June 27, 1939. P. WARE 2,163,646

TUNING CIRCUIT

Filed Aug. 8, 1936 2 Sheets-Sheet 1

Fig. 1

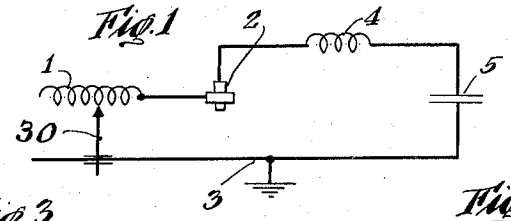


Fig. 3

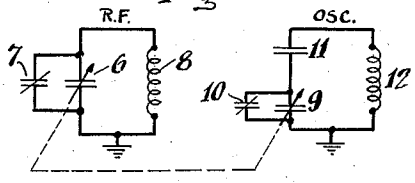


Fig. 5

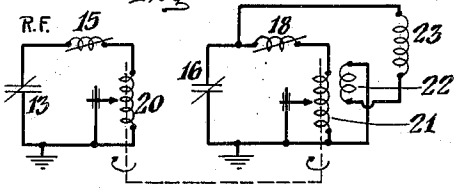


Fig. 4

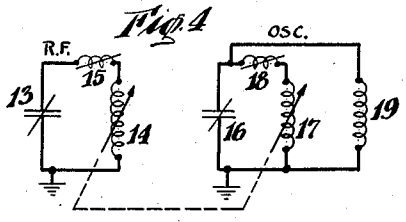


Fig. 6

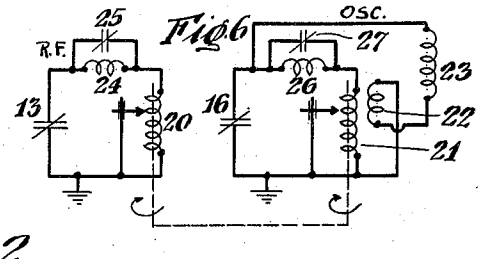
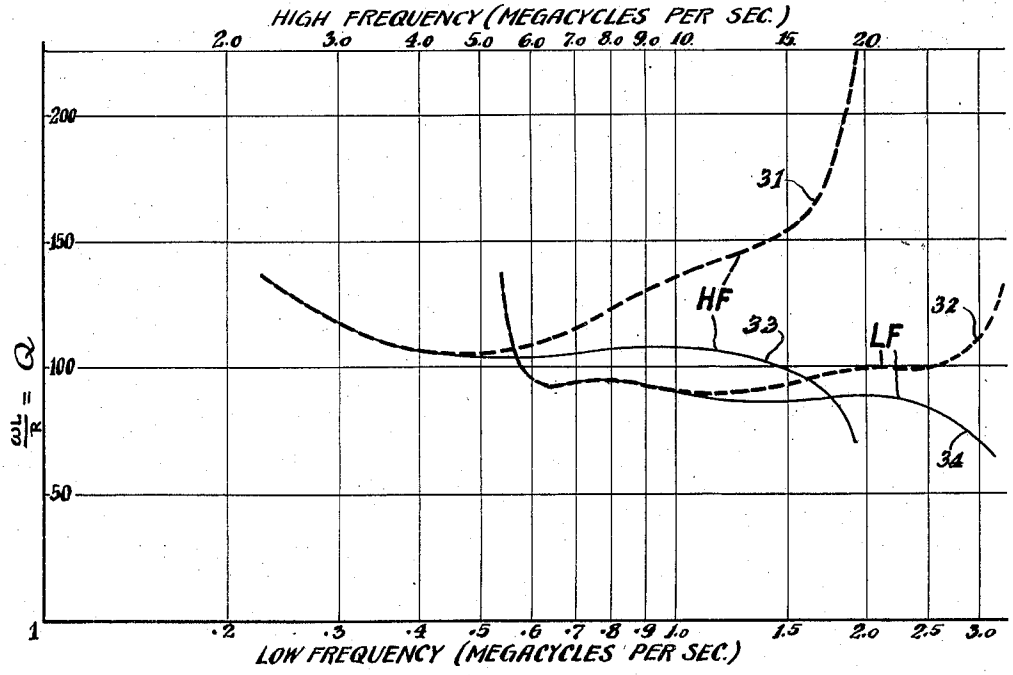


