Oct. 14, 1941. F. N. JACOB 2,259,250

SECURING ALIGNMENT IN A PLURALITY OF RESONANT CIRCUITS

Original Filed Dec. 1, 1938 2 Sheets-Sheet 1

Fig. 1.

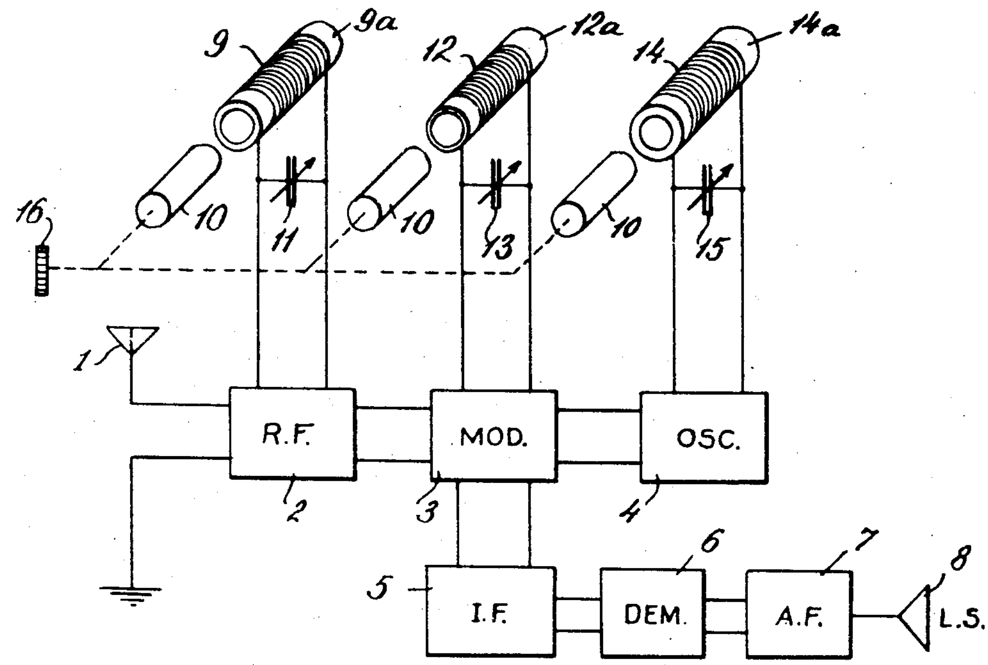
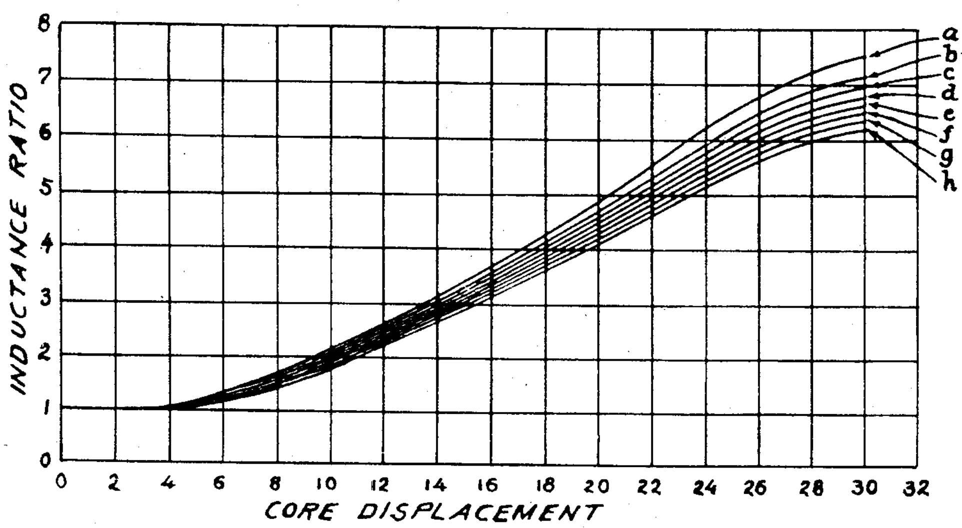


Fig. 2.



