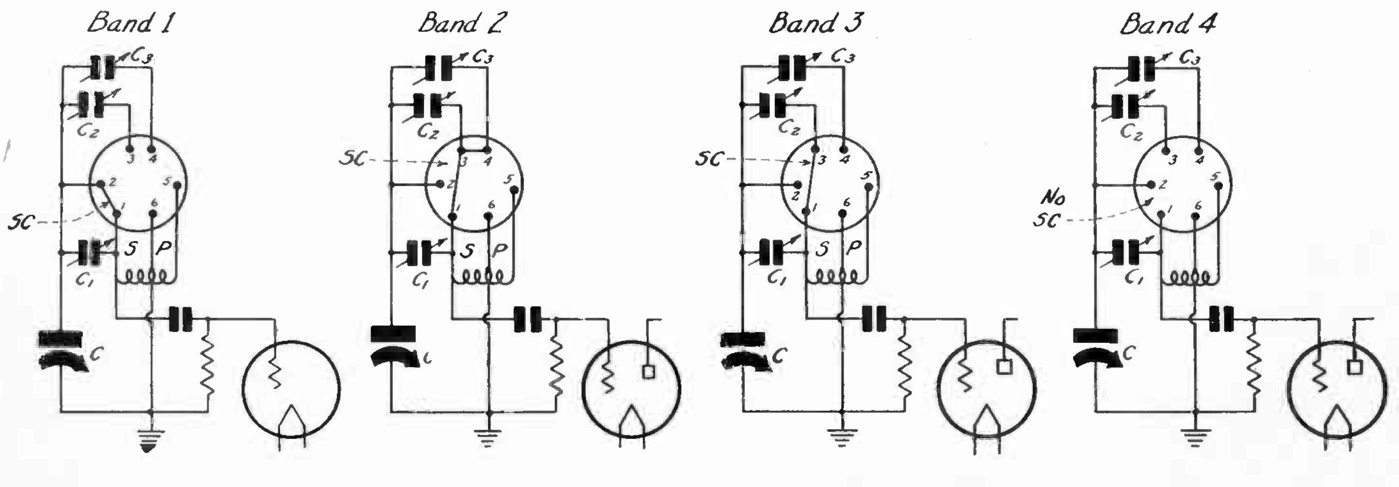


The switching arrangement of series capacity as accomplis hed through the coil form. SC stands for short circuit.

THE 868 PHOTOTUBE

CHARACTERISTICS AND OPERATION OF LIGHT-SENSITIVE VALVE

THE 868 is a phototube of the gaseous type. It has two elements, a semi-cylindrical, caesium-coated, silver cathode, and a central-wire anode. A small amount of argon gas is used in this phototube, its function being to increase the sensitivity.

CHARACTERISTICS

Anode Supply Voltage	90 max.	Volts
Anode Current	20 max.	Microamperes
Static Sensitivity	55	Microamperes per Lumen
Dynamic Sensitivity (1000 Cycles)	50	Microamperes per Lumen
Dynamic Sensitivity (5000 Cycles)	48	Microamperes per Lumen
Gas Amplification Factor*	Not over 7	
Load Circuit Resistance	0.1 to 5.0	Megohms
Window Area of Cathode		0.9 Square Inch
Maximum Overall Length		4-1/8"
Maximum Diameter		1-3/16"
Bulb		T-8
Base		Small 4-Pin

**Gas Amplification Factor is given as the ratio of sensitivity at rated voltage to the sensitivity at a voltage sufficiently low (approximately 25 volts) to eliminate gas-ionization effects.*

When light falls on the cathode of the 868, electrons are emitted. These electrons are attracted to the anode made positive by the application of an external voltage, and thus permit current to flow in the external circuit. Under recommended operating conditions, the number of electrons emitted by the cathode, and consequently the photo-electric current, depends not only on the amount of light falling on the cathode, but also on the color of the light as well as on the frequency of light modulation.

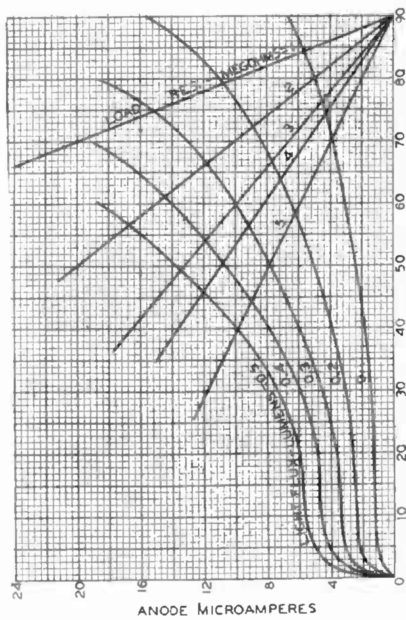
Spectral Sensitivity

The 868 is sensitive over the entire visible spectrum and has sensitivity peaks in the infra-red and ultra-violet regions, say RCA Radiotron Co., Inc., and E. T. Cunningham, Inc. The 868 is light-sensitive at wavelengths from 3,000 to 10,000 angstrom units. (The angstrom is a unit of wavelength and is equal to 10^{-10} meters.) Cut-off at 3,000 angstrom units is due to the glass bulb. The large response of the 868 to wavelengths in the infra-red region of the spectrum makes this tube particularly useful in sound reproduction and television applications where tungsten-filament lamps are employed as light sources.

The light source to be used depends upon the requirements of the system. Since the response of phototubes is greater for certain colors of light, the color of the light source is important, for some special applications the response of the 868 can be altered by means of a suitable color filter. The light source used to obtain the characteristics is described under "Conditions for Testing."

Operation of the 868

During operation, the cathode of the 868 should never be permitted to reach too high a temperature nor should it be subjected to an excessive amount of light. Too high a temperature will result in the volatile cathode coating being deposited on the insulating surfaces of the bulb with consequent impairment of the sensitivity and life. A 10% increase in temperature reduces the sensitivity of the 868 about 15%. It is recommended that operating temperatures do not exceed 50° C. If the cathode is subjected to an excessive amount of light during operation, the sensitivity of the phototube may be appreciably reduced. If subjected to direct sunlight during operation, it will probably be permanently damaged. When subjected to sunlight, although not in operation, the 868 will have its sensitivity temporarily reduced by an amount, and for a period of time, dependent upon the length of exposure. The amount of light and the anode voltage on the 868 should be adjusted to values which do not cause the maximum anode current to exceed 20 microamperes. Excessive light or anode voltage will cause the gas to become conductive, a condition indicated by a slight blue glow. If the glow is allowed to persist for more than a few second, or occurs frequently, the tube loses sensitivity and ability to respond uniformly to modulated light. The anode voltage should never exceed 90 volts. For large amounts of light, it is recommended that the anode voltage be decreased to the lowest value which will give the desired output.



The average characteristics of the 868 are determined with a tungsten-filament lamp as a light source. The lamp is

(Continued on next page)

Wavemeter Coil and Condenser Values

(Continued from preceding page)

heterodynes, the uniform frequency span can be achieved. Taking as the lowest frequency band, 48 to 172 kc, the difference in between the frequencies is 124 kc. So for each of the next three bands the same difference is maintained, and the coils made accordingly.

However, as stated, different series capacities are used in other than the lowest-frequency band which has no series element. As plug-in coils are to be prepared anyway, it is feasible to use a six-prong tube form, although only three contacts will be necessary for any one coil. Thus socket spring No. 6 represents ground, common to all coils, and also the common point of the tapped winding which, in its two parts, represents the tuned circuit and the pickup winding. Socket spring No. 1 represents the connection looking toward the grid circuit. The automatic switching in of series capacities is illustrated in a diagram herewith.

Switching Arrangement

The switching is as follows:

Band 1: Tapped coil SP connected to 1, 5 and 6, as in all instances. Series capacity C1 shorted out, others not used, so the full tuning capacity is present Band 2: The three series condensers C1, C2 and C3, are in parallel for this next lowest frequency band. Band 3: C1 and C2 are in parallel for the series capacity.

Band 4: C1 alone is in series with the tuning condenser.

The values of inductance and capacity follow:

Tuning condenser, 406 mmfd.

C1, C2, C3, 64 mmfd. each, a commercial value, adjusted so for Band 4 the capacity of C1 is 57.7 mmfd., for Band 2 C2 is 21.3 mmfd. and for Band 3 C3 is 32 mmfd. Thus by paralleling, the capacities in series are: Band 1 = 57.7 mmfd., Band 2 = 79 mmfd., and Band 3 = 111 mmfd. Band 4 = 0. The inductances and frequencies:

Band 1 = 48 to 172 kc. L = 28,000 microhenries (Ceff = 420). Band 2 = 172 to 296 kc. L = 10,000 microhenries (Ceff = 88).

Band 3 = 296 to 420 kc. L = 4,800 microhenries (Ceff = 65.7). Band 4 = 420 to 544 kc. L = 3,000 microhenries (Ceff = 50.7).

The values Ceff = effective maximum capacity, with series condensers in circuit.

THE TWO-TUBE

Regenerative Detector and St

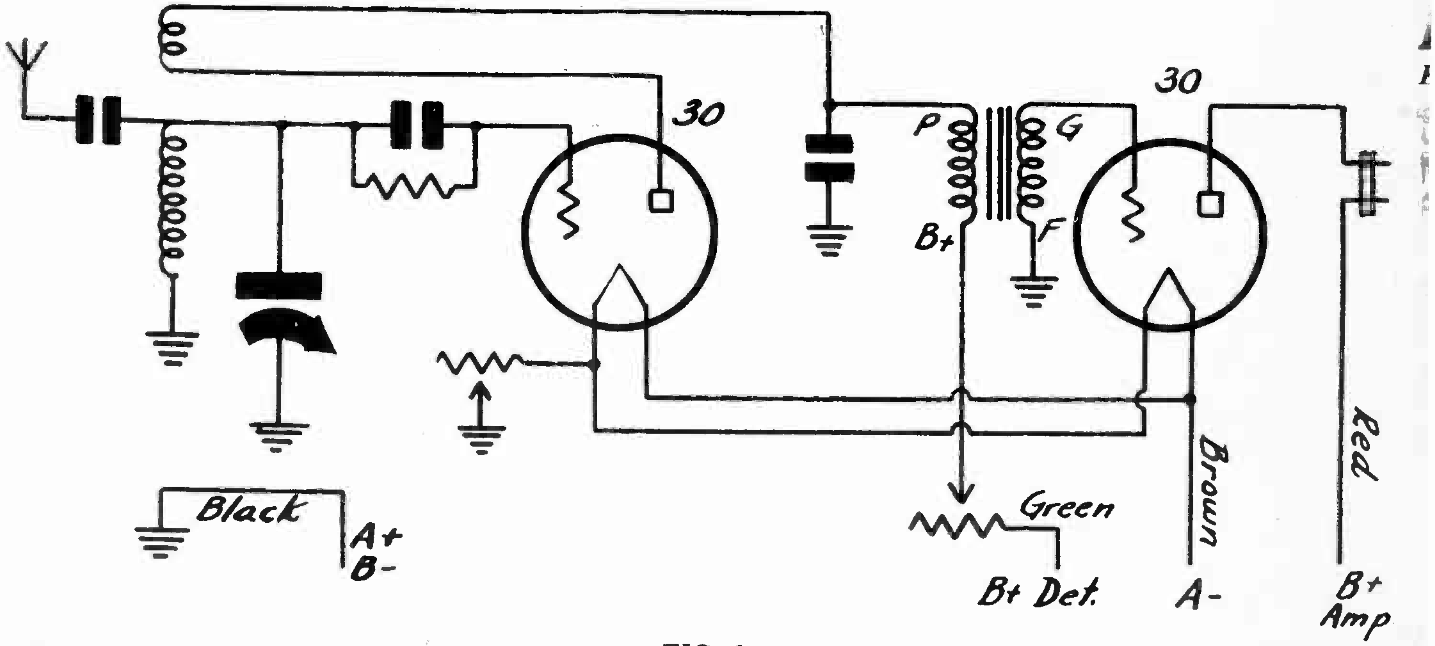


FIG. 1

The circuit diagram of a two-tube, battery-operated short-wave receiver that can be built and operated most economically.