Fig. 2



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TUNING CIRCUIT

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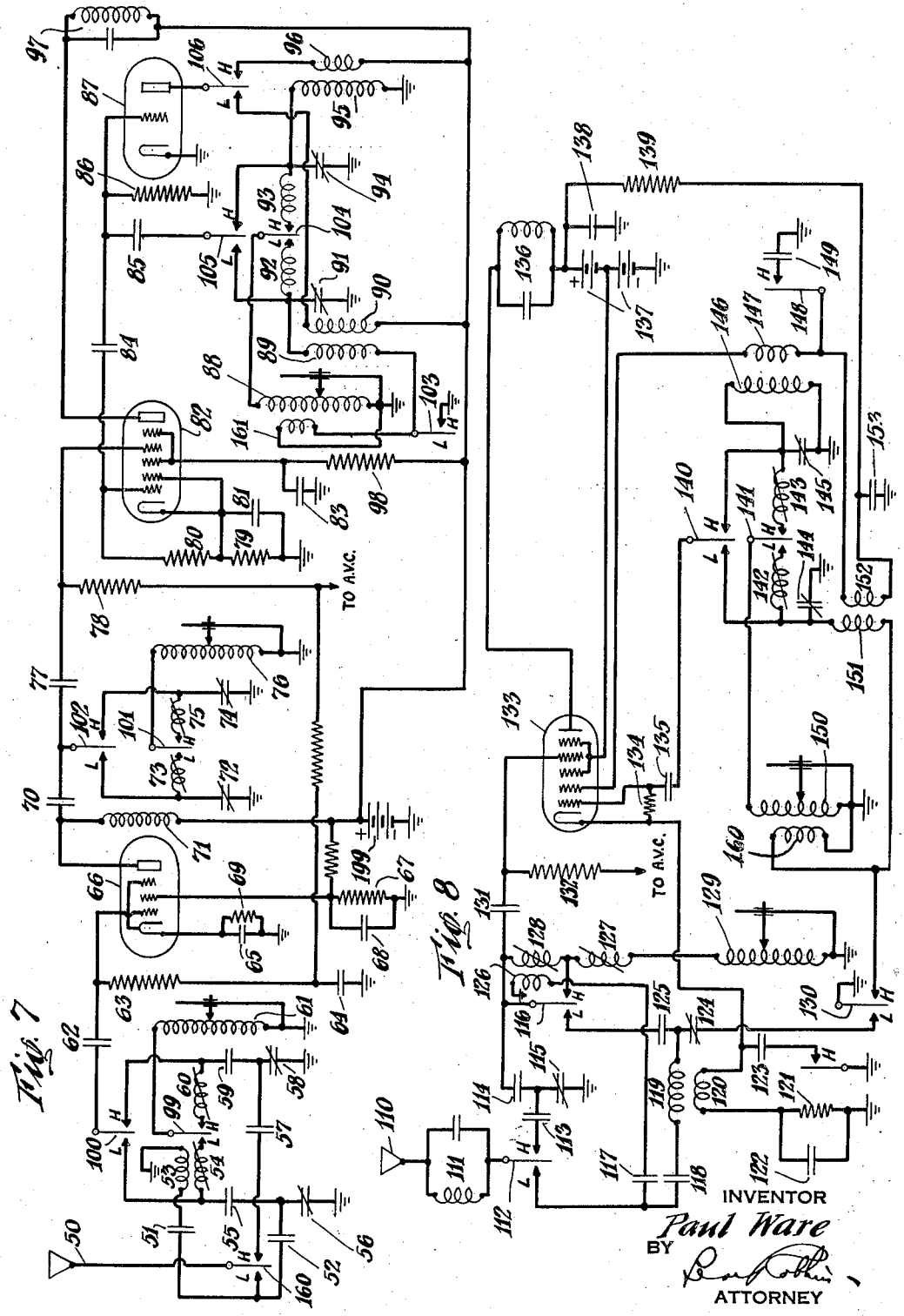


Fig. 7

Fig. 8

Patented June 27, 1939 2,163,646

UNITED STATES PATENT OFFICE

2,163,646

TUNING CIRCUIT

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Application August 8, 1936, Serial No. 94,928

5 Claims. (Cl. 250—40)

This invention relates to improvements in radio tuning circuits having variable inductances.

Certain of its objects are to improve the efficiency and range of such circuits.

Another object is to furnish a means for holding in step, or "track", the several circuits required in superheterodyne pre-selection.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth including the illustrations in the drawings.

