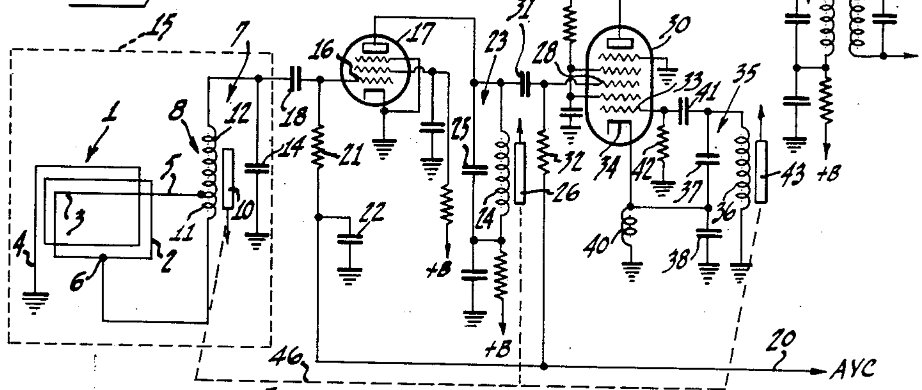
March 18, 1952 W. F. SANDS 2,589,736

LOOP ANTENNA INPUT CIRCUITS

Filed Oct. 6, 1948 2 SHEETS—SHEET 1

Fig. 1.



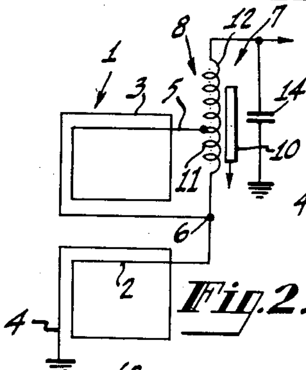


Fig. 2.

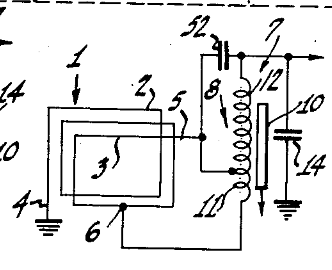


Fig. 3.

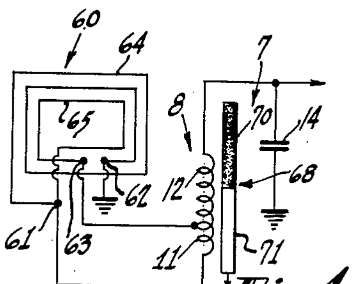


Fig. 4.

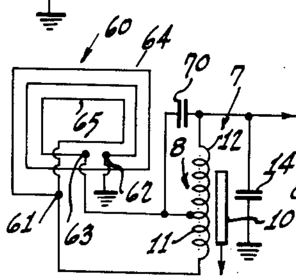


Fig. 5.

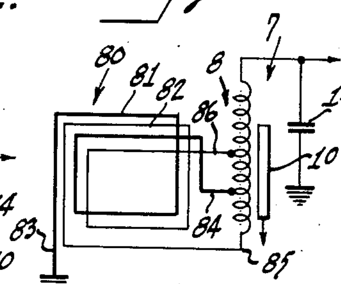


Fig. 7.

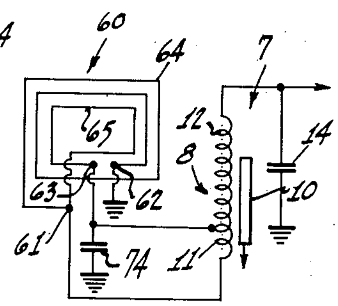


Fig. 6.

