Feb. 22, 1944. J. A. RANKIN 2,342,491

TUNABLE LOOP ANTENNA CIRCUIT

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Fig. 1.

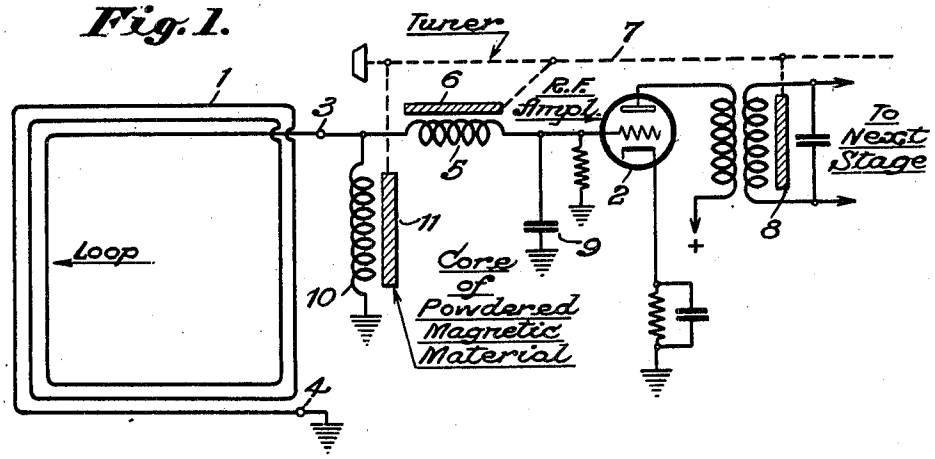


Fig. 2.

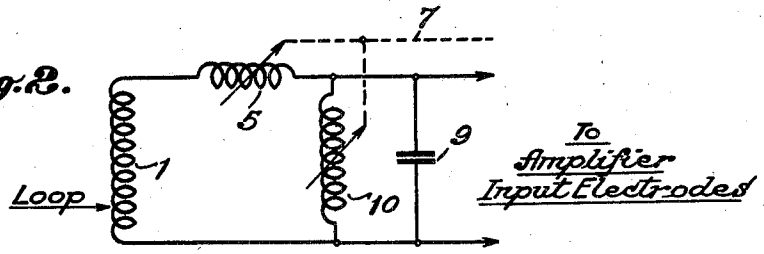


Fig. 3.

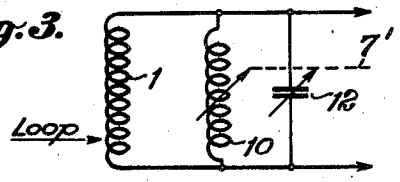
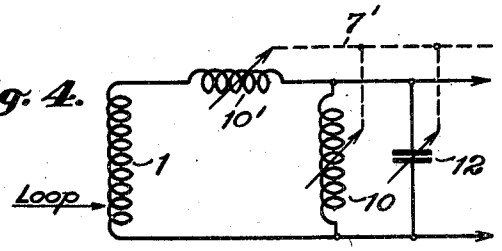


Fig. 4.



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Fig. 5.

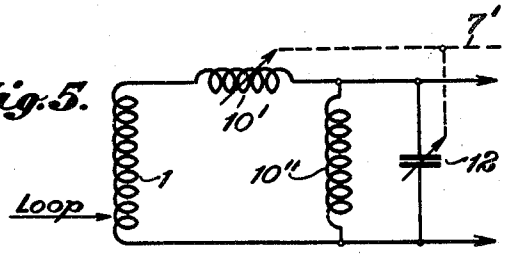


Fig. 6.

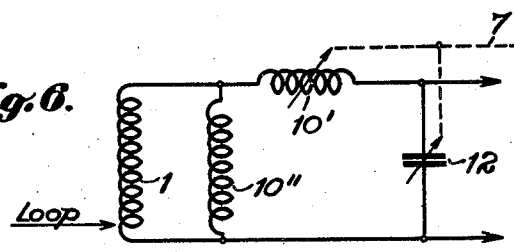


Fig. 7.

