

Nov. 10, 1942.

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2,301,324

RADIO FREQUENCY COUPLING SYSTEM

Filed Dec. 18, 1940

3 Sheets-Sheet 1

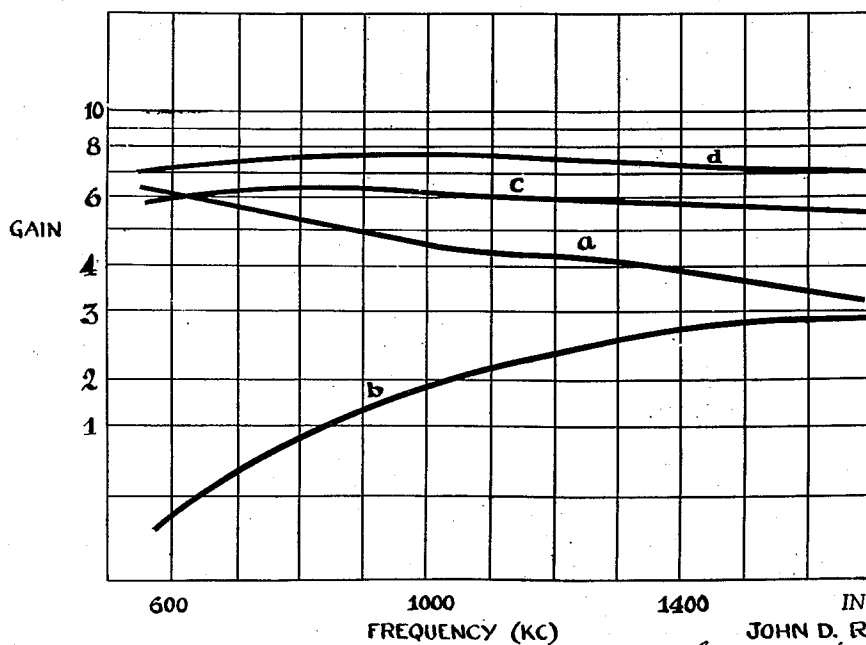
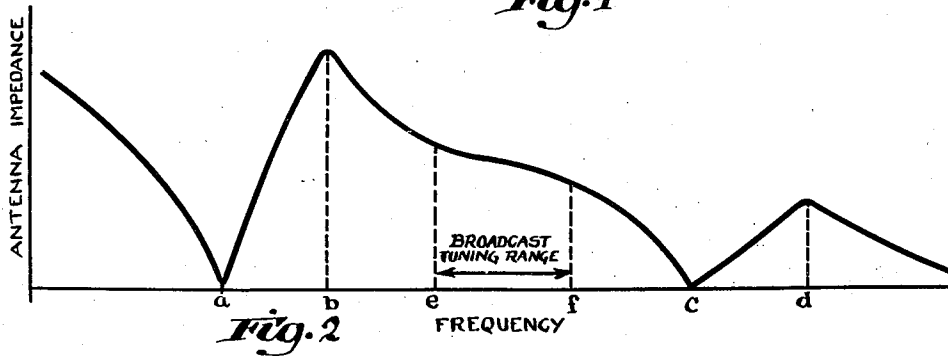
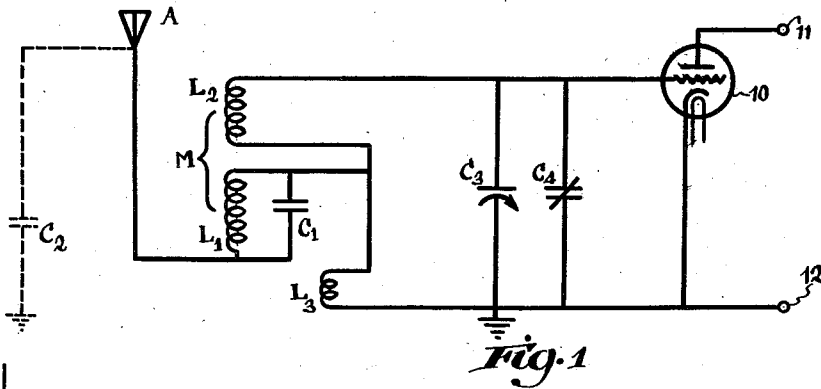