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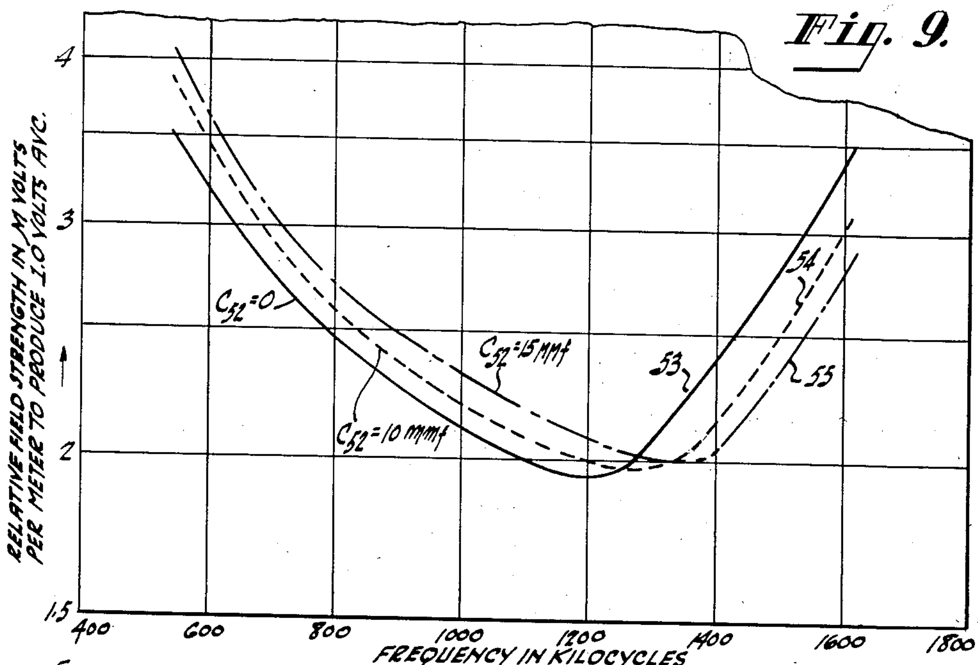
Fig. 9.



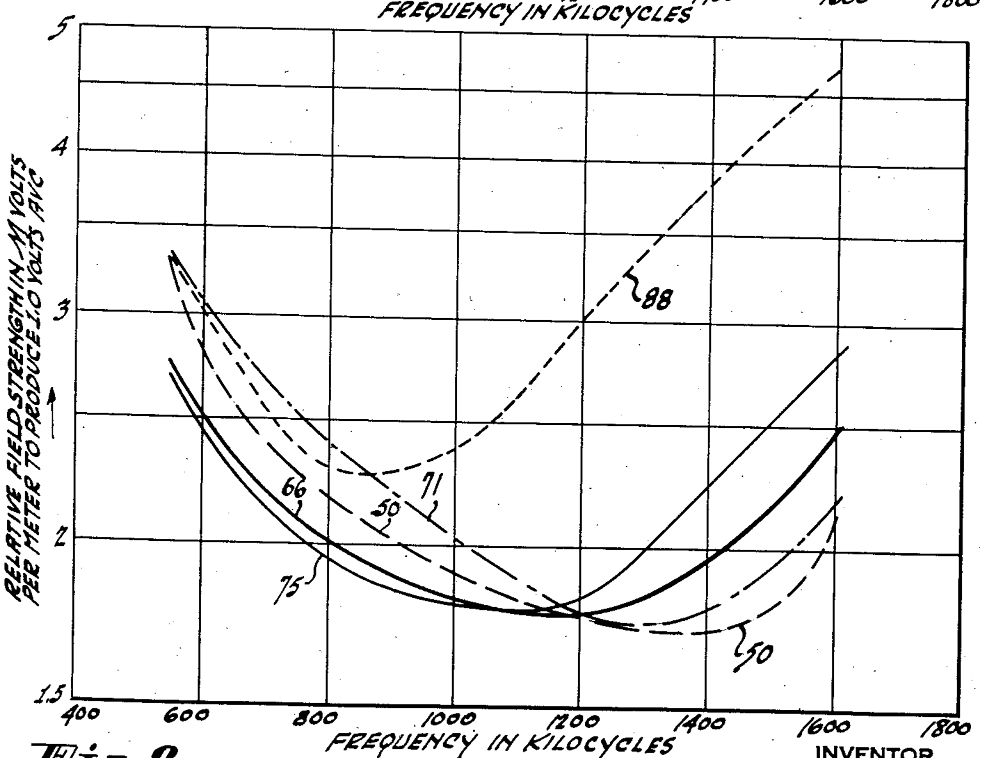


Fig. 8.

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LOOP ANTENNA INPUT CIRCUITS

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7 Claims. (Cl. 250—20)

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This invention relates generally to antenna input circuits and particularly to permeability-tuned loop antenna circuits for radio receivers.

A loop antenna for a broadcast receiver is conventionally associated with a variable capacitor-tuned input circuit. However, a capacitor-tuned input circuit used in connection with a loop antenna has a number of disadvantages. Thus, in order to obtain the desired tuning range the variable capacitor must have a large capacitance at the low frequency end of the tuning range, with the result that the total impedance of the tuned circuit at that frequency is low. This, in turn, reduces the sensitivity of the antenna input circuit at the low frequency end of the tuning range, and the signal-to-noise ratio is poor. Another disadvantage of a capacitor-tuned antenna input circuit is the unpleasant acoustic feedback howl which may be caused by vibration of the capacitor plates.