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SECURING ALIGNMENT IN A PLURALITY OF RESONANT CIRCUITS

Original Filed Dec. 1, 1938 2 Sheets-Sheet 2

Fig. 3,

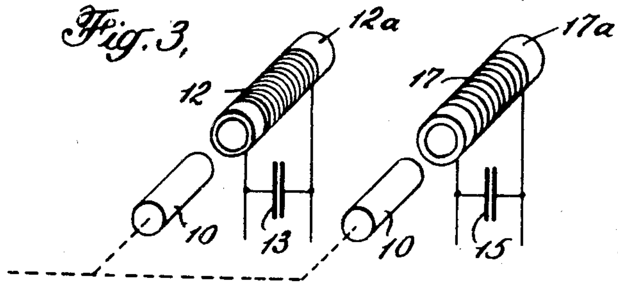


Fig. 4,

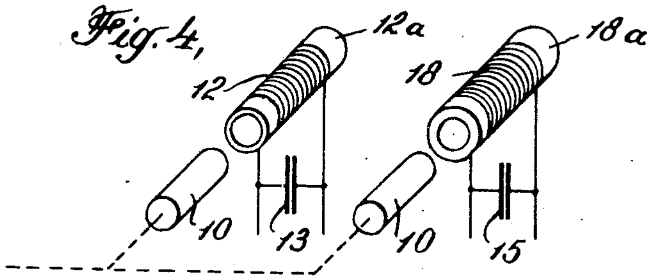
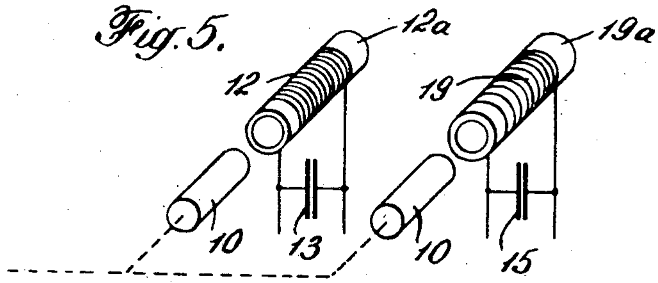


Fig. 5.



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Patented Oct. 14, 1941

2,259,250

UNITED STATES PATENT OFFICE

2,259,250

SECURING ALIGNMENT IN A PLURALITY OF RESONANT CIRCUITS

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Continuation of application Serial No. 243,315, December 1, 1938. This application July 5, 1940, Serial No. 344,146

28 Claims. (Cl. 250—40)

This invention relates to high-frequency resonant systems, and more particularly to systems employing multiple variable inductance devices such as are employed, for example, in radio receivers.

In general, radio receivers employ a plurality of variably tuned resonant circuits to permit the selection of any desired signal within a relatively wide range of frequencies. These resonant circuits are usually tuned by means of a single control, to simplify the operation of the receiver. The attainment of satisfactory single-control tuning requires that the several individual units of the system remain in proper agreement as to their frequencies as the system is tuned over the frequency range.

If the receiver is of the tuned radio-frequency type, in which all of the high-frequency amplification is performed at the frequency of the desired signal, the several variably tuned resonant circuits must all be tuned closely to the same frequency for each position of the tuning control. In the superheterodyne type of receiver, in which most of the high-frequency amplification takes place at a fixed intermediate frequency, usually lower than the lowest desired signal frequency, the resonant frequency of one of the variably tuned resonant circuits must differ from that of the remaining variably tuned resonant circuits by a practically constant amount. The difference is equal to the intermediate frequency, the frequency of the oscillator circuit usually being higher than that of the remaining variably tuned resonant circuits by this amount. The circuits which are tuned to the signal frequency may be designated as the "preselector" of the superheterodyne receiver. When the oscillator frequency is higher than the signal frequency, the oscillator circuit must be tunable over a higher but narrower range of frequencies than that covered by the preselector.

When several resonant circuits are all tuned to the same frequency, they are said to be in "alignment". When the oscillator resonant circuit of a superheterodyne radio receiver maintains the proper frequency difference with respect to the other variably tuned resonant circuits, it is said to "track" with the other circuits. In either case, however, the problem is to maintain a desired relation between the resonant frequencies of two or more variably tuned resonant circuits. In this specification and the appended claims, therefore, I shall use the term "alignment" to indicate that the desired relation is substantially realized, it being understood that I am using this term to include also, in the case of a superheterodyne radio receiver or other similar system, the condition of "tracking" of one of the resonant circuits at a constant frequency difference with respect to the remaining resonant circuits.

