April 21, 1942. R. A. WEAGANT 2,280,562

TUNABLE NONDIRECTIVE LOOP CIRCUITS

Filed July 2, 1940

Fig. 1

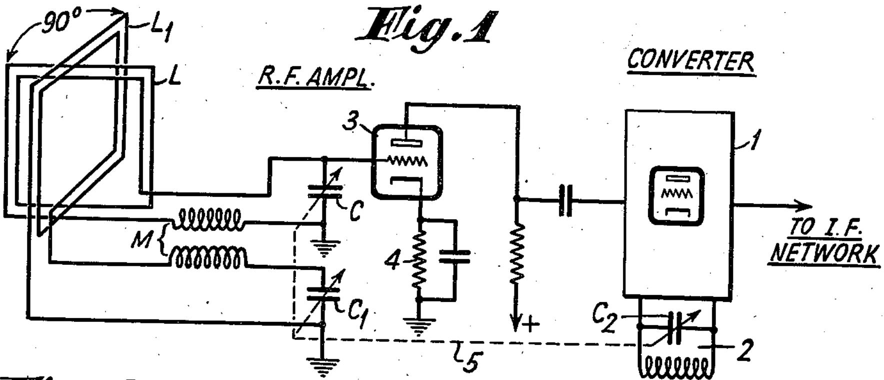



Fig. 2

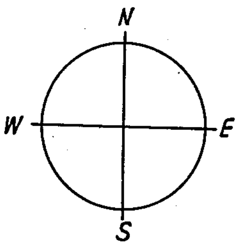



Fig. 3

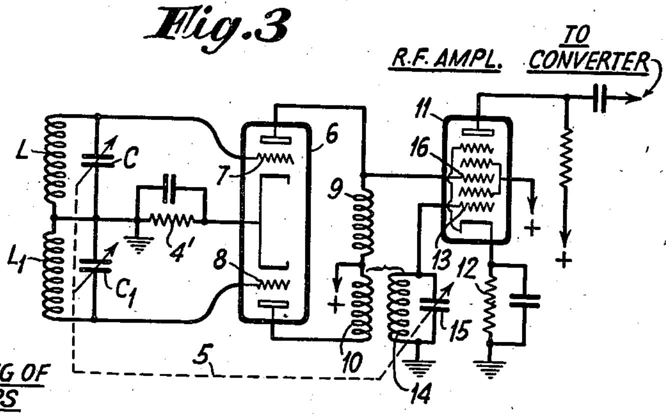



Fig. 5

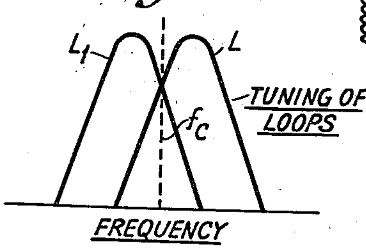



Fig. 4

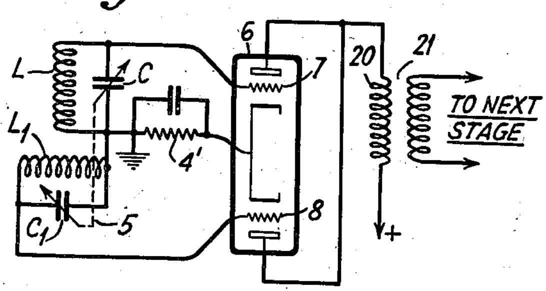
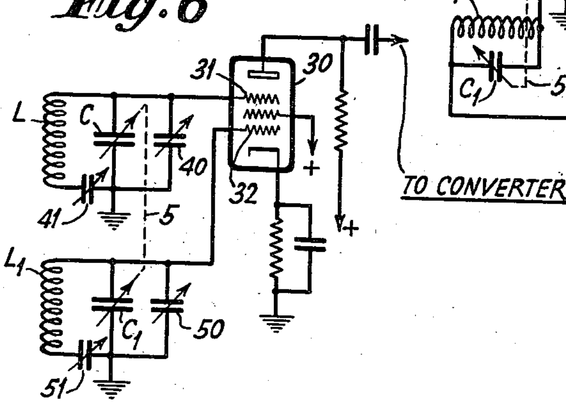



Fig. 6

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# UNITED STATES PATENT OFFICE

2,280,562

## TUNABLE NONDIRECTIVE LOOP CIRCUITS

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Application July 2, 1940, Serial No. 343,539

5 Claims. (Cl. 250—20)

My present invention relates to radio receivers provided with tunable loop antenna circuits, and more particularly to tunable loop antennae having non-directive characteristics.