These disadvantages of prior antenna input circuits can be overcome if the loop antenna is associated with a permeability-tuned input circuit. A permeability-tuned circuit has the advantage of compactness and light weight, and furthermore, the circuit can be mounted in any part of the receiver chassis. Excellent performance has been secured in the past with a rod type antenna in conjunction with a permeability-tuned input circuit. However, a rod type antenna is unsuitable for broadcast receivers in view of its detrimental body capacity effects, its low sensitivity in shielded buildings and the unsightly appearance of a rod extending beyond the cabinet. For these reasons a loop antenna is the preferred antenna in the broadcast receiver field. Unfortunately, the sensitivity of a loop antenna coupled to a conventional permeability-tuned input circuit is very low. Even the best previously known permeability-tuned loop input circuits have sensitivities that are low compared to that of a variable-capacitor tuned input circuit. The sensitivity of a conventional permeability-tuned loop input circuit is low because the resonant circuit coupled to the loop antenna must have a comparatively large inductance so that the broadcast range can be covered by variation of the effective inductance of the tuned circuit. Accordingly, the inductance of the loop antenna must be made small which results in a reduced pickup of the electromagnetic wave energy and thus explains the low sensitivity. One of the best available prior circuits of this type has been disclosed by G. L. Beers, in U. S. Patent 2,383,286. Even this circuit has a low sensitivity at the high

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frequency end of the broadcast band and its performance is therefore not optimum for use in broadcast receivers.

It is the principal object of the present invention, therefore, to provide novel permeability-tuned loop antenna circuits which have sensitivities comparable to or better than that of a variable capacitor-tuned antenna input circuit.

A further object of the invention is to provide more efficient coupling between a loop antenna and the permeability-tuned input circuit of a radio-receiver with a resultant improvement in sensitivity over the entire tuning range and particularly over the high frequency end of the tuning range.

A further object of the invention is to provide permeability-tuned loop antenna circuits having a high signal-to-noise ratio and a high "Q" and hence a better performance.

A loop antenna input circuit in accordance with the present invention may be termed a duo auto-transformer, that is, the loop antenna is tapped at an intermediate point as is the inductor associated with the loop. Thus, the loop antenna as well as the inductor functions as an auto-transformer. A circuit of this type combines the advantages of a series tuned circuit associated with a loop antenna with that of an auto-transformer where an intermediate point of the inductor is connected to a loop antenna terminal as taught by Beers. Accordingly, the loop antenna circuit of the invention combines the advantages of the series tuned circuit having a high sensitivity at the high frequency end with the advantages of the Beers circuit which has a high sensitivity at the low frequency end of the tuning range.

The duo auto-transformer of the invention may also be modified to form an inverted duo auto-transformer by opening an intermediate portion of the loop antenna to provide a pair of terminals. These circuits may be further improved by the provision of an additional capacitor which will further increase the sensitivity at the high frequency end of the tuning range.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 is a circuit diagram of a portion of a superheterodyne receiver embodying the duo auto-transformer circuit of the present invention;

Fig. 2 is the equivalent circuit diagram of the loop antenna input circuit illustrated in Fig. 1;

Fig. 3 is a modification of the duo auto-transformer circuit of Fig. 1 including an additional capacitor;

Figs. 4 to 6 are circuit diagrams of modifications of the inverted duo auto-transformer circuit of the present invention;

Fig. 7 is a circuit diagram of another embodiment of a loop antenna circuit in accordance with the invention; and

Figs. 8 and 9 are graphs which represent the sensitivity of the circuits of Figs. 1 to 6 over the broadcast tuning range.

Referring now to the drawings in which like components are designated by the same reference numerals, and particularly to Fig. 1 there is illustrated an antenna input circuit in accordance with the present invention including loop antenna 1. Loop antenna 1 consists of two portions, 2 and 3, which are connected together to form one continuous loop. Loop antenna 1 has three terminals, 4 and 5, being connected to the free ends of antenna portions 2, 3 and terminal 6 being connected to the junction point of the two antenna portions. In other words, antenna terminal 6 is connected to an intermediate point of loop antenna 1.