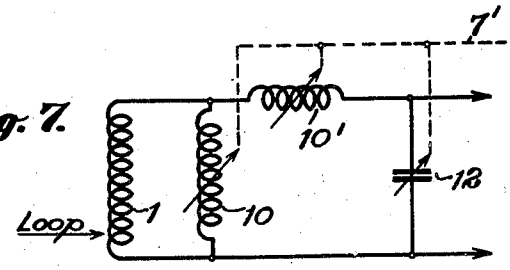
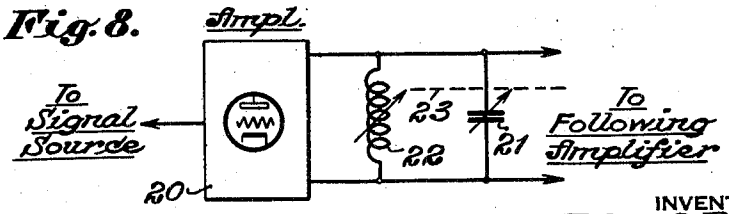


Fig. 8.



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TUNABLE LOOP ANTENNA CIRCUITS

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Application August 28, 1941, Serial No. 408,601

9 Claims. (Cl. 250—40)

My present invention relates to tunable loop antenna circuits, and more particularly to improved tuning arrangements for loop antennae.

As is well known, the inductance of a loop antenna depends upon the area enclosed by the loop, the wire thereof and the number of turns. To secure maximum performance in a loop antenna, that is, to secure maximum signal voltage pick-up, the "effective height" of the loop and "Q" should be high. The effective height may be increased by increasing the area bounded by the loop turns, or the number of turns of wire on the loop may be increased. Of course, both of these expedients may be employed. Either of these expedients increases the loop inductance, and hence, makes it difficult to tune the loop over a desired frequency range. Further, the inherent distributed capacity is increased by these expedients, and this also tends to reduce the tuning range when tuning is accomplished by a variable tuning condenser. In the case of broadcast receivers operating over a frequency range of 530 to 1700 kilocycles (kc.), it becomes difficult to use a loop antenna of sufficient inductance to give substantially maximum signal voltage pick-up and yet employ either inductance, or condenser, tuning over the required frequency range.

Accordingly, it is one of the main objects of my present invention to provide a loop antenna circuit which is maximized as to inductance thereby to approximate ideal signal voltage pick-up conditions, and simultaneously to provide a tuning means for the circuit which is adapted to cover a desired frequency range which in the absence of the invention is unattainable with the aforesaid maximum inductance value.

Another important object of my invention is to improve the tuning range of the loop antenna circuit of a broadcast receiver while maintaining maximized inductance in the loop circuit; there being utilized an auxiliary inductance element in circuit with the loop and tuning reactance to insure the aforesaid characteristics.

Another object of my invention is to provide a tunable loop antenna circuit for a broadcast receiver, operating in a range of 530 to 1700 kc., wherein the tuning element is a variable permeability tuner in series with the loop; there being arranged in shunt relation to the loop an adjustable inductance element which is variable in magnitude with the tuner variation, thereby to maintain maximized inductance in the loop without reduction of said frequency range.

Another object of my invention is to provide a loop antenna adapted to be varied in tuning by a variable condenser arranged in shunt relation to the loop; there being utilized in association with the loop and variable condenser an adjustable inductance element which is varied concurrently with the variable condenser, thereby to maintain maximum loop inductance over a predetermined frequency range.