JUST what is the fascination of short waves? What lies belows 200 meters that should make radio fans stay home afternoons and sit up most of the night to listen to the activity in the short wave region? There are police signals—orders from headquarters to patrol cars to rush to the scenes of crimes—front page news in the making. There are amateurs talking to one another and to the world at large. While there is not much thrill in listening to one boy say to another: "Hello, hello, OM, how are you gettin' me?" there is a certain thrill in eavesdropping when you can do it without danger of getting caught at it, and there is always a chance that the amateur will say something else. There are signals between airplanes in the air and ground stations, the pilot giving reports of his location and of his progress and the ground station giving the pilot information about the weather on ground where he may intend to land in an hour or so.

There are television signals, not understandable to the human ear, and sometimes not to the eye even under the best conditions, but they are in the air and are a constant reminder that the human mind is wrestling with a difficult problem with evidence of early victory.

Broadcasting, Too

These are not the only interesting features of short waves. There is real broadcasting on the waves below 200 meters, much below. Some of this is done in North America, some in Central America, some in South America, and a great deal is done in Europe. South Africa, New Zealand, and Australia do their share.

The most interest fact is not they broadcasting is done in these various countries, but that the signals can be received in this country almost any day and directly, not through a relay station.

Not only can they be received, but they can be brought in with very inexpensive receivers. Whereas an eight tube broadcast receiver may not reach out more than 3,000 miles, a two tube short wave set will usually reach out the greatest distance measurable on this earth.

What Short Waves Are

The ordinary broadcast receiver has a wavelength range of 200 to 550 meters (1500 or 500 KC), which means that it can resonate or tune only to stations broadcasting in that wavelength band. Some have a so-called "short wave" switch which extends the tuning range down to 75 meters, but as the real short wave band is from 200 down to 15 meters, these receivers can get only a small portion of the interesting transmissions and not the most interesting at that. Airplane stations, for example, are mostly to be found in the 40 to 60 meter band, although some also broadcast on 90 to 100 meters. Foreign broadcast stations are almost below 60 meters. Thus a real short wave receiver is neded to get the most interesting broadcasts. As the receiver we are about to describe tunes from 200 down to 15 meters, it will get everything there is

Photocell Tube In

(*Continued from preceding page*)

operated at a color temperature of 2870° Kelvin. In testing practice, the lamp is rechecked for color temperature and candlepower at least every 100 hours of operation. The light falling on the cathode of the phototube is restricted to a spot one-half inch indiameter. The center of the spot is located on the cathode at 2-7/16" measured from the bottom of the shoulder on the contact pins. An incident light of 0.1 lumen, an anode potential of 90 volts, and a load resistor of one megohm is used by us in making all tests on this phototube except where other conditions are specified.

We took some families of characteristic curves for the 868 at different anode voltages and anode currents with various values of load and light flux. A variation in output of less than 4 decibels may be expected if the cathode is scanned with a very small beam. When a high degree of uniformity is required, it can be obtained by spreading the incident light over as large a portion of the cathode as possible.

When used with light sources varying at audio frequencies, the 868 has a response at 10000 cycles per second only 17 per cent less than that at 100 cycles per second. This is a loss of two decibels. The fidelity of this phototube at 25 volts is assumed to be 100 per cent throughout the frequency range. At 25 volts, ionization of the argon gas is at minimum, and the 868 behaves like a vacuum type of phototube. At voltages above 25 volts, greater amplification is obtained because of the increased current produced by the ionized gas.

The load resistance used with the 868 depends upon the application. In general, the larger values of load resistance give

DOERLE SW SET

age of Audio in Compact Size

By Frank André
Harrison Radio Company

to be heard on short waves. And, by merely plugging in a different coil, it can also bring in stations in the regular broadcast band.

The three most important points in building an efficient short wave receiver are—the circuit, the selection of the proper parts, and the correct placement of these components. The circuit we shall employ is one of proven merit and reliability. It has been seen under many different names such as Schnell, Doerle, Oscillodyne, etc. In this circuit a part of the signal is transferred from the plate of the detector tube back to the grid of the same tube, thus reamplifying and building up the signal to a high level. This process is called "regeneration" and it makes this circuit admirably suited to short-wave work. In the past 15 years, the author has designed and constructed over 175 different short wave receivers, and this experience and training are utilized to the fullest extent in the present receiver.

Good Insulation Necessary

Short waves differ from regular or broadcast wavelengths in that they travel through space and penetrate to far corners of the world with much greater ease. Notwithstanding this fact we must chose the insulating material in our short wave receiver with careful discrimination, or else the faint impulses which are collected by our antenna will not follow in the paths we have set for them, but will wander off and be lost by the wayside. Wood, composition, and other substances that may be quite satisfactory as insulation in a broadcast receiver would introduce so high losses at higher frequencies as to nullify any advantage gained by scientific design and careful wiring. The most satisfactory all-around insulation material (considering durability, moisture absorption, deterioration, and cost) is Bakelite, in either the moulded or laminated form. Consequently, when purchasing material for your receiver it would be wise to make sure that all high frequency insulation is of this material. This is especially true in the case of the sockets, as in them we have the filament contacts, which are at ground potential, the grid contact, which is at high radio frequency potential, and the plate terminal, all firmly held by insulating material within the small radius of ⅜". Incidentally, the less dielectric in a high frequency field, the lower the effective r-f resistance. This results in an overall gain in sensitivity and in one of the reasons for using the subpanel or "wafer" type of socket. It employs a minimum of material, yet it is rigid and makes good contact to the prong of the tube or coil. Three UX (four prong) sockets are needed, two for the tubes and one for the coil.

Antenna Coupling Condenser

One of the most important yet simplest pieces of apparatus used in a short wave receiver of the type described is the antenna coupling condenser (C1). In its simplest form, it may be nothing more than two short lengths of insulated wire twisted together or two parallel small metal plates about 1" square insulated from each other and so arranged that the spacing between there plane faces may be varied, thus changing the capacity. The purpose of this condenser is to vary the degree of coupling between the antenna and the grid of the detector tube. Its proper manipulation, about which more will be said later, will often spell the difference between losing a station or bringing it in full and clear. As it is in the antenna circuit its insulation must be watched carefully in order to minimize losses. We therefore use a type which has a bakelite bottom with mica insulation between the plates. The capacity is varied by the screw adjustment which provides sure control.

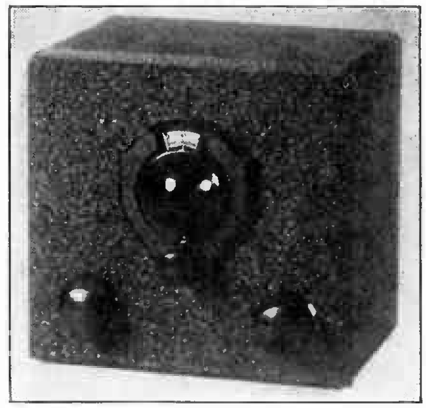


FIG. 2
Front view of the two-tube, battery-operated short-wave receiver.

The grid connection (C3) is a fixed condenser with mica dielectric, moulded in solid bakelite to exclude moisture and to prevent capacity change or noise. Its capacity is .0001 mfd. (100 mmfd.). The grid leak R3 is metalized carbon and it has pigtail leads to facilitate soldering it into the circuit. The R-F bypass condenser (C4) is exactly the same as C3. The variable tuning condenser (C2) in another part in the selection of which extreme care must be exercised if maximum results are to be expected. Here we choose the midget condenser of a well-known manufacturer of short wave apparatus for its compact size, solid construction, and all bakelite insulation. The remaining condenser in our list of parts is C5, the regeneration smoothing condenser, which, rated at 0.5 mfd., may be of the small bypass type.

As this receiver is designed for operation with different types of tubes from different sources of filament power, the rheostat must be of a proper size to drop the applied voltage to the correct operating value. Figuring this out by the use of Ohm's law, we find that any value between 10 or 20 ohms will do nicely.

Regeneration Control

The regeneration control (R2) consists of a variable resistor which is connected in series with the detector plate voltage as shown in the diagram. Its function is to permit the manual control of the voltage applied to the detector tube and thus to control the degree of regeneration. Being in such a critical position it must naturally be smoothly operating and so designed as not to introduce noise into the receiver. Any good grade unit using a graphite element will serve for our purpose. The value should be 50,000 ohms.

The audio frequency transformer AFT should be selected with the thought in mind that the higher the grade and the larger and heavier it is the better the re-

(Continued on next page)

nproves With Use

larger outputs up to the limiting values of tube resistance and distortion. The resistance of this phototube is a function of the anode voltage and the incident light, and varies from one or two megohms up to 1000 megohms. The resistance decreases with the amount of incident light and increases with anode voltage up to the point at which gas amplification takes effect, after which it decreases. For a given value of load resistance, distortion will depend upon the phototube current.

Since the 868 is a high-resistance device, it is extremely important that the insulation of associated circuit parts and wiring be good. Insulation resistances which are high compared to that of the tube must be employed if good operation and low distortion are to be obtained. For the same reason, the capacities between the various associated circuits should be kept as low as possible. It is essential that the base and socket of the 868 be kept clean in order to minimize leakage conductance.

Stability is a very important characteristic of phototubes. All our 868's are aged for a number of hours prior to final test. This process insures good stability during their useful life. Un-aged tubes may vary over 6 decibels in the first two hours of use; aged tubes should not show over 2 decibels variation.