Loop antenna 1 is connected to permeability-tuned input circuit 7 comprising inductor 8 which includes core 10 of paramagnetic material. A paramagnetic material is defined as a material having a magnetic permeability greater than that of a vacuum, which is unity. The magnetic permeability of a paramagnetic material may be independent of the magnetizing force or it may vary with the magnetizing force, in which case the material is called ferromagnetic. Antenna terminal 5 is connected to a point intermediate of the ends of inductor 8 so that inductor 8 consists of two coil portions, 11 and 12. Antenna terminal 6 is connected to the low alternating-current potential terminal of inductor 8. Antenna terminal 4 is connected to ground, that is, to a point of fixed alternating-current reference potential. It is preferred to ground antenna terminal 4 to the common return lead or chassis, as shown, because if antenna terminal 4 is not directly grounded but is maintained at some other relatively fixed alternating current potential there may be an effective series resistance between antenna terminal 4 and ground which will reduce the effective "Q" of the input circuit. However, in some cases it may be necessary or desirable to maintain antenna terminal 4 at a fixed alternating-current potential instead of grounding it directly.

Capacitor 14 is effectively connected across inductor 8 and loop antenna portion 2. Thus, capacitor 14 is preferably connected, as illustrated, between the high alternating-current potential terminal of inductor 8 and ground. The loop antenna input circuit of the invention generally indicated by box 15 and which may be termed a duo auto-transformer circuit, is coupled to control grid 16 of radio frequency amplifier 17 through coupling capacitor 18. The cathode of amplifier 17 is grounded as illustrated and its screen grid is connected to +B through a suitable dropping resistor which may be bypassed to ground as illustrated. An AVC voltage may be derived in a conventional manner and impressed

through lead 20 on control grid 16 through resistor 21 having its cathode end grounded for alternating currents through capacitor 22. Radio-frequency output circuit 23 is connected between a suitable voltage source indicated at +B and the plate of amplifier 17. Output circuit 23 includes inductor 24 and capacitor 25 connected in parallel. Inductor 24 includes paramagnetic core 26 which may be moved to vary the inductance of inductor 24 and thereby the resonant frequency of output circuit 23.

Output circuit 23 is coupled to signal grid 28 of pentagrid converter tube 30 through coupling capacitor 31. The AVC voltage is impressed on signal grid 28 through lead 20 and resistor 32. The screen grids of converter tube 30 are connected to +B as illustrated.

The oscillator section of converter tube 30 includes oscillator grid 33 and cathode 34. Oscillatory circuit 35 is coupled between grid 33 and cathode 34 and includes inductor 36 across which are connected capacitors 37 and 38 arranged in series. The junction point of capacitors 37, 38 is connected to cathode 34 which is grounded through choke coil 40. The high alternating-potential terminal of oscillatory circuit 35 is coupled to control grid 33 through coupling capacitor 41. Grid leak resistor 42 is connected between oscillator grid 33 and ground. Inductor 36 includes paramagnetic core 43. Oscillatory circuit 35 is connected in the manner of a Colpitts oscillator. The intermediate frequency wave developed by frequency converter 30 may be obtained from resonant circuit 44 coupled to the anode of converter 30 to which is coupled output circuit 45.

Paramagnetic cores 10, 26 and 43 are preferably movable in unison as indicated at 46. The permeability of paramagnetic core 10 should be substantially higher than that of paramagnetic core 43. Thus, it is preferred that the effective permeability of inductor 8 be larger than 20 and of the order of 30. The effective permeability of an inductor may be defined as the ratio of the inductance of the inductor with its core fully inserted, divided by the inductance of the inductor with the core fully removed. The effective permeability of an inductor is a function of the geometry of its coil and its core and of the material of the core. High effective permeabilities may readily be obtained with a paramagnetic core consisting of a ferrite which consists of a mixture of the oxides of various bivalent metals with ferric oxide Fe_2O_3. The general formula of a ferrite is Me_1O: Me_2O: Fe_2O_3, where Me_1 may be a metal such as nickel, copper, manganese and magnesium and where Me_2 may be a metal such as zinc or cadmium. A ferrite core may be produced by intimately mixing the finely divided metallic oxides, compacting the mixture by compression molding and heating it to a temperature of between 1,000 and 1,600 degrees centigrade.

On the other hand, paramagnetic core 43 may consist of one of the various types of powdered iron and a suitable casting resin so that the permeability of core 43 is considerably lower than that of core 10. The permeability of paramagnetic core 26 should be not larger than that of core 10 and not smaller than that of core 43. In other words, core 26 may consist of a ferrite having a high permeability or of powdered iron having a low permeability. It is also feasible to make the permeability of core 26 smaller than that of core 10 while that of core 43 is still smaller than that of core 26. In that case, both cores 26 and 43 may consist of powdered iron but core 43 may contain a larger amount of binder to reduce its permeability.