Still other objects of the invention are to improve generally the efficiency of tunable loop antenna circuits, and more especially to provide loop circuits for broadcast receivers which are reliable in operation and 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 drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Figure 1 shows a circuit diagram of a tunable loop antenna embodying the invention,

Figure 2 schematically shows a modification,

Figures 3 to 7, inclusive, show further modifications,

Figure 8 shows the invention applied to a tunable amplifier circuit.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, the numeral 1 in Figure 1 designates a loop antenna of a predetermined area and turns of wire. Since the manner of constructing such loops is well known to those skilled in the art, it is merely necessary to point out that in broadcast receivers operating in the 530 to 1700 kc. band such loops are used as antennae. Considering the tube 2 to be the first signal amplifier, the high potential terminal 3 of the loop is usually connected to the signal grid through the coil 5, assuming that a so-called permeability tuner is used to vary the receiver tuning. Such a tuner, as is very well known at present, comprises an inductance coil having an adjustable core composed of comminuted magnetic material held together by a binder. The core 6 is adjusted in position by a mechanical device, shown as the dotted line 7, which concurrently adjusts the core 8 of the inductance tuner of the following tuned amplifier stage. Of course, all

the tunable circuits, where permeability tuning is used, have the cores thereof adjusted by the common mechanical mechanism 7.

The condenser 9, connected between the grid end of coil 5 and ground, resonates the coil 5 and loop 1 to the desired frequencies. Otherwise the circuit details of the amplifier 2 are shown as well known in the art. The terminal 4 is shown at ground potential. The auxiliary variable inductance 10, also of the adjustable comminuted, or powdered, magnetic material core type, has its core 11 arranged for mechanical adjustment by the mechanical control 7. The coil 10 is connected from terminal 3 to ground. That is to say, coil 10 is effectively in shunt with the loop 1, while coil 5 is in series therewith. It is understood, of course, that when cores 6 and 11 are entirely within the coils thereof, then the inductances 5 and 10 are maximum. When the cores are out of the coils, then the coil inductances are a minimum. This is true for all the coils whose cores are displaced by mechanism 7.

Assume, first, that coil 10 is out of the circuit. If the inductance of loop 1 is made high so as to have maximum signal voltage fed to the amplifier 2, it will be found that the tuning range of the input circuit of tube 2 will be substantially less than the 530 to 1700 kc. range desired. This is due to the fact that the inductance of loop 1 is in series with the inductance of coil 5, and, hence, the maximum to minimum inductance ratio of the circuit is much lower than that of coil 5 alone. The maximum to minimum inductance ratio of coil 5 should be of the order of 10:1 to cover a frequency range of the order of 3:1. It is found that using a high inductance loop in series with such a coil results in a reduction of the said 10:1 ratio to a value such that the frequency range is greatly reduced.

According to my invention the coil 10 is shunted across the loop so as to provide an effective inductance for loop 1 and coil 10 which is equal to the reciprocal of the sum of the reciprocals of L_1 and L_{10}. Hence, the effective inductance in series with tuner coil 5 is much less than the inductance of loop 1 at the different settings of tuner mechanism 7. Of course, the coil 10 may be constructed in any desired manner to secure any desired effect on the variation of the inductance of the tunable circuit. For example, the core 11 may be given various shapes, or the windings of coil 10 may be arranged to suit the designer's purposes. If the tuning range is 530 to 1700 kc., loop 1 may be designed to have maximum signal voltage pick-up such as would, in the absence of coil 10, greatly reduce the range. Coil 10 is constructed and arranged so as to have its inductance vary in the same sense as the inductance variation of coil 5; the rate of variation of the inductance of coil 10 will depend upon the various factors which have to be satisfied. Physical dimensions for loop 1, coil 5, coil 10 and condenser 9 are not given, because they are entirely dependent on the purposes to which the receiver is to be put. Design factors will usually limit the inductance of loop 1 to from 10 to 20 times the value that would be used in the absence of coil 10.

In order to present a clear picture of my invention, the following explanation and illustrative examples are given: Let it be assumed that coil 10 is removed from the circuit, and that the inductance of loop 1 is 15 microhenries (mh.). Further, let it be assumed that the tuning range is to be 3:1 in extent; for example, from 550 kc. to 1650 kc. If coil 5 has a minimum inductance of 120 mh. and a maximum inductance of 1200 mh., the maximum and minium of the entire circuit will be 1200 plus 15 for the maximum value, and 120 plus 15 for the minimum value. The ratio of 1215 mh. to 135 mh. equals 9:1. As the frequency range is equal to the square root of the inductance range, the resultant frequency range will be 3:1.