The 868 gives best results under constant use. In case the tube is not in service for one month or more, the normal characteristics of the tube may change somewhat but can be restored by a short period of operation (usually about one hour) under normal operating conditions.

The tube is very popular in garage-door-opening relay systems.

(*Continued from preceding page*)
sults will be. A unit with a ratio of 2½:1 up to 5:1 is satisfactory.

The remaining miscellaneous items are: A radio frequency choke (L3) which should be of the short wave type, two Fahnestock clips, a four wire battery cable, a twin tip jack to accommodate the tips of the phone cord, a vernier dial, knobs for the rheostat and the regeneration control, hook-up wire, and assorted nuts and screws. The only one of these about which anything need be said is the vernier dial. The dial is attached to the shaft of the tuning condenser and employs a ratio reduction with friction drive to facilitate the very fine, close tuning necessary in operating a short wave receiver. There should be no back lash in this unit as that would roughen the control and render it practically useless.

Coils

The coils are wound on polished bakelite forms 1⅜" in diameter and 1 1/16" long. They have a standard prong arrangement enabling them to be plugged into a UX socket, and thus it is an easy matter to change the inductance so as to cover the desired wavelength band. The bases of old radio tubes may also be employed for this purpose, but it is necessary that they be of real bakelite and not of a high loss composition. Break the glass bulb and remove the stem and cement in the base. Heating the prongs with a hot soldering iron will enable you to shake out the old solder.

Holes are drilled in the side wall above each prong as shown in Fig. 3. The placement of these holes will be determined by the number of turns and the spacing between the primary winding (L1) and the tickler winding (L2). Make sure that both windings are in the same direction. Fig. 3 shows how the coil would look if it were opened out and clearly indicates the proper prongs to use and the method of winding. Winding data follow:

Coil	Wavelength Range	L1	Spacing Between L1 and L2	L2	Wire
A	15 to 23 meters	3¾ turns*	⅛"	5¾ turns	No. 28 DSC
B	23 to 45 meters	6¾ turns*	1/16"	5¾ turns	No. 28 DSC
C	45 to 115 meters	15¾ turns*	⅛"	6¾ turns	No. 28 DSC
D	115 to 200 meters	38¾ turns*	⅛"	9¾ turns	No. 29 DSC

*Spaced ⅛" between turns. All other windings close wound.

After winding, paint the coils with a coating of thin clear lacquer and solder the prongs.

Chassis and Panel

Although it is possible to purchase a complete kit for the construction of this short wave receiver, which includes all the parts specified, wound coils, and a stamped metal chassis panel with all holes drilled, there are probably some who would prefer to make their own chassis and panel. For them the following dimensions are given:

Panel 7" high by 7½" long

Chassis 7½" long by 5" wide by 2½" deep. The material used may be either heavy sheet iron or aluminum (which is easier to work). The construction may be easily determined by a study of the illustration. The finish is left to the taste of the builder. It is essential that the apparatus be located exactly as shown.

Now that we have our chassis completed and our parts laid out before us we can start assembling the receiver. The logical and most advisable sequence for this procedure is as follows: Mount C1 on the left rear of the chassis. Next, attach the ground clip to the chassis with a nut and screw, putting a soldering lug under the nut. (Important! When a screw and nut hold a soldering lug be sure to scrape the paint off the mounting hole so that the screw head can make solid contact to the chassis and provide a good ground.) Mount the rheostat to the left and regeneration control to the right ends of the panel. Attach the sockets to the underside of the chassis, positioning them so as to have all the filament prongs (*large* contact holes) toward the left. Soldering lugs are mounted under the nuts shown. Now place the audio transformer under the chassis and attach it with four screws. For ease in wiring put the F and G terminals nearer the amplifier tube and the P and B plus nearer the detector tube. The twin tip jack is next mounted in an oval hole 1⅜ by ½" on the right rear of the chassis. The three fixed condensers C3, C4, and C5, the grid leak R3, and the R-F choke L3 are self-supporting when wired into the receiver and require no mounting provision. The one remaining item is the variable tuning condenser C2 and this is mounted above the chassis deck in the hole drilled for it.

Soldering

A great deal of time and trouble can be saved by being sure that the soldering iron tip is always clean. Clean the tip with a metal file or with sandpaper and tin the iron by dipping the point into soldering flux and applying solder. Always use a fully hot iron, and be sure the solder applied flows into the connection. If the iron is not hot enough, poor connections known as cold joints result. This is the greatest cause of noisy and scratchy reception. Before soldering a connection, first apply a little soldering paste to the joint. Touch the soldering iron to the bar or wire of solder and pick up a little solder with the iron. If the iron is clean, the solder will stick to the iron and not roll off. Now press the point of the iron to the connection and hold it there until the solder flows in and forms a smooth surface. With a little care and patience you will have a completed set that will justify your expectations and of which you will be truly proud.

Wiring

The wiring of this receiver is simple. By following instructions and checking against the schematic diagram, no difficulty should be encountered. Place every part, and wire exactly as shown, making all connections as direct and short as possible. The soldering lugs that you have placed under five of the nuts are grounds to the chassis and are indicated by the ground symbol in the diagram. The antenna clip is soldered to one terminal of C1. A wire is pushed through a ¼" hole in the chassis and out through the eyelet that forms the other contact of the ACC and is then soldered to the eyelet. The other end is soldered to the F of the coil socket. From this contact a wire is continued to the front center of the chassis and out through a hole up to the stator terminal of C2. C3 and R3 are placed parallel and from the F of the coil contact to the G of the detector tube socket. C4 is soldered directly across the F— and G of the coil socket. F— is also connected to the nearby ground chassis lug.

From G the R-F choke is attached to P terminal of AFT. P of the coil socket is wired to P of the detector socket. The arm of the rheostat R1 is connected to chassis and the other end is wired to the F of the tubes (the filaments of both tubes are connected in parallel). The yellow A— lead of the battery cable runs to the F— of the tubes. B terminal on the AFT is connected to one lug of R2, the regeneration control and also to C5. The other lead of C5 is grounded to the chassis. The maroon B detector battery lead is soldered to the free lug of R2. G of the transformer and G of the amplifier tube are connected. F of the transformer is wired to chassis. P of the amplifier tube is connected to one of the twin tip jacks and the red B amp. battery lead to the other. The black battery lead A B— is soldered to a lug under the nut holding the jack. When wiring is completed check carefully for any errors.

Tubes and Batteries

Two type 01A or 30 tubes may be used, the only difference being in the filament voltage required. The 01A's may be lighted by four dry cells in series or a six volt storage battery and as they are rated at 5 volts the rheostat must drop the extra volt. Type 30 tubes are much more economical as they operate at only 2 volts and in addition draw ¼ the current of the 01A's. The two volts can be obtained from 2 1½ volt dry cells in series (the rheostat being used to dissipate the extra volt) or from a two volt cell of a storage battery. It is very important that the tubes used be the finest obtainable as the use of inferior or cheap tubes will result in poor operation.

One or more 45 volt B batteries are required. They are connected as shown in Fig. 4. The detector plate voltage should be determined by trial and may be 22½, 45, or 67½ volts. The amplifier plate voltage may be from 45 to 135 volts. The higher this voltage generally the greater the volume will be.

Accessories

The aerial may be any type of ordinary receiving antenna about 100 feet long. Locate as high as possible and clear of any nearby objects. You may use the aerial on your long wave receiver by employing a SP-DT switch. The best ground is a ground clamp soldered to the cold water pipe. Other good grounds are rods driven into moist earth, steam radiators, copper plates buried in the ground, etc.

The phones should be of good quality and very sensitive so as to enable the operator to detect faint signals. More than one pair may be used so that your friends may listen in at the same time. Connect the phones in series.

Testing the Receiver

Connect the antenna and ground, insert the tubes in the sockets, plug in the phone tips and place any coil in the coil socket. Then connect the A battery *only* and turn the rheostat on. The tubes should light and if they fail to do so check over the wiring. If the tubes light remove them and complete the battery connections.

Operation

The rheostat should be set at the lowest point at which the receiver will operate satisfactorily. Now turn on the B battery. At some point in the turning of the regeneration control a rushing noise will be heard. This point is just before the tube goes out of oscillation and it is here that the signals are strongest.

Different classes of stations will be found on different coils, and the following charts will give you an idea where and, most important, the best time to look for the desired stations.

Coil A— Daylight—Amateurs, Ships, Foreign broadcasts.
Coil B— Dusk and Dawn—Amateurs, Airships, Trans-oceanic Telephone, Foreign broadcasts.
Coil C— Dark—Amateurs, Coast Guard, Airplanes, some Police calls.
Coil D— Dark—Police calls, Television, Phone amateurs.

Short waves are subject to great vagaries and many curious and baffling phenomena are to be noticed. A foreign station may be received like clockmark for days, and then, suddenly, for no apparent reason, it may disappear completely for several minutes or days. It takes some time and patience to master the knack of short wave tuning, which is totally unlike operating a regular broadcast receiver, and until one does so, the full efficiency of this little receiver cannot be brought out fully.

[Other Illustration on Front Cover]

AN A-F BRIDGE METER

TUNING BY EITHER VARIABLE COIL OR CONDENSER STRIKES BALANCE INDICATED BY NULL POINT IN PHONES

By James J. Lafferty

THOSE who are dealing with sound apparatus, such as audio frequency amplifiers and oscillators, frequently require a means for measuring the frequency. Suppose, for example, that an audio oscillator has been built for testing the frequency response of an amplifier. What frequency does it generate at any particular setting of the frequency control? Or it may be found that an amplifier gives a strong response on a certain note. What is the frequency of that note? It is usually possible to compare the notes with those of a piano, but a piano is not a convenient piece of laboratory apparatus. It is almost as impractical to move the device to be tested as it is to move the piano to the laboratory or other testing place. Moreover, the frequencies generated by the piano are not continuous, but occur only in definite ratios, and for the higher frequencies the actual frequency difference between two successive notes is large. Something portable and continuously variable is required for measuring audio frequencies, something that corresponds to a wave meter in radio.

Audio Frequency Meter

A very simple audio frequency meter is based on the Wheatstone bridge principle, and is shown in diagram in Fig. 1. The frequency to be measured is impressed on the primary of the audio transformer at the point marked Fx. The secondary of this transformer is connected between two of the vertices of the bridge. Across the other two vertices is connected a headset or other sensitive sound detector.

In two of the arms of the bridge two equal resistances, R, are used. In one of the other a fixed resistance, R1, and a small variable resistance, r, are placed. In the fourth arm a tuned circuit consisting of an inductance L and a capacity C is used for balancing the R1 arm.

The coil and the condenser will have some resistance. When the LC circuit is in tune with the impressed frequency, this is the only impedance in the fourth arm, and it must be balanced with R1 and r. When L and C are in tune and when R1 + r balances the resistance in series with the coil and condenser, no sound will be heard in the phones. If the same coil is used all the time, the resistance in the fourth arm will remain nearly constant. Hence, R1 may be equal to the minimum value of the resistance in the fourth arm, and r then will need to be large enough only to cover the variation in the resistance of L.