Fig. 3

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3 Sheets-Sheet 2

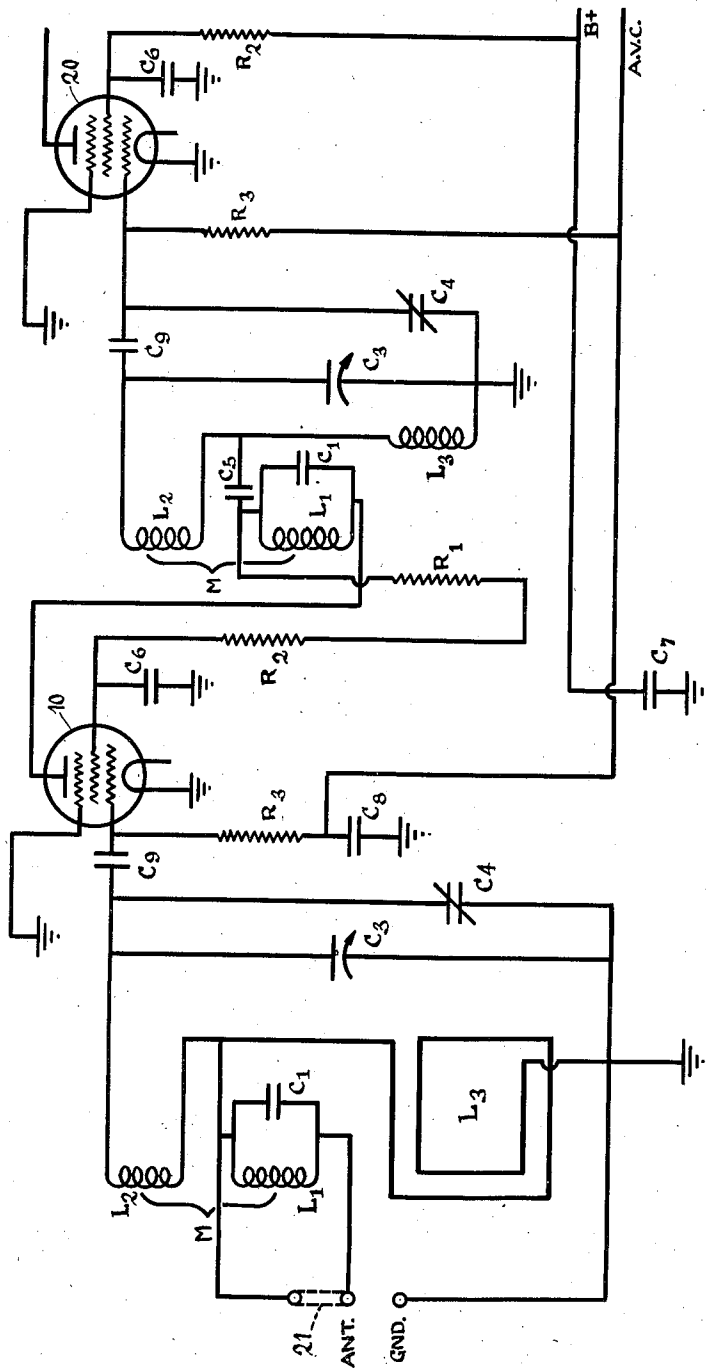


Fig. 4

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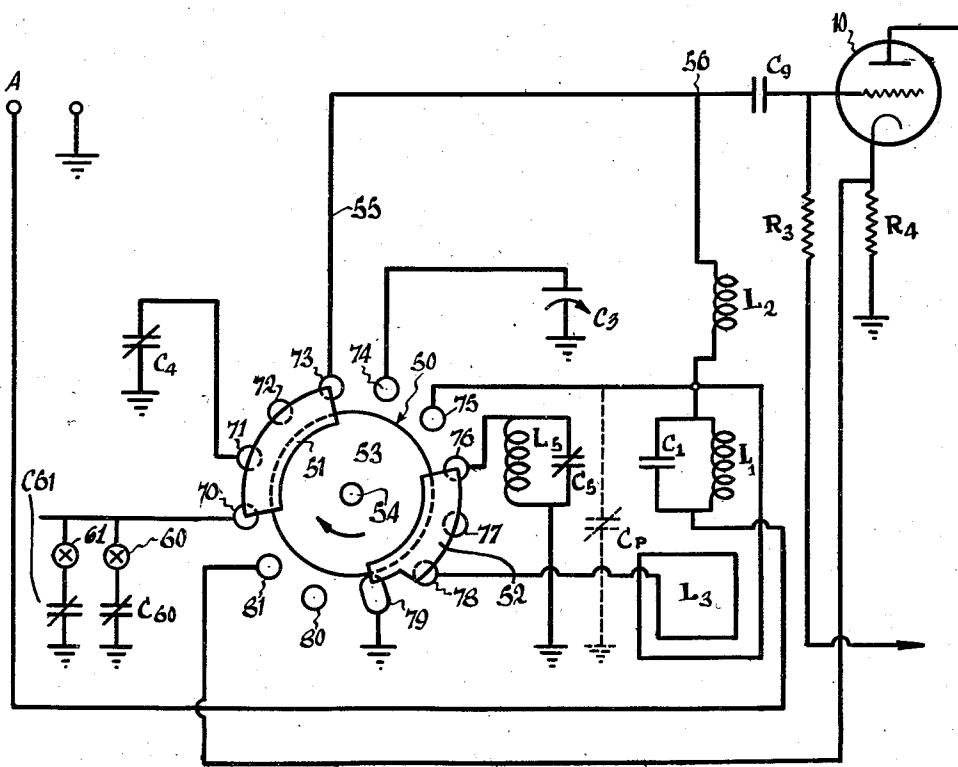
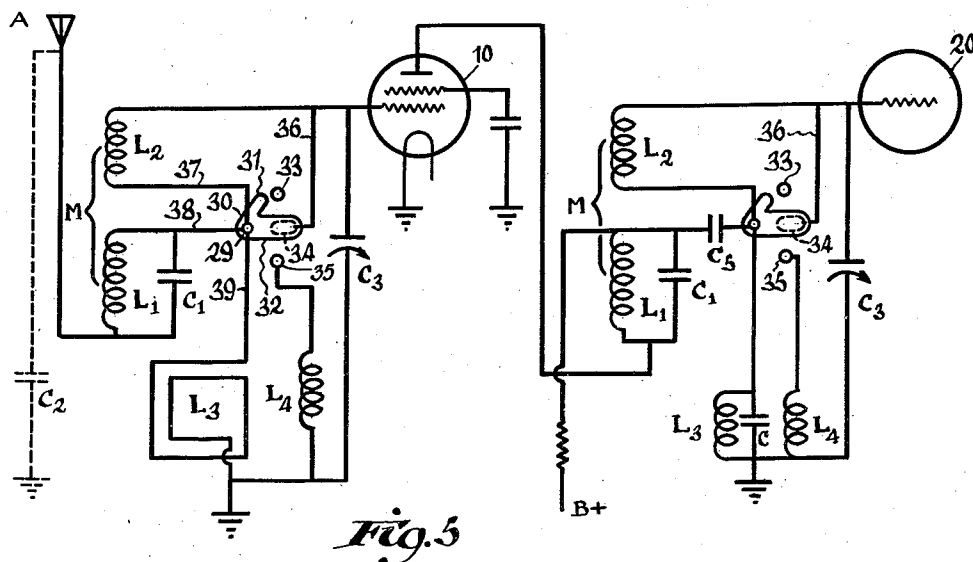
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RADIO FREQUENCY COUPLING SYSTEM

Filed Dec. 18, 1940

3 Sheets-Sheet 3



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2,301,324

RADIO FREQUENCY COUPLING SYSTEM

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Application December 18, 1940, Serial No. 370,688

13 Claims. (Cl. 250—20)

This invention relates to the transfer of radio or high frequency energy and is particularly concerned with coupling systems by which alternating currents at radio frequency may be transferred from one circuit to another in a radio receiver.

The coupling system of the present invention has special application to, although it is by no means limited to, modern multiband radio receivers and certain aspects are of particular advantage in receivers of the superheterodyne type which use a combination of a built-in and an external antenna system. For facility of explanation the invention will be described in its application to radio receivers, but its adaptation to other uses will be apparent to persons skilled in the art.

Due, to a large extent, to the type of coupling systems at present in use, the performance of radio receivers in general leaves much to be desired with respect to sensitivity, selectivity, stray noise pick-up, and uniformity of proper response in relation to one or more of these conditions. With the superheterodyne type of receiver the signal-to-image ratio is often insufficient and interference with the desired signal frequently results. The present invention provides improved performance in these respects. To bring about such improved performance and to do this in a simple manner with a saving in manufacturing cost, are important objects of the present invention.

A particular object of the invention is to provide a radio-frequency coupling system, improved in one or more of the above respects, for use in the input system of a radio receiver but which is also suitable for interstage use.

A further object is to provide a coupling circuit having the advantages indicated which may be utilized not only in receivers designed for the standard broadcast band but also in multi-band receivers, and which, in the latter case, requires a minimum of parts and a minimum of switching for band change purposes.

A further object is to provide a radio frequency coupling system involving a combination of magnetic coupling and direct coupling, having the advantage that the gain through such system is maintained exceptionally uniform throughout a given range of frequencies.