It is, of course, essential that input circuit 7 should have the highest possible effective permeability in order to tune the loop input circuit over the required tuning range and to obtain good sensitivity. The effective permeability of radio frequency circuit 23 should also be high but need not necessarily be as high as that of input circuit 7 since the tuning range is not limited by a fixed loop inductance. On the other hand, the effective permeability of oscillatory circuit 35 must be somewhat lower than that of input circuit 7 because the tuning range of the oscillatory circuit is considerably smaller than that of the input circuit. The above mentioned materials are admirably suited for this purpose.

The operation of the loop antenna input circuit of the invention may best be understood by reference to Fig. 2 which is the equivalent circuit diagram of the duo auto-transformer circuit. For convenience, antenna portions 2 and 3 have been shown separately. It is to be understood that loop antenna 1 may also be arranged physically with two distinct portions as illustrated schematically in Fig. 2. It will readily be seen that antenna portion 2 is connected in series with inductor 8 between ground and the high alternating-current potential terminal of the circuit. The two loop portions 2 and 3 are physically arranged in such a manner that their inductances are in aiding phase. Furthermore, the capacitive coupling of the two loop portions 2 and 3 is also in aiding phase as may be seen by reference to Fig. 1.

The loop antenna input circuit of Fig. 3 combines the advantages of a conventional loop antenna connected to a series tuned circuit (corresponding to Fig. 2 with loop portion 2 removed) with that of a loop antenna coupled to an auto-transformer (corresponding to Fig. 2 with loop portion 2 short-circuited) as taught by Beers.

The conventional loop antenna connected to a series tuned circuit is most sensitive at the high frequency end of the tuning range. This can be readily understood by the following analysis. When the core is fully inserted into the series coil of the circuit, the circuit is tuned to the low frequency end of the band and most of the inductance of the antenna input circuit is represented by the series coil and its core. Accordingly, the loop antenna inductance is a comparatively small portion of the entire inductance of the input circuit resulting in a reduced efficiency of the circuit because less voltage is delivered to control grid 10. At the high frequency end of the tuning range the core is withdrawn from the series coil and accordingly the inductance of the series coil is a smaller portion of the entire inductance of the loop antenna input circuit. Since now the inductance of the loop antenna represents a larger portion of the total inductance, the efficiency of the antenna circuit is improved at the high frequency end of the tuning range.

The Beers loop antenna circuit which includes an auto-transformer, is more sensitive at the low frequency end of the tuning range than at the high frequency end. At the low frequency end of the tuning range the core fully penetrates the auto-transformer. Accordingly, the loop antenna is effectively tapped across a large portion of the inductance of the coil. The circuit accordingly is very efficient and has a good sensitivity. However, at the high frequency end of the tuning range the core is withdrawn from the auto-transformer. Consequently, the loop antenna is effectively tapped across a small impedance because the tap of the auto-transformer may be considered to move effectively to such a position that the antenna is connected across a smaller portion of the coil. It will be evident that this impedance mismatch results in a loss of sensitivity at the high frequency end of the tuning range.

The duo auto-transformer circuit of the invention as illustrated in Figs. 1 and 2 combines the advantages of the two conventional circuits and therefore has a high sensitivity across the entire tuning range which is comparable to or larger than that of the conventional variable capacitor tuned antenna input circuit. Thus, at the low frequency end of the tuning range core 10 fully penetrates inductor 8. At this position of core 10 the circuit has the high sensitivity of the Beer's circuit which is still further increased due to the presence of antenna portion 2 serially connected with respect to inductor 8. At the high frequency end of the tuning range, core 10 is fully withdrawn from inductor 8. The core should be withdrawn in the direction indicated by the arrows Figs. 1 and 2, that is, toward coil portion 11. Now, the comparatively smaller sensitivity of the Beers circuit is increased by loop portion 2 in the manner pointed out hereinabove.

Loop antenna 1 preferably consists of a Litz wire, that is, a stranded cable where the strands are mutually insulated from each other. This will increase the Q of the circuit and thereby improve its performance. For the same reason, inductor 8 should consist of a Litz wire. Furthermore, inductor 8 should preferably be wound with a universal progressive winding, that is, with a multilayer winding which will increase the Q of the coil and permit a higher ratio of inductance to capacitance of tuned circuit 7. This, in turn, will also improve the sensitivity of the tuned circuit. Furthermore, antenna portion 2 should include at least 30 per cent of the total number of turns of loop antenna 1, but may include up to 50 per cent of the total number of antenna turns. This will provide a higher antenna inductance in series with inductor 8 which contributes to the better performance of the circuit at the high frequency end of the tuning range.