A radio receiver may be tuned over a range of frequencies by capacitance variation, by inductance variation, or by a combination of capacitance and inductance variation. Inductance variation is now readily and efficiently accomplished by "permeability tuning," which consists in employing a ferromagnetic core movable relatively to an inductance coil. As the core enters the coil, the inductance of the coil is increased. The ratio of the inductance of the coil with the core partially or fully inserted to the air-core inductance of the coil, is the inductance increase factor due to the core, and is called the "effective permeability" of the core at that particular position with respect to the coil. The frequency of a resonant circuit including such a variable inductance device is inversely proportional to the square root of the inductance, so that as the core is withdrawn from the coil the resonant frequency increases. The frequency decrease when the core is inserted, expressed as the ratio of the initial frequency with the air-core coil to the new frequency with the core inserted, is equal to the square root of the effective permeability of the core for each position of the core.

One of the unique advantages of permeability tuning is that the core, when inserted into the coil, increases the inductance of the coil by a factor which, broadly speaking, is independent of the inductance value of the coil. Thus both the inductance and capacitance values in each circuit may be chosen to secure the best performance, and no difficulty of thus limiting the frequency range which can be covered arises. In capacitance-tuned systems, and in other types of inductance-tuned systems, however, this difficulty of limiting the tuning range is controlling, as is well known.

It might be supposed that, with coils of the same physical dimensions, a particular core would produce precisely the same inductance change regardless of differences in the air-core inductance values, so that the range covered by a permeability-tuned circuit would be completely independent of the inductance value in the circuit. This, however, is not the case. While it is true that for very small differences in inductance value, the resulting differences in the effective permeability of the cores are inappreciable, nevertheless for differences in inductance value such as might be desirable to control the performance of different circuits in a radio receiver, the effective permeability of identical cores differs sufficiently to prevent such circuits from remaining in alignment. Moreover, in cases where it is desired to tune two circuits over two different frequency ranges, as for example in the preselector and oscillator circuits of a superheterodyne radio receiver, it is not sufficient merely to employ coils of different inductance values but of like physical dimensions, with identical cores, since here again the circuits will not track.

It has been proposed to use differently shaped cores in the preselector and oscillator circuits of a superheterodyne radio receiver, and this method, if properly applied, will secure tracking. Alternatively, it is possible to employ series and shunt coils in the oscillator circuit so that it will track with the preselector circuits using identical cores. Both of these expedients are difficult and expensive compared with the means disclosed herein.

It is an object of my invention to provide means whereby a plurality of resonant circuits employing coils of similar inductance values may be tuned, by identical cores moving in unison, over two or more different frequency ranges, and may be maintained in alignment without the employment of additional corrective components.

It is a further object of my invention to provide means whereby a plurality of resonant circuits employing coils of different inductance values may be tuned, by identical cores moving in unison, over the same frequency range and may be maintained in alignment without the employment of additional corrective components.

Another object of my invention is to provide means whereby a plurality of resonant circuits employing coils of different inductance values may be tuned, by identical cores moving in unison, over two or more different frequency ranges and may be maintained in alignment without the employment of additional corrective components.

In accordance with my invention, the rate of change of inductance as a ferromagnetic core enters an inductance coil may be varied, without appreciably altering the air-core inductance value of the coil, by slightly changing the diameter of the coil. Thus two coils of substantially the same inductance values and axial lengths but of somewhat different diameters may be employed, with two identical ferromagnetic cores arranged to enter the coils in unison, to tune two resonant circuits over two different frequency ranges. Even though the two coils have substantially the same air-core inductances, the rate of change of inductance of the larger-diameter coil as its cooperating core is introduced is lower than that of the other coil, so that the resonant circuit including the larger-diameter coil is tuned over a narrower range of frequencies, by a given displacement of the cores, than is the circuit including the smaller-diameter coil. It is not necessary that the circuits have the same initial resonant frequency, so long as they are aligned at the high-frequency end of their respective tuning ranges by capacitance adjustment.

In practice, for example, the first inductance device might be employed to tune the oscillator and the second inductance device to tune the preselector in a superheterodyne radio receiver. In this case, the oscillator is tuned over a range of frequencies higher than that covered by the preselector due to the fact that the capacitance in the oscillator circuit is smaller, and the oscillator frequency range is narrower than that of the preselector because of the greater diameter of the oscillator coil. This arrangement provides satisfactory tracking in most instances, but somewhat improved tracking may be realized, if necessary, by winding one of the coils so that its winding pitch varies along its axial length in such a way as to produce a varying rate of change of inductance of this coil and hence provide a substantially constant frequency difference between the two resonant circuits as the cores are inserted.