A still further object is to provide a coupling system from which a uniform gain may be obtained independently of the capacitance of the input circuit. In the case of coupling to an antenna the coupling system of the invention makes

the uniformity of gain over the tuning range independent of the capacitance of the antenna.

In the case of a built-in antenna the invention provides a low impedance built-in loop antenna which with suitable switching means may be used to advantage in tuning throughout the lowest frequency band but which becomes a high impedance loop antenna constituting the entire secondary inductance for a higher frequency band. If desired the switching means may be so arranged that the loop serves as an electrostatic pick-up member for a still higher frequency band. This results in a considerable saving in the cost of receiver manufacture.

Such a loop may in accordance with the invention, be of a substantially fixed nature thus simplifying the design and effecting further savings in cost.

The novel features that I consider characteristic of my invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation together with additional objects and advantages thereof will best be understood from the following description of specific embodiments when read in conjunction with the accompanying drawings, in which:

Figure 1 illustrates an exemplary coupling system applied to the input system of a single band radio receiver.

Figure 2 is a graph showing the characteristic impedance of the antenna system of Figure 1 with respect to frequency.

Figure 3 is a graph illustrating the effect of both direct and magnetic coupling involved in Figure 1. Curve (a) shows the gain with magnetic coupling only; curve (b) with direct coupling only; curve (c) combined direct and magnetic coupling, and curve (d) shows how the gain rises yet remains uniform when the capacitance of the antenna is increased.

Figure 4 shows an antenna and interstage coupling system applied to the radio frequency circuits of a receiver incorporating a built-in loop antenna.

Figure 5 is a schematic circuit for a three-band receiver also incorporating a coupling system according to the invention for use with the lowest frequency band and direct capacity coupling for use with the higher frequency bands.

Figure 6 illustrates a modified antenna circuit for a multiband receiver, in which a built-in loop antenna serves as the pick-up means for all of three bands.

Referring now to Figure 1, the input circuit in-

cludes the antenna A, inductance L_1 , the capacitance C_1 , which shunts inductance L_1 , and the inductance L_3 which must be small in relation to L_1 and the lower end of which is connected to ground. The input circuit is completed through the effective antenna-to-ground capacitance C_2 . The output circuit includes the inductance L_2 and the tuning condenser C_3 and the inductance L_3 the latter being electromagnetically uncoupled from L_1 and L_2 and being a common element to both circuits, directly coupling them together. C_4 is a trimmer condenser of the adjustable type. Coils L_1 and L_2 are preferably electromagnetically coupled, as by a mutual inductance M . The first tube of the receiver, which may be a radio frequency amplifier is indicated at 10 and its output may be taken from terminals 11 and 12 in a manner well known in the art.

It will be observed that the respective circuits are electromagnetically coupled by reason of the mutual inductance M , and direct coupled through inductance L_3 . Inductance L_3 is not electromagnetically coupled with either L_1 or L_2 .

As will hereinafter be more particularly described in connection with the succeeding figures, when a built-in antenna is desired and the radio receiver is housed in a cabinet of relatively large dimensions such as a console or large table model, the inductance L_3 may be advantageously constructed in the form of a loop which has a small inductance and therefore a low impedance. L_3 may be conveniently constructed by passing one or two turns of insulated wire around the back edge of the cabinet but it may be wound around the cabinet in other ways or even built in or concealed upon the cabinet walls. In the case of a small table model receiver where the dimensions of such a loop are so limited that a sufficiently large area for adequate signal pick-up cannot be obtained, it is possible to utilize the advantages of the invention for use with external antennae by designing the inductance L_2 so that it, rather than the inductance L_3 constitutes built-in pick-up means. In such case inductance L_2 is made in the form of a loop and inductance L_3 constructed in the form of a small coil having a small inductance.

The inductance L_2 may be chosen so that it constitutes the major portion of that required to tune the output circuit over the standard broadcast band, the remaining portion being derived from L_3 which is small compared to L_2 , for example L_3 may be of the order of $\frac{1}{15}$ of L_2 .

L_1 is preferably a large inductance of the order of thirty-five times the inductance of L_2 to which it is electromagnetically coupled as shown. It is desirable to increase the coefficient of coupling as the inductance of L_1 increases. In practice, the inductance of coil L_1 is limited by reason of the fact that absorption points or standing waves may be encountered in L_1 within the tuning range of the output circuit if too many turns are used. By proper design of the coil, however, it is possible to obtain a large value of inductance without experiencing difficulty of this nature.