Radio receivers of the standard broadcast type often utilize tunable loop antennae because of the compactness of the system, and the elimination of an external aerial. However, the usual type of loop antenna is directive, and possesses a figure of eight characteristic. Hence, the set operator is confused when tuning to a station which lies in a direction such that little response is had from the receiver. Further, when the receiver is of the portable type, a loop antenna causes substantial variation in receiver output as the receiver is moved from place to place. Various expedients have been tried to overcome, or compensate for, the directive effect of the loop antenna.

One of the main objects of my present invention is to provide a signal receiving system which utilizes at least two tunable loop antennae which are so related that the system has a non-directive signal pick-up characteristic.

Another important object of my invention is to provide a radio receiver having a signal collection network which is omnidirectional, and which includes at least a pair of tunable loop circuits so constructed and arranged as to feed signals to a common utilization circuit in phase quadrature relation.

Still other objects of my invention are to improve generally the simplicity and efficiency of receivers equipped with loop antennae, and more especially to provide a loop receiver which is economically manufactured and assembled.

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 shows a circuit embodying one form of the invention,

Fig. 2 illustrates the omni-directional characteristic of the loop circuit,

Fig. 3 shows a modification,

Fig. 4 illustrates a further modification,

Fig. 5 shows the resonance curves of the loop circuit in Fig. 4,

Fig. 6 shows a modification of the arrangement in Fig. 4.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 a signal receiver, say of the standard broadcast type operating over a range of 550 to 1700 kilocycles (kc.). The receiver may be of the superheterodyne type, and, in that case, has a converter stage which is fed with broadcast signals and locally-produced oscillations. The latter are provided by a separate local oscillator, or they may be provided by the oscillator section of a combined local oscillator-first detector tube. The numeral **2** denotes the tunable tank circuit of the oscillator. The signals are fed to the signal grid of the mixer tube through a network comprising a radio frequency amplifier tube **3**. Tube **3** has its plate coupled to the signal grid of the mixer tube by resistance and capacity.

The cathode of tube **3** is connected to ground through the self-biasing resistor **4** properly bypassed for signal frequency currents. The signals are collected by a pair of loops L and $L_1$ arranged at right angles with respect to a common vertical axis, the latter being shown as a dotted line. In other words, the planes of the two fixed loops L and $L_1$ are mutually perpendicular.

The coil L is connected in shunt with the variable tuning condenser C, while the loop $L_1$ is in shunt with tuning condenser $C_1$. The low potential sides of condensers C and $C_1$ are at ground potential. Mutual coupling M is provided between the two loops. The high potential side of condenser C is connected to the signal input grid of tube **3**. A common mechanical adjusting device **5**, shown as a dotted line, may be employed for adjusting in unison the rotors of condensers C, $C_1$ and condenser $C_2$. The frequency range of circuit **2** will differ from that of the signal frequency range by the operating intermediate frequency (I. F.) value. Of course, loops L and $L_1$ will be tuned to a common signal carrier frequency. The reactive coupling M is relatively loose, and, therefore, current in LC due to loop $L_1$ is in quadrature with current in LC due to signals picked up by loop L. The magnitudes of the loops should be so related that the potential induced in L by $L_1$ is equal to that produced by signals in loop L. The two currents applied to tube **3**, and due to the loops L and $L_1$, never oppose. It can be demonstrated by a rigorous mathematical analysis (which need not be included herein) that the signal current applied to the input electrodes of tube **3** is equal to the signal voltage picked up by either loop divided by the sum of the resistances of the loop circuits. It is assumed that the signal voltage pick-ups of the loops are equal, and that the resistances thereof are also equal.

Fig. 2 shows the type of antenna characteristic possessed by the signal collector network of Fig. 1. It will be observed that the system is omni-directional. Equal signal voltages are induced in the loops, and transmitted to the input electrodes of tube **3**, regardless of the orientation of the receiver collector network. Hence, the set may be shifted from place to place, or signals may be tuned in from any direction of the compass, and no variation in signal pick-up will occur.