Figure 1 illustrates a portion of a tuning circuit employing a variable inductance coil;

Figure 2 is a graph having curves representing the Q of certain coil assemblies over a range of frequencies;

Figure 3 illustrates conventional variable condenser tuning;

Figure 4 shows a variable inductance tuning arrangement;

Figure 5 shows another inductance tuning arrangement;

Figure 6 shows a modified inductance tuning arrangement;

Figure 7 shows a radio circuit employing inductance tuning; and

Figure 8 shows a modified radio circuit.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the construction of parts without departing from the spirit of the invention. In the following description and in the claims, parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

In the drawings, Figure 1 represents a slide wire variable inductance coil 1 whose terminals are by way of slip ring and brush assembly 2 and by way of moving contactor 30 and ground connection 3. The structure of such a device is described in detail in my co-pending applications Ser. No. 31,823 filed July 17, 1935, and Serial Number 94,927, filed August 8, 1936, the latter filed concurrently herewith.

A series arrangement of fixed end inductance 4 and fixed condenser 5 is connected between slip ring brush assembly 2 and ground 3.

The components 1, 4 and 5 may constitute a tunable resonant impedance whose voltage at various frequencies may be obtained across the terminals of condenser 5. It has been found that a tuning ratio of 10:1 is feasible with such an arrangement. As this necessitates a high frequency end limiting inductance as small as 1% of the total inductance at the low frequency extreme, it is necessary to have the resistance of the end inductance low in order to develop the needed voltage at and near the high frequency extreme. The end inductance might comprise a certain number of unused turns at the high frequency end of the variable coil 1, but it is preferable to use a separate component in series with the variable coil unit.

One advantage of this arrangement resides in the fact that the entire variable coil may be utilized for varying the inductance. In addition this arrangement has the advantage of enabling the use of an end inductance of better characteristics than an equivalent part of the unused turns on the variable coil, for the reason that under practical design limitations the form factor and losses of such unused end turns of the variable unit are worse than those that can be obtained in a practical design of a separate coil. It will thus be apparent that, by the arrangements described, the high frequency resistance of end inductance 4 is less than the resistance of a portion of the variable inductance 1 of equal inductive value or, in other words, the ratio of the reactance to the resistance for coil 4 is greater than for such part of coil 1 as would be required in the circuit if coil 4 were not used. This ratio is commonly used to designate the characteristics of an inductive coil. The ratio is usually expressed mathematically as

$$Q=\frac{2\eta fL}{R}$$

In Figure 2 are shown curves representing the improvement in the

$$Q=\frac{2\pi fL}{R}$$

of the coil combination obtained by using a separate end inductance instead of a number of unused turns at the end of the variable coil. The dotted curves 31 and 32 represent the value of Q over two frequency ranges for a given variable coil with proper end inductances 4 and capacitances 5 in each range. The solid curves 33 and

34 show the Q of the variable coil over these ranges with the same capacities as used for curves 31 and 32, respectively, but without the use of the separate end inductances 4. It follows that the tuning range for a variable inductance and fixed capacity may be increased by the use of the end inductance, because the resistance of the circuit in the region of the high frequency extreme has been lowered and hence the limit where an acceptable value of impedance is obtainable has been moved out to a higher frequency.

The increased frequency range made possible by this tuning system introduces another problem in the design of tuning circuits. This is where the variable inductances are employed as pre-selectors in superheterodynes. The pre-selector consists of one or more resonant circuits tunable to the frequency of the incoming signal and another tunable resonant circuit determining the frequency of the local oscillator. It is customary in superheterodynes always to maintain the oscillator at a frequency differing from the tunable incoming signal resonant circuits by an approximately constant amount called the intermediate frequency. The method or procedure of maintaining this frequency difference during tuning is usually spoken of as "tracking".

The methods employed to track variable condenser tuning circuits and variable inductance tuning circuits in superheterodynes will be better understood by reference to Figures 3, 4, 5 and 6.

Figure 3 shows the customary method of tracking variable condenser operated pre-selectors in superheterodyne circuits. The variable capacities 6 and 9 are electrically and mechanically similar and mounted on a common shaft. The radio frequency circuit comprises variable capacity 6, minimum frequency adjusting capacity 7, and fixed inductance 8. In order to track the oscillator over the required restricted range, fixed capacity 11 is placed in series with variable capacity 9 in the oscillator circuit and fixed inductance 12 in the oscillator circuit is given a smaller value than fixed inductance 8 in the radio frequency circuit. A minimum adjusting capacity 10 is connected in shunt with variable capacity 9.

