Feb. 14, 1933. R. A. BRADEN 1,897,231

ANTENNA COUPLING CIRCUIT

Filed March 2, 1931

Fig. 3

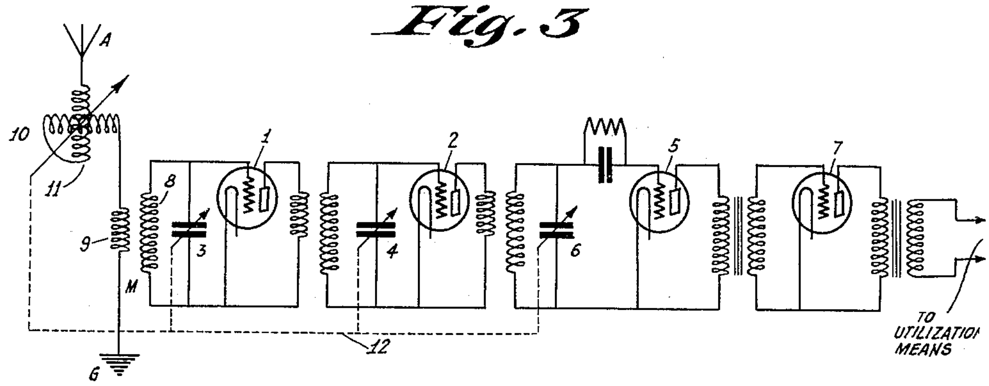


Fig. 4

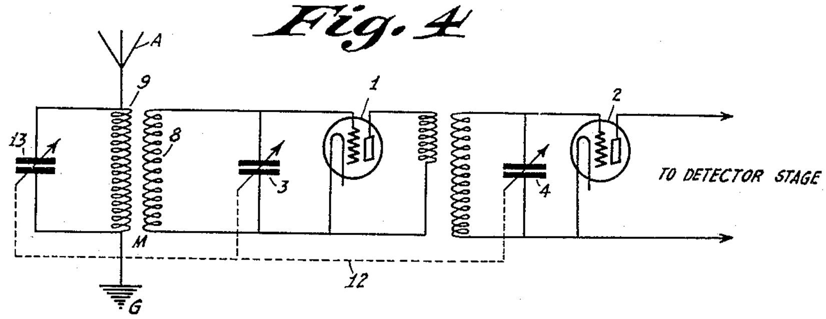


Fig. 1

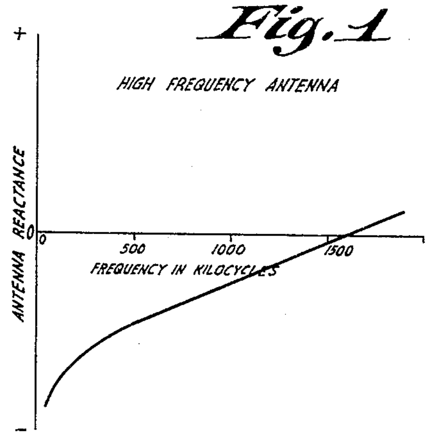
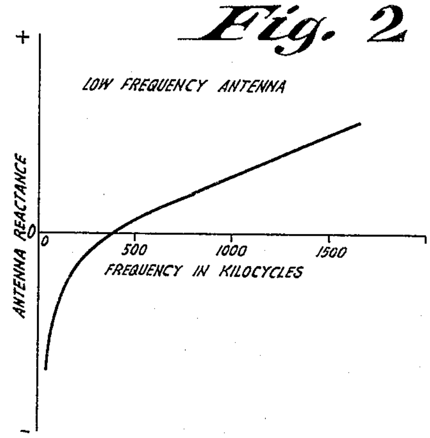


Fig. 2



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Patented Feb. 14, 1933 1,897,231

UNITED STATES PATENT OFFICE

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ANTENNA COUPLING CIRCUIT

Application filed March 2, 1931. Serial No. 519,504.

My present invention relates to high frequency receiving systems, and more particularly to antenna coupling circuits utilized in broadcast receivers.

Antenna coupling circuits used in broadcast receivers are of two general types. In one type, the antenna is tuned to a frequency higher than 1500 kilocycles, and, in the other, the antenna is tuned to a frequency lower than 550 kilocycles. The first, or high frequency antenna circuit, is efficient only at high frequencies, and the second, or low frequency antenna circuit is efficient only at low frequencies. The reason for this is the variation of reactance with frequency, and the resultant change from the optimum coupling condition. If an antenna is resonant to a high frequency, its reactance, at all lower frequencies, will in an approximately linear manner become more negative. On the other hand, the converse is true of an antenna resonant at a low frequency.