Range of Meter

The range of audio frequencies that can be measured with this arrangement is the same as the range of the tuner LC. If the range is to be small, the condenser alone may be variable, and it may take the form of a regular variable condenser. However, it should be larger than the ordinary broadcast tuning condensers. A gang of four 0.0005 mfd. condensers might be used, all connected in parallel, making a total capacity of 0.002 mfd. This minimum capacity of this condenser might be of the order of 50 mmfd. The ratio of maximum to minimum would then be 40, and the frequency range would be 6.32. If we use a coil of one henry, the frequency range would be from 3,500 to 22,000 cycles. Some of these will not be audible. If we use a coil of 4 henries the range would be about 1,800 to 11,000 cycles per second. These are all audible. By putting a fixed condenser of 0.002 mfd. across the variable the range could be extended. This fixed condenser should have a value equal to the maximum value of the variable. Additional condensers of 0.002 mfd. could be added to extend the range downward as low as desired.

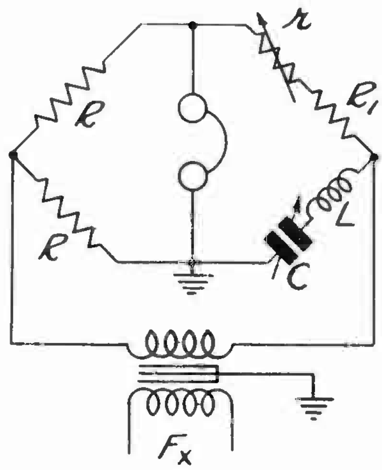


FIG. 1

A bridge arrangement for the measurement of audio frequencies. The instrument may be made direct reading by calibrating the scale and by engraving the frequencies on the dial.

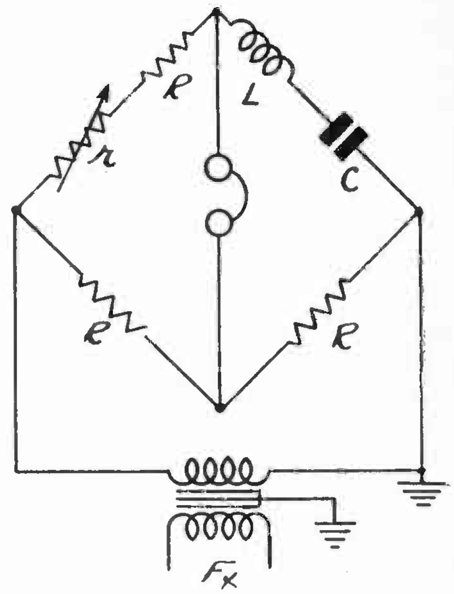


FIG. 2

A variation of the bridge circuit for measuring audio frequencies. In each case the variable element, whether capacity or inductance, should be connected on the ground side of the circuit.

If the coil L is varied continuously, as by means of a variometer, the condenser can have a fixed value, but it should be variable in definite steps. What these steps should be would depend on the range of the variometer. It is quite possible to get an inductance range of 9-to-1 with a variometer, or a frequency ratio of 3-to-1. Suppose the maximum inductance is 200 millihenries and that a condenser of 1 mfd. is used. This would make the lowest frequency 356 cycles and the highest with this condenser 1,070 cycles. The next condenser should pick up this frequency when the inductance is 200 millihenries. This would require a condenser of 0.111 mfd. This would make the frequency 3,200 cycles per second. The next condenser, which should have a value of 0.0122 mfd. This would put the highest frequency at 9,600 cycles per second. These values are all based on the supposition that the range of the variometer is 9-to-1.

When the condenser is continuously variable the rotor of that condenser should be connected to the grounded side of the headphones. The phones should be ground because they will be in contact with the operator. However, this is not an essential since only audio frequencies are involved. If the inductance is grounded, that should be put on the ground side of the condenser.

An alternative connection as shown in Fig. 2 may be used, which is produced simply by interchanging the supply leads with those of the phones. In this case the phones are not grounded on either side, but the supply transformer is. If the inductance is to be varied the positions of the coil and the condenser should be interchanged.

Resistances R should be wire-wound. It is not absolutely essential that they be non-inductive, provided that the inductance be exactly equal, as well as the two resistances. Of course, it is preferable that they be non-inductive. Two resistances constructed exactly alike and measuring the same resistance on direct current should be all right, but it is important that they also be placed in similar positions with respect to ground conductors, for otherwise they will have different distributed capacities.

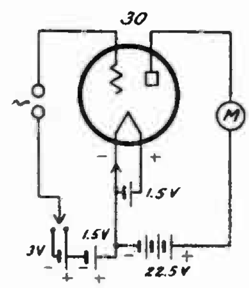
Resistances R1 and r should be non-inductive as well as non-capacitive, for these must in every instance be balanced against the pure resistance, that of the tuned arm when that is in resonance. Any departure from equality in the two R arms will give incorrect values of frequency, and reactance in the R1 arm will make balance impossible. Slight residual sound in the phones at optimum balance may be attributed to these reactances, and also to the presence of harmonics in the tone supplied. Since the circuit must be calibrated, unbalance would not be a serious matter were it not for the fact

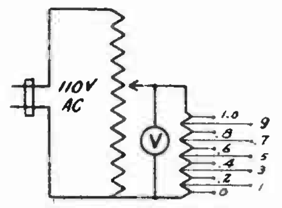
(Continued on next page)

VTVM CALIBRATIONS

RANGES OF 0.1 TO 1.5 AND FROM 1.5 TO 3.0 VOLTS COVERED, USING A 30 TUBE AND SMALL BATTERIES

By Herman Bernard





THE vacuum tube voltmeter should be part of the equipment in every radio laboratory, no matter how humble. The reason is that a-c voltages may be read accurately, no matter in what sort of circuit they are present, and no matter what the frequency, for the VTVM draws no current from the measured source and is non-reactive in a measuring sense. The range depends on the bias and plate voltages, and somewhat on the filament voltage, and the accuracy is high so long as the calibration is done over the negative region of the effective bias, a-c signal considered as working against the d-c bias. The curves shown on the following two pages, for 0.1 to 1.5 volts, and from 1.5 volts to 3 volts, were on the no-grid-current basis.

The curves may be used as they are found, if the 30 tube is in the socket, and the voltages are 1.5 on the filament, 22.5 volts on the plate, in both instances, and the bias switched from 1.5 volts to 3 volts negative, to afford the two ranges of voltages. The accuracy will not be as high as practical, since there may be some slight difference in the tube characteristic. However, for greater accuracy the calibration may be done by the constructor, an easy task since the approximation of the new case is fairly closely given in the curves herewith.

Use of Potentiometer

The plotting in the regions of low voltages usually requires that a potentiometer be put across the a-c line, of suitable wattage rating. At 110 ohms there would be 1 ampere, at 220 ohms one-half ampere, at 330 ohms one-third ampere, etc., but if the voltmeter used does not draw much current (e.g., is of the rectifier type), the potentiometer may be of much higher resistance, without limiting the needle swing by the high series resistance of the part of the potentiometer between high side of the line and arm.

Beside the VTVM design is shown the scheme for getting low voltages. The potentiometer arm is connected to one side of a series of ten equal resistances and the variable arm of the potentiometer is moved until the reading on the voltmeter is whatever is desired, say, 1 volt for the lowest voltage ranges. Then, since the total is thus divided into tenths by the equal resistors, the top tap of the series represents the full 1 volt, the bottom tap represents 0 volt, and the taps in between give the values in steps of 0.1 volt. The moving arm may be slid up so that the meter reads 10 volts, whereupon each the voltage between each tap of the series arm will be 1 volt.

Meters Don't Read to Zero

The usual a-c line meters, in fact, even rectifier type a-c meters with full-scale deflection at 5 volts, are not calibrated for less than 0.5 volt, and therefore some such method as outlined must be used.

If a 2.5-volt transformer is accessible, the series arm may be put across the 2.5 volts, hence the voltage between two adjoining taps is 0.25 volt. In any event the input to the VTVM is the voltage between arm and lower terminal of the line. And the voltage that the a-c voltmeter reads is the true voltage, whether the meter is high or low resistance, that is, draws little or much current. However, as stated, if the potentiometer across the line is of high resistance (thousands of ohms), and the meter draws considerable current, the needle may not move much, because the voltage has been dropped so considerably due to the high current through the large resistance. Therefore low-resistance potentiometers, of suitably high wattage rating, are preferable for the run of meters.

Curves Are for RMS

The calibration is made by connecting to a given d-c voltage as bias, which in general may be accepted as the limit of a-c that may be calibrated. When the a-c is equal to the static bias there is no grid current readable on a 0-100 microammeter.

The voltage calibration will be on the basis of what the meter itself is calibrated for. If there is no marking on the meter the calibration is in root mean square volts. If there is a marking it will disclose that the meter is a peak voltmeter (also called crest voltmeter). It will be one or the other type. The peak voltage is 1.41 the rms voltage and, and the rms voltage is 0.707 of the peak voltage, so conversion from one to the other is easy. The scales reproduced herewith are for rms voltage calibration.

It is preferable to have a 0-500 microammeter for the current indicator, but a 0-1 milliammeter with fifty scale divisions (20 microamperes per division) will do, if one is particularly observant at the lower voltage calibration points. Some estimating has to be done, but only as low as 10 microamperes, which is half of a scale division. This is neither difficult nor risky.

Useful Instrument

When the calibration is completed one will have an instrument that serves numerous purposes. A-c may be read, at high or low radio or audio frequencies, even when there is even practically no current flowing in the circuit. In resistance-coupled amplifiers, for instance, the total voltage drop may be desired, and may be obtained by inserting a small series resistance and multiplying the measured smaller voltage gy the quotient of the total resistance divided by the measured-circuit resistance. Thus, if a series resistor of 1,000 ohms gives a reading of 1 volt, and the total resistance is 90,000 ohms, the total voltage is 90 volts.

The filament voltage is always a consideration, for it must be just the same as it was when the calibration was run, provided the tube has not seriously deteriorated. Adjustments of filament voltage may prove troublesome, and therefore a small 10-cent dry cell of 1.5 volts is used directly to heat the filament. While this will not give long service, it is no doubt well worth while to put in a fresh cell on practically every occasion that the VTVM is to be used, should there be a lapse of weeks between such uses, or even from day to day, if the VTVM has been used for any long period of testing.