In the system of Fig. 3 the phase quadrature relation between the signal voltages collected by the two loops is produced in a different manner. In this case, it will be understood that coils L and $L_1$ represent the two loop antennae arranged as shown in Fig. 1, and are located in mutually perpendicular fashion. The junction of the coils is grounded, while condensers C and $C_1$ are arranged in shunt with each of coils L and $L_1$, respectively. A twin triode tube **6** is provided, although two separate tubes may be used in place thereof. The signal grid **7** of one of the triodes of tube **6** is connected to the ungrounded side of condenser C, while the signal grid **8** is connected to the ungrounded side of condenser $C_1$.

The cathodes of both triodes are connected in common through a biasing resistor **4'** to ground, the resistor being appropriately bypassed for signal frequency currents. The plates of the triodes of tube **6** are connected in series through a coil **9** and a coil **10**, the junction of the two coils being connected to a source of positive potential. The following tube **11** is the radio frequency amplifying tube, and it may be a tube of the penta-grid type such as the 6L7. The cathode thereof is connected to ground through a self-biasing network **12**, while the first grid **13** thereof is connected to ground through coil **14** of a tunable signal circuit. The latter includes a variable tuning condenser **15**. Coils **10** and **14** are magnetically coupled. The third grid **16** of tube **11** is connected to the plate end of coil **9**, and the positive screen grids surround grid **16**. The plate of tube **11** is resistance-capacity coupled to a converter in the manner shown in Fig. 1. The dotted line **5** denotes the uni-control adjusting mechanism for the rotors of the tuning condensers C, $C_1$ and **15**.

The following explanation is given in connection with this circuit arrangement to demonstrate that the characteristic of Fig. 2 will be secured with the circuit of Fig. 3. The potential induced in coil **14** is in the same or opposite phase as that across coil **10**. The current flowing through circuit **14**—**15** is in phase with the potential induced across coil **14**. Therefore, the potential applied to grid **13** is in quadrature with the potential across coil **10**. Furthermore, the potential produced across coil **9** due to the loop L, and the potential produced across coil **14** due to the loop $L_1$ are in quadrature. Proper adjustments of coil **9** and the reactive coupling between coils **10** and **14** will give equal amplitude in the output of tube **11** for equal input potentials to the grids of tube **6**. In other words, regardless of the orientation of the signal collector network, there will be fed to the converter network signal voltage of substantially uniform amplitude. It will, therefore, be seen that the arrangement of Fig. 3 differs from that of Fig. 1 in that the two loops supply equal signal voltages to a push-pull amplifier stage, and that the latter furnishes to a pair of spaced control electrodes of an amplifier tube signal voltages in phase quadrature. Hence, the coupling network between tubes **6** and **11** in Fig. 3 provides the phase quadrature relation which is produced by the reactive coupling M in Fig. 1.

In Fig. 4 there is shown still another mode of securing the phase displacement of 90 degrees between the signal voltages collected by the two loops. In this case, the tube **6** of Fig. 4 has the same input network as in the case of Fig. 3. The plates of the tube are connected in common to a source of positive potential through the primary winding **20** of the radio frequency transformer **21**. The secondary winding may be coupled to the input electrodes of a following stage, which may be the signal input network of the converter stage. The arrangement in Fig. 4 differs from that in Fig. 3 in so far as the tuning of each of the loops is concerned.

In Fig. 5 there is graphically shown the manner of tuning the two loops in the arrangement of Fig. 4. Assuming a mean frequency ($f_c$), then each of the loops is detuned by an equal frequency amount from the center, or mean, frequency. That is to say, the variable condenser C will adjust the tuning of loop L through a given frequency range. The condenser $C_1$ will vary the loop $L_1$ through a second frequency range. The condensers C and $C_1$ may be relatively constructed so that as the common adjusting control **5** is varied to select different signal frequencies, each loop will constantly differ in frequency from the other loop by the same frequency amount, but the mean frequency between the two spaced loop frequencies will be a desired mean signal frequency ($f_c$). This results in a phase displacement of the signal voltages applied to grids **7** and **8**, and by properly detuning the loops in opposite senses the phase displacement can be made to assume a quadrature relation. With such a quadrature relation between the signal voltages applied to grids **7** and **8** there will be secured the omni-directional characteristic of Fig. 2.

Fig. 6 shows a modification of the arrangement of Fig. 4 wherein in place of two separate space discharge devices there is utilized a tube **30** whose grids **31** and **32** have the signal voltages in phase quadrature applied thereto. Furthermore, there is shown the manner in which variable condensers C and $C_1$ may be made exactly similar, and yet tune their respective loops L and $L_1$ so as to secure the opposite mistuning shown in Fig. 5. In other words, whereas in Fig. 4 the variable condensers C and $C_1$ would require relative shaping of their rotors so as to maintain a constant difference frequency between two loop circuits over the entire broadcast range, in Fig. 6 the variable condensers may be constructed alike. Each of the loop circuits are provided with series and shunt padder condensers which may be adjusted to provide the constant frequency difference between the loop circuits over the entire tuning range of the receiver.

