

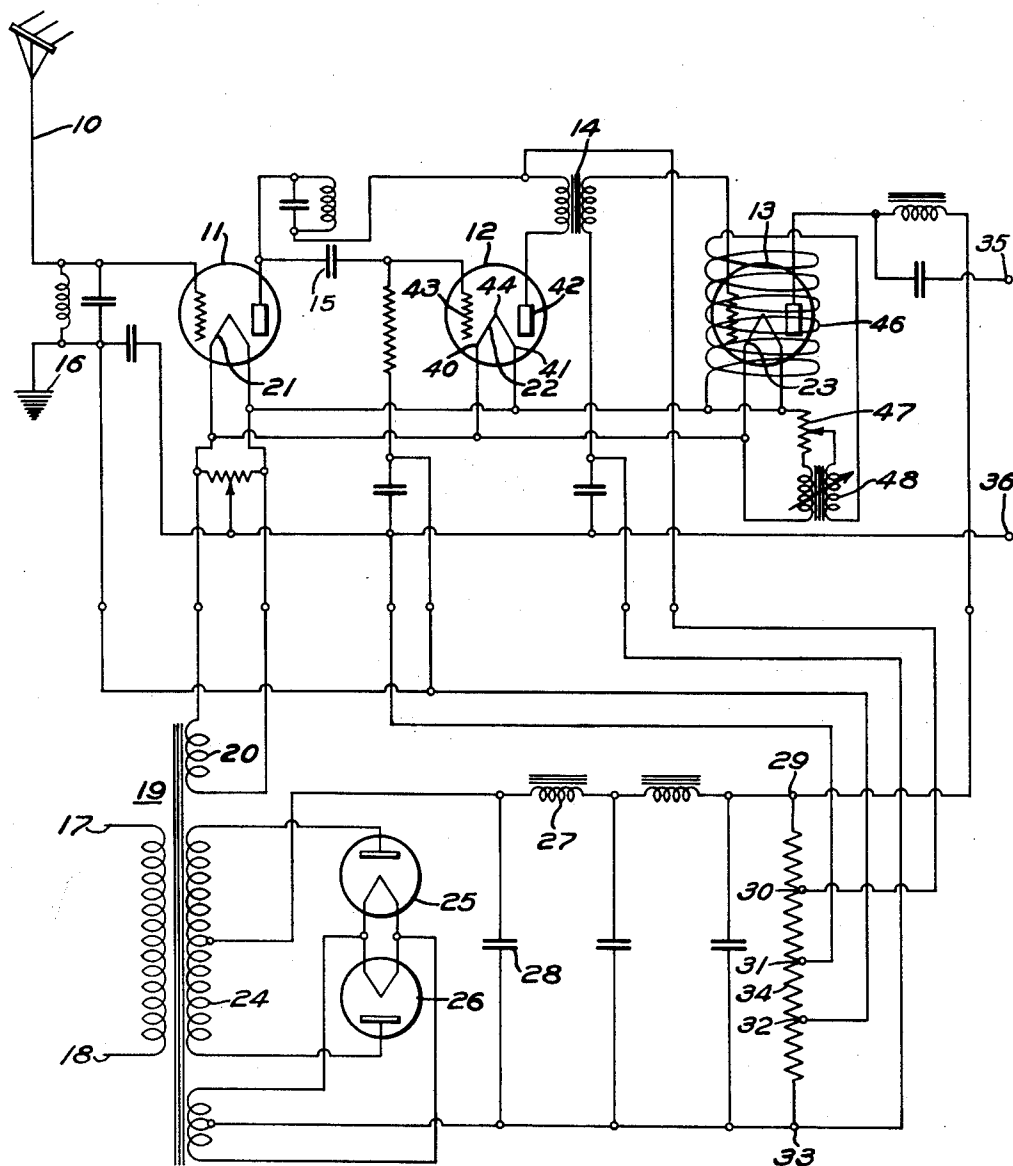
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NEUTRALIZING DEVICE

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NEUTRALIZING DEVICE

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This invention relates to neutralizing devices and especially to such devices for neutralizing a substantial part of the hum produced by the alternating current in apparatus containing thermionic tubes.