The value of L_1 is so related to the values of C_1 and C_2 that this portion of the circuit C_2 , C_1 , L_1 , is resonant far below any frequency to which the output circuit can be tuned, L_3 offering a negligible impedance to low frequencies by reason of its small inductance.

The inductance of L_3 and the capacity C_1 may be fixed so that the high frequency resonance of the circuit C_2 , C_1 , L_3 , will be far above the highest frequency to which the output circuit can be

tuned. At these frequencies L_1 is equivalent to a small capacitance in shunt with C_1 .

The mutual inductance between coils L_1 and L_2 is preferably such that it aids the direct coupling across inductance L_3 . It is also preferable to so wind and pole the inductances L_1 and L_2 that the capacity coupling between their high sides is a minimum and that which exists is in aiding phase. This may be accomplished by winding L_1 and L_2 in the same direction and connecting the terminating end of L_1 to the starting end of L_2 . In this manner freedom from shift of the tuning of the output circuit for different capacitances across the input circuit, and greater attenuation of high frequencies above the tuning range of the output circuit, are obtained.

It will be seen that the arrangement just described has an input circuit which is resonant at two points. First, at a frequency far below any to which the output circuit can be tuned and, second, at a frequency far above any to which the output circuit can be tuned. This will be seen by reference to Fig. 2 in which the impedance of the input circuit is plotted against frequency. The first or low frequency resonance of the input circuit is at a , whereas the second or high frequency resonance thereof is at c ; b and d denote anti-resonance points. The approximate position of the standard broadcast band of 530 to 1700 k. c. is indicated between frequencies e and f , and it will be observed that the input circuit is capacitively reactive throughout this range of frequencies, since the impedance is falling as the frequency increases.

The combination of electromagnetic and direct coupling with the low and high frequency resonances of the input circuit results in a uniform signal transfer or voltage gain from the antenna to the tuning condenser C_3 across the output circuit. This uniformity manifests itself over the entire tuning range of condenser C_3 . Since both resonances of the input system are far removed from the tuning range of the output circuit the system is inherently free from shift in tuning with the range of antennae normally encountered in practice. That is, with antennae having capacitances of from 10 to 300 micromicrofarads, the antenna gain remains flat over the band for any such antenna and the tuning of condenser C_3 is substantially unaffected. The manner in which the gain remains substantially constant over the tuning range is apparent upon examination of Figure 3, curve (c), in which gain is plotted against frequency.

With the system above described, the selectivity of the receiver is maintained regardless of the antenna capacitance since the antenna resonances are maintained far removed from the tuning range. The gain increases with increase in antenna capacitance. For instance curve (d) in Figure 3 indicates the approximate gain with an antenna having three times the capacitance of that used in plotting curve (c). The gain does not, however, vary more than 2-1 for a 10-1 variation in antenna capacitance. A comparison with the non-uniform gain of magnetic coupling alone or direct coupling alone may be made by referring to curves (a) and (b) of Fig. 3. It may be explained that the curves of Fig. 3 were taken with the coils connected as previously described, L_3 being shorted for curve (a) and L_1 being shorted for curve (b).

As a specific example of values that may be used with the circuit above described for use with

the broadcast band of approximately 530 to 1700 k. c., I have found the following to be satisfactory:

$L_2=224$ microhenries

$L_3=13$ microhenries

$L_1=5890$ microhenries

$M=392$ microhenries

$k=36\%$

L_2 effective= 196.5 microhenries

$C_3=10-430$ micromicrofarads

$C_1=55$ micromicrofarads

$C_2=10-300$ micromicrofarads

$C_4=2-20$ micromicrofarads

Distributed capacitances:

$L_1=8.7$ micromicrofarads

$L_2=8.2$ micromicrofarads

$L_3=23$ micromicrofarads

The foregoing values are such that the resonance frequency of $C_2 C_1 L_1$ in the input circuit is between 110 and 245 k. c., frequencies far below the lowermost end of the tuning range of approximately 530 to 1700 k. c. The resonance frequency of $C_2 C_1 L_3$ in such circuit is between 5100 and 7800 k. c., frequencies far above the uppermost limit of said range. It is to be understood that these values are illustrative merely and that the advantages of the invention may be realized by utilizing values that will bring the resonance frequency of the first-mentioned circuit to the order of one-half or less of the lowermost frequency of the tuning range and of the second-mentioned circuit to the order of two times or more the highest frequency of said range.