My invention is also applicable to the case where two coils of substantially different inductance values but of the same axial length are employed in two resonant circuits which are to be tuned over the same frequency range by the introduction of identical cores in unison. In order to compensate for the tendency for the rate of change of inductance to be greater in the coil having the higher inductance as the cores enter the coils, the higher-inductance coil, which has a greater number of turns of finer wire than the other coil, is, in accordance with my invention, wound on a form of somewhat larger diameter than that employed for the lower-inductance coil. In this way, the rates of change of inductance of the coils are made equal, and the two resonant circuits in which the coils are used, having been aligned by capacitance adjustment at the high-frequency end of the tuning range, are tuned to the same frequency by a given displacement of the cores. An arrangement such as this might be employed, for example, in a radio receiver in which it is desired, to employ a high-inductance coil in the first resonant circuit in order to obtain higher gain between the antenna and the first amplifying vacuum tube.

The principles of my invention are equally useful in a combination of the above two cases, where it is desirable to employ coils of substantially different inductance values but of the same axial length to cover different frequency ranges. In this third case, let it be assumed for example that the narrower frequency range is to be covered by the coil with the smaller inductance. In this case, the latter coil is somewhat larger in diameter than the other coil to allow for the narrower frequency range it is to cover, but allowance is made for the fact that it has substantially less inductance than the other coil and for that reason tends to have a lower rate of change of inductance. Additionally, the winding pitch of one of the coils may vary along its axial length, in order to produce a varying rate of change of inductance of this coil and hence a substantially constant frequency difference between the resonant circuits including the coils as the cores are inserted. A coil system such as this might be advantageously employed in a superheterodyne radio receiver in which it is desired to use a relatively small coil in the oscillator circuit in order to improve the oscillator frequency stability, and where at the same time the oscillator resonant circuit must cover a narrower range of frequencies than the preselector.

This is a continuing application of my copending application Serial No. 243,315, filed December 1, 1938.

My invention will be better understood by reference to the drawings, in which:

Fig. 1 is a schematic diagram, partly in block form, of a superheterodyne radio receiver embodying one form of my invention;

Fig. 2 is a family of curves illustrative of my invention; and

Figs. 3, 4 and 5 show various modified pairs of coils suitable for use in the superheterodyne radio receiver of Fig. 1.

Referring to Fig. 1, the receiver comprises antenna 1, radio-frequency amplifying stage 2, modulator stage 3, local oscillator 4, intermediate-frequency amplifier 5, demodulator 6, audio-frequency amplifier 7, and reproducer 8. It will be understood that a power supply, not shown, furnishes the proper operating potentials and currents for the various stages of the receiver. The resonant circuit of radio-frequency amplifying stage 2 includes a variable inductance device comprising inductance coil 9 and cooperating ferromagnetic core 10, and an adjustable capacitor 11. The resonant circuit of the modulator stage 3 includes an inductance device comprising inductance coil 12 and cooperating ferromagnetic core 10, and an adjustable capacitor 13. Oscillator 4 has associated with it a resonant circuit including a variable inductance device comprising inductance coil 14 and cooperating ferromagnetic core 10, and an adjustable capacitor 15. Cores 10 are substantially identical and are ganged together by suitable mechanical means as indicated by the dotted line, so as to enter coils 9, 12 and 14, respectively, in unison upon actuation of tuning knob 16.

Coil 9 comprises a relatively large number of turns and has a high inductance in order to improve the gain between antenna 1 and the first amplifying stage 2. Coil 12 has fewer turns and therefore less inductance than coil 9. The circuits including coils 9 and 12, however, must be tuned over the same range of frequencies by actuation of cores 10. This requirement is met in accordance with my invention by winding coil 9 on coil form 9*a* having a somewhat larger outside diameter than that of a coil form 12*a* carrying coil 12. It will be understood that Fig. 1 is merely symbolic as to coils 9, 12 and 14, which in practice have many more turns than are shown.

In the illustrative embodiment of Fig. 1 of the drawings, it is assumed that coils 12 and 14 have closely the same inductance value, although they might, as pointed out above, have different inductance values. However, the oscillator 4 must be tuned over a range of frequencies higher and also narrower than that covered by the remaining two circuits. These requirements are met, in accordance with my invention, by winding coil 14 on a form 14*a* having a somewhat larger outside diameter than either of coil forms 9*a* or 12*a*, and by proper adjustment of capacitor 15 to secure alignment at or near the high-frequency end of the tuning range.