An equivalent pair of circuits for pre-selection employing variable inductances is shown in Figure 4. The radio frequency circuit here comprises variable inductance 14, adjustable minimum frequency inductance 15 (to be referred to as the end inductance) and adjustable fixed capacity 13. The restricted range oscillator circuit consists of variable inductance 17, adjustable minimum frequency end inductance 18 and adjustable fixed capacity 16. In addition, there is the inductance 19 connected in shunt with the capacity 16. The variable inductances 17 and 14 are similar electrically and mechanically and are on a common control shaft for tuning purposes.

The variable capacity method of Figure 3 and the variable inductive tuning method of Figure 4 will yield similar tracking characteristics. With either of these methods the frequency difference between the radio frequency and oscillator circuits may be made exactly equal to the intermediate frequency at three different points over a tuning range and by proper design and adjustment these points of exact tracking may be so positioned in the tuning range that the deviation from perfect tracking between these points will be at a practical minimum for this arrangement. This condition exists when the maximum deviation between points and at the ends of the tuning range is about equal.

By making end inductances 15 and 18 as separate components similar to inductance 4 in Figure 1, an increased tuning range is made possible but the increased tuning range makes the tracking points more widely spaced thus resulting in increased deviation from perfect tracking between points. An additional tracking correction is therefore desirable in such a system adapted for use for an expanded tuning range.

Figure 5 shows an improvement over the tuning circuit of Figure 4 where in the ganged variable coils 20 and 21 of the type indicated in Figure 1 and set forth in detail in my above-mentioned co-pending applications have been added, together with a mutual coupling coil 22 coupled to the variable coil 21.

I have found that if the shunt inductance 19 shown in Figure 4 is moved so as to have an inductive relationship with variable coil 17 the tracking may be materially improved. As shown in Figure 5 this is accomplished by dividing the shunt inductance into two parts, 22 and 23, and disposing the part 22 concentrically inside or outside of variable coil 21 so that it will inductively couple therewith. It will be noted from Figure 5 that the mutual inductance between coils 22 and 21 will vary with the tuning because as the moving contactor is moved upward less and less turns of coil 21 will be in the circuit, the part of the variable inductance 21 below the contactor being short circuited as shown. The coils 22 and 23 constitute a shunt around the parallel resonant circuit. If coil 22 is connected so that its polarity causes the inductance of the whole circuit to be reduced instead of increased, and suitable physical conditions are provided, such as the size and location of coil 22 at its optimum position with respect to variable coil 21 and the optimum selection of the sizes of coil 23, end coil 18 and fixed capacity 16, then the tracking is found to be greatly improved in a wide range circuit over that which is possible with the three point arrangement of Figure 4. It is to be understood that the adjustment of components of the oscillator circuit of Figure 5 are made with a given set of component adjustments of its cooperating radio frequency circuit and with a predetermined intermediate frequency.

Figure 6 shows a modification of the circuit of Figure 5 wherein individual adjusting capacities 25 and 27 are shunted around fixed end coils 24 and 26, respectively, in place of the directly adjustable and similarly disposed end coils 15 and 18 of Figures 4 and 5. This modification permits the use of standard commercial adjustable "trimmer" condensers and other standard parts.

Figure 7 shows a complete pre-selection system for a superheterodyne radio receiving set employing three variable inductance tuners of the type indicated in Figure 1 and described in my co-pending cases, mechanically operating in unison on a single shaft (i. e., ganged), thus affording single control for tuning. The tube 66 is a radio frequency amplifier, the tube 82 is a modulator and tube 87 is an oscillator tube. One of the inductive tuning units 61 is employed to tune the circuit of the antenna 50. A second variable inductance unit 76 is employed for tuning the output of tube 66 (which is also the input of tube 82) at radio frequency. The third inductive tuning unit 88 is for the purpose of maintaining the frequency of the circuit of oscillator tube 87 at a substantially fixed frequency spacing from the

frequency of the two other radio frequency circuits. This frequency difference or spacing provides the intermediate frequency which is supplied to the fixed intermediate frequency amplifier by circuit 97. Circuit 97 is the primary circuit of the first intermediate frequency transformer of a standard superheterodyne circuit. There may be one or more such transformers tuned to the intermediate frequency. The intermediate frequency circuit and the audio frequency output circuit may be of standard design.