An object of the invention is to apply means to the audio stage of a radio receiving set for neutralizing a substantial portion of the double-frequency hum produced by the alternating-current power supplied to such set. More specifically, it is an object of the invention to establish an alternating magnetic field in the immediate neighborhood of one of the audio tubes of the set to produce a periodic change in the velocity of the electrons to the anode of the tube and to thus neutralize, to a large extent, the double-frequency component of the hum inherent in the set.

The single figure of the drawing is a diagram of apparatus and circuits embodying my invention.

It has heretofore been customary to carefully so design and manufacture the various elements of an alternating-current radio receiving set that the hum produced by the use of alternating current will be reduced as much as possible. The design of such elements has not always been successful in reducing the hum to the desired minimum and, furthermore, the additional care required in manufacturing the set has added considerably to the cost of producing it. Instead of carefully designing each portion of the set to reduce the hum to a minimum, it is one of the purposes of this invention to apply a neutralizing device to one of the stages of the set to neutralize a substantial portion of the hum produced by the several elements of the set. As the audio stage is generally the last stage of the set, it is preferred to apply this neutralizing device to one of the tubes of the audio stage.

This neutralizing device preferably comprises a magnetic means for producing an alternating magnetic field in the neighborhood of this audio tube which means is preferably a coil surrounding the tube. The field of this coil makes a periodic change in velocity of the electrons and, if formed in proper phase, will neutralize a substantial portion of the normally inherent hum-producing component in the output circuit.

In the drawing is disclosed various elements common to a radio receiving set although it is not intended to limit the invention to the particular number, type, arrangement or purpose of the elements so disclosed.

The circuit diagram contains the antenna 10

for receiving the radio signal and also a radio amplifier 11, detector tube 12 and audio amplifier 13. If desired, the number of radio or audio tubes may be increased. However, these three tubes constitute the basic and well known stages of a radio receiving set. Other elements of the diagram, such as the transformer 14, condenser 15 and ground 16, are too well known to need detailed description.

Connections 17 and 18, by which the apparatus may be attached to an alternating current supply, such as the usual 110-volt commercial circuit, are installed at a convenient place in the apparatus. A transformer 19 has its primary coils attached to these connections 17 and 18 and has its secondary coils arranged to supply the various power needs of the apparatus. The secondary coil 20 of the transformer 19 supplies current for heating the filaments 21, 22 and 23 of the various tubes. Another group of secondary coils of the transformer 19 lead to a full-wave rectifier such as that composed of the two rectifying tubes 25 and 26 in conjunction with a wave filter including inductances 27 and condensers 28. Various taps 29, 30, 31, 32, and 33 along the resistance 34 across the output of the rectifier permit the connections thereto for the various B and C voltages required in the operation of the apparatus. The output of the set is across the terminals 35 and 36 to which a loud speaker is usually connected.

In my copending application filed jointly with Lee Sutherlin as co-inventor Serial No. 210,262, on August 3, 1927, are described the various causes that contribute to the production of a hum-producing current in an alternating-current-operated set. One of the most troublesome of these causes is the so-called electrostatic or three-halves-power double-frequency current produced in the plate by the effect of the potential drop along the alternating-current-heated filament.

Take for example, the filament 22 in the tube 12, although other tubes of the set could also be used as illustrations. Alternating current passes through this filament between the ends 40 and 41. The voltage is constantly changing from a maximum to zero and then to a maximum of the opposite sign. But, during the cycle, one part of the filament may be of zero voltage and other parts of maximum voltage of opposite signs. The heating effect of this current causes the filament to be in a state adapted to give off electrons, and the B voltage applied between the filament and the plate 42 will drive these elec-

trons across the space under the control of the signal current coming in on the grid 43.