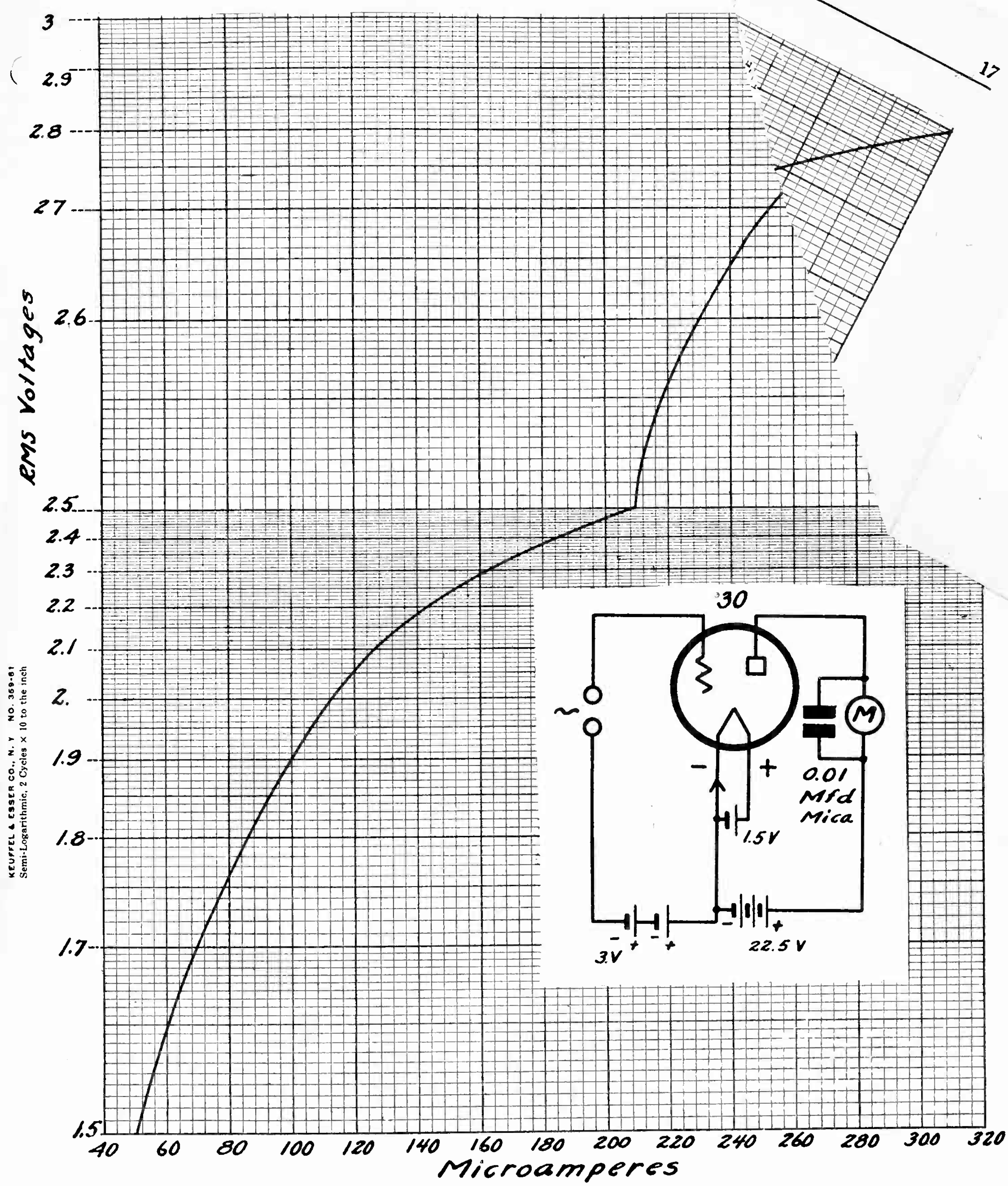
Percentage Modulation

What will appeal to many is the fact that percentage modulation may be measured. Really it is effective percentage modulation and applies to a single tone. First the carrier amplitude or voltage is measured, without modulation. Then the voltage of the r-f carrier is measured

AUDIO METER

(*Continued from preceding page*)

that it makes it difficult to locate the balance point exactly. Since harmonics will not balance out (if they did the meter would not work), and since they cause confusion with the fundamental, the supply wave should be as pure as possible, or else the operator must learn to listen to the fundamental alone. This may be difficult to do in view of the fact that the pitch of a tone is determined more by the difference between the harmonics than by the fundamental. In other words, even if the fundamental is entirely absent from the current in the phones, the fundamental tone would still be heard.



Calibration of a vacuum tube voltmeter, using the 30 tube, 1.5 volts on the filament, 22.5 volts on the plate and negative bias of 3 volts. The upright column represents rms voltages (ac) and the horizontal microamperes. The diagram is shown in the inset.

when modulation is introduced. Then the difference between the two values is taken. This difference is divided by the carrier voltage alone and multiplied by 100 to yield percentage. Thus when there is no modulation impressed even by a broadcasting station, or by an amateur, the measurement can be made in terms of a voltage in a receiver, e.g., input to detector, then another measurement made when a single tone is emitted, as when a station sends an audio oscillation on a time signal, or an amateur sends some similar single tone. Hence some one could phone you to tell him his percentage modulation and you could do it. The monotone of amateur phone transmission may be taken as a single tone, and so may the keying.

The voltage across a speaker voice coil

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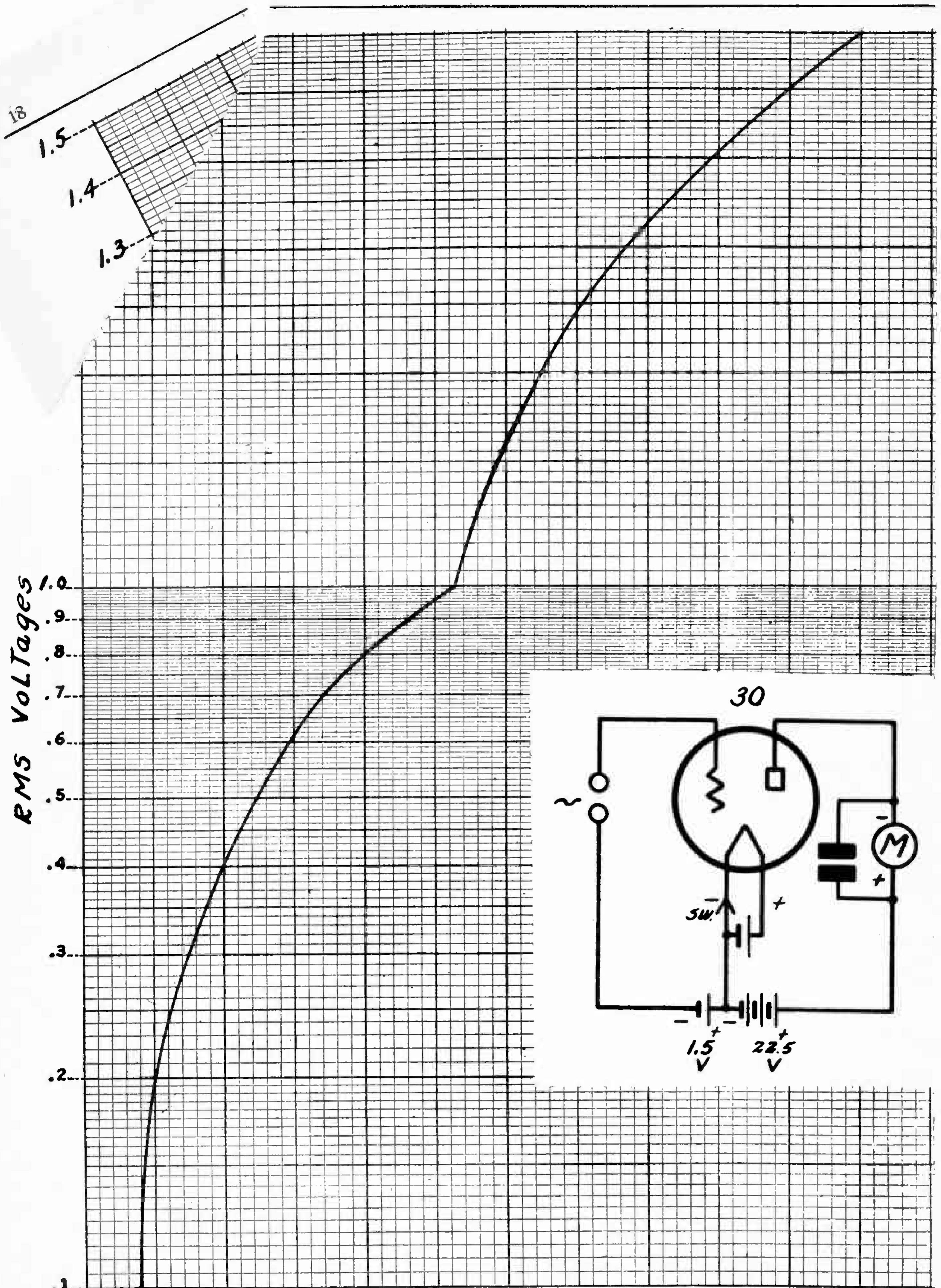

The range of the vacuum-tube voltmeter is lower, the readings being for 0.1 to 1.5 volts. The range may be selected by switching.

(*Continued from preceding page*)
may be measured, even with the ranges included in the present instrument, and also the voltage gain in an r-f or a-f amplifier, by taking the measurement at the grid of one tube (grid to grid return) and dividing it into the voltage measured at the grid of the next tube. You can tell whether an r-f coil in a working receiver is shorted, and of course the a-c voltages across filaments may be accurately read.

Radio University

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Two Oscillators

KINDLY SHOW simple oscillators for the 30 tube, no modulation, battery operation, and 56 tube, a-c operated, with line frequency as modulation.—E. M. S.

These diagrams are given herewith. The same coil and condenser system is used in both, and that is the reason for the special Hartley oscillator in the case of the 30. While the Hartley is generally rated as one of the readiest oscillators, it so happens that this battery-type circuit is not always dependable, and in some constructional instances there would be no oscillation. Probably this would be due to the effective grounding of B minus through stray capacity. The frequency then has something to do with this phenomenon, so if the range is low, as 50 to 150 kc, there should be no trouble in this direction. The full coil shown with tap then may be used simply as secondary, with an r-f choke as separate tickler, in the event of no oscillation in the battery model. The inductance of the total winding (full 1,300 turns), is 25 millihenries, so 400 mmfd. would be required to strike 50 kc. A condenser of rated 350 mmfd. would do it, considering some trimmer capacity used, also the distributed capacities in the circuit. The broadcast band would be represented by tenth harmonics. Any commercial intermediate frequency could be lined up with the a-c model, due to presence of modulation, but if modulation is required also in the battery model, this may be accomplished by grid blocking, using a grid leak value around 8 meg., rather critical for assurance of modulation at all frequency settings of the tuning condenser. Note carefully whether modulation is present, then absent, as the condenser is rotated the full distance. If this trouble arises, increase the leak resistance. The battery model will confine its output to the output lead, but the a-c model will feed through the line somewhat, although the condition is minimized by the series block circuit, consisting of 0.1 meg. and 0.05 mfd., near ground symbol.