Now, if the loop inductance is increased to 150 mh., and the same coil is used at 5, the frequency range will be 1350 mh. divided by 270 mh. or $\sqrt{5:1}$. The resulting frequency range will then be reduced from 3:1, to $\sqrt{5:1}$, or 2.24:1. However, if coil 10 is included as a fixed inductance, the effective inductance looking into the circuit comprising loop 1 and coil 10 in shunt may be made to look like 15 mh., if coil 10 is given a value of 16.55 mh. This, however, results in a reduction in the voltage applied to the grid of tube 2. Hence, if coil 10 is made variable and with a higher inductance than 16.55 mh., the grid voltage obtained will likewise be greater. For example, coil 10 may be variable over a 10:1 range from 30 to 300 mh. The effective inductance looking into the loop and coil 10 in shunt will be 25 mh. when coil 10 has minimum inductance, and 100 mh. when coil 10 has its maximum inductance value.

This means that if coil 5 is made to have a minimum inductance of 110 mh. and a maximum inductance of 1100 mh. (10:1 range), the circuit minimum will be 135 mh. while the maximum inductance of the circuit will be 1200 mh. The range of inductance of the circuit will then be 1200 divided by 135 or 8.9, and the frequency range will be substantially 3:1. Had a slightly lower value of minimum inductance for coil 10 been used, the tuning range would have been exactly 3:1. The advantage here is that at the high frequency end of the range the variable coil 10 has approximately twice as much inductance as the equivalent fixed coil 10, and at the low end of the frequency range the ratio of improvement is nearly twenty times. The coil inductances required do not have a greater range (10:1), but the improvement in gain is substantial.

In Figure 2 there is shown a modification of the manner of connecting auxiliary coil 10 in the loop circuit. Here, the coil 10 is connected in a closed series circuit with loop 1 and tuner coil 5. This arrangement is not as preferable as the arrangement of Figure 1, because with this arrangement the maximum loop inductance will be limited in value, and, hence, the voltage transferred to the grid circuit will be less.

The invention is not restricted to use with a permeability tuner for loop 1. In Figure 3 the loop 1 is shown shunted by a variable condenser 12 to tune the loop circuit over the desired broadcast range of 530–1700 kc. In this case the inherent distributed capacity across loop 1, caused by increase of the inductance of the loop, shunts the tuning condenser 12. This tends to reduce the frequency range of the loop circuit. Hence, auxiliary coil 10 is shunted across the loop and tuning condenser, and the coil is constructed in the same manner as shown in Figure 1. The mechanical adjustment device 7' has the core of coil 10 coupled thereto so as to adjust the inductance of coil 10 in the same sense as the

variation of condenser 12. In this case the coil 10 tends to maintain the frequency range of the circuit. This is due to the fact that both the inductance and capacitance in the circuit are changed simultaneously. As the resonant frequency is proportional to the reciprocal of the product of the inductance and capacitance, if both are varied the range required of either is less.

As an example: To produce a frequency range of 3:1 ratio it is necessary to have a capacity range of 9 to 1 with a fixed inductance. However, if the inductance is also varied and the inductance variation maximum to minimum is 3:1 then with a capacity variation of 3:1, maximum to minimum, the frequency range will be maintained at 3:1, or the square root of the product of the ranges of the inductance and capacity.

In Figure 3 the distributed capacity of the loop reduces the frequency range, because it is directly across the tuning condenser 12 and adds to the minimum circuit capacity. As an example: for a 3:1 tuning range the capacity range should be 9:1, and might be from 50 to 450 micromicrofarads (mmf.). If the distributed capacity of the coil is 10 mmf. the new maximum to minimum values would be 460 to 60, or a ratio of 7.66 to 1 with a resulting frequency range of 2.77 to 1. The above, of course, assumes a fixed coil 10 which, when made variable, overcomes this to restore the frequency range to the original 3:1 ratio. To expand the practical example, let it be assumed that the tuning range offered by the condenser alone is 2.77 to 1 which is a capacity range of 7.66 to 1. If coil 10 is made of proper magnitude and variation so that the variation of inductance in the circuit is 1.175 to 1, then the tuning range of the system will be

$$7.66 \times 1.175 = 9:1$$

which corresponds to a frequency range of 3:1. Quite obviously for every value of loop inductance there will be required a different magnitude and variation of coil 10 to produce this 1.175 to 1 inductance change. The sense of variation of coil 10 is the same as that of capacitance 12.