When the mid point 44 of the filament is of zero voltage during the cycle, the effective voltage for driving the electrons is that impressed across the filament and plate 42. At this particular instant, a section of the filament at the end 40 may be at the negative maximum potential of the alternating current, with the result that the voltage driving the electrons across the space is greater than at the mid point. At the same instant, the end 41 has a section at the positive maximum potential, with the result that the electron-driving voltage is less at this point than at the center of the filament. If there was a linear relation between the electron-driving voltage and the current in the anode or plate, the greater potential at one end of the filament might exactly compensate for the lesser potential at the other end. As the relation is of the order of the three-halves power, there is not this compensation, but a difference that produces surges in the anode circuit when first one end and then the other end of the filament reaches a negative maximum potential. As this phenomena occurs twice during each cycle, a double-frequency component is produced in the plate circuit which will produce hum in the loud speaker.

Likewise, the other tubes will also have this electrostatic double-frequency alternating-current component in their plates, with the result that the final audio stage will very likely have, in its plate circuit, the resultant of this double-frequency alternating-current component of the various tubes of the set.

A mathematical derivation of this alternating-current double-frequency component is as follows: The current flowing to the anode from the cathode may be calculated by the use of the well known Langmuir formula

$$i_p = N i e^{\frac{3}{2}}$$

where i_p is current from a hot filament of length 1 to a radio tube anode, e is the potential difference between the cathode and the anode and N is proportional to the number of electrons available at the cathode.

In the case of a three-electrode tube the Langmuir formula takes the form

$$i_p = N I (E_p + \mu E_g)^{\frac{3}{2}}$$

where E_p is anode voltage; E_g is grid voltage; and μ is the amplification constant of the tube.

Applying the foregoing formula to current between filament and anode, the potential difference between the anode and any point on the cathode at a distance x from the mid point thereof is represented by

$$e = e_p + \frac{x}{2L} E \sin pt$$

In accordance with the Langmuir formula, the current flowing to the plate from a small element dx will be represented by

$$di_p = N \left\{ e_p + \frac{x}{2L} E \sin pt \right\}^{\frac{3}{2}} dx$$

In ordinary receiving tubes, the filament voltage E is small compared to e_p . Hence, this expression may be expanded and written

$$Di_p = N (e_p)^{\frac{3}{2}} \left\{ 1 + \frac{3xE}{4Le_p} \sin pt + \frac{3x^2E^2}{16L^2(e_p)^2} \sin^2 pt \right\} dx$$

Substituting for N the value as given above and dropping the terms of powers higher than the second of $\frac{E}{e_p}$ gives

$$di_p = N o (e_p)^{\frac{3}{2}} \left\{ 1 + \frac{3xE}{4Le_p} \sin pt + \left(\frac{3x^2E^2}{16L^2(e_p)^2} - \frac{KE^2}{4L^2(e_p)^{\frac{3}{2}}} \right) \sin^2 pt \right\} dx \quad 80$$

Upon integration, this gives for the total anode current

$$i_p = N o (e_p)^{\frac{3}{2}} \left\{ 2L + \left(\frac{LE^2}{16(e_p)^2} - \frac{KE^2}{4(e_p)^{\frac{3}{2}}L} \right) (1 - \cos 2pt) \right\}$$

This shows that the anode current consists of direct current component

$$N o (e_p)^{\frac{3}{2}} \left\{ 2L + \frac{LE^2}{16(e_p)^2} - \frac{KE^2}{4(e_p)^{\frac{3}{2}}L} \right\}$$

and an alternating current component

$$N o (e_p)^{\frac{3}{2}} \left(\frac{LE^2}{16(e_p)^2} - \frac{KE^2}{4(e_p)^{\frac{3}{2}}L} \right) \cos 2pt$$

which is of double frequency.

As the usual commercial supply is of 60 cycles this alternating-current component will be of 120-cycle frequency.

Another hum-producing cause is the effect of the alternating magnetic field set up by the alternating current passing through the filament. This field deflects the electrons from the straight path that they would otherwise follow between the cathode or filament and the anode or plate. During each cycle of the alternating current, a magnetic field of one sign, as, for instance, positive will be built up to a maximum and then decreased to zero and built up into a magnetic field in the other direction. Accordingly, the changing magnetic field will affect the passage of the electrons twice during each cycle with the result that a double-frequency hum-producing component will also be present in the cathode circuit due to this cause. This so-called magnetic hum, however, is generally opposite to the electrostatic effect.