* * *

Thermostatic Trimming

RECENTLY you explained how a small trimmer condenser, thermostatically controlled, could be used to improve the tracking of a superheterodyne oscillator. If this trimmer affects only the minimum capacity, how will the circuit track at the lower frequencies? It seems to me that in order for this system to work out correctly it would be necessary to move an entire plate of the condenser by the thermostat. What do you have to say on this subject?—E. W. J.

You are right. It would be necessary to vary a whole plate. But deviation from tracking is most serious at the high frequency end where the trimmer practically controls the tracking. Hence if the thermostatic condenser affects the minimum only, the tracking will be improved.

* * *

Change of Frequency with Temperature

HOW does the frequency of an oscillator or resonant circuit vary with frequency? Does it go up or down?—L. J. W.

In nearly all resonators the frequency decreases as the temperature increases. If we consider a mechanical resonator, the frequency decreases because the temperature decreases the stiffness and also because it increases the dimensions. If we consider a circuit composed of an inductance and a capacity the frequency decreases because the inductance increases and also the capacity. That inductance increases is obvious from the fact that the physical dimension of inductance, when expressed in henries, is a length. The linear dimensions of the coil increase as the temperature goes up. The capacity is also dependent on dimensions in the same way. If the capacity is measured in electrostatic units, the physical dimension is a length, and the same conclusions apply as for the coil. When the capacity is measured in farads, the dimensions are the same but multiplied by a constant.

* * *

Mysterious Capacity

IN A TEST OSCILLATOR that I constructed I measured the minimum capacity, with coil out, as my system is the differential method that does not permit coil inclusion, and got a value of 31 mmfd. The maximum was measured at 437 mfd. This should yield a frequency ratio of 3.62. Of course I do not expect such a ratio, as the coil capacity would reduce it, but the fact is that when the ratio is established experientally it is reduced to 2.7, which is quite a difference. Since nothing is added save the distributed capacity of the coil, which I am unable to measure directly, I was led to suspect that, but it is a honeycomb, and it is well known the capacities of such windings are exceedingly small. Also I tried the coil in another set-up, replacing a previous coil, and the frequency range was increased a little over what previously obtained, due to a honeycomb replacing a solenoid, that is, the lower distributed capacity of the coil I had been doubting. So I am left up a tree, as I need a ratio of around 3, certainly no less than 2.8 to 1. What do you suggest?—I. K. L.

Turn on the oscillator at a position previously established for beating with some carrier, and notice whether the beat is not heard right away, but begins to build up with a rising or falling frequency characteristic. If the rise or fall is quick it denotes that the mysterious capacity is arising from the tube operation, and that the orthodox view of the mechanical aspect of capacity can not be strictly applied, for the capacity does increase in your case when the tube is functioning. This could be readily explained if there is a large capacity to ground from some tube element other than control grid. When the space stream starts flowing it becomes a finite resistance relating this large other element capacity back to the tuned circuit. Use a tube of extremely small elemental capacities. A much more general cause is the absence of grid leak and stopping condenser, as the leak serves as a check on grid current, or at least increases the negative bias proportionate to the increase in grid current. Thus, without leak and condenser the input impedance would be low. The effect may be gauged on the basis of a capacity. First, let us consider a short circuit across the tuned circuit. Call the resultant frequency zero. It can be seen then that the frequency is lower, the lower the input impedance. One also can realize that the equivalent of a short circuit to the tuned circuit, or constant that will establish zero frequency, is an infinite capacity. Hence, decrease of input impedance is in the direction of a short circuit or infinite capacity, an effect which is true, though the inherent cause may be resistance. However, decreased resistance across the tuned circuit, or increased series resistance in the tuned circuit, has the same effect, that of lowering the frequency, the same effect as has a parallel capacity.

* * *

Confused on VTVM

IN A VACUUM TUBE voltmeter that I am attempting to establish as a permanent fixture in my small laboratory, I have difficulty in reading the lower values of current on a O-1 milliammeter which has bars equalling 20 microamperes (fifty bars for the entire scale).

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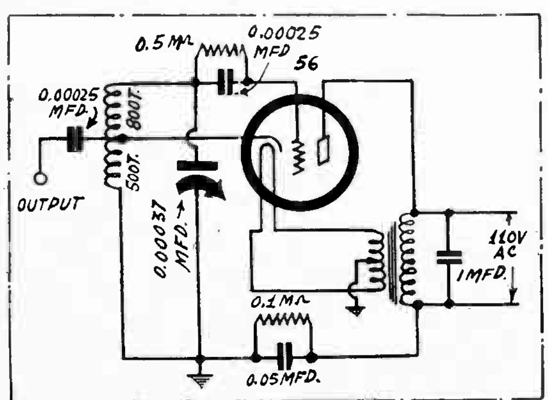
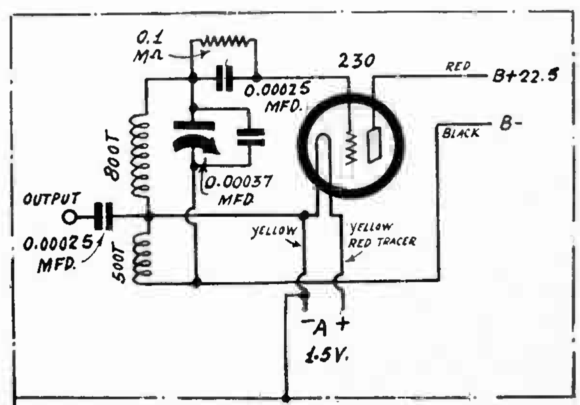
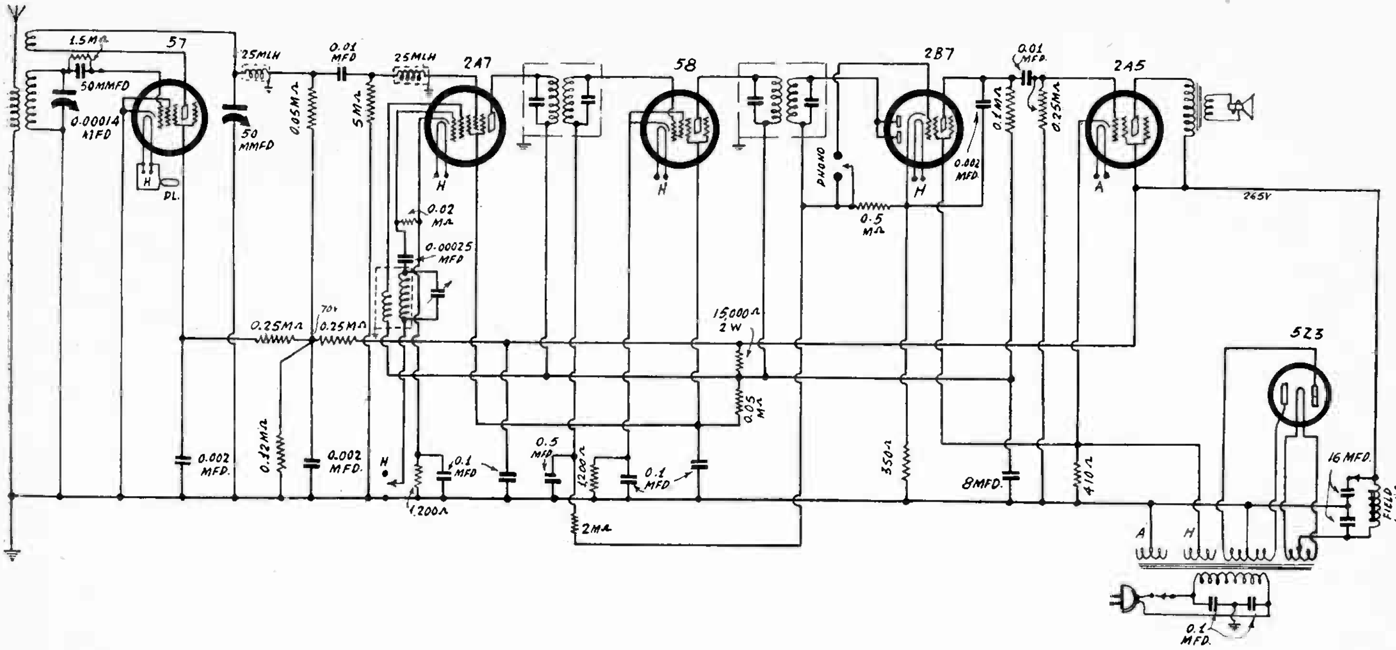


An a-c-operated, constantly-modulated test oscillator, using the 56 tube.



Battery model Hartley oscillator, with tapped coil used as here also, but not as reliably.



Circuit for changing the incoming frequency to audible values and impressing these values and a new oscillation on a modulator tube, for feeding to the intermediate amplifier. Some troubles encountered in this system are mentioned in the text.

Therefore, it is necessary to do some estimating, and when I communicate my data to a curve I find that there is a decided departure from regularity. In this I am confused, since I am not certain whether there are errors due to my reading of the current, or whether there is no error, and the curve should be a bit erratic. Should there be any sharp points in the curve?—I. E. D.

There is no remedy for your main trouble of not being able to read accurately the smaller values of current except to use a more sensitive d-c milliammeter in the plate circuit. When the full-scale deflection is less than 1 milliampere the instrument is usually called a microammeter. The errors due to misreading, or inaccurate estimating, are serious and you can not overcome them by "smoothing out" the curve, since you can not tell which points to favor in the process, and moreover there may be some natural irregularities in the curve. That is, one should not expect that the curve will be entirely symmetrical, but there may be the equivalent of a few kinks in it. This, however, would not mean there would be any sharp points. Curves never develop sharp points, and simply drawing a straight line from one point to another introduces artificiality and error of considerable magnitude. When you use the proper plate circuit meter you will be able to plot curves for ranges such as 0.1 volt to 1.5 volts, 1.5 to 3 volts, etc.

* * *

True SFL Condenser

IS THERE such a thing obtainable as a true straight frequency line condenser, that is, one that will yield a really straight line for the full tuning "curve" from maximum to minimum? I am keenly desirous of building a test oscillator that has such a tuning curve, so that I may use a 2-to-1 frequency range, and simply multiply a scale by 2, 3, 4, etc., for the various harmonic values.—O.K.D.