Anode power for the modulator tube 82 is supplied from the battery 199 connected to the lower part of circuit 97 as shown.

There are a number of single pole two-position switches disposed throughout the pre-selector and it is understood that all of these switches are mechanically attached to a common actuating means so that they are either all simultaneously snapped to position L or to position H. Position L connects all of the components so as to operate over a low frequency wave range which may cover .54 to 2.50 mc/s. (megacycles per second) and when in the position H the circuit components are of such size and connection as to enable tuning the system over a high frequency range which may be adjusted to cover 2.30 to 18.00 mc/s.

Considering the antenna tuning circuit which is connected to the input terminals of radio frequency amplifier tube 66, when the switches are in the low frequency position L signal current entering the system by way of antenna 50 is divided just to the left of switch 160 and part of the current passes through capacitance 51 and choke coil 53 to ground. The choke coil 53 is designed to resonate at a frequency below the lower limit of the low frequency range. Current also passes in the other branch of the divided antenna circuit through capacitance 52 to a junction between capacitance 55 and grounded capacitance 56 which together form the resonant circuit fixed capacitance for the low frequency range. The inductance of this range comprises adjustable end inductance 54 and the variable inductance 61.

The stepped-up voltage developed across the tuned impedance of this resonant circuit is then led by way of switch 100 and capacitance 62 to the control grid of tube 66 and by way of ground and capacity 65 to the cathode of tube 66. Throughout most of this range coupling from the antenna is supplied through the branch containing capacity 52 and near the low frequency end of this range resonant choke 53, coupled to end inductance 54 is employed for the purpose of improving the step-up in this region.

With the switches in the high frequency position H current entering the system by way of antenna 50 is carried through capacitance 57 to a point connected between the two resonant circuit capacities 58 (grounded) and 59. High frequency range end inductance 60 and the variable inductance 61 are connected across capacities 58 and 59. The voltage across the tunable impedance thus formed is led through switch 100 and capacity 62 to the control grid of tube 66 and by way of ground and capacity 65 to the cathode of tube 66 as previously described. Resistance 63, high compared with the resonant circuit impedance, is for the purpose of supplying automatic volume control voltage in the usual manner across the input terminals of tube 66. Capacity 62 is for passing radio frequency and preventing the short circuiting of the automatic volume control voltage through the tuning system. Capacitance 64 is for by-passing purposes and capacitance 65 is a by-pass around the biasing resistance 69.

The second radio frequency tuning circuit comprises for the low frequency range capacitance 72, end inductance 73 and the variable inductance 76, and for the high frequency range capacitance 74, end inductance 75 and likewise variable inductance 76. The choke coil 71 is effectively connected across the output terminals of tube 66 and is employed to supply that tube with anode power from the battery 199. The characteristics of the choke 71 are such as to afford the highest impedance over the entire tuning range of the system without causing resonance at any frequency within that range. The capacitance 70 is for the purpose of passing radio frequency current and blocking the D. C. current from battery 199 from being short-circuited by the tuning components. Capacitance 77 and resistance 78 are employed in the same manner for tube 82 respectively as capacitance 62 and resistance 63 are in the case of tube 66. The path of the radio frequency current between tubes 66 and 82 is from the anode of tube 66 by way of capacitances 70 and 77 to the control grid of tube 82 as shown, with the tunable impedance interposed between this line and ground as shown. This variable impedance which is tuned in unison with the antenna input circuit already described accomplishes two purposes. One is to afford amplification when cooperating with the tube 66 and the second purpose is that of increasing the radio frequency selectivity. Capacitance 81 by-passes cathode biasing resistance 79 for tube 82 as shown.

The oscillator tuning circuits are as follows: When the switches are in their low frequency position the resonant circuit is by variable inductance 88, end inductance 92 and fixed capacitance 91. In shunt with fixed capacity 91 is the shunt inductance divided into two parts 89 and 161. The part of the shunt inductance 161 is the equivalent of coil 22 in Figures 6 and 5. When the switches are in the high frequency position H the tunable resonant circuit of the oscillator comprises the same variable inductance 88, the end inductance 93 and the fixed capacity 94, in shunt with which is the shunt inductance 95. The feed-back or tickler circuit for the low frequency range runs from the anode of tube 87 through the switch 105 and the tickler coil 90 to the positive pole of battery 199, and for the high frequency range from the anode through tickler inductance 96 to the positive pole of the same battery. On the low frequency range the polarity of coupling between coils 90 and 89 is such as to produce oscillations and likewise on the high frequency range the coupling between coils 96 and 95 is of such polarity as to produce oscillations. The resonant tuning circuits just described are connected by way of switch 105 through capacitance 85 to the control grid of tube 87 and the resistance 86 is for the purpose of producing a suitable bias. The oscillations thus developed by the circuits in cooperation with tube 87 are supplied by way of capacitance 84 to the oscillator grid of modulator tube 82. The resistance 80 is for the purpose of additionally adjusting the bias of tube 82 as the strength of the oscillator voltage may vary.

Tube 82 may be one of the well known pentagrid types such as 6A7 or 6A8 wherein the second grid out from the cathode is known as the anode grid. The connection shown in Figure 7 where this grid is connected to the cathode is not un-

usual, and enables retention of the desirable conversion gain properties of the pentagrid with the use of a separate oscillator tube as 87.

The two radio frequency tuning circuits employed in Figure 7 are for the purpose of affording a much better superheterodyne image ratio than could be obtained with a single radio frequency pre-selection circuit. Two important advantages obtained with a variable inductance method over the customary condenser tuned method are considerably wider tuning range per switch position, and improved radio frequency amplification on the shorter waves. The wider tuning range made possible with this system results in greater economy due to the reduction in the number of circuits required, and also enables the use of considerably longer short wave dial scales with greater accuracy than is possible with present condenser tuned systems.

An important advantage of inductive tuning especially where wide frequency tuning ranges may be covered, as with this system, is that a substantial amount of fixed capacitance remains in the circuit at all times. At the high frequency end of a range where condenser tuning is employed, a large part of the total resonant circuit capacitance is due to the wiring and input or output electrodes of the associated tubes. On the other hand with inductive tuning a much less proportion of the fixed capacitance is made up of the circuit and tube capacitances.

In certain applications it may be desirable to employ a shunt coil across the fixed capacity of the radio frequency circuit, as across the capacitance 13 of Figure 4 as well as the fixed inductance 19 across the fixed capacity 16 of the oscillator circuit.

It has been found that the presence of the choke coil 71 in the output of tube 66 of Figure 7 has aided the tracking of this stage with the antenna input tuning stage tunable by variable inductance 61. This is because the slight frequency range restricting effect of choke 71 about equals the restricting effect of the antenna circuit by coupling to the tunable resonant circuit.

Figure 8 shows a superheterodyne pre-selector employing two variable inductance units 129 and 150. These variable inductances are similar electrically and mechanically and are mounted on a common shaft for single control of tuning.

These variable inductance units are individually shielded as in the case of the three variable inductance units shown in Figure 7.

The radio frequency signals enter the pre-selector through antenna 110 and pass through wave trap 111. This trap is resonant to the intermediate frequency and is customarily employed in single pre-selection circuits to prevent reception of signals in the region of this frequency. On the low frequency range all of the switches are in the position L and the antenna signals for this range pass through switch 112 and are divided through capacitances 117 and 118. Those passing through capacitance 117 go to ground through coil 126 which is designed to resonate below the low frequency limit of this range. Those passing through capacitance 118 go through inductance 119 to the joint between series capacitances 124 and 125, capacitance 124 being connected to ground by switch 130 on this range. It will be observed that the capacitances 124 and 125 in series constitute the resonant circuit fixed capacitance for the low frequency range. The remainder of the low frequency resonant circuit is through switch 116 and end inductances 128, 127 in series and the variable inductance unit 129.

The size of inductance 119 is chosen so that the antenna circuit effective capacitance in conjunction with capacitance 118 and capacitance 124 will resonate outside the high frequency limit of the low frequency range. The coupling of the antenna circuit to the input resonant circuit over the low frequency range is by mutual inductance between coils 126 and 128, and by the common capacitance 124.

On the high frequency range all of the switches are in the position H and the operation of the antenna input circuit is as follows: From antenna 110 and through trap 111 and switch 112, signals are fed through capacitance 113 to the joint between capacitances 114 and 115, which in series constitute the fixed capacitance of the resonant circuit for this range. In shunt with capacitances 114 and 115 is the end inductance 127 (end inductance 128 being shorted out on this range by switch 116) and the variable inductance 129. The coupling between the antenna circuit and the input resonant circuit on the high frequency range is by common capacitance 115.

The resistance 132 is for conveying automatic volume control voltage to the control grid of tube 133, and the capacitance 131 is for passing radio frequency current and preventing the short circuiting of the automatic volume control voltage by the tuning components.

The oscillator tuning circuit operates over the low frequency range by variable inductance 150, end inductance 142 and the fixed capacitance 144. The oscillator circuits are arranged to run at a higher frequency than the radio frequency circuits. To restrict its range a shunt inductance is connected across and is made a part of the low frequency resonant circuit. This shunt inductance is divided into two parts, coil 151 and the mutual coil 160. The mutual coupling between coil 160 and the variable inductance 150 varies with the tuning in the manner explained in the description relating to the coil 22 in Figs. 5 and 6.

The oscillator high frequency range resonant circuit is by the same vehicle inductance 150 and by end inductance 143 and fixed capacitance 145. The oscillator on this range also runs at a higher frequency than its cooperating radio frequency circuit, and for this purpose its range is restricted by the shunt inductance 146.

The tube 133 may be one of the well known pentagrid types 6A7 or 6A8 wherein the first and second grid from the cathode are respectively the oscillator grid and oscillator anode.

The feed back or tickler circuit for the oscillator low frequency range is from this anode grid through coils 147 and 152 and resistance 139 to positive terminal of battery 137, capacitances 153 and 138 being for by-passing purposes. The oscillator high frequency range feed back circuit is the same as that used on the low frequency range excepting that the coil 152 is effectively shorted to ground by way of by-passing capacitance 149 when the switch 148 is in the position H. The polarity of mutual coupling between coils 147 and 146 and also between coils 152 and 151 is such as to produce oscillations. The mutual coil 160 is shorted to ground on the high frequency range by switch 130.

The resistance 134 and the capacitance 135 are connected as shown and are for the purpose of producing the desired oscillator grid bias in tube 133. The resistance 132 is for the purpose of conveying automatic volume control voltage to

the control grid of tube 133 and the capacitance 131 passes radio frequency current but prevents the short circuiting to ground of the automatic volume control voltage by way of the tuning components.

The output of tube 133 is from its plate through resonant circuit 136 to the positive terminal of battery 137. The circuit 136 is tuned to the intermediate frequency and this circuit may comprise the tuned primary of the first of one or more intermediate frequency transformers disposed in the usual circuits employed in superheterodyne receivers. The third and fifth grids of tube 133 are connected to a tap on the battery 137 as shown.

The coil 120 which is coupled to coil 119 is connected between the cathode biasing resistor 121 and the cathode of tube 133, resistance 121 being by-passed by capacitance 122. The coil 120 is employed only on the low frequency range and its size and degree of mutual coupling with inductance 119 as well as its positioning along the coil 119 are such as to improve the superheterodyne image ratio of the circuit. This is desirable where a single pre-selector circuit is used as in Fig. 8, and it may also be employed in a double pre-selector, as Fig. 7, altho it is not shown in Fig. 7.

The several variable inductance units shown in connection with the circuits of Fig. 7 and Fig. 8 are individually shielded to prevent pick-up of undesired signals and noise as well as to protect them from atmospheric dust and dirt. The circuits just described could be extended to cover more than two frequency ranges if desired.

The coil size for the variable inductances is limited by the highest frequency to which it is desired to tune and must be such as to ensure that the tuning range does not pass over its natural frequency. At the same time it is desirable to make the coil as large as possible in order to have the average impedance high over the tuning range. If any turns are in the circuit while tuning through the natural frequency, there is usually enough mutual inductance between these turns and the shorted unused part of the coil to cause a serious loss in performance at and near this point, and for this reason the coil geometry and number of turns are chosen so as to have this natural frequency fall just outside the high frequency limit of the highest frequency range to be tuned.

There are methods of tuning through this natural frequency point, and these are described in my co-pending application Serial No. 95,332, filed August 11, 1936.

In operating over the two ranges with the same variable inductances by switching between two sets of suitable circuit components and arrangements, it has been found desirable to divide the total frequency coverage so that less range is covered in the low frequency than in the high frequency switch positions. This is because the considerably larger fixed capacity required to tune the low frequency range renders the average impedance over this range lower than that of the high frequency range if the tuning of the two ranges is equal. By making the low frequency coverage less than the square root of the total frequency coverage of the two ranges, its end inductance is increased and hence its fixed capacity is decreased, thus improving the impedance of the low frequency range. The larger the end inductance the greater the advantage described in connection with the curves of Fig. 2.

It will be observed in Fig. 8 that the tracking aid coil 160 (and likewise coil 161 in Fig. 7) is in circuit only on the low frequency range as it is not found to be necessary on the high frequency range. In general tracking errors are less the farther removed the tuning range is from the fixed intermediate frequency, and the narrower the tuning range. The natural frequency of coil 160 (and coil 161) must be such when shorted out on the high frequency range by switch 130 in Fig. 8 (or switch 103 in Fig. 7) that it is outside the limits of the high frequency range.

Unlike condenser tuning where the impedance of the circuit tends to be lower at the lower frequency end of a tuning range, the variable inductance offers an additional advantage in the ease of obtaining uniform oscillations over a given range. The increasing impedance as the circuit is tuned toward the lower frequency end of a range with this inductive tuner enables the use of a high frequency oscillator feed back circuit whose natural frequency is outside the high frequency range, such a degree of feed back being sufficient to produce stable oscillations over a much wider range than would be possible without additional feed back aids in condenser tuned circuits. The natural frequency of the feed back circuit is usually determined not only by the feed back coil itself but also by its mutual coupling to any other circuit plus the additional inductance and capacitance of the connecting leads and associated tube. The high frequency feed back coils just described are shown as 147 and 96 respectively in Figs. 8 and 7. Stable oscillations are readily obtainable with the system just described over a frequency range of over 10 to 1 which requires a reactive ratio of over 100 to 1. The feed back or tickler coil may be partly or wholly arranged inside the variable coil as outlined in my co-pending application Serial No. 31,823, or may be coupled to the shunt inductance 146 by coil 147 as shown in Fig. 8.

This application is a continuation in part of my co-pending application for Radio apparatus, Serial No. 31,823, filed July 17, 1935.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A resonant circuit for tuning within a predetermined frequency range comprising a slide wire variable inductance, a fixed inductance in series therewith, whereby the magnitude of said variable inductance may be varied between its maximum value and substantially zero during tuning over said predetermined frequency range, and a capacitance bridged across the series arrangement, the Q of said fixed inductance at a given frequency within said frequency range being higher than the Q of said variable inductance at said frequency when said variable inductance is adjusted to an inductive magnitude equal to that of said fixed inductance, whereby the impedance of said resonant circuit throughout the high frequency region of said range is improved, where

$$Q=\frac{2\pi fL}{R}$$

L being the inductance and R being the high frequency resistance of the inductance element

or portion of the inductance element in question and f being the frequency.

2. A resonant circuit for tuning within a predetermined frequency range comprising a variable inductance and a fixed inductance in series, and a capacitance bridged across the series arrangement, the Q of said fixed inductance at a given frequency within said frequency range being higher than the Q of said variable inductance at said frequency when said variable inductance is adjusted to an inductive magnitude equal to that of said fixed inductance, where

$$Q=\frac{2\pi fL}{R}$$

L being the inductance and R being the high frequency resistance of the inductance element or portion of the inductance element in question and f being the frequency.

3. A resonant radio circuit for tuning within a predetermined frequency range comprising a variable inductance capable of reduction to substantially zero inductive value during tuning and a fixed inductance in series therewith, and a fixed capacitance bridged across said series combination of inductances, the radio frequency resistance of said fixed inductance at a given frequency within said frequency range being less than the radio frequency resistance of said variable inductance at said frequency when the variable inductance is adjusted to an inductive magnitude equal to that of said fixed inductance, whereby to improve the impedance of the said resonant circuit in the high frequency region within the said predetermined tuning range.

4. A resonant circuit for tuning within a predetermined frequency range comprising a slide wire variable inductance, a fixed inductance in series therewith whereby the magnitude of said variable inductance may be varied between its maximum value and substantially zero during tuning over said predetermined frequency range, a capacitance bridged across the series arrangement, and an adjustable capacitance in shunt with said fixed inductance whereby to enable adjustment of the high frequency limit of said tuning range.

5. A resonant radio circuit for tuning within a predetermined frequency range comprising a variable inductance capable of reduction to substantially zero inductive value during tuning and a fixed inductance in series therewith, and a fixed capacitance bridged across said series combination of inductances, the ratio of reactance to radio frequency resistance of said fixed inductance at a given frequency within said frequency range being higher than the ratio of reactance to radio frequency resistance of said variable inductance at said frequency when the variable inductance is adjusted to an inductive value approximately equal to that of said fixed inductance, whereby to improve the impedance of the said resonant circuit throughout at least the high frequency half of the said predetermined tuning range.

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