A third cause of hum-producing current results from the operation of the rectifier. The wave filter attached to the rectifying tubes has to be very carefully designed and manufactured to produce a constant voltage. If inexpensive materials are used there is apt to be a double-frequency alternating-current component also produced in the set generally in phase with the electrostatic component. The alternating current supplied to the transformer 19 changes in direction twice during each cycle. This alternating voltage is theoretically changed by the rectifier to a constant direct-current voltage but, in case the rectifier elements are not exactly designed, this direct-current voltage will be slightly pulsated at each maximum of the alternating current. This pulsation will be of the order of the double frequency of the alternating current due to the fact that the rectified current will have an increment of voltage during each change in direction of alternating current. As this change in direction occurs twice during each cycle there will be a pulsating component of double the frequency.

Accordingly, it has been discovered that an alternating-current receiving set has a hum mainly produced by a component in the plate circuit of double the frequency of the alternating current supplied to the set for power purposes.

It is the purpose of this invention to provide means for neutralizing the major portion of this hum-producing component in the circuit of the set. It is desirable to apply this neutralizing device to an audio stage of the set in order to neutralize as much as possible of the accumulated hum-producing component. A preferred form of the device is disclosed in the circuit drawing by the elements 46, 47 and 48.

It is desired to produce an alternating field in the immediate neighborhood of one of the audio tubes of the set to produce a periodic change in the velocity of the electrons travelling to the plate and thus neutralize the major portion of the double-frequency variation normally produced in the plate circuit of the tube 13. This alternating field is preferably produced by a coil 46 surrounding one of the audio tubes of the set. The phase and magnitude of this alternating field can be regulated by a potentiometer 47 and a variable-voltage iron-core transformer 48 connected to the alternating-current supply and preferably to the same circuit supplying the heating current for the tubes.

The voltage across the secondary of the transformer 48 is approximately 90° out of phase with the voltage drop across the resistance 47. A proper combination of these voltages enables one to choose the desirable phase relation of the current flowing through the neutralizing coil 46 to neutralize the hum-current component in the tube.

By way of example, and not to be considered limited thereto, the coil 46 is one of the tests consisted of several hundred turns of No. 18 wire surrounding the power amplifier in one of the prominent commercial radio receiving sets. This test proved that the major portion of the hum was eliminated by the neutralizing effect of the coil 46.

It is evident that means of applying the field to the tube and of shifting the phase of the field may be employed otherwise than that shown. In some cases, it might be advantageous to apply the field to one of the audio tubes preceding the power-output tube if more than one tube should be used in the audio stage.

It is also possible that better results might be obtained, in some cases, by designing the set to produce a larger double-frequency alternating component than is now the case in order that it

may be more completely neutralized by the neutralizing device applied to the last audio stage. It is apparent that, with this neutralizing device, the various parts of the set do not have to be so carefully designed and assembled or made out of such expensive material, to minimize this double-frequency alternating component because this component will be neutralized before the output is reached.

It is also apparent that the invention, although described as applied to a radio receiving set, is not limited to such application but may also be applied to other apparatus using tube structure in which a hum is produced by alternating current.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim is my invention:

1. An apparatus having a plurality of electron tubes, alternating-current connections for supplying power to the cathodes of said tubes, and means for neutralizing a substantial portion of the hum normally produced in the output supply of said apparatus by the alternating current, said means including a coil surrounding one of said tubes.

2. An apparatus having a plurality of tubes, an anode and a cathode in said tubes, alternating-current connections for supplying heating current to the cathodes of said tubes, and a coil connected to said alternating current connections surrounding one of said tubes for neutralizing substantially the major portion of the double frequency hum produced in said tube by the use of alternating current.

3. An apparatus having a plurality of tubes, an anode and a cathode in said tubes, an alternating-current source for supplying heating current to the cathodes of said tubes, and conductors connected to said alternating-current source positioned outside one of said tubes to set up a magnetic field which crosses the space between the anode and the cathode of said one tube for neutralizing substantially the major portion of the double-frequency hum produced in said tube by the use of alternating current.

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