There is no such condenser on the market yet, but two companies are preparing to produce it. The condensers now obtainable may have a fairly straight tuning curve for most of the span, but run off at extreme capacity settings. If the plates are manufactured solely on the basis of computation such trouble and other disturbances are likely to be present. The better method is to shape an experimental set of plates on the basis of the calculations, then run a curve, frequencies plotted against dial settings, and carefully note the divergences from the desired shape of the curve, or straight line. Then the plates have to be filed down to conform to the actual requirements, and finally the condenser will emerge as one that truly follows the desired tuning course. One of the proposed new condensers of the true straight-frequency line type will have a rotor that turns 270 degrees and the other a rotor that turns 330 degrees. The true straight line results when a definite minimum capacity is used, and this would be prescribed. Or, if the prescription is, say 20 mmfd., that capacity may be measured backwards, so to speak, by adjusting until the frequency ratio is exactly as specified (2 to 1), for only when the minimum is as specified will that ratio obtain, and when it does obtain the 20 mmfd. are present. As you know, if the curve is strictly straight line, the entire tuning may be plotted accurately simply by the known points of the two extreme frequencies, as a straight line is drawn between the two points. Also, if such a condenser is to be used in a multi-band receiver, as for instance for short waves or "all" waves, the one trimmer would suffice for the coils for all bands, since the requirement is that the minimum capacity always must be the same. Then the problem that arises is to keep the inductance close to the requirement and have the same coil and wiring stray capacities. The trimming capacity in such an instance should be an air-dielectric condenser, as the mica types, whether compression or even vacuum impregnated, do not hold their capacity values sufficiently.

* * *

Mixing Detected Audio

SOME TIME ago you printed a circuit the performance of which was as follows: An incoming signal was received in the usual t-r-f manner and reduced to audible frequencies. Then an oscillator was set going at a frequency not related to the incoming carrier, and on this oscillator was impressed the modulation values derived in the first instance. Repeat points and other troubles were to be avoided, but it was intimated the circuit itself had troubles, although I do not remember your stating what they were. Will you kindly enlighten me as to this very interesting system?—L. T. S.

The diagram herewith represents the idea. Merely as an illustration, the first tube is made regenerative, and its audio output component alone is utilized as input to the 2A7, the choke preventing r-f passage. In reality the 2A7 is used in one instance as local oscillator at the steady frequency and in the other instance as modulator. The output modulated carrier, which you may call the intermediate frequency, then is amplified as usual. The system works, but is troublesome due to the difficulty of establising just the right coupling to the intermediate amplifier from the local fixed-frequency oscillator. Note that both this oscillator and the channel of amplification it feeds are at the same frequency, therefore the oscillator has a strong tendency to drive the channel into oscillation. To avoid this, more filtration is needed than shown, also the coupling has to be slight. Since for strong response tighter coupling would be necessary, and since it is not easy enough for commercial practice to establish the proper compromise between the two, the circuit as yet is in its experimental form, although of course it has possibilities. Experimenters may get a kick out of trying this method.

* * *

Standard Frequency Transmissions

WILL YOU PLEASE give me some information as to standard frequency transmission by the United States Government, as I understand that the accuracy of the transmission is as good as one part in a million?—L. W. D.

The Bureau of Standards, Department of Commerce, transmits standard frequencis from its station, WWV, Beltsville, Md., every Tuesday. The transmissions are on 5,000 kc per second. The transmissions are given continuously from 12 noon to 2 p.m. and from 10 p.m. to midnight, Eastern Standard Time. The transmissions can be heard and utilized by persons equipped for continuous-wave reception throughout the United States, although not with certainty in some places. The accuracy of the frequency is at all times better than one cycle per second (one part in five million). The transmissions consist mainly of continuous, unkeyed carrier frequency, giving a continuous whistle in the 'phones when received with an oscillating receiving set. For the first five minutes the general call, CQ de WWV, and an announcement of the frequency are transmitted. The frequency and the call letters are given every ten minutes thereafter. The Bureau invites reports on reception. In this connection a numerical rating is given by the Bureau and well must be susceptible of adjustment, and the circuit is adjusted to the scale by may be used in general for abbreviated descriptions of reception conditions: (1), hardly perceptible, unreadable; (2), weak, readable now and then; (3), fairly good, readable with difficulty; (4) good, readable; (5), very good, perfectly readable.

* * *

Short-Wave Factors

IN REGARD to the problem of losses occurring in vacuum tubes, how do these affect the highest frequency to which the circuit will respond Has the utilization of energy any reference to the stability of the circuit? How does the time of flight of electrons figure in the picture?—K. E. D.

The losses may be grouped as heat losses, and on their magnitude depends considerably the highest frequency at which the tube may be made to oscillate reliably, that is, repeatedly under the same voltaging conditions, etc. New dielectrics are being used in tubes and sockets for experimental purposes to help keep down these losses. In one dielectric the heat loss decreases as frequency increases, based on tests made in the 75-centimeter region. In general, the shortest wave length at which the tube will oscillate may be determined, and the selection of inductance and capacity would be on this basis, since the resonant circuit must be made to meet the conditions. The tube capacity, condenser minimum capacity, wiring capacity, etc., have much to do with this, for in the higher frequencies they constitute a large part of the total tuning capacity, unlike conditions found in the broadcast span of frequencies. The available power that can be supplied from the voltaging sources must exceed the losses in the circuit. This comes under the heading of the ratio of circulating or stored energy to the energy absorbed from the circuit, sometimes referred to as decrement, kva-to-kw ratio, or flywheel effect. The third consideration is the time of the flight of electrons from the cathode to the anode of a tube under the influence of the accelerating voltage. This governs the phase angle between the plate current and the plate voltage, as H. N. Kozanowski, of Westinghouse Electric & Manufacturing Company, points out. Hence, the efficiency is concerned. The allowable heat dissipation in the tube governs the output directly. In connection with the first consideration, minimum inductance and capacity values, it is important to have these quantities held extremely low in the tube itself. We have come to regard elemental capacity in a tube as something quite expected, but at high frequencies the inductance of the elements and outleads plays an important part, for what might be merely capacities at broadcast frequencies become inductances also, at high frequencies. Tube elements should be small and widely spaced. The 852 and the 846 have these features. But on account of the distance between plate and filament the time of flight of electrons is appreciable (10^{-4} seconds), making the minimum plate voltage rather high. Instead of using a circuit of lumped inductance and capacitance a Lecher wire system, which behaves as a transmission line with uniformly-distributed constants, may be used. When its physical length corresponds to a quarter wavelength or some multiple, it behaves as a parallel tuned circuit. Shorter waves with higher output and efficiency therefore are made possible. By designing the tube and the Lecher wire system to be equivalent to a continuous concentric pipe transmission line, the tube is electrically indistinguishable from the line, and outputs of 20 kw have been obtained at 6 meters, compared to maximum value of 1 kw for other type tubes. Electron oscillators developed by Barkhausen and Kurz are in general limited to a very small powers. A tube has been developed experimentally, consisting of a straight axial filament and a two-sector cylindrical anode. When the magnetic field is parallel to the filament, oscillations of the negative resistance type, as developed by A. W. Hull, are obtained. By inclining the magnetic field about five degrees a new type of oscillation is developed, called magnetostatic oscillation. A 40-centimeter oscillator has developed power as great as 10 watts with an efficiency of 8 per cent. By using a smaller anode diameter and stronger magnetic field the wavelength can be decreased, and approximately 2 watts power have been obtained at 18 centimeters (about 7¼ inches wavelength) and one watt at 9 centimeters.

* * *

Uniformity

SOME MENTION was made in a recent issue of your magazine about the stabilization of an oscillator by a method developed by Herman Bernard, and I would like further information about the nature of the stabilization and also some key to the selection of constants. Can you state the theory in a few words?—K. E. C.

The Bernard method of stabilization of an oscillator establishes frequency stability, hence also amplitude stability, since when the frequency is stable the amplitude is stable, by using series resistance. The frequency is, of course, the reciprocal of time. The amplitude is the strength of the oscillation. Hence, uniform-strength oscillation obtains. The method is to use a series, unbypassed resistor in the grid circuit, as where grid circuit is tuned and plate circuit provides feedback, the resistor having the opposite effect to that of the frequency-determining circuit. In an oscillator, assuming usual quantities of mutual inductance, etc., the oscillation intensity is greatest at the highest frequencies of tuning, but when the resistor is interposed, it is selected of such value that the circuit just oscillates at the highest frequency. As the frequencies are lowered, by using more tuning capacity, the effect of the resistor diminishes. So the circuit without resistor has a rising characteristic (greater amplification the higher the frequency) while the effect of the resistor is to contribute a falling characteristic. when one condition works against the other equally the result is uniformity. In some instances, as with a grid leak and condenser type oscillator, grid circuit stabilization becomes quite a task, as the resistor has to be selected to a trying accuracy. However, in that event plate circuit stabilization is used, again an unbypassed used, now in series with the plate leg. It may be between the plate and the coil or between the coil return and B plus. Experimental values for small oscillators that provided stabilization by the Bernard method were 9,000 ohms for grid circuit and 12,000 ohms for plate circuit. In general, the plate circuit stabilization is effectuated with a resistance equal to about 1.0 per cent. mutual resistance of the plate-grid circuit. The method to pursue for experiments independent of data just supplied would be to have the oscillator oscillating, with no attempt at stabilization, and note the change in plate current as the tuning is done slowly from one capacity extreme to the other. Then introduce a resistance that is too high, say, 25,000 ohms in the grid circuit for a negative-bias type oscillator, or for a grid-leak-condenser type oscillator, 50,000 ohms in the plate leg. Then oscillation will fail at the higher frequencies. Gradually reduce the resistance until oscillation just returns at the highest frequency that can be generated. The closeness with which the resistance is selected determines the degree of stability. The plate needle may be watched as guide and should not change more than 2 parts in 1,000. The frequency stability then would be of the order of 0.05 per cent. The means whereby the frequency stability is achieved is the circuiting of the load in such a manner as to make the behavior of the tube like that of a pure resistance. Once the circuit is stabilized, either way, it stays stabilized. It makes no difference whether grid circuit or plate circuit stabilization is used. Stability is stability.

* * *

Oscillator as VTVM

IN THE ABSENCE of a separate vacuum tube voltmeter can I measure the percentage modulation present in my r-f test oscillator by the plate current readings, and if so how?—J. K. E.

The method you probably have in mind, that of using the plate current change caused by modulation introduction, compared to plate current without modulation, is not accurate. However, you can make the r-f oscillator tube serve the purpose by first calibrating it as a non-oscillating vacuum tube voltmeter, by introducing known values of a.c. and ascertaining the plate current for each such introduction. Then you may run a curve relating plate currents to grid voltages. If you have a leak-condenser type oscillator put a much larger capacity across the leak if the a-c line frequency is to be used. Then after the calibration is completed you may obtain the percentage modulation as follows: Subtract the higher voltage present when there is modulation from the voltage obtained without modulation, multiply this difference by 100, and divide the product thus obtained by the amount of the oscillation intensity without modulation. If A is the difference between the two readings and a is the reading without modulation the formula is

$$\text{Modulation Percentage} = \frac{100A}{a}$$

* * *

Circuit Suited to a Scale

HOW IS IT POSSIBLE to have a test oscillator follow a pre-calibrated scale (commercial production) when there are so many variable factors associated with the tube circuit, coil, condenser, voltages, etc.?—O. W. S.