It will be understood that the several coil forms may have the same inside diameter and act as guides for cores 10 as the latter enter coils 9, 12 and 14, respectively, or that other suitable means may be employed for guiding cores 10. Also, any suitable means may be employed for actuating the cores by adjustment of the single tuning knob 16. The cores 10 are substantially identical and are displaced equal amounts. Coils 9, 12 and 14 have the same axial length and the same relative positions with respect to cores 10.

In operation, cores 10 are fully withdrawn from coils 9, 12 and 14, respectively, and the resonant circuits are aligned at the high-frequency end of the tuning range by means of adjustable capacitors 11, 13 and 15. As the cores are gradually inserted, the inductances of coils 9 and 12 increase at the same rate, so that the resonant circuits including these two coils remain tuned to the same frequency. These circuits constitute the preselector portion of the receiver. The inductance of coil 14, however, increases at a lower rate, since the oscillator must cover a narrower range of frequencies for the same core displacement. Thus the three variably tuned resonant circuits of the receiver remain in practically exact alignment regardless of the position of cores 10 with respect to the coils. If, for example, the radio-frequency and modulator resonant circuits are tuned from 535 to 1560 kilocycles and the intermediate frequency of the receiver is 465 kilocycles, the oscillator frequency must vary from 1000 to 2025 kilocycles. The inductances of coils 9 and 12, therefore, must be increased by a factor of 8.5, whereas the inductance of coil 14 is multiplied by a factor of only 4.08. With identical cores and coils of the same inductance value, this requirement is met, in accordance with my invention, by properly relating the diameter of each coil to the frequency range to be covered by the resonant circuit of which it forms a part.

As to the actual differences in diameters which will be required under particular circumstances, it will at once be apparent that they will be determined by the inductance values required and the frequency range to be covered. It may be stated that the effective permeability of a particular core decreases as the diameter of the coil with which it is being used increases, other conditions being equal, and that the effective permeability of a particular core increases as the inductance of the coil with which it is being used increases, other conditions being equal.

Fig. 2 of the drawings shows the variation in the ratio of the inductance with the core partially or fully inserted to the air-core inductance, or the effective permeability of the core at each displacement, when a particular core is inserted into coils of the same axial length and of the same wire size, but of different diameters. As pointed out earlier in this specification, the small variation in inductance values of the several coils due to the differences in their diameters has an inappreciable effect upon the effective permeability of the core used with them. The coils upon which the curves of Fig. 2 are based have an axial length of 1.6875 inches, and the outside diameters of the coil forms for curves *a*, *b*, *c*, *d*, *e*, *f*, *g* and *h* are 0.340, 0.345, 0.350, 0.355, 0.360, 0.365, 0.370 and 0.375 inch, respectively. The inside diameter of each form is 0.316 inch. The core has an axial length of 1.875 inches and a diameter of 0.3125 inch. From the curves, it is evident that the inductance ratio or effective permeability of the core is increased from 6.2 to 7.6 by decreasing the outside diameter of the coil from 0.375 to 0.340 inch. It will be understood that the curves of Fig. 2 are merely illustrative of the practice of the invention and show the performance of a particular set of coils with a particular core. These curves, therefore, are not to be taken as in any way limiting the scope of my invention.

By plotting the coil diameter against the frequency ratio obtained by the use of a particular core in coils of the same axial length and of the same wire size, it is possible to determine the constants of an equation which expresses with reasonable accuracy the relation between coil diameter and frequency ratio. For the coils and particular core of Fig. 2, this equation is

$$R=4.825-6.2D$$

where R is the frequency ratio and D is the diameter of the coil form expressed in inches. Equations for other combinations of coils and cores will be of the same form, but will have different values for the constants.

In Fig. 3 of the drawings, coil 17 has less inductance than coil 12, and is wound on a form 17*a* of somewhat larger diameter than form 12*a*. The resonant circuit including coil 17, therefore, is tuned over a range of frequencies higher and narrower than that covered by the resonant circuit including coil 12. In Fig. 4, coil 18 has substantially the same inductance as coil 12, and is wound on a form 18*a* which is somewhat larger in diameter than form 17*a* of Fig. 3. Coil 18 is wound with a varying pitch, the turns being relatively widely spaced at the end at which the core 10 enters the coil and relatively close together at the other end. This arrangement not only provides a narrower and higher frequency range for the oscillator, but also insures substantially exact tracking throughout the tuning range of the receiver in which the coil system of this figure is employed. Fig. 5 is a modification of the arrangement of Fig. 4, in that coil 19 is of varying pitch similar to coil 18 of Fig. 4, but has less inductance than coil 12. Coil form 19*a* is of somewhat larger diameter than form 12*a*. The difference in frequency between the preselector and oscillator resonant circuits is substantially constant with this arrangment for every position of movable cores 10.

