SWITCHLESS MULTIBAND RADIO APPARATUS

[Diagram of electric circuit with labels and connections]

Fig. 1.

Fig. 3.

Fig. 4.

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This invention relates to high-frequency apparatus suited for operation in any of two or more frequency bands, and particularly relates to multiband radio receivers.

Heretofore, in multi-band receivers and the like, in changing from one frequency band to another, switches have commonly been used in various ways to change the inductances of the tuned or tunable high-frequency circuits; in some cases, the switches were employed to shunt or short-circuit those portions of the coils not used in the higher bands; in other cases, the switches were used to shift the circuit connections from one set of coils used for one band to another set of coils used for another band. Aside from the question of their cost, such switches have been a source of trouble because their contact resistance increases with age and so increasingly adversely affects the performance; moreover, the inductance of these switches and the variations of their inductance is a further source of difficulty in the manufacture and operation of multiband receivers one or more of whose bands are in the ultra-high portion of the frequency spectrum.

In accordance with the present invention, the use of band-change switches is dispensed with and the changeover from one frequency band to another is effected without use of switches, plug contacts or other similar switching expedients: the coil or coils not to be used for a selected band remain in circuit but are effectively disabled by insertion therein of high-loss magnetic core structure which reduces the Q of the unused coil or coils to very low magnitude.

More particularly, and in preferred forms of the invention, as a low-loss core is being moved in any one of the coils of a circuit for tuning it within a selected band of frequencies, a high-loss core, mechanically connected to the low-loss cores moving in the remaining coil or coils of the circuit to maintain the Q thereof at insignificantly low value.

Further in accordance with the invention, the capacitance in shunt to the coil of a lower-frequency band is usually greater than the capacitance in shunt to the coil of a higher frequency band to decouple the two circuits.

The invention further resides in the methods of and in the features of combination, construction and arrangement hereinafter described and claimed.

For more detailed understanding of the invention, reference is made to the accompanying drawings in which:

Figure 1 is a schematic diagram of a portion of a radio receiver;

Figures 2, 2A and 2B are explanatory figures referred to in discussion of the tuning of circuits shown in Figure 1;

Figures 3 and 4 are explanatory figures referred to in discussion of the materials used in the cores of Figure 1;

Figures 5 and 6 are explanatory figures referred to in discussion of Figure 1;

Figures 7 and 8 disclose multi-band circuits using modifications of the invention;

Figure 9 illustrates a different mechanical arrangement of the cores for multi-band operation; and

Figure 10 illustrates an oscillator circuit using the core arrangement of Figure 9.

As typical of radio apparatus employing the invention, reference is made to Figure 1 which discloses the front end or high-frequency portion of a multi-band superheterodyne receiver tunable through two bands substantially separated in the frequency spectrum and in which the changeover from reception in one band to reception in another band is effected without recourse to any coil switching. For purposes of explanation and without limitation of the invention thereto, it is assumed the receiver is tunable for reception of signals in a "low" band from 0.54 to 1.6 megacycles (the present AM broadcast band) and in a "high" band from 86 to 108 megacycles (the present FM broadcast band).

In the input circuit of tube 10, which serves as the radio frequency amplifier tube, are permanently connected in series the coil 13A tunable for reception in the "high" band and coil 14A tunable for reception in the "low" band. Similarly, in the input circuit of the mixer tube 11 are permanently connected in series the coil 13B tunable for reception in the "high" band and coil 14B tunable for reception in the "low" band. The local oscillator 12, whose output is injected into the mixer tube 11 for conversion of the received signals to the intermediate frequency at which further amplification is effected by an intermediate-frequency amplifier generically represented by the block 17, comprises in circuit with the tube 12 a coil 13C tunable through the proper range of frequencies for the "high" band and the coil 14C tunable through the proper range of frequencies for the "low" band; these coils are also permanently connected in series.

In the particular arrangement shown in Figure 1, the coils 13A, 13B and 13C are tunable through the range of frequencies corresponding with the "high" band by the low-loss cores 18A, 18B and 18C respectively, and the coils 14A, 14B and 14C are tunable through the "low" band by the low-loss cores 19A, 19B and 19C respectively. The cores 18A-18C and 19A-19C may be of any of the known types of cores used in the so-called permeability tuning. They may be solid plugs of copper or brass or the like or they may be of powdered iron; in either case, the movement of
the core within the corresponding coil substantially changes the inductance of the coil but has slight effect upon its effective alternating current resistance so that the Q of the coil remains high.

\[ Q = \frac{vL}{R} \]

With the low-loss core structures in the positions shown in Figure 1, their movement is effective to tune the coils A, B, and C for reception of signals in the "high" band. It should be noted that the coils A, B, and C are also in circuit but they are ineffective for the reason that there is disposed within them the high-loss cores A, B, and C respectively, whose construction and characteristics are later more specifically discussed.

To adapt the receiver for reception of signals in the "low" band, all of the core structures are moved upwardly from the position shown in Figure 1 so that the low-loss cores A, B, and C are replaced in the coils A, B, and C by the high-loss cores A, B, and C which effectively disable the tube and without recourse to any switching. This same movement of the core structures is effective to position the low-loss cores A, B, and C within the "low" band of coils A, B, and C, so that further adjustment of the cores effects tuning of the bands and the band changeover or selection may be more fully understood by reference to Figure 2 which shows four significant positions of cores A, B, and C with respect to coils A, B, and C. It shall be understood that the coils and cores of Figure 2 correspond with those of any one of the circuits or stages of Figure 1 or other figures later discussed, and that the insertion and withdrawal of the cores may be effected by movement of the cores, or the cores, or both.

With the cores A, B, and C in the #1 position of Figure 2, which corresponds with the positions of the cores disclosed in Figure 1, and assuming the low-loss core is of magnetic material, the inductance of coil 13, because of maximum insertion of core 18 and coil 14 is at its maximum and the associated circuit is therefore tuned to the low frequency limit of the "high" band, Figure 2A. For the #1 position of the cores, the high-loss magnetic core 20 is of magnetic material, the inductance of coil 13 and the Q of this coil is consequently so low that although it is in circuit with coil 13, it has inappreciable resonant effect and in any event prevents response of the receiver to signals in the "low" band. For the #1 position of the cores, the low-loss core 18 is far removed from the coils 13 and 14 and has no appreciable effect upon them.

As the core structures are moved from the #1 position towards the #3 position, Figure 2, the per-cent insertion of low-loss core 18 in coil 13 becomes less and less; and again assuming this core is of magnetic material, the inductance of coil 13 progressively decreases with consequent increase in the frequency to which it is tuned, Figure 2A. Throughout this same range of movement, the high-loss magnetic core 20 remains to substantial extent within the coil 14 and effectively damps the response of the low frequency circuit. In brief résumé, as the cores are moved from the #1 position toward the #3 position, the circuit comprising coils 13 and 14 is tuned through the "high" band, Figure 2A. It shall, of course, be understood that if the core 18 is of non-magnetic material, such as copper or brass, the #1 position of core 18 affords the minimum inductance of coil 13 and the highest frequency of the "high" band; whereas, the #2 position of core 18 will afford the maximum inductance of coil 13 and the minimum frequency of the "high" band.

As the core structures are moved from the #2 position to the #3 position, Figure 2, the high-loss core 20 is removed from the "low" band coil 14 and inserted in the "high" band coil 13 thus to reduce the Q of coil 13 to such low value that there is negligible response to signals in the high band. For this position of the core structures, the tuning core 18 of coil 13 is substantially removed therefrom and has inappreciable effect upon it. However, for the #3 position of the core structures, the low-loss core 18 is about to enter the "low" band coil 14. Assuming the tuning core 19 is of magnetic material, the inductance of coil 14 is at a minimum, and the circuit is resonant at the high-frequency end of the "low" band, Figure 2B. As at this time, the high-loss core 20 is well removed from the coil 14 whose Q is therefore of high value and the circuit is consequently sensitive to signals at or immediately adjacent the high-frequency end of the "low" band.

For continued movement of the core structures from the #3 position towards the #4 position, the low-loss core 18 is to greater and greater extent inserted in the coil 14 progressively raising its inductance and so tuning the circuit to lower and lower frequencies of the low band until finally for 100% insertion of the core, the circuit is resonant at the low frequency end of the "low" band, Figure 2B. Throughout this range of movement of the core structures, the high-loss core 20 remains within the "high" band coil 13 and so effectively damps its response to any signals in the high band. Assuming the core 19 is of non-magnetic material, such as copper or brass, the relation between the frequency response and core position, Figure 2B, is, of course, reversed.

From this discussion of Figure 2, it should now be clear that adjustment of the core structures of Figure 1, which are preferably all magnetically interconnected for movement in unison, is effective to tune the several circuits of either the "high" band or the "low" band and without any switching in or out of coils in the changeover from one band to the other. The cables, rods or the like for mechanically coupling the cores are generically represented by members 8. Furthermore, in the superheterodyne circuit shown, the reception of signals in the undesired band is effectively prevented because the insertion of the high-loss core 20 in the unused coil of the oscillator is effective to prevent generation of oscillations within the frequency range of that coil, and consequently even though some signals from the undesired band reach the mixer tube 14, there are no locally produced oscillations which can beat therewith to produce intermediate frequency signals which can be passed by the I.F. amplifier 17.

In the specific oscillator circuit shown in Figure 1, one terminal of the "high" band coil 13C is connected through condenser 22 to the control grid 21 of tube 12, and one terminal of the "low" band coil 14C is connected to the anode 23 of tube 12. The other terminals of the coils are connected together, so that they are effectively in series, so far as radio frequencies are con-
cerned, between the grid and anode of the tube 12. A positive terminal of suitable source of anode supply voltage is connected, as shown, to an intermediate tap 24 of "low" band coil 14C. Accordingly, when the high-loss core 20C is inserted in the "low" band coil 14C, the oscillator circuit is of the Colpitts type, the coil 13C serving as the significant inductance of the oscillating circuit and the "low" band coil 14C serving as a choke coil in the plate-voltage supply lead. When the high-loss core 20C is inserted in the "high" band coil 13C, the oscillator circuit is of the Hartley type, the coil 13C serving as the significant inductance of the oscillator circuit and the damped "high" band coil 13C may serve as a choke for parasites.

In the system shown in Figure 1, the coil 13A serves as the secondary of a transformer, the terminals of whose primary winding 24 are connected by transmission line 25 to a dipole antenna 26. At its electrical mid point, the primary winding 24 of the high band transformer 24—13A is connected to a coil 26A which serves as a primary winding for the "low" band transformer, whose secondary is the coil 14A. By this arrangement, use of band-changeover switches in the antenna circuit is also avoided. The purpose of the coupling condensers 27, 28 and grid resistors 29, and all other circuit components not specifically discussed are well understood by those skilled in the art.

By way of example, each of the "low" band coils 14A and 14B for the specific receiver discussed may be one-quarter inch in diameter, one inch long and comprise 220 turns of No. 37 wire. The shunt condensers 25A and 25B for the "low" band coils 14A, 14B may be 100 micro-microfarads. When a high-loss core 20 (Fig. 2) is of cold rolled steel and has a diameter of 0.246 inch and a length of one inch, the Q of the associated "low" band coil drops from about 60 to less than 40 as indicated by the solid line curve 30 of Fig. 3. Moreover, and as appears from curve 30, the Q of the coil remains high until the end of the core closely approaches the adjacent open end of the core, the zero insertion point of Figure 3, and reaches a very low value when the core is inserted to only a slight extent. Furthermore, the Q of the coil remains low and substantially constant as the core is greater and greater extent inserted. When the high-loss core 20 is of sintered powdered iron, prepared as disclosed and claimed in copending application, Serial No. 770,720, filed August 26, 1947, by Robert L. Harvey, the change in Q of the coil, as shown by curve 31 of Fig. 3, is somewhat more rapid as the core approaches the open end of the coil, the zero insertion point, and the Q of the coil when the core is inserted therein is somewhat lower than for the cold rolled steel core. However, so far as the coils used for the standard broadcast frequencies and lower frequencies are concerned, the high-loss cores 20 may be of cold rolled steel.

At very much higher frequencies, for example, those of the order of 100 megacycles, the Q of the "high" band coils is reduced to a much lower value when the high-loss cores of sintered powdered iron instead of drill rod, cold rolled steel or the like. As shown by curve 32 of Fig. 4, the Q of the "high" band coil is reduced from more than 160 to about 5 when the high-loss core is of sintered powdered iron, whereas when the high-loss core is of cold rolled steel, the minimum Q is materially higher, as shown by curve 33 of Fig. 4. The "high" band coil 14 upon which Fig. 4 is based is a quarter inch in diameter and one inch long and consists of five turns of No. 18 wire, the effective shunt capacity 34, Fig. 1, inherent in the "high" band coil was 13 micro-microfarads.

For all bands, the high-loss core should be of magnetic material to concentrate the flow of the field flux through the core and for the very high frequency bands, sintered powdered magnetic material or its equivalent is preferred in order to attain deep penetration of the core by the flux.

In general, as the losses in the core are due to eddy currents, the resistance of the core should not be too low, for in such case the flux is repelled to such extent that the effective losses are low. On the other hand, if the resistance of the core is too high, the eddy currents are small and again the effective core losses are low. There is however a broad optimum range of resistance varying as a function of frequency, for which the core losses are high enough to afford the desired damping. The magnetic permeability of the core should be high to force the flux to penetrate deeply into the core despite the repelling effect of the eddy current field.

For purposes of this invention, a coil may be considered to be high Q when the Q is in excess of 50 although in most cases the Q is 50 or even much higher. Whatever may be the Q of the band-coils, the unused coils may be retained in circuit if the Q is reduced by a factor of about 10 upon insertion of the high-loss coil.

When, as in the circuit of Fig. 1, the same high-loss core is used at different times to damp both a "low" band coil used in the standard broadcast range and a "high" band coil used at frequencies of the order of 100 megacycles, it is desirable that the high-loss core of sintered powdered iron. When in band changing, a high-loss core is selectively inserted in band coils used at frequencies of the order of standard broadcast frequencies or lower, it may be of cold rolled steel or similar magnetic material. As in Fig. 6, different high-loss cores 20 and 20D are used for inserting in different coils, those which are inserted in coils functioning at frequencies much lower than 100 megacycles, may be of cold rolled steel, drill rod or the like.

The curves 35 and 36 of Fig. 5 indicate the effect upon the Q of the "high" band circuit of Fig. 1 with different values of shunt capacitance across the "low" band core. More specifically, curve 35 shows the relation between the shunt capacity of the "low" band coil and the Q of the "high" band coil with the high-loss core removed from the low band core; the curve 36 shows the relation between the capacity across the "low" band coil and the Q of the high band coil with the high-loss core inserted in the "low" band coil. As apparent from these curves, the capacity across the "low" band should be at least about three times the effective capacity 24, from the high potential side of the "high" band coil to ground to avoid undesired damping or of coupling of the damped coil of the "high" band circuit. With the cores in position for reception in the "high" band, the large condenser across each of the "low" band coils effectively by-passes it so that although it is in series within the tuned loop comprising a "high" band coil and a condenser 34, its resistance effect does not damp the "high" band circuit.

The curves 37 and 38 of Fig. 6 are of the Q of the "low" band coil with the high-loss core respectively out and in the "high" band coil and with
various capacitors shunting the "low" band coil. From these curves, it appears the use of substantial capacity across the "low" band coil to preserve the high Q of the "high" band coil for reception in the "high" band does not adversely affect the Q of the "low" band coil as used for reception in the "low" band.

It shall be understood that the invention is not limited to use with multi-band receivers suited only to receive sound programs in the standard broadcast band and one or more ultra high-frequency broadcast bands: one or all of the bands may be for televised programs; furthermore, one or more of the bands may be for reception of amplitude-modulated signals whereas one or more of the other bands may be for frequency-modulated signals, and, in such cases, if necessary, the appropriate intermediate frequency-amplifier and second detector are included in circuit beyond the converter tube concurrently with the band-changer of the preceding portion of the receiver. The band shifting of the intermediate frequency-amplifier may be effected by use of high-loss cores, as above described, or the changeover may be effected by switching as in my Patent #2,167,605.

It shall also be understood that the tuning of the coils of the several bands need not be effected by low-loss cores mechanically coupled to the high-loss cores used for band-shifting; for example, as shown in Fig. 7, the tuning of the band coils 13 and 14 may be effected by condensers 45 and 46 respectively which may, if desired, be mechanically coupled for actuation by a common dial having suitable scales for the different bands. The band-shifting is effected by insertion of the high-loss core 20 into that coil whose Q is to be so greatly reduced as to preclude reception, for example of signals in the corresponding band. Though only a single circuit is shown, in Fig. 7, it shall be understood that the same arrangement may be used in the other circuits of the associated receiver, transmitter or other multi-band radio equipment.

In the arrangement shown in Fig. 8, representing a single-stage of any multi-band radio apparatus, the same low-loss core 18 is selectively insertable in either the "high" band coil 13 or the "low" band coil 14, and is adjustable therein for tuning. Concurrently with insertion of core 18 in the high band coil 13, the high-loss core 20 is inserted in the low band coil 14 to minimize its Q for band shifting generally as above described. When the range of frequencies covered by the "low" band coil 14 is suitably low, the high-loss core 20 may be of cold rolled steel, drill rod, or the like. When the low-loss core 18 is withdrawn from coil 13 and inserted into the coil 14 for tuning in the low band, a second high-loss core 20D is concurrently inserted in the "high" band coil 13 to reduce its Q to negligible value. When the range of frequencies covered by the "high" band coil 13 is in the ultra high-frequency portion of the spectrum, the high-loss core 20D should be of sintered powdered iron.

It shall, of course, be understood the invention is not limited to use with radio gear suited to cover only two bands but may be extended to as great a number of bands as desired by use of a suitable number of high-loss cores and low-loss cores mechanically inter-coupled and with their spacing properly selected in accordance with the spacings between the coils to effect the desired changeover, which, as apparent from the foregoing, is accomplished by insertion of high-loss cores in all of the coils except the one corresponding with the band in which operation is desired.

For a large number of bands, the physical overall length of the core-and-coil system may become quite great and require long leads to associated tube or tubes. In such cases it may be desirable to employ a band-shifting turret arrangement such as schematically shown in Fig. 9. As apparent from the drawings, the half-core coils 13A, 14A, 15A and 16A for one stage of the apparatus are permanently electrically connected in series and are symmetrically arranged about the axis 39 of a turret head 40 which supports a low-loss core 18 and a plurality of high-loss cores 20, corresponding in number with one less than the total number of band coils. To select a particular band, the turret head 40 is withdrawn to the position shown in Fig. 9 and rotated to bring the low-loss core 18 into alignment with that one of the coils corresponding to the band to be selected. The turret is then moved towards the coils to effect insertion of the low-loss core 18 in the selected band coil and concurrently to move the high-loss cores 20 into each of the remaining coils. If the equipment is for spot-frequency operation, nothing further is required, but if the selected band is to be tunable, the tuning may be effected either by adjustment of a variable condenser across the selected coil, or as shown in Fig. 9, the low-loss core 18 may be moved axially of the selected coil in any suitable manner, as by adjustment of the knob 41 on the threaded shaft 41 of the low-loss core 18. This arrangement is suited, for example, for band shifting of the amplifier or converter stage of a multi-band superheterodyne receiver.

The arrangement shown in Fig. 9 may also be used for switchless band shifting of an oscillator stage, such as shown in Fig. 10 in which the tube 42 is used as a cathode follower and the tube 43 is used as a grounded grid amplifier. The impedance 44 is common to the cathode return circuits of the tubes 42-43 and couples to the output circuit of tube 42 to the input or grid circuit of tube 43. The condenser 45 between the grid of tube 42 and the anode of tube 43 serves as a feed-back condenser for supplying to the grid of the tube 42 excitation of the proper phase and magnitude to insure continuous generation of oscillations at the frequency determined by that one of the coils 13C, 14C and 15C in which is inserted the low-loss core 18. The high-loss cores 20 in the other coils so effectively damp them that they are ineffective in production of oscillations.

From the foregoing, it will be apparent to those skilled in the art the invention is not limited to the particular arrangements disclosed, and that changes and modifications may be made within the scope of the appended claims.

What is claimed is:

1. A multi-band circuit selectively tunable to and throughout different frequency bands without switching comprising independent frequency-selective circuit means including separate tuning coils respectively corresponding with the different bands and electrically connected in series, low-loss core structure mechanically connected for insertion in a selectable coil for tuning thereof, high-loss core structure, and means mechanically interconnecting said core structures for movement in unison concurrently to move the low-loss core structure into a selectable coil for tuning to the corresponding band and to move
the high-loss core structure into the remainder of said coils to minimize their Q and render them relatively non-selective.

2. A multi-band circuit selectively tunable without switching comprising independent frequency-selective circuit means including separate tuning coils respectively corresponding with the different bands, electrically connected in series, and mechanically interconnecting said core structures for movement in unison concurrently to move the low-loss core structure into a selectable coil for tuning to the corresponding band and to move the high-loss core structure into the remainder of said coils to minimize their Q and render them relatively non-selective.

3. A multi-band circuit tunable over spaced bands of signal frequencies, said circuit comprising a pair of conductors providing a signal transfer path, a high band coil and an independent low band coil electrically connected in series across said path, a fixed capacitor across the low band coil, a capacity connected between said pair of conductors, the capacitance across said low band coil being at least three times as great as the capacitance between said conductors, low-loss core structure moveable into a selectable coil to tune said selectable coil throughout the corresponding band, and high-loss core structure interconnected for movement in unison with said low-loss core structure into the other of said coils to minimize its Q and render it relatively non-selective.

4. A multi-band superheterodyne receiver tunable without switching to different signal frequency bands comprising a heterodyne section and a local oscillator section, each of said sections comprising independent frequency selective circuit means including separate tuning coils electrically connected in series and respectively corresponding with the different bands, low-loss core structure a selectable set of corresponding coils of the different sections for operation of the receiver in the corresponding band, and high-loss core structure concurrently inserted in the remainder of the coils to minimize their Q and render them relatively non-selective.

5. A multi-band tuning stage selectively tunable to one of a plurality of substantially different frequency ranges without switching contacts comprising in combination, a plurality of tuning circuits each circuit having an associated inductive winding, said inductive windings being electrically connected in series and having substantially different inductance values for effective tuning response in each of said frequency ranges, frequency range select means comprising a plurality of separate interspersed relatively high and low loss core sections mechanically intercoupled along a common axis for unitary movement with respect to said inductive windings, and means moving said range select means there by selectively moving a high loss core section in inductive coupling relation to a first of said inductive windings and simultaneously selectively moving a low loss core section in inductive coupling relation to another inductive winding to provide inductive response and effective response of said last named winding and associated tuning circuit to signals within the adjusted frequency range of the first inductive winding and associated tuning circuit, and said low loss core section including properties for causing response of the associated circuits to signals within a different frequency range associated with said further inductive windings.

6. A multi-band oscillator including circuits selectively operative as a Hartley oscillator in a "low" frequency band and as a Colpitts oscillator in a "high" frequency band, comprising an electronic amplifier device having at least an anode, a control electrode and a cathode, two tuning coils of substantially different inductance having one end of each connected together, the coil of the higher inductance having a high potential end terminal connected to the anode and an intermediate terminal connected to the cathode of the amplifier, a first capacitor connected between said control electrode and the free end terminal of the coil of lower inductance, a second capacitor shunting the coil of higher inductance, and high-loss magnetic core structure selectively variably insertable in one or the other of said coils thereby to damp the oscillator circuits connected therewith, for changing the oscillator from one mode of operation to the other.

7. A multi-band oscillator having a tuned circuit and a feedback lead for supplying excitation to continue oscillations at a frequency determined by said tuned circuit, said oscillator being selectively operative without switching in two bands as a Hartley oscillator and a Colpitts oscillator respectively, said oscillator tuned circuit comprising a pair of oscillator tuned circuit leads, a first capacitor, two inductive windings, a circuit serially connecting said windings and said first capacitor between said leads, an intermediate connection on a first of said windings, a second capacitor shunting said first winding, a circuit connecting said feedback lead to said intermediate connection, a damping structure comprising a high-loss core for reducing the Q of one of said windings upon movement into proximity therewith, thereby effectively rendering the winding inoperative, a low loss tuning core structure, and means mechanically interconnecting said core structures for movement in unison concurrently to move the low-loss core structure into proximity with one of said windings for tuning the corresponding oscillator circuit and to move the damping structure into proximity with the other of said windings, whereby a Colpitts oscillator circuit is effectively provided when the damping structure is in proximity with said first winding and a Hartley oscillator circuit is effectively provided when the damping structure is in proximity with the other winding.

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