There are not many variable factors, and it is feasible to have the test oscillator follow the scale to a reading accuracy of ½ per cent. The coil's inductance must be held to an accuracy of 0.1 per cent. The minimum capacity in circuit setting this trimmer properly, using some broadcasting station or other source as standard. If the test oscillator operates at a lower frequency fundamentally, then use an harmonic of the test oscillator to beat with a broadcasting station. Besides, the values of resistances and capacities for grid leak, grid condenser, tuning condenser, etc., must be duplicated closely, as they may be by following the recommendations of the designer as to what make and type of parts to use.

Station Sparks

By Alice Remsen

TROUBLE IN THE AIR

Interesting rumors are flying around Radio Row thick and fast. A survey of the radio field has been started by Federal order and the result may be the scrapping of the present Federal radio commission and government regulation of air advertising may come into being. Just exactly what this will mean to advertisers in general may be imagined. It is to be hoped that something will be done anent objectionable "medicine show" methods of putting over laxatives and other medicines, which have raised murmurs from protesting listensers.

BORDEN TRIES IT THIS WAY

Borden has instituted a new live talent angle in small towns. This sponsor will use the talent of local stations instead of using either an expensive hook-up or electrical transcriptions. Twenty-one small stations will carry local fifteen minute periods twice a week for thirteen weeks, each using its own talent. A good break for the artists. . . . A survey conducted by Ulmer Turner, radio editor of the Chicago Herald-Examiner, in an endeavor to find out whether listeners like studio applause and laughs coming through their loudspeaker, brought a vigorous "No" in response. So far as I am personally concerned, a quiet studio is infinitely to be preferred, but some sensitive artists cannot work without applause or laughs. The lively audience seems to get them in the mood for making wise-cracks and telling jokes. . . . Have just been listening to the new Babo Surprise Party over WEAF, Sundays, 1:30 p.m. EST, starring eleven-year-old Mary Small as Miss Babo, with the Will Wirges Orchestra. This was the first program, and it revealed a swiftly moving half-hour with Frank Parker as the surprise guest artist doing two numbers, "Only a Rose" and "Easter Parade, as only Frank can do them. Molasses and January also did a stunt. Mary Small is surprisingly mature in her work. She speaks and sings intelligently, smoothly and well, showing the result of good coaching. The Will Wirges Orchestra is an excellent combination, well directed. No time wasted on excess blurbs. A very entertaining half-hour. . . . Irene Beasley was rumored as slated for the Phil Baker spot when it came East, but a newcomer to NBC, Martha Mears, was on the opening New York program. However, Irene, together with three other NBC acts, Jackie Heller, the Crusaders and Vic and Sade, are slated for a big build-up via Chicago and NBC networks, so she's getting a good break anyhow. . . .

CURTAIN!

Feel rather depressed. Two of my best friends passed away last week. Jean Gordon, who was widely known as a Scotch comedienne, and one of the finest characters it has ever been my privilege to know, and Henry Santley, of the music publishing Santley Brothers, youngest of the family and loved by all the music and radio folk for his sunny disposition and good fellowship. They will both be missed and mourned by many. . .

ALL THE WAY FROM CATALINA

Jan Garber, that lively and diminutive band leader, is in the Catalina Islands for eight weeks. Trust Jan to find a warm spot while the wintry winds are blowing. His commercial will be conveyed to Columbia networks via wires strung across the Channel to Los Angeles. . . . Friends of Jack Foster, one-time radio editor of the New York World-Telegram, will be glad to know that he is rapidly recuperating down in Southern Pines, North Carolina. Jack has gained twenty pounds, says his face looks like a full moon and his clothes don't fit him any more. He expects to be back on Broadway in June. That's jolly good news, isn't it? . . . Tess Gardella, "Aunt Jemima," took Helen Morgan's place on the WABC Bisodol program recently. . . .

WHERE THEY COME FROM

Where do they all come from? Ernest Cutting, head of the audition department of NBC, says they're from the four corners of the earth. Aspirants for microphone honors take up Mr. Cutting's time each day for six hours. Hundreds are on the waiting list. Out of those hundreds it is probable that two or three prospects may turn up. Many heard are fair singers or actors, many more are useless, few make the grade. . . . Raymond Knight's Kuckoos have been sold commercially. A.C. Spark Plugs will be the sponsor; contract for twenty-six weeks, with option; date set for March 21st; half-hour each Saturday night on NBC coast-to-coast hook-up. . . . Martha and Hal, formerly spotted in New York over NBC networks, are now singing six mornings a week on WGY, Schenectady. . . . Howard Phillips, who worked a great deal for NBC a few years ago, is set to start a commercial series via NBC networks in March. . . . John Barker, musical comedy baritone, is getting a big build-up at WLW, the Nation's Station in Cincinnati. WLW is advertising some, too. . . . The Sizzlers are back from Cleveland, with Charlie Bayha still handling them. . . . There is a new children's show on Station WLS, Chicago, featuring Hal O'Halloran and Malcolm Claire; three times a week. Thursday, Friday and Saturday at 8:00 a.m. CST; Hal in the role of Steamboat Bill, and Claire as Spareribs, spinner of negro dialect fairy stories. . . . Asher and Little Jimmy Sizemore are now heard each day except Sunday over WSM, Nashville, at 5:30 p.m. Little Jimmy, who is Asher's son, is only five years old and has memorized over a hundred mountain songs, which he sings with great gusto. . . . Princess Wahletka, who formerly caused international vaudeville audiences to gasp with her uncanny mind-reading ability, may now be heard by radio audiences over Station WHOM, New York, daily at 12:45 p.m. except Fridays, and Sundays at 5:15 p.m. Her personality is great and her talks always entertaining and intelligent. . . . Mark Warnow, who is one of Columbia's outstanding conductors, is also the youngest of their maestros. He is only thirty-three. Despite his youth, however, Mark has several fine sustaining programs each week, and a commercial program "Forty-five Minutes in Hollywood, sponsored by Borden. . . . A new series opened on Columbia last week—the New Oxol Trio, Brooke, Dave and Bunny. . . .

FRED WARING IN BIG BUSINESS

Fred Waring, who used to carry his office around in his vest pocket, now occupies the entire floor of a New York office building, and he has an office staff of twelve people. He has his own private rehearsal hall. Brother Tom has his private office here; the principal piece of furnishing in Tom's office is a piano, for Tom composes in odd moments. Fred has no less than fifty-six steel cabinets of music, which contain at least fifty thousand scores and orchestrations. Oh, yes! Fred Waring is in the music business with a big letter "B." . . . It is the voice of Tommy McLaughlin which you hear with the Ted Black orchestra over WABC on the "Voice of Romance" broadcasts sponsored by Venida. . . . Duke Ellington and his orchestra have a special Pennsylvania train of a baggage car, two sleepers and a diner for the first leg of their trip out to Hollywood. . . . Gertrude Niesen is still singing at the Casino de Paree, booked there by the Columbia Artists Bureau. The Do, Re, Mi Girls are playing vaudeville around New York, booked by the same bureau. . . . Connie Boswell is doing a swell job on her new commercial job with the Casa Loma band. . . .

Jimmy Melton has gone Columbia, appearing over WABC on the two-period Ward program each Sunday night. Melton graduated to NBC starring honors from the old Roxy Gang, the Revelers, and now CBS. . . . Bob Pierce, who is heard over WMCA every Monday, Wednesday and Friday at 10:30 a.m. in a program of poetry and philosophy, has an ambition—he wants to buy a duck and dog farm and invite Joe Penner, Albert Payson Terhune and Mahoney's flea circus to the housewarming. I'll say that's ambition with a sense of humor, Bob! Hope you realize it!

The Doughboy and the King

I SAW him standin' out there all alone,
A-lookin' far away across the space
Where men were fightin' hard to hold their own.
He stood like that a while—then turned his face.

A bully face it was, so quiet, strong;
With eyes so kind, yet burnin' like a coal—
Those eyes that watched so much of hellish wrong,
And lips that couldn't speak a coward's role.

And when he turned and spoke to those about,
They looked at him with love, as brothers can;
Saluted willingly. And can you doubt
Saluted not the king, but just the man?

And this was Albert, king and soldier, too.
But, say—I never thought I'd try to sing
Of kings—but he's an ace. You bet it's true.
He's every inch a man, though born a king.

—From "Liberty Aflame," by Roland Burke Hennessy (1918).

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F. J. Hoffman, 1019 Wolfram St., Chicago, Ill.
Harry E. Howell, R.R. No. 1, Blacklick, Ohio.
Russell B. Hewitt, 349 E. Ravenswood Ave., Youngstown, Ohio.
A. E. Nugent, 762 Central Ave., Dunkirk, N. Y.
Greg. Dillon, 7008 - 21st N.E., Seattle, Wash.
Carl Skinner (Radio & Sound Applications), 2944 So. Michigan Ave., Chicago, Ill.
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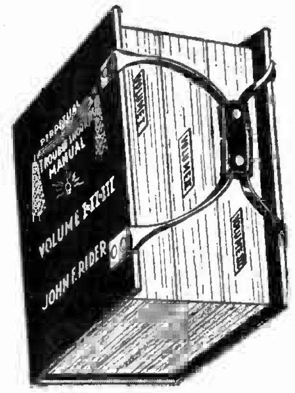

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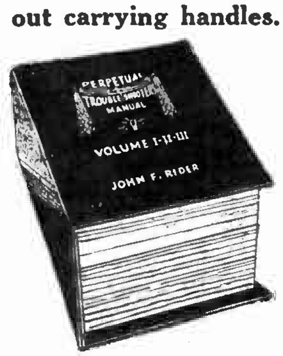

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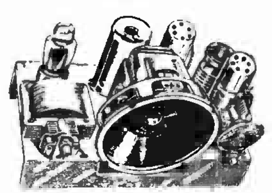

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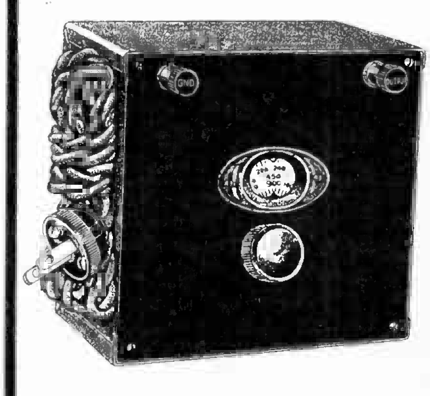

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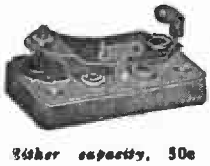

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