This manner of securing constant frequency difference between a pair of tuned circuits is well known to those skilled in the art, and it is not believed necessary to provide any further explanation other than to point out that shunt condenser **40** and series condenser **41**, as well as shunt condensers **50** and series condenser **51**, may be inserted in their respective loop circuits. Once they are relatively adjusted they will enable the loop circuits to be equally and oppositely mistuned with respect to the mean frequencies of the tuning range. As pointed out in connection with Fig. 4, there will be produced in the common plate circuit of tube **30** a signal voltage which is of the same amplitude regardless of the orientation of the loops L and $L_1$. In this arrangement the signal voltages applied to grids **31** and **32**, and derived from loops L and $L_1$, will be in phase quadrature relation.

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 may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination with an electron discharge tube provided with at least a cathode, a control electrode and an output electrode, a pair of loop antennae, of equal resistance magnitude and equal signal voltage pick-up, whose planes are arranged in mutually perpendicular manner, means associated with each antenna for tuning it to a desired signal frequency, means reactively coupling said loops sufficiently loosely whereby signal current induced in one of the tuned loop antennae circuits by the second loop antenna is in quadrature with signal current induced in the said one loop circuit by signals directly collected by said one loop antenna, and means for applying the signal voltage developed across one of said loops between the control electrode and cathode of said tube.

2. In combination with an electron discharge tube provided with at least a cathode, a control electrode and an output electrode, a pair of loop antennae of equal resistance magnitude and equal signal voltage pick-up, whose planes are arranged in mutually perpendicular manner, means associated with each antenna for tuning it to a desired signal frequency, means reactively coupling said loops sufficiently loosely whereby signal current induced in one of the tuned loop antennae circuits by the second loop antenna is in quadrature with signal current induced in the said one loop circuit by signals directly collected by said one loop antenna, and means for applying the signal voltage developed across one of said loops between the control electrode and cathode of said tube, and said reactive coupling being so chosen that the signal voltage applied between said control electrode and cathode is substantially uniform at a desired signal frequency throughout the orientation of said loops.

3. In combination with an electron discharge tube provided with at least a cathode, a control electrode and an output electrode, a pair of loop antennae, of equal resistance magnitude and equal signal voltage pick-up, whose planes are arranged in mutually perpendicular manner, means associated with each antenna for tuning it to a desired signal frequency, means reactively coupling said loops sufficiently loosely whereby signal current induced in one of the tuned loop antennae circuits by the second loop antenna is in quadrature with signal current induced in the said one loop circuit by signals directly collected by said one loop antenna, and means for applying the signal voltage developed across one of said loops between the control electrode and cathode of said tube, and said reactive coupling being so relatively loose whereby the signal voltage impressed between said control electrode and cathode is independent of the orientation of said loops.

4. In combination with an electron discharge tube provided with at least a cathode, a control grid and a plate, at least two loop antennae, of equal resistance magnitude and equal signal voltage pick-up, arranged in mutually perpendicular manner, means for tuning each antenna to a common signal carrier frequency, means reactively coupling said loops sufficiently loosely whereby signal current induced in one of the tuned loop antennae circuits by the second loop antenna is in quadrature with signal current induced in the said one loop circuit by signals directly collected by said one loop antenna, and means for applying the signal voltage developed across one of said loops between the grid and cathode of said tube.

5. In combination with an electron discharge tube provided with at least a cathode, a control grid and a plate, at least two loop antennae, of equal resistance magnitude and equal signal voltage pick-up, arranged in mutually perpendicular manner, means for tuning each antenna to a common signal carrier frequency, means reactively coupling said loops sufficiently loosely whereby signal current induced in one of the tuned loop antennae circuits by the second loop antenna is in quadrature with signal current induced in the said one loop circuit by signals directly collected by said one loop antenna, and means for applying the signal voltage developed across one of said loops between the grid and cathode of said tube, and said coupling being inductive and being so chosen that the signal voltage applied between said grid and cathode is substantially uniform at a desired signal frequency over 360 degrees orientation of said loops.

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