As a guide in applying my invention in specific cases I give the following constructional details of an illustrative embodiment, from which it will be clear that only relatively slight differences in diameter are sufficient to secure the required results.

In a particular embodiment of my invention in accordance with Fig. 1 of the drawings for use over the frequency range from 535 to 1560 kilocycles and with an intermediate frequency of 465 kilocycles, cores 10 have a length of 1.875 inches and a diameter of 0.3125 inch. Coil 9 has an air-core inductance of 211 microhenries, coil 12 an air-core inductance of 72 microhenries, and coil 14 an air-core inductance of 41 microhenries. Coil form 9*a* has an outside diameter of 0.350 inch, coil form 12*a* an outside diameter of 0.340 inch, and coil form 14*a* an outside diameter of 0.368 inch. All the coil forms are of Bakelite tubing and have an inside diameter of 0.316 inch. Suitable adjustable capacitors are provided to permit adjusting the resonant frequency of each resonant circuit, with the core withdrawn from the coil, at or near the highest frequency in the range which it is to cover.

It will be understood that where the expression "coil diameter" is used in this specification and the appended claims, reference is made to the mean diameter of the winding itself. If a bank winding is employed, for example, the coil diameter as used herein would refer to the mean diameter of the several layers of the winding.

It will also be understood that where in the specification I state that one circuit is "tunable over a narrower range of frequencies" than a second circuit, reference is made to the fact that the ratio of the maximum frequency to which the first circuit is tunable to the minimum frequency to which the same circuit is tunable is less than the equivalent ratio for the second circuit. Where it is stated in the specification that one circuit is "tunable over a higher range of frequencies" than a second circuit, reference is made to the fact that the minimum frequency of the first circuit is higher than the minimum frequency of the second circuit and that the maximum frequency of the first circuit is higher than the maximum frequency of the second circuit.

Having thus described my invention, what I claim is:

1. A system for selectively receiving any one of a number of signals differing in frequency including a first resonant circuit having a first adjustable capacitor, a first inductance coil and a first ferromagnetic core; a second resonant circuit having a second adjustable capacitor, a second inductance coil of materially higher inductance value than said first coil, and a second ferromagnetic core substantially identical with said first core; and means for moving said cores in unison relatively to said coils; said second inductance coil having the same length as said first coil but having a diameter greater than that of said first coil so that said circuits are tuned to practically the same frequency at each position of said cores.

2. An article of manufacture, comprising a tuning system including plural inductance coils of substantially the same axial length but of different diameters and self-inductance values, and substantially identical ferromagnetic cores movable in unison relatively to said coils, the diameters of said coils being so related to the self-inductance values of said coils as to produce substantially the same rate of change of inductance of each of said coils due to the motion of said cores.

3. An article of manufacture, comprising a tuning system including plural inductance coils of substantially the same axial length and self-inductance value and wound upon tubes having substantially the same internal diameter but different wall thicknesses, and substantially identical ferromagnetic cores movable in unison relatively to said coils, the diameter of said cores being substantially equal to the internal diameter of said tubes and the wall thicknesses of said tubes being such as to produce a specified relationship between the rates of change of inductance of said coils due to the motion of said cores.

4. An article of manufacture, comprising a tuning system including plural inductance coils of substantially the same axial length but different self-inductance values and wound upon tubes having substantially the same internal diameter but different wall thicknesses, and substantially identical ferromagnetic cores movable in unison relatively to said coils, the diameter of said cores being substantially equal to the internal diameter of said tubes and the wall thicknesses of said tubes being such as to produce a specified relationship between the rates of change of inductance of said coils due to the motion of said cores.

5. An article of manufacture, comprising a tuning system including plural inductance coils of substantially the same axial length and self-inductance values but wound upon insulating tubes having substantially the same internal diameter but different wall thicknesses, and substantially identical ferromagnetic cores movable in unison relatively to said coils, the diameter of said cores being substantially equal to the internal diameter of said tubes and the wall thick-

nesses of said tubes being so related to the self-inductance values of said coils as to produce substantially the same rate of change of inductance in each of said coils due to the motion of said cores.