Whatever the antenna reactance may be there is a certain optimum coupling to the first tuned circuit which gives the greatest signal strength. Closer coupling than the optimum value reduces both signal strength and selectivity. Looser coupling causes loss of signal strength, and a slight increase in selectivity. If the antenna reactance is low, the optimum coupling is secured with a small value of mutual inductance. If the antenna reactance is high, the greatest obtainable amount of mutual inductance may be insufficient to give optimum coupling.

Specifically, if the antenna were tuned above 1500 kilocycles the best results would be secured if the coupling to the following tuned circuit were loose when receiving signals in the neighborhood of 1500 kilocycles, and gradually became closer as the tuning was varied to receive signals of lower frequency. But, in order to tune the antenna to a frequency higher than 1500 kilocycles, the amount of series inductance i. e., the coupling coil, must be kept small; this limits the obtainable coupling to a very small amount, which, at 550 kilocycles, is only a small fraction of the optimum coupling. If the coupling coil is increased in size, and a series condenser is inserted to keep the resonant frequency of the antenna from changing, the antenna reactance at low frequencies is proportionately higher, and the obtainable coupling is no closer to the optimum value than before.

Now, I have discovered a method of, and devised novel arrangements for, eliminating the difficulty described above, and to get efficient energy transfer from the antenna to the receiver at all wave frequencies, it being proposed as the main object of the present invention to tune the antenna to a frequency close to that to which the receiver is tuned, either higher or lower, but preferably higher; to adjust the coupling so that it approaches as close to the optimum condition as is desired; and, then, to cause the antenna tuning to vary in such a way, as the receiver is tuned to higher or lower frequencies, that the optimum coupling value remains substantially constant.

Another object of the present invention is to provide a broadcast receiver provided with a frequency selecting means, and additional means, adapted to be simultaneously actuated with said selecting means and to be connected to an antenna circuit, for tuning said latter circuit to a different frequency than said receiver.

Still other objects of the invention are to improve generally the efficiency of broadcast receivers, and to particularly provide, in such a receiver, an arrangement for coupling an antenna to the receiver which is reliable in operation, and economically assembled in the receiver.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing,

Fig. 1 graphically shows the operation of a high frequency antenna,

Fig. 2 graphically shows the operation of a low frequency antenna,

Fig. 3 diagrammatically shows a receiver circuit embodying the invention,

Fig. 4 diagrammatically shows a circuit embodying a modified form of the invention.

Referring to the accompanying drawing in which like characters of reference indicate the same elements in the different figures, there is shown in Fig. 1 the effect of maintaining an antenna circuit tuned to a high frequency, for example above 1500 kilocycles. It will be observed that the reactance of the antenna is essentially capacitative, and that the antenna is efficient only at the high frequencies, since its reactance is too high at lower frequencies.

In Fig. 2 there is shown graphically the effect of maintaining an antenna circuit tuned to a relatively low frequency, for example below 550 kilocycles. In this case, it will be noted that the reactance of the antenna circuit is essentially inductive, and the antenna is efficient only at the low frequencies, because its reactance is too high at high frequencies to permit efficient operation with the same coupling that works well at low frequencies. Obviously due to the variation of reactance with frequency, as demonstrated in Figs. 1 and 2, maintenance of the optimum coupling condition between the antenna circuit and the first tuned circuit to which the antenna is coupled, must necessarily involve changes in the coupling with changes in frequency transmitted through the coupling.

In the present invention, it is a main object to maintain coupled antenna and receiver circuits at the optimum coupling value, or at a desired coupling less than the optimum but in a definite ratio thereto. This object is attained, not in the usual manner, by adjusting the coupling, but by adjusting the antenna, as the receiver is tuned, in such a way that the optimum coupling value is equal to the actually existing coupling, or has a definite ratio thereto, this being preferably accomplished without physically disturbing the coupling elements between the antenna and the first tuned circuit.

In Fig. 3 there is diagrammatically shown a receiver circuit of the well known tuned radio frequency type, which embodies a plurality of electron discharge tubes 1, 2 each of the tubes having a tunable input circuit, the input circuits being tuned by variable condensers 3, 4. The output circuit of each tube is coupled in cascade, in a manner well known to those skilled in the art, to the tuned input circuit of a succeeding tube. The output circuit of the tube 2 is coupled to the tunable input circuit of a tube 5, connected for detection in the well known manner, and having its input circuit tuned by a variable condenser 6. The output circuit of the detector tube 5 is coupled in the conventional manner to one, or more, stages of audio frequency amplification 7, only one stage being shown for the sake of simplicity. The amplified audio output is coupled in the usual manner to any desired type of utilization means, such as a loud speaker and the like.