In Figure 4 the variable condenser 12 not only has the auxiliary inductance coil 10 in shunt relation therewith, but a second auxiliary inductance coil 10' is connected in a closed series circuit with loop 1 and coil 10. The cores of 10' and 10 are arranged for mechanical adjustment by adjusting means 7' of the variable condensers of the cascaded signal tuned circuits. In this circuit arrangement the coils 10' and 10 are chosen so that the entire circuit is resonant at the desired signal frequency even though the loop inductance might be extremely high and have high distributed capacity. The coils 10 and 10' will have the same sense of variation as that of the tuning condenser.

There are situations wherein the type of circuit shown in Figure 4 one of the auxiliary coils is invariable. Thus, the coil 10 of Figure 4 may be replaced by coil 10'' of constant value. In this modification the function of 10'' as shown in Figure 5 is to provide the correct matching inductance for the combination of loop 1 and inductance 10' so that capacitance 12 will resonate with inductance 10' to the desired frequency range. Coil 10' acts to increase the tuning range when a loop of high inductance and high distributed capacitance is employed. The sense of variation of 10' is the same as that of the capacitance 12.

The modification shown in Figure 6 differs from that shown in Figure 5 in that the invariable coil 10'' is connected directly in shunt with the loop 1. The auxiliary coil 10' is arranged in a closed series circuit comprising coil 10'' and 10' and variable condenser 12. In this circuit arrangement the adjustable core of coil 10' is mechanically adjusted by tuning mechanism 7' with the rotors of the variable condensers 12. The functions and circuit relations of coils 10' and 10'' are similar to those discussed for those of Figure 5.

In Figure 7 there is shown a modification of the arrangement of Figure 4 wherein the variable coil 10 is placed directly in shunt across loop 1, instead of being directly in shunt across the variable condenser 12 as shown in Figure 4. This modification differs from that shown in Figure 4 because it permits the use of an extremely high loop inductance, and if the Q of coil 10 is high, the voltage transferred to the grid circuit will be high.

It will be noted that in the aforedescribed circuits two or more reactance elements are varied simultaneously to obtain the desired frequency range, so that reactance elements of lower maximum to minimum range may be used, or by using a high ratio of maximum to minimum ratio of reactance elements a large (high inductance, high distributed capacity) loop may be used to obtain the desired frequency range. This concept may, also, be applied to a tuned radio frequency amplifier circuit to increase the tuning range thereof. For example, in Figure 8 there is shown an amplifier 20, say in a broadcast receiver operating in a range of 530 to 1700 kilocycles. The amplifier may be coupled to a following amplifier tube by a network which comprises a variable tuning condenser 21 which has connected in shunt relation thereto a variable inductance element 22.

The variable inductance element 22 may be of the type shown in Figure 1, and, in that case, the adjustable core of coil 22 will be mechanically coupled with the uni-controlled tuning mechanism 23 so that it can vary its position with the rotors of the tuning condensers of the cascaded circuits. The inductance magnitude of coil 22 will be varied in the same sense as the capacity variation of condenser 21. By means of a circuit arrangement of this type the frequency range can be extended over a range up to and beyond 2,000 kc., while using the variable condensers normally employed for the narrower frequency range.