In order to reduce the losses likely to result, all inductances and coil L_2 in particular should be made with multi-strand wire such as "Litz" wire and may advantageously be wound upon a core of comminuted iron. This latter type of winding may also be found desirable for the purpose of increasing the degree of coupling between coils L_1 and L_2 .

With a superheterodyne type of receiver there commonly occur spurious responses such as those caused by an "image," or by the harmonics of the oscillator plus and minus the intermediate frequency. This is a serious problem in receiver design. The coupling system of the present invention affords increased attenuation of such responses over conventional designs since at high or image frequencies the voltage impressed on the output circuit by the input circuit is developed almost exclusively across L_3 , since the reactance of C_1 is low compared to the reactance of L_1 at high frequencies. The reactance of L_2 is high compared with that of C_3 at image frequencies and the distributed capacity of L_2 tends to raise it still higher. Consequently the voltage developed across C_3 due to the image signal is only a small part of that developed across L_3 . Additional capacity may be shunted across L_2 , for instance the trimmer condenser C_4 , in order to tune it to image frequencies and thus raise its impedance thereto. An alternative design is one in which capacity C_3 is fixed and L_2 is varied for tuning over the range. This enables the designer to further control this attenuation to spurious responses as with inductance tuning the point of maximum attenuation may be made to move along with and in the same direction as the tuning of the desired signal, thus enabling a high ratio of signal-to-image response to be obtained.

Referring now to Figure 4, I have there shown a circuit in which the coupling system of the

present invention may be used not only in the antenna system but for interstage purposes. Corresponding parts are marked similarly to Figure 1 and the circuits are generally the same except for the addition of interstage coupling. In Fig. 4, however, I have shown a blocking condenser C_5 for the purpose of avoiding subjecting the tuning condenser C_3 to a high D. C. potential and a shunt feed resistor R_1 for the purpose of obtaining a proper operating potential on the plate of the amplifier 10. Resistor R_1 is in such case made of sufficient size to avoid serious loading of the output circuit due to the fact that it is effectively in shunt with the inductance L_3 of the interstage circuit. L_3 in the antenna circuit is shown as, and it preferably is, an internal loop antenna of relatively large area of the type previously alluded to while L_3 in the interstage amplifier is merely a small coil having the same inductance. When operated without an external antenna it is generally desirable to short-circuit L_1 as by a strap 21 as indicated at the left of Fig. 4.

Resistances R_2 and R_3 are for the purpose of maintaining proper potentials on the grids of tubes 10 and 20, and C_6 , C_7 , C_8 are by-pass condensers, and condensers C_9 are blocking condensers for preventing direct current from flowing in the parts of the circuits indicated. These are conventional elements and do not form any part per se of the present invention.

In Fig. 5 I have shown the invention applied for use with a three-band radio receiver. The circuit illustrated is similar to Fig. 4. Switching means are provided so that appropriate circuits may be made for the additional bands. The switch may conveniently take the form shown, in which switch 30 has a short arm 31 and a long arm 32, and is pivoted at 29 at which point the leads 37, 38 and 39 may be connected. Contacts 33, 34 and 35 may be provided for cooperation with the switch 30. Contact 34 is elongated somewhat so that the short arm 31 will cooperate therewith when such arm is in proper position.

For facility of explanation I will describe the switching means with respect only to the antenna circuit of Fig. 5. With the switch 30 in the position shown in Fig. 5 the inductance L_2 is shorted through contact 34 and lead 36 and the inductance L_3 forms the entire inductance in the output circuit to which the input circuit is coupled by capacitance C_1 . This capacitance may be made small to facilitate proper coupling. Inductance L_3 and condenser C_3 may be so related that this tunable circuit may be used for tuning over an intermediate range of frequencies such as the police band.

With the switch 30 turned clockwise from the position shown, arm 31 contacts the extended portion of contact 34 and maintains the short on inductance L_2 . Arm 32 makes contact at 35 and places inductance L_4 in shunt with inductance L_3 thus increasing the frequency to which the tunable circuit L_3 , L_4 , C_3 may be tuned. The circuit thus made may be used for short wave reception.

With the switch 30 turned counter-clockwise from the position shown in Fig. 5, the short is removed from inductance L_2 and the same circuit is obtained as is shown in Fig. 4 for use in tuning over a lower frequency range such as the standard broadcast band. It will be noted that an additional capacitance C may be shunted across L_3 in the interstage circuit in order to compensate for the capacitance inherent in loop L_3 .