6. A system for selectively receiving any one of a number of signals differing in frequency including a first resonant circuit having a first adjustable capacitor, a first inductance coil and a first ferromagnetic core; a second resonant circuit having a second adjustable capacitor, a second inductance coil of substantially the same inductance value as said first coil, and a second ferromagnetic core substantially identical with said first core; and means for moving said cores in unison relatively to said coils; said second inductance coil having the same length as said first coil but being of a diameter sufficiently greater than said first coil and having a winding pitch so varying that when said capacitors are adjusted to produce a desired frequency difference between said circuits at one position of said cores, said frequency difference will be substantially constant for every position of said cores.

7. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and said coils having different diameters, all of the turns of each of said coils being actively included in the corresponding circuit during operation, at least one of said coils having a varied winding pitch axially, the coil diameters being so related and the varied winding pitch being so arranged that a tuned frequency relation between said circuits effected by said adjusting capacitors for one position of said cores is maintained for all positions of said cores.

8. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and said coils having different values of self-inductance and having different diameters, all of the turns of each of said coils being actively included in the corresponding circuit during operation, at least one of said coils having a varied winding pitch axially, the coil diameters being so related and the varied winding pitch being so arranged that a predetermined difference in tuned frequency between said circuits may be maintained for all positions of said cores.

9. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and tubes of insulating material having internal diameters substantially equal to the diameter of said cores to receive said cores for axial movement therein, said coils being disposed around said tubes and said tubes having different wall thicknesses, whereby a desired tuned frequency relation between said circuits is maintained for different positions of said cores relatively to said coils.

10. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and tubes of insulating material having internal diameters substantially equal to the diameter of said cores to receive said cores for axial movement therein, said coils being disposed around said tubes and said tubes having different wall thicknesses, said coils having different winding pitches, whereby a tuned frequency relation between said circuits effected by said adjusting capacitors for one position of said cores is maintained for all positions of said cores.

11. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and tubes of insulating material having internal diameters substantially equal to the diameter of said cores to receive said cores for axial movement therein, said coils being disposed around said tubes and said tubes having different wall thicknesses, at least one of said coils have a varied winding pitch axially, whereby a predetermined difference in tuned frequency between said circuits may be maintained for all positions of said cores.

12. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, all of the turns of each of said coils being actively included in the corresponding circuit during operation, at least one of said coils having a varied winding pitch axially, the varied winding pitch being so arranged that a tuned frequency relation between said circuits effected by said adjusting capacitors for one position of said cores is maintained for all positions of said cores.

13. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, said coils having substantially the same axial length and having different diameters, all of the turns of each of said coils being actively included in the corresponding circuit during operation, at least one of said coils having a varied winding pitch axially, the varied winding pitch being so

arranged that a predetermined difference in tuned frequency between said circuits may be maintained for all positions of said cores.

14. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and tubes of insulating material having internal diameters substantially equal to the diameter of said cores to receive said cores for axial movement therein, said coils being disposed around said tubes and said tubes having different wall thicknesses, said coils having substantially the same axial length, at least one of said coils having a varied winding pitch axially, whereby a tuned frequency relation between said circuits effected by said adjusting capacitors for one position of said cores is maintained for all positions of said cores.

15. A high-frequency system, including the combination of a plurality of variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores relatively to said coils, said cores having substantially the same diameter, and tubes of insulating material having internal diameters substantially equal to the diameter of said cores to receive said cores for axial movement therein, said coils being disposed around said tubes and said tubes having different wall thicknesses, said coils having substantially the same axial length and having different winding pitches, whereby a predetermined difference in tuned frequency between said circuits may be maintained for all positions of said cores.

16. An article of manufacture comprising a tuning system for high frequency purposes including plural inductance coils wound upon tubes having substantially the same internal diameter but different wall thicknesses, and substantially identical ferro-magnetic cores movable in unison relatively to said coils, the diameter of said cores being substantially equal to the internal diameter of said tubes and the wall thickness of said tubes being such as to produce a specified relationship between the changes of inductance of said coils due to the motion of said cores.

17. A permeability tuning device including two inductance coils and two ferromagnetic cores simultaneously movable relatively to said coils, all of the turns of each of said coils being active for all operative conditions, at least one of said coils having an axially varied winding pitch arranged to establish a desired relation between the inductance change rates produced by movement of said cores relatively to said coils, for the purpose of maintaining an established alignment between two circuits including said coils.