To explain the operation of the circuit in Figure 8 to a greater extent, the resonant frequency of a parallel tuned circuit is expressed by

$$\frac{1}{2\pi\sqrt{LC}} = f$$

where f is the resonant frequency and L and C are the inductance and capacitance respectively. If only one of the elements of L or C is changed, the frequency change is equal to the reciprocal of the square root of that change. For example, if C is changed 9:1, then f is changed $\sqrt{9:1}$, or 3:1. However, if both L and C are changed, then f is proportional to

$$\frac{1}{\sqrt{LC}}$$

If the change in C is 9:1, and the L change is 9:1, 9×9 equals 81, so that f change equals the square root of 81 or 9:1. In other words, f is dependent on the square root of the product of L and C, and by changing both simultaneously the results are

greater than by changing only one. This explains why coil 22 and condenser 21 are concurrently varied to extend the frequency range.

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 a loop antenna, a variable reactance element connected with the loop for tuning the same over a range of frequencies to be received, said loop antenna in order to increase its signal pick-up being so constructed as to have an inductance which greatly exceeds that which will resonate with said reactance element over said range of frequencies, at least one variable inductance element connected in circuit with said loop and operable to allow the reactance element to tune the antenna circuit over the mentioned frequency range, and means for simultaneously adjusting said reactance element and said inductance element in such relative senses that operation over said range of frequencies is maintained and said increased signal pick-up is achieved.

2. In combination with a loop antenna, a first variable inductance connected with the loop for tuning the same over a range of frequencies to be received, said loop antenna in order to increase its signal pick-up being so constructed as to have an inductance which greatly exceeds that which will resonate with said first variable inductance over said range of frequencies, a second variable inductance connected in shunt with said loop and operable to allow the first inductance to tune the antenna circuit over the mentioned frequency range, and means for simultaneously adjusting said first and second inductances in such relative senses that operation over said range of frequencies is maintained and said increased signal pick-up is achieved.

3. In combination with a loop antenna, a variable condenser connected in shunt with the loop for tuning the same over a range of frequencies to be received, said loop antenna in order to increase its signal pick-up being so constructed as to have an inductance which greatly exceeds that which will resonate with said variable tuning condenser over said range of frequencies, at least one variable inductance element connected in circuit with said loop and operable to allow the variable condenser to tune the antenna circuit over the mentioned frequency range, and means for simultaneously adjusting said variable condenser and said inductance element in such relative senses that operation over said range of frequencies is maintained and said increased signal pick-up is achieved.

4. A signal-collecting system for radio receivers tunable over a prescribed range of wave frequencies, comprising a loop antenna, a condenser and a variable-permeability type inductance arranged in series, said loop antenna being so constructed as to have a much too large inductance value to allow the variable-permeability type inductance alone to tune the circuit over said frequency range, and an inductive reactance shunting the loop antenna of such value as to allow the variable-permeability inductance to tune the antenna circuit over the mentioned frequency range.

5. A signal-collecting system as defined in claim 4 wherein the inductive reactance is variable and is so mechanically linked to the variable-permeability inductance as to be co-actuated therewith by the same means.

6. A signal-collecting system for radio receivers tunable over a prescribed range of wave frequencies, comprising a loop antenna, a variable condenser shunting said loop antenna, said loop antenna being so constructed as to have a much too large inductance value to allow the variable condenser alone to tune the circuit over said frequency range, and an inductive reactance connected in circuit with said loop and of such value as to allow the variable condenser to tune the antenna circuit over the mentioned frequency range.

7. A signal-collecting system as defined in claim 6 wherein the inductive reactance is connected in shunt with the loop antenna.

8. A signal-collecting system as defined in claim 6 wherein the inductive reactance is variable and is so mechanically linked to the variable condenser as to be co-actuated therewith by the same means.

9. A signal-collecting system for radio receivers tunable over a prescribed range of wave frequencies, comprising a loop antenna, a condenser and a variable-permeability type inductance arranged in series, said loop antenna being so constructed as to have a much too large inductance value to allow the variable-permeability type inductance alone to tune the circuit over said frequency range, a second variable-permeability type inductance shunting the loop antenna of such value as to allow the first variable-permeability inductance to tune the antenna circuit over the mentioned frequency range, said inductances each being provided with an adjustable ferromagnetic core, and means for simultaneously adjusting said cores.

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