In Fig. 6 I have shown a modification of the circuit shown in Fig. 5, as applied to the antenna circuit. L_1 and L_2 again illustrate the coupling transformer. The inductance L_3 is constructed as a built-in loop antenna and serves as a pick-up member for all three bands. The inductance L_3 constitutes a low impedance loop for the lowest frequency band, a high impedance loop for the middle frequency band and a capacitive antenna member for the highest frequency band.

The switching means 50 in Fig. 6 may be conveniently made by mounting a pair of partial sectors 51 and 52 of conductive metal on an insulating disc 53 mounted for rotation about pivot 54. Appropriate leads from the respective circuits are connected to predetermined contacts 70-81 located in a circle and each being equidistant from pivot 54. The switch has four operating positions for switching in, respectively, a push button control for the standard broadcast band, manual tuning for such band, an intermediate band such as a police band and a high frequency or short wave band.

With switch 50 in the position shown, the receiver is arranged for push button control. The input circuit may be traced from the external antenna connection A, through the parallel circuit C_1 , L_1 , inductance L_3 , contact 73, switch member 52, elongated contact 79 and thence to ground. The output circuit is from ground, through 79, 52, 78, L_3 , L_2 , junction 56, and condenser C_3 to the grid of tube 10. Across the output circuit may be placed one of a number of preadjusted capacitances C_{60} , C_{61} , etc., only two of which are shown, by actuation of one of the push buttons 60, 61, etc. This parallel branch runs from ground, through C_{60} for example, push button switch 60, contact 70, switch member 51, contact 73 and lead 55 to the junction point 56. Condenser C_4 is the trimmer condenser for the broadcast band manual tuning condenser C_3 and may be preadjusted at the factory so that its capacitance does not detune the push button tuning circuits. The short wave tuning circuit L_5 C_5 is shorted with the switch in the position shown. The other contacts of the switch are open circuited.

If the switch 50 be now turned clockwise one position the push button tuning circuits are discarded and the manual tuning condenser C_3 is inserted across the output circuit. The other circuits are not changed except the short wave tuning circuit L_5 C_5 previously shorted is disconnected from ground.

If the switch be now moved a second step in a clockwise direction the trimmer C_4 for the manual tuning condenser C_3 is removed from its position across the output circuit and the secondary L_2 shorted by means of switch member 51 making contact between contacts 73 and 75. The antenna-to-ground and grid-to-ground paths of the input and output circuits respectively remain otherwise unaffected since a path is maintained through L_3 , switch member 52 and contact 79. However, tuning condenser C_3 remains across L_3 which in this case constitutes the entire output circuit inductance. A trimmer condenser C_p for lining up the police band coil may be used if desired. C_p may be permanently connected as shown since it shunts the small inductance L_3 and consequently its adjustment has negligible effect upon lower frequency bands.

Finally, if the switch is moved clockwise three steps from that shown in Fig. 6 the coil L_2 remains shorted but short wave coil L_5 with its

trimmer C_5 in parallel therewith is placed across the circuit. C_3 remains in shunt with the output circuit. This enables the set to be used for short wave reception, the coil L_3 serving as an electrostatic pick-up member since it is connected in circuit at one end only through contact 75. Contact 73 is disconnected from arm 52 in this position. Due to the cut-out in switch member 52 there is no contact made between member 52 and contact 70 in this position.

Since member 52 contacts member 81 in this last position any desired auxiliary switching of a point to ground may be accomplished. For instance, contact 81 may be connected to cathode as shown in order to short circuit resistance R_4 , thereby reducing the bias potential on the grid of tube 10. This increases the amplification of the tube 10 for short wave reception.

The low impedance loop antenna described if of simple construction well adapted to be placed in or upon console model or large table model radio receivers by merely passing one or two turns therearound. This type of loop is of particular advantage in that it has a symmetrical directional pattern presenting large angles over which the signal strength is good and relatively small angles over which it is weak. This permits it to be more or less fixed with respect to the cabinet thus obviating the necessity of special mounting for rotation. With the conventional type of loop antenna consisting of a relatively large number of turns the directional pattern is non-symmetrical due to the antenna effect of the high end of the coil and the angle in which poor signal strength occurs is so large that a rotatable mounting is required.

Having thus described my invention, I claim:

1. A radio frequency coupling system comprising an input circuit having a series capacitance and a tuned output circuit, the input circuit comprising an inductance and a capacitance in parallel therewith, said inductance and capacitance being such that their resonant frequency is at least one-half the lowest frequency of said tuned output circuit, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a separate inductance common to both circuits magnetically uncoupled to the other inductances, said separate inductance having a low value such that it resonates with said parallel capacitance and said series capacitance at a frequency approximately twice the highest frequency of said tuned output circuit.