The secondary inductance coil 8, connected across the variable condenser 3 in the tuned input circuit of the first radio frequency amplifier 1, is coupled, as at M, to the primary inductance coil 9 connected in the antenna circuit A, grounded as at G. A variometer 10 is connected in series with the primary coil 9 in the antenna circuit, and the variometer rotor 11 is mechanically coupled for simultaneous movement with the rotors of the variable condensers 3, 4 and 6. This mechanical coupling may be arranged in any well known and desirable manner, and is accordingly, conventionally represented by the arrows connecting dotted line 12, the latter functioning as a common tuning and coupling control.

As explained heretofore, by means of the variable inductance in series with the antenna and the coupling coil 9, it is possible to maintain a substantially constant optimum coupling value between the coils 9 and 8 during tuning throughout the broadcast range. This is accomplished, in the circuit shown in Fig. 3, by tuning the antenna to a frequency close to that to which the receiver circuits 3, 4 and 6 are tuned, either higher or lower, but preferably higher; adjusting the coupling so that it approaches as close to the optimum value of M as is desired; and, then, designing the variometer 10 in such a manner that the antenna tuning is at all times higher (or lower), and different from the frequency to which the circuits including the variable condensers 3, 4 and 6 are tuned.

Specifically, the antenna circuit might be tuned to 1650 kilocycles when the receiver circuits 3, 4 and 6 are tuned to 1500 kilocycles; to 1100 kilocycles when the receiver circuits are tuned to 1000 kilocycles; and to 605 kilocycles when the receiver circuits are tuned to 550 kilocycles, it being observed that these figures are given for illustration only, and are not necessarily representative of a preferred construction.

The desired optimum coupling value remains substantially constant, by means of the aforementioned design, for the reason that the amount of coupling which must be used to obtain the greatest current in the tuned circuit (which is, of course, the optimum coupling) depends on both the frequency and the antenna reactance; and the effect of varying the frequency is compensated by varying the antenna reactance. The optimum coupling is given by the equation:

$$(1) \quad \omega M = Z_1\sqrt{R_1/R_2}$$

where $\omega = 2\pi \times$ frequency.

M = mutual inductance between antenna and first tuned circuit

Z_1 = antenna reactance ($=R_1+{}_jX_1$)

R_1 = antenna resistance

R_2 = resistance of tuned circuit.

This equation may be rewritten as:

$$(2) \quad M = Z_1/\omega\sqrt{R_1/R_2}.$$

Now if R_1/R_2 is considered to be constant (which is not far from the truth), the optimum coupling M will be constant if the ratio Z_1/ω is constant. Under the specified condition, that the antenna is tuned to a frequency either higher or lower than the frequency of the tuned circuit, (and therefore higher or lower than the signal frequency), the resistance R_1 will be small compared with the reactance X_1, and therefore, we may write as a good approximation

$$(3) \quad M = X_1/\omega\sqrt{R_1/R_2}.$$

It is now evident that to maintain optimum coupling (or a desired coupling smaller than optimum), it is only necessary to control the antenna reactance so that

$$\frac{X_1}{\omega}$$

is constant.

A modified form of the invention is shown in Fig. 4 wherein the antenna circuit A, 9 and G, is tuned by a variable condenser 13 shunted across the coupling coil 9. The rotor of the condenser 13 is mechanically connected for simultaneous variation with the rotors of the variable condensers 3, 4 and the variable condenser 6 of the detector stage 5, not shown in order to preserve simplicity. It is to be understood that the arrows and dotted line 12, in Fig. 4, will be any desired type of mechanical adjusting means, well known to those skilled in the art, whereby a common tuning and coupling control means is provided.

It is to be understood, furthermore, that the variable series inductance in Fig. 3, and the variable shunt capacity in Fig. 4 are shown by way of example only, to illustrate two methods of adjusting the reactance of an antenna and that variable capacities either in series or shunt, or both, or variable inductances in series or shunt, or both, or combinations of variable capacities and variable inductances, could be used.

Again, the antenna circuit in each of Figs. 3 and 4 is tuned to a frequency different from, and higher than, (or lower than) the frequency to which the succeeding receiving circuits are tuned, utilizing in the case of Fig. 4 any arrangement in the prior art wherein the tuning condenser 13 has its rotor mounted for common mechanical movement with the rotors of the condensers of the succeeding stages and so proportioned relative to the latter that the desired frequency difference is secured. The rotor on the shaft could be turned, or offset, with respect to the other tuning condensers. It would also be possible to use more or fewer plates on the antenna condenser; to make the total inductance at the antenna circuit different from that in the amplifier stages; or to cut the plates of the antenna condenser to a special shape to produce the required frequency difference. A similar arrangement can be adopted in the case of Fig. 3, the variometer rotor in such case being designed to secure the same results.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications in the circuit arrangements, as well as in the apparatus employed may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. A method of efficiently transferring energy from an antenna circuit to a receiver circuit at all frequencies in a receiver frequency range, which consists in tuning the receiver to a desired frequency, adjusting the coupling between the antenna and receiver to substantially the optimum value desired, and causing the antenna tuning to vary simultaneously with the receiver tuning through a frequency range different from the said receiver range in such a manner that the said coupling value remains substantially constant.

2. A method of efficiently transferring energy from an antenna circuit to a receiver circuit at all frequencies in a receiver frequency range, which consists in tuning the receiver to a desired frequency, adjusting the coupling between the antenna and receiver to substantially the optimum value desired, and causing the antenna tuning to vary simultaneously with the receiver tuning through a frequency range higher than the receiver range in such a manner that the optimum coupling value remains substantially constant.

3. The method of maintaining the coupling between an antenna circuit and a tuned receiving circuit at a substantially constant optimum value throughout a desired signal fre-

quency range which consists in tuning the receiving circuit through said frequency range, and simultaneously tuning said antenna circuit through a frequency range differing at all points from said signal range by an amount such that the antenna reactance bears a constant ratio at all of said points to the antenna frequency.

4. The method of maintaining the coupling between an antenna circuit and a tuned receiving circuit at a substantially constant optimum value throughout a desired signal frequency range which consists in tuning the receiving circuit through said frequency range, and simultaneously tuning said antenna circuit through a higher frequency range differing at all points from said signal range by an amount such that the antenna reactance bears a constant ratio at all of said points to the antenna frequency.

5. The method of maintaining the coupling between an antenna circuit and a tuned receiving circuit at a substantially constant optimum value throughout a desired signal frequency range which consists in tuning the receiving circuit through said frequency range, and simultaneously tuning said antenna circuit through a lower frequency range differing at all points from said signal range by an amount such that the antenna reactance bears a constant ratio at all of said points to the antenna frequency.

6. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a desired frequency range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

7. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, a succeeding tunable oscillation circuit, means for coupling said oscillatory circuit and tunable circuit, means for tuning said tunable circuit through a desired frequency range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

8. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a broadcast range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the broadcast range, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

9. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a frequency range of the order of 550 to 1500 kilocycles, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range of the order of 605 to 1650 kilocycles.

10. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a desired frequency range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, said resonating means comprising an adjustable reactor arranged for mechanical uni-control with said common tuning means, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

11. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a desired frequency range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, said resonating means comprising an adjustable condenser arranged for mechanical uni-control with said common tuning means, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

12. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, at least two succeeding tunable oscillation circuits, means for coupling said oscillatory circuit and one of the tunable circuits, an electron discharge tube coupling said tunable circuits, a common means for simultaneously tuning said two tunable circuits through a desired frequency range, and means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, said resonating means comprising an adjustable inductor arranged for mechanical uni-control with said common tuning means, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range.

13. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, a succeeding tunable oscillation circuit, means for coupling said oscillatory circuit and tunable circuit, means for tuning said tunable circuit through a desired frequency range, means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range, the coupling means comprising a transformer, and said resonating means consisting of an adjustable reactance in series with the transformer primary.

14. A radio receiver comprising an oscillatory circuit providing a source of modulated radio frequency energy, a succeeding tunable oscillation circuit, means for coupling said oscillatory circuit and tunable circuit, means for tuning said tunable circuit through a desired frequency range, means, in said oscillatory circuit, for simultaneously resonating the latter through a frequency range differing from the desired range, the relation between said ranges being such that the electrical value of said coupling means is substantially a constant throughout said desired range, said coupling means comprising a transformer, and said resonating means consisting of an adjustable condenser in shunt with the transformer primary.

15. A method of transferring signal energy of the broadcast range from an antenna to the tunable input circuit of a radio frequency amplifier consisting in resonating the antenna through a frequency range differing from the broadcast range, but substantially overlapping the latter in a manner such that said energy is efficiently transferred.

16. A method of transferring signal energy of the broadcast range from an antenna to the tunable input circuit of a radio frequency amplifier consisting in resonating the antenna through a frequency range higher than the broadcast range, but substantially overlapping the latter in a manner such that said energy is efficiently transferred.

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