18. A permeability tuning device including two inductance coils of different diameters and two ferromagnetic cores simultaneously movable relatively to said coils and of substantially the same diameters, all of the turns of each of said coils being active for all operative conditions, at least one of said coils having an axially varied winding pitch arranged to establish a desired relation between the inructance change rates produced by movement of said cores relatively to said coils, for the purpose of maintaining an established alignment between two circuits including said coils.

19. A permeability tuning device including two circuits each having an inductance coil and a ferromagnetic core, said cores being movable simultaneously relative to said coils, said coils being wound upon tubes having different wall thicknesses and substantially the same internal diameters, at least one of said coils having an axially varied winding pitch, the varied winding pitch being so arranged and the coil diameters being such that an established alignment of the circuits may be maintained for all positions of said cores.

20. A permeability tuning device including a plurality of insulating tubes, a plurality of inductance coils wound upon said tubes respectively, said tubes having substantially the same internal diameters and different wall thicknesses, and ferromagnetic cores movable in unison in said tubes relatively to said coils, the diameters of said cores being substantially equal to the internal diameters of said tubes.

21. A permeability tuning device including a plurality of inductance coils wound upon insulating tubes having substantially the same internal diameters and different wall thicknesses, and ferromagnetic cores movable in unison in said tubes relatively to said coils, the diameter of said cores being substantially equal to the internal diameter of said tubes and at least one of said coils having an axially varied winding pitch.

22. A permeability tuning device including at least two inductance coils of different inner diameters, an insulating coil form for each of said coils, a ferromagnetic core for each coil for tuning said coils, said cores having substantially the same cross-section and being movable in unison within and relative to said coils, and supported and guided within said coil forms.

23. A permeability tuning device including at least two inductance coils of different diameters, coil forms respectively supporting said coils, ferromagnetic cores of substantially the same cross-section movable relatively to said coils in unison by single control, and means including said coil forms for guiding the cores in smooth sliding relation from within said coils.

24. In an inductor structure including at least two coil windings each having a movable ferromagnetic core by which the self-inductance of the windings may be progressively changed to obtain a desired relation between two simultaneously permeability-tuned resonant circuits with single control, each of which circuits includes one of said windings, the method which comprises varying the pitch of the winding of one of said coils along at least a portion of its length to provide substantially constant frequency alignment of said circuits within a relatively wide range of frequencies.

25. A high-frequency system including two variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to the corresponding coil for tuning purposes, and means for simultaneously tuning said circuits by movement of said cores in unison relatively to said coils, the radial spacing of one of said cores from its coil being different from the corresponding spacing of the other core from its coil, at least one of said coils having a varied winding pitch along at least a portion of its length, said

spacings being so related and said varied pitch being so arranged that substantially constant frequency alignment of said circuits is effected within a relatively wide range of frequencies.

26. A single control permeability tuning system operative over a wide range of frequencies and including two simultaneously tuned resonant circuits, each of said circuits having a coil winding and a ferromagnetic core movable relative to said winding, said coil windings and cores adapted to produce substantially identical inductance changes in said circuits upon substantially identical core movements, means for aligning said circuits at the high-frequency end of the range, and means including variation in the pitch of one of said windings along at least a portion of its length to provide substantially constant frequency alignment throughout said range.

27. A single control permeability tuning system including two simultaneously tuned resonant circuits, each of said circuits having a coil winding and a ferromagnetic core movable relative to said winding, said coil windings and cores adapted to produce such inductance changes as will tune said circuits over two different frequency ranges of equal frequency coverage upon substantially identical core movements, means for aligning said circuits at the high-frequency ends of said ranges, and means including variation in the pitch of one of said windings along at least a portion of its length to provide alignment of said circuits at a substantially constant frequency difference throughout said ranges.

28. A permeability tuned superheterodyne system including two variably tuned resonant circuits, each of said circuits including an inductance coil, a capacitor, and a ferromagnetic core movable relatively to its corresponding coil, and means for simultaneously tuning said circuits by movement of said cores in unison relatively to said coils, the effective permeability of one of said cores upon its associated coil being different from that of the other core upon its associated coil, all of the turns of each of said coils being actively included during operation, at least one of said coils having a varied winding pitch axially, said varied winding pitch being so arranged and said permeability effects being so related that substantