

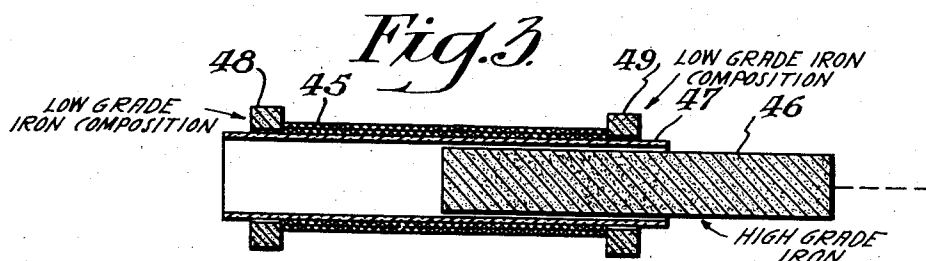
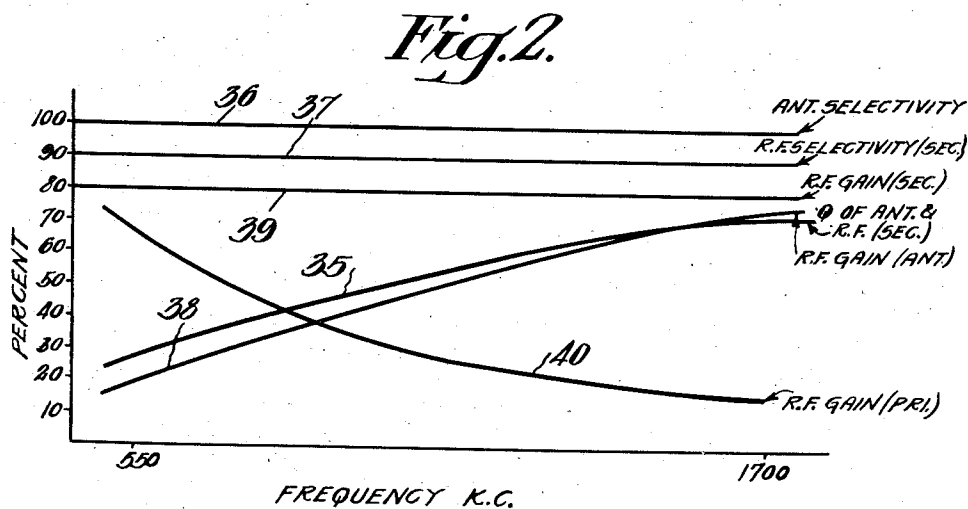
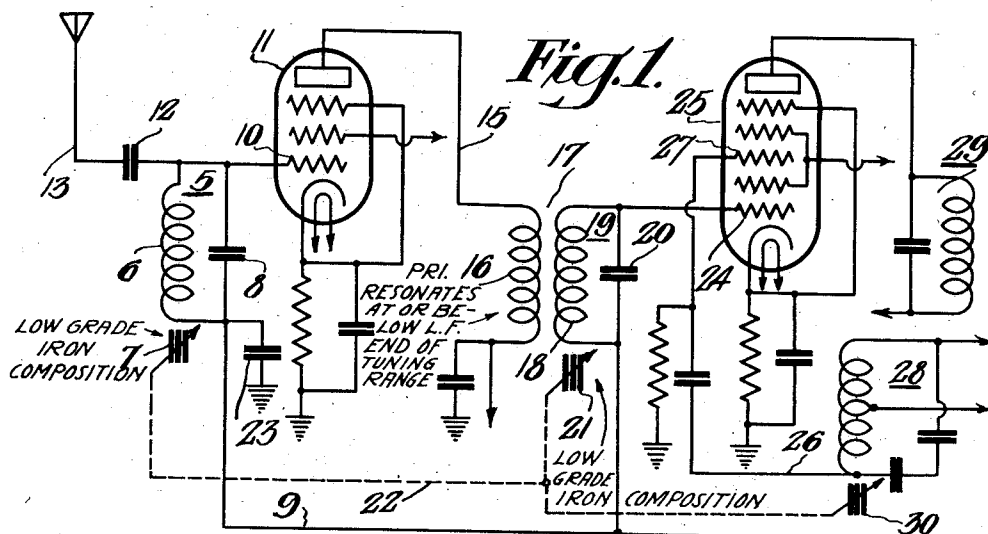
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VARIABLE PERMEABILITY TUNING SYSTEM

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VARIABLE PERMEABILITY TUNING SYSTEM

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4 Claims. (Cl. 250—40)

This invention relates to variable permeability tuning systems for radio signal receiving circuits and the like, in which the tuning through predetermined frequency ranges is controlled by inductance variation in connection with fixed capacity elements.

The inductance variation is provided by movement of a core element relative to a tuning inductor in each circuit, the usual arrangement comprising a solenoid inductance winding provided with a molded cylindrical core of comminuted magnetically permeable material arranged to be moved axially into and out of one end of the winding between a position substantially wholly within, to a position substantially wholly without, the confines of the winding, thereby varying the permeability of the inductance core area and the frequency response of the tuned circuit of which the inductor forms a part.

In present broadcasting systems, it is desirable to provide the same degree of selectivity, that is, the same kc. band-width, throughout a given tuning range for signal receiving circuits and the like, in order that various closely spaced signal channels may be selected without interference, the present separation between signal channels being at 10 kc. as is well known.

In accordance with the present invention, there is provided an improved variable inductance or permeability tuning system having an inductance winding and a movable tuning core as the variable tuning element in one or more tuned circuits, in which the inductance increasing effect of the core on the winding is less than the resistance increasing effect, whereby the signal to noise ratio through a predetermined tuning range may be substantially constant.

It is an object of the invention to provide a tuning system of the character referred to in which the gain and/or signal to noise ratio, while tuning over a predetermined frequency band, is high and substantially constant, whereby it is adapted for use in radio signal receivers and particularly for automobile receivers and the like in which it is highly desirable to make the gain in the antenna input circuit as high as possible and yet substantially uniform over the signal receiving band.

It has been found that in order to provide constant selectivity in a variable permeability tuned circuit, the Q of the circuit must vary substantially proportionally to variations in frequency. In tuning from 1500 to 550 kc., therefore, in the present broadcast band, for example, the Q of the signal receiving circuits provided

with variable permeability tuning must vary in approximately the same 3:1 ratio as the ratio of the frequency change over the said tuning band.

It is, therefore, also an object of the present invention to provide an improved variable permeability tuning system wherein the Q of the tuned circuits may be made to vary in a predetermined manner with frequency variation in tuning, to provide a predetermined or substantially constant selectivity over the tuning band as hereinbefore referred to.

The signal input circuit of a radio signal receiving system is normally coupled to a low impedance signal supply circuit such as that provided by an antenna or signal collector, in which the gain is proportional to the Q of the input circuit. Accordingly, it is a further object of the present invention to provide an improved variable permeability tuning system wherein the signal input circuit may be coupled to a low impedance source and tuned over a predetermined range, while maintaining the overall gain of the tuning system substantially constant, although the gain in the input circuit varies in proportion to the variation in the Q of the input circuit.

It is also an object of the present invention to provide an improved permeability tuning system wherein a tuning inductance of the movable core type is provided in each tuned signal conveying circuit for tuning control, having a relatively low cost core material therein providing an improved and predetermined control of the variation of the Q of the tuned circuits.

It is also a further object of the present invention to provide an improved variable permeability radio tuning system involving a plurality of signal conveying circuits having variable inductance tuning elements therein, including movable tuning cores providing a Q in each circuit which varies with tuning proportional to the frequency, thereby providing a uniform selectivity over a predetermined tuning band, and means in at least one of said circuits for altering the gain therein in a predetermined manner, thereby to compensate for gain variation with tuning in another of said circuits.

The invention will, however, be further understood from the following description when considered in connection with the accompanying drawing, and its scope is pointed out in the appended claims.

In the drawing,

Figure 1 is a schematic circuit diagram of a

variable permeability tuning system embodying the invention.

Figure 2 is a graph comprising a series of curves illustrating certain operating characteristics of the system of Fig. 1, and

Figure 3 is a cross sectional view, on an enlarged scale, of a variable permeability tuning unit for one of the circuits of Fig. 1.

Referring to Fig. 1, 5 is a tunable signal conveying circuit comprising a tuning inductance 6 which is varied by means of a suitable movable core element 7 providing variation in the permeability of the core area of the inductance 6, and a shunt fixed capacitor 8 for the inductance. The circuit is provided with an AVC connection as indicated at 9 and is connected at the opposite end to the signal input grid 10 of a signal amplifier tube 11, which may here be considered as the input or R. F. amplifier stage of a superheterodyne radio signal receiving system.

The tuned circuit 5 is coupled through a capacitor 12 to a low impedance signal input circuit such as an antenna circuit 13 for supplying signals to the first amplifier stage through the tuned circuit 5.

The tube 11 is provided with a signal output circuit 15 including the primary winding 16 of an interstage coupling transformer 17. The secondary 18 and a shunt capacitor 20 are included in a tuned circuit 19 similar to the tuned circuit 5 and tunable through the same frequency range by a second movable core element 21 connected for unitary control with the core element 7, as indicated by the dotted connection 22. The tuning circuit 19 is likewise connected with the AVC lead 9 which is bypassed to ground as indicated at 23. The high potential side of the circuit 19 is connected to the signal input grid 24 of a signal mixer or first detector tube 25. A local source of oscillations, represented by an oscillator circuit 28, is connected through a circuit 26 to a second signal input grid 27 of the first detector. The oscillator is preferably also provided with a para magnetic core 30 ganged with the other cores for tuning to a frequency differing from that of the circuits 5 and 19 by a constant difference or intermediate frequency. The intermediate frequency is derived from a tuned intermediate frequency output circuit 29.

While the invention is described in connection with the R.-F. and first detector circuits of a superheterodyne receiver, it may be applied to any signal conveying channel wherein a series of tunable signal circuits are provided in cascade. In the present example, the tuning inductance 6, and the tuning inductance 18 provided by the secondary of the transformer 17 are normally high Q solenoid windings preferably of the accumulative type, of Litz wire, and provided with movable core elements 7 and 21, respectively, which move into and out of the low potential ends, as indicated, to vary the permeability, and the tuning of the circuits in which the inductances are connected through predetermined frequency ranges. In the present example, this may be considered to be the broadcast band from 550 to 1500 kc. in each of the circuits 5 and 19, and from 1000 to 1950 kc. in the oscillator circuit 28, thereby providing an intermediate frequency of 450 kc.

As hereinbefore referred to, the selectivity of the tuning system and the signal to noise ratio are preferably substantially constant throughout the tuning range, and in order to obtain this characteristic with variable permeability tuning

means, the Q of the circuits must vary with frequency.

As is known, the Q of a circuit is equal to the reactance divided by the R.-F. resistance and in the case of the inductance tuned circuit shown, equals

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

in which R is the R.-F. resistance and L is the inductance of the winding in the circuit. The Q of the circuit may also be defined as

$$Q = \frac{f_0}{f_2 - f_1}$$

in which f_0 is the resonance frequency of the circuit, f_1 is the frequency below resonance at which the signal response is 70.7 percent off resonance and f_2 is the frequency above resonance at which the response is 70.7 percent off resonance. In other words, the Q of the circuit, as herein considered, is equal to the resonance frequency divided by the selectivity represented by the effective pass band of the circuit. For example, at 500 kc. with the 70.7 percent selectivity response characteristic 5 kc. wide, the Q of the circuit may be said to be 100, while at 1500 kc., with the same selectivity characteristic, the Q is 300. Thus, with a frequency change of 1:3, it will be seen that for a constant selectivity characteristic, the Q of the circuit must vary in the same proportion of 1:3.

Utilizing hydrogen reduced iron as disclosed, for example, in the patent to Speed 1,274,952, comprising small particles of the size of 10 microns in a suitable insulating binder for the cores 7 and 21, the Q at the high frequency end of the tuning range may be of the order of 70, while at the low frequency end of the tuning range it may be of the order of 150. Thus, in addition to being relatively costly, this type of core material tends to vary the Q of the circuits with frequency in an opposite manner to that desired for maintaining constant selectivity.

However, a tuning inductance and core arrangement may be provided for variable permeability tuning which permits a variation of the ratio of the inductance and damping or resistance changing effects and the Q of the circuit, in proportion to the variation in frequency over the tuning range. In this connection, it has been found that the same core material having particles of approximately 100 microns in size in a suitable binder may provide a reduction in the Q at the low frequency end of the tuning range to approximately 15, as compared to 70 at the high frequency end, and that the same results may be obtained with a low grade of Swedish sponge iron, also preferably hydrogen reduced, costing a small fraction of the iron referred to.

By suitably proportioning the higher grade reduced iron and the cheaper sponge iron, any desired ratio between the inductance and damping or resistance increasing effect of the core and the value of the Q of a circuit may be obtained, and any desired rate of change may be produced with tuning. For example, at present it has been found possible to produce cores providing substantially constant Q by utilizing 10 parts of the higher grade reduced iron with particles of 10 micron size and 4 parts of low grade sponge iron with particles of 100 micron size.

For use in the circuit shown, to provide a variation of Q in a 3:1 ratio in tuning through the

range from 1500 to 500 kc., approximately 9 parts of low grade sponge iron with particles of 100 micron size are combined with one part of the higher grade reduced iron with particles of 10 micron size in a suitable insulating binder. This has been found to provide a Q of 70 at the high frequency end of the tuning range and a Q of approximately 23 at the low frequency end, thereby complying with the desired ratio of 3:1 in conformance with the change in frequency necessary to produce a constant selectivity in the tuned circuits 5 and 19.

The falling off of the Q of the antenna and secondary circuits with tuning variation is indicated in Fig. 2 by the curve 35, while the resultant constant selectivity of the antenna and R.-F. circuits 5 and 19, respectively, is represented by the curves 36 and 37.

The R.-F. gain in the antenna circuit 5 falls with the Q of the circuit as indicated by the curve 38 and results from the coupling of this circuit with a low impedance input circuit such as that provided by the antenna system 13. The R.-F. gain of the secondary circuit 19, however, remains substantially constant throughout the tuning range with variation of Q as indicated by the curve 39. The curves above referred to are slightly displaced, particularly curves 36—37—39, to indicate the response of the circuits more effectively.

The foregoing will be seen more clearly from a consideration of the fact that the gain at 500 kc. equals the gain at 1500 kc. as shown below:

$$2\pi 500LQ = 2\pi 1500 \frac{L}{9} 3Q$$

To provide substantially a constant gain and signal to noise ratio, as well as constant selectivity, the loss of gain in the R.-F. antenna circuit is compensated by causing the primary 16, coupled to the secondary circuit 19, to resonate in or below the lower frequency end of the tuning range so that the R.-F. gain of the primary 16 increases with a decrease in frequency, in accordance with the curve 40, as the circuits are tuned. This compensates for the decrease in the gain of the antenna circuit indicated by the curve 38, thereby providing an overall gain which is substantially constant for the combined tuning system.

Furthermore, as the Q decreases with frequency in tuning, it is evident that the inductance increasing effect of the core is less than the damping or resistance increasing effect as the core enters the inductance winding in each circuit, the cores being so constituted that the desired variation in the Q is obtained, thereby to establish substantially a constant noise to signal ratio and selectivity over the tuning range of the variable permeability tuned circuit in which the inductance winding is provided at the tuning unit.

Referring now to Fig. 3, a tuning inductance is shown of the type adapted for use in the antenna or signal input circuit of Fig. 1 and illustrating a modification of the core arrangement. The tuning or inductance winding is indicated at 45 and as hereinbefore referred to, is preferably of the accumulative type and provided with a movable tuning core element 46 which is movable into and out of one end of a coil form on which the winding 45 is supported. In the present example, however, the core 46 may be wholly of one kind of ferro-magnetic material, such as hydrogen reduced iron, while the lower grade iron, such

as sponge iron, may be included in two end rings 48 and 49 surrounding the coil form at the ends of the winding 45 as shown.

With this arrangement, as the coil element 46 is moved into the winding fully it lies within the end rings and establishes a magnetic circuit through them whereby their resistance and damping increasing effect is imparted to the winding and the circuit in which it is used, to cause a reduction in the Q of the circuit as before described with the composite core, in which all of the core material is placed in the movable core element.

In the form shown in Fig. 3, the core element 46 should be of sufficient length to extend fully through and between both rings 48 and 49. Thus, as the core 46 is moved into the winding 45 the end rings are caused to be increasingly effective to impart the desired resistance and damping to the tuning of the winding.

In manufacturing, this arrangement somewhat simplifies the process required, for the reason that the core elements may be made of differing materials, the low grade iron being included in the rings and the high grade iron being included in the movable core 46 or the latter may also include a proportion of the lower grade iron, depending upon the characteristic desired.

With the core element 46 withdrawn from the high frequency position, the rings are not effective to damp or change the resistance of the winding to any appreciable degree. Thus, it will be seen that the core may be divided into units, each containing a different proportion of low grade and high grade ferro-magnetic material. The core may be in part of one material or group of materials and in part of another material or group of materials, all of which are effective to control, in the manner described, the relation of the inductance or tuning to the effective resistance or damping of the circuit in which the inductance is connected.

I claim as my invention:

1. In a variable permeability tuning system for radio signal circuits, the combination of a tuning inductance winding, means providing a movable tuning core element for said inductance winding comprising a molded body of comminuted magnetically permeable material so constituted that the inductance increasing effect of the core is less than the resistance increasing effect thereof as said core is moved into close relation to the inductance, one of the magnetic ingredients of said core being sponge iron in predominating proportion to other ingredients therein comprising hydrogen reduced iron in such relative proportion that variation of the Q of the winding with frequency is reversed from the normal variation, and increases with frequency as the tuning of said winding is increased toward the high frequency end of the tuning range thereof.

2. In a variable permeability tuning system, a tunable radio signal circuit comprising a tuning inductance winding, a capacitor connected in shunt relation thereto, a movable tuning core for said winding containing low grade comminuted iron in predominating proportion with high grade comminuted iron such that the Q varies substantially proportionally to the change in frequency of the circuit as the core is moved, whereby the selectivity of said circuit is rendered substantially constant over the tuning range of said circuit, and means responsive to frequency variations for compensating the variation of the Q of

said circuit to maintain substantially constant signal gain through said system.

3. In a variable permeability tuning system, a tunable radio signal circuit comprising a tuning inductance winding, a capacitor connected in shunt relation thereto, a movable tuning core for said winding comprising a plurality of finely divided ferro-magnetic materials of different resistance changing effects in predetermined proportion providing a Q for the circuit which varies substantially proportionally to the change in frequency of the circuit as the core is moved, whereby the selectivity of said circuit is rendered substantially constant over the tuning range of said circuit, and means responsive to frequency variation for compensating the variation of the Q of said circuit to maintain substantially constant signal gain through said system.

4. In a variable permeability tuning system, a tunable radio signal circuit comprising a tuning inductance winding, a tuning capacitor connected in shunt relation thereto, and a movable tuning core for said winding comprising finely divided ferro-magnetic material of mixed quality and predetermined proportion providing a Q for the circuit which varies substantially proportionally to the change in frequency of the circuit as the core is moved, whereby the selectivity of said circuit is rendered substantially constant over the tuning range of said circuit, one of the ferro-magnetic constituents of said core being sponge iron in predominating proportion to other ingredients therein.

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