In one particular embodiment of the circuit of Fig. 1, loop antenna 1 had a rectangular shape with rounded corners and was wound in flat form with 28 turns. Antenna portion 2 had 12 turns and antenna portion 3 had 16 turns; the mean area of the loop was 0.022 m.^{2}. Inductor 8 had a universal progressive winding of Litz wire and a coil length of 1½ inches, the coil being wound on a 0.271 inch outer diameter thin-walled coil form. Core 10 had an outer diameter of ¼ inch and a length of more than 1½ inches and consisted of ferrite.

Fig. 8 illustrates the relative field strength in microvolts per meter which is required at loop antenna 1 to produce an AVC voltage of 1 volt, these voltages being plotted against frequency in kilocycles. Curve 50 illustrates the performance of the loop antenna circuit of Figs. 1 and 2. It will be noted that the sensitivity increases as curve 50 approaches the bottom of the graph. Curve 50 shows clearly the superior sensitivity of the loop antenna input circuit of Figs. 1 and 2 particularly at the high frequency end of the tuning range.

The Q of resonant circuit 7 may be further improved by increasing the ratio of the diameter of coil 8 to its length. In conventional receivers the ratio of coil diameter to length is comparatively small because the diameter of the coil is small. This ratio could, of course, be increased by increasing the length of the coil. This, however, would increase the tuning stroke required to cover a given range, which is undesirable. On the other hand, if the diameter of the coil is increased, the tuning range may become too small. It may be desired in accordance with the present invention to make the diameter of inductor 8 larger than .2 inch. In that case, core 10 should have a diameter to fit within the coil and a high permeability such as may readily be obtained by the use of a ferrite material. Accordingly, the inductance range of inductor 8 should be at least 10 to 1. The length of inductor 36 may be equal to that of inductor 8.

Fig. 3 illustrates a modification of the duo auto-transformer of Fig. 1 and may be substituted for box 15 in Fig. 1, as may be the antenna circuits of Figs. 4 to 7 which will be described hereinafter. The loop antenna input circuit of Fig. 3 comprises loop antenna 1 connected to resonant circuit 7 in the same manner as previously described. The only difference of the circuit of Fig. 3 over the duo auto-transformer of Fig. 1 is the provision of capacitor 52. Capacitor 52 is connected between the high alternating-current potential terminal of inductor 8 and antenna terminal 5 which is connected to an intermediate point or tap on the inductor. The circuit comprising capacitor 52 and coil portion 12 is resonant at a frequency above the tuning range of circuit 7. Capacitor 52 will provide a better sensitivity at the high frequency end of the tuning range. Furthermore, it will improve the image attenuation particularly at the low frequency end of the band.

Fig. 9 shows curves 53, 54 and 55 which indicate the relative field strength in microvolts per meter which is required to produce an AVC voltage of one volt. This data is plotted against the frequency in kilocycles. Curve 53 shows the sensitivity of the circuit of Fig. 1, that is, the circuit of Fig. 3 without capacitor 52. Curves 59 and 53 are not comparable, however, because the circuit constant for which the two curves were plotted were not identical. Curves 54 and 55 were obtained with capacities of 10 and 15 micromicrofarads respectively for capacitor 52. It will be observed that an increase of the capacitance of capacitor 52 will increase the sensitivity at the high frequency end of the band with a slight loss of sensitivity at the low frequency end of the tuning range.

Fig. 4 illustrates a modification of the loop antenna input circuit of the invention which may be termed an inverted duo auto-transformer. Loop antenna 60 is coupled to resonant circuit 7 including inductor 8 and capacitor 14. The outer or free ends of loop antenna 60 are connected together to form terminal 61. An intermediate portion of the loop antenna is opened to form two more terminals 62 and 63. Accordingly, the antenna consists of two antenna portions 64 and 65 which together form one continuous loop between terminals 62 and 63.

Antenna terminal 61 is connected to the low alternating-current potential terminal of inductor 8. Antenna terminal 63 is connected to an intermediate point or tap of the inductor. Antenna terminal 62 is connected to ground, that is, it is maintained at a fixed alternating-current potential. It will be observed that the equivalent circuit of Fig. 4 is represented by Fig. 2. Antenna portion 64 corresponds to antenna portion 2 of Fig. 2 and antenna portion 65 corresponds to antenna portion 3 of Fig. 2. The two antenna portions 64 and 65 are physically arranged in such a manner that their inductances are an aiding phase. However, the capacitive coupling between antenna portions 64 and 65 is bucking. Otherwise, the circuit of Fig. 4 functions essentially in the manner of the circuit of Fig. 1. The sensitivity of the circuit of Fig. 4 is illustrated by curve 66 of Fig. 8. It will be observed that the inverted duo auto-transformer circuit of Fig. 4 has a fairly uniform and high sensitivity over the entire tuning range.

Core 68 of inductor 8 in Fig. 4 may consist of two portions 70 and 71. Core portion 70 consists of a material having a low permeability and a high Q, that is, a low loss. Thus, core portion 70 may, for example, consist of carbonyl powdered iron with a suitable casting resin which combines low permeability with low losses. Core portion 71 consists of a material having a high permeability and a high Q such as ferrite. The length of core 68 should be such that regardless of the tuning movement of the core it is always fully within inductor 8 so that the Q of the inductor is maintained at a substantially constant and high value over the entire tuning range. The tuning range is given by the square root of the ratio of the effective permeabilities of core portions 70 and 71. It is to be understood that core 68 may be used in conjunction with any one of the circuits illustrated in Figs. 1 to 7. Alternatively, a ferrite core such as illustrated at 10 in Fig. 1 may be used in conjunction with the circuit of Fig. 4.

Fig. 5 illustrates a modified inverted duo auto-transformer circuit. The circuit of Fig. 5 is identical with that of Fig. 4 except that a capacitor 70 is connected between the high alternating-current potential terminal of inductor 8 and antenna terminal 63. Capacitor 70, therefore, is connected across coil portion 12 in the same manner as is capacitor 52 of Fig. 3. Core 10 may consist of ferrite material. The performance of the circuit of Fig. 5 is illustrated by curve 71 of Fig. 8. Curve 71 shows that the circuit of Fig. 5 has a better sensitivity at the high frequency end than the circuit of Fig. 4 which is represented by curve 66. However, the sensitivity at the low frequency end of the band is slightly smaller.

Fig. 6 illustrates still another modification of the inverted duo auto-transformer circuit in accordance with the invention. The circuit of Fig. 6 is identical with that of Fig. 4 except that a capacitor 74 is connected between antenna terminal 63 and ground. Capacitor 74 accordingly is connected in parallel with antenna portions 65 and 64. Curve 75 illustrates the performance of the circuit of Fig. 6. It will be seen that capacitor 74 improves the performance of the circuit at the low frequency end of the tuning range but the performance at the high frequency end of the tuning range is decreased.

The circuit of Fig. 7 comprises loop antenna 80 consisting of two separate conductors 81 and 82 wound in a bifilar winding or loop. Conductor 81 has one of its terminals 83 connected to ground or maintained at a fixed alternating-current potential. The other terminal 84 of conductor 81 is connected to an intermediate point of inductor 8. The other conductor 82 of loop antenna 80 has one of its terminals 85 connected to the low alternating-current potential terminal of inductor 8. The other terminal 86 of conductor 82 is connected to another intermediate point of inductor 8. It will be seen that terminal 84 is connected to a point on inductor 8, intermediate tap 86 and terminal 85.

Antenna conductor 82 is connected in the manner of the Beers circuit referred to. Accordingly, the circuit performs better at the low frequency end of the tuning range than at the high frequency end. This is due to the fact that conductor 82 is connected across a small impedance at the high frequency end of the tuning range as has already been explained. Antenna conductor 81 adds to the sensitivity of the circuit and functions essentially like another Beers circuit. At the high frequency end of the tuning range, that is, when core 10 is removed from the inductor, there is an inductance represented by conductor 81 in series with a portion of inductor 8. Curve 88 of Fig. 8 illustrates the sensitivity of the circuit of Fig. 7. The sensitivity may be improved by connecting antenna terminal 85 to ground either directly or through a capacitor thereby to maintain the alternating-current potential of the terminal constant.

There have thus been described various permeability-tuned loop antenna input circuits which have a sensitivity which is comparable to or greater than that of a variable capacitor tuned loop antenna input circuit. The circuits of the present invention are superior to prior art permeability-tuned loop antenna circuits and have all the advantages inherent in permeability tuners.

What is claimed is:

1. In a radio receiver, a loop antenna having at least three terminals, at least one of said terminals being connected to an intermediate point of said antenna, an inductor including a paramagnetic core, means for moving said core to vary the inductance of said inductor, one of said antenna terminals being maintained at a relatively fixed alternating-current potential, the other two antenna terminals being connected respectively to one terminal and to an intermediate point of said inductor, a first capacitor effectively connected between the free terminal of said inductor and said one of said antenna terminals, and a second capacitor connected between said free terminal and said intermediate point of said inductor.

2. In a radio receiver, a loop antenna having a first and a second terminal, an inductor including a paramagnetic core, means for moving said core to vary the inductance of said inductor, said first antenna terminal being maintained at a relatively fixed alternating-current potential, said second antenna terminal being connected to an intermediate point of said inductor, an intermediate point of said antenna being connected to one terminal of said inductor, a first capacitor effectively connected between the other terminal of said inductor and said first antenna terminal, and a second capacitor connected between said other terminal and said intermediate point of said inductor.

3. In a radio receiver, a loop antenna having at least three terminals, at least one of said terminals being connected to an intermediate point of said antenna, an inductor including a coil and a paramagnetic core, means for moving said core to vary the inductance of said inductor, said core consisting of two portions, one of said portions having a higher permeability than the other portion, said portions having both a low loss and being of such a length that regardless of the movement of said core said core is always fully within said coil, thereby to maintain the Q of said inductor at a substantially constant value, one of said antenna terminals being maintained at a relatively fixed alternating-current potential, the other two antenna terminals being connected respectively to one terminal and to an intermediate point of said inductor, a first capacitor effectively connected between the free terminal of said inductor and said one of said antenna terminals, and a second capacitor connected between said free terminal and said intermediate point of said inductor.

4. In a radio receiver, a loop antenna having its free ends connected together to form a first terminal, said antenna having an intermediate portion opened to provide a second and a third terminal, an inductor including a paramagnetic core, means for moving said core to vary the inductance of said inductor, said first antenna terminal being connected to a terminal of said inductor, said second antenna terminal being maintained at a relatively fixed alternating-current potential, said third antenna terminal being connected to an intermediate point of said inductor, a first capacitor connected between the free terminal of said inductor and said second antenna terminal, and a second capacitor connected between said free terminal and said intermediate point of said inductor.

5. In a radio receiver, a loop antenna having its free ends connected together to form a first terminal, said antenna having an intermediate portion opened to provide a second and a third terminal, an inductor including a paramagnetic core, means for moving said core to vary the inductance of said inductor, said first antenna terminal being connected to a terminal of said inductor, said second antenna terminal being maintained at a relatively fixed alternating-current potential, said third antenna terminal being connected to an intermediate point of said inductor, a first capacitor connected between the free terminal of said inductor and said second antenna terminal, and a second capacitor connected between said intermediate point of said inductor and said second antenna terminal.

6. In a superheterodyne receiver, a loop antenna having a first and a second terminal, said first antenna terminal being maintained at a fixed potential, a first inductor including a first paramagnetic core, said second antenna terminal being connected to an intermediate point of said inductor, one terminal of said inductor being connected to an intermediate point of said antenna, a capacitor connected between said first antenna terminal and the free terminal of said inductor, a radio frequency amplifier stage having its input terminals connected to said capacitor, a radio frequency output circuit coupled to said amplifier stage and comprising a second inductor, said second inductor including a second paramagnetic core, a local oscillator comprising an oscillatory circuit, said oscillatory circuit having a third inductor including a third paramagnetic core, and means for moving said cores in unison to vary simultaneously the inductance of said inductors, the permeability of said first core being larger than that of said third core and the permeability of said second core being not larger than that of said first core and not smaller than that of said third core.

7. In a superheterodyne receiver, a loop antenna having at least three terminals, at least one of said terminals being connected to an intermediate point of said antenna, a first inductor including a first paramagnetic core, one of said antenna terminals being maintained at a relatively fixed alternating-current potential, the other two antenna terminals being connected respectively to one terminal and to an intermediate point of said first inductor, a first capacitor effectively connected between the free terminal of said inductor and said one of said antenna terminals, a second capacitor connected between said free terminal and said intermediate point of said inductor, a radio frequency amplifier stage having its input terminals connected to said first capacitor, a radio frequency output circuit coupled to said amplifier stage and comprising a second inductor, said second inductor including a second paramagnetic core, a local oscillator comprising an oscillatory circuit, said oscillatory circuit having a third inductor including a third paramagnetic core, and means for moving said cores in unison to vary simultaneously the inductance of said inductors, the permeability of said first core being larger than that of said third core and the permeability of said second core being not larger than that of said first core and not smaller than that of said third core.

WILLIAM F. SANDS.

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