2. A radio frequency coupling system comprising an input circuit and an output circuit, means magnetically coupling said circuits, means independent of magnetic coupling for directly coupling the same and means for tuning the output circuit, said independent means consisting of a loop.

3. A radio frequency coupling system comprising an input circuit and an output circuit, the input circuit comprising an inductance and a capacitance in parallel therewith, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a capacitance, an independent inductance common to both circuits, said independent inductance being of the order of one fifteenth of the second inductance and one five-hundredth of the first inductance.

4. A radio frequency coupling system comprising an input circuit and an output circuit, the input circuit comprising an inductance and a

capacitance in parallel therewith resonating at a low frequency, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a capacitance, an independent inductance common to both circuits, said independent inductance being of the order of one fifteenth of the second inductance and one five-hundredth of the first inductance and resonating with said input circuit at a high frequency, said output circuit including means for varying the frequency over a tuning range which is approximately centered between the aforesaid resonant frequencies of the input circuit.

5. A radio frequency coupling system comprising an input circuit and an output circuit, the input circuit comprising an inductance and a capacitance in parallel therewith, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a capacitance, an independent inductance directly coupling both circuits, said independent inductance being in the form of a loop.

6. A radio frequency coupling system comprising an input circuit and an output circuit, the input circuit comprising an inductance and a capacitance in parallel therewith, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a capacitance, an independent inductance directly coupling both circuits, said independent inductance being in the form of a loop, and said output circuit comprising means for varying the frequency to which it may be tuned.

7. A radio frequency coupling system comprising an input circuit and a tuned output circuit, the input circuit comprising an inductance and a capacitance in parallel therewith, said output circuit comprising an inductance magnetically coupled to the first mentioned inductance and a capacitance, an independent inductance directly coupling both circuits, said input circuit being resonant at frequencies far removed from those to which the output circuit can be tuned, said independent inductance being in the form of a loop.

8. A multiband radio receiver including a radio frequency coupling system comprising an input circuit, a tuned output circuit, means for magnetically coupling the said circuits, inductive means consisting of loop operatively connected into both circuits and thereby directly coupling the same at least one auxiliary circuit for changing the tuning range of said output circuit to a higher frequency band, one of said circuits including a wire for short circuiting part of said magnetically coupled means, switching means for connecting said loop into said auxiliary circuits so that said loop may optionally constitute either a low impedance device for the lowest frequency band, or a high impedance device for a higher frequency band.

9. In a radio receiver, a radio frequency coupling system comprising an input circuit including a loop inductance and a parallel resonant circuit, and a tuned output circuit including said loop and an inductance magnetically coupled to the inductive element of said parallel resonant circuit.

10. In a radio receiver, a radio frequency coupling system comprising an input circuit including a loop inductance and a parallel resonant circuit, and a tuned output circuit including said loop and an inductance magnetically coupled to the inductive element of said parallel resonant circuit, the said input circuit having resonances respectively far below the lowest frequency of the range through which the output circuit is tuned, and far above the highest frequency of said range.

11. In a radio receiver, a radio frequency coupling system comprising an input circuit including a loop inductance and a parallel resonant circuit, and a tuned output circuit including said loop and an inductance magnetically coupled to the inductive element of said parallel resonant circuit, the said input circuit having a resonant frequency of the order of one-half or less of the lowest frequency of the range through which the output circuit is tuned and having another resonant frequency of the order of two times or more the highest frequency of said range.

12. In a three band radio receiver, a radio frequency coupling system comprising an input circuit including a loop inductance and a parallel resonant circuit, auxiliary circuit means including an adjustable condenser, a short circuiting element and a coil, and switching means for connecting and disconnecting said auxiliary circuit means but maintaining said loop in circuit whereby the same may act as a low impedance loop pick-up of signals in the lower frequency band, a high impedance loop pick-up for signals in the middle frequency band and an electrostatic pick-up member for the reception of signals in the highest frequency band.

13. In a multi band radio receiver, a radio frequency coupling system comprising an input circuit including a loop inductance and a parallel resonant circuit, a tuned output circuit including said loop and an inductance magnetically coupled to the inductive element of said parallel resonant circuit, auxiliary circuit means including an adjustable condenser, a short circuiting element and a coil, for optional inclusion in said circuits, and switching means for connecting and disconnecting said optionally included means but maintaining said loop in both circuits whereby the same may act as a low impedance loop pick-up of signals in the lowest frequency band, a high impedance loop pick-up for signals in an intermediate frequency band and an electrostatic pick-up member of signals in a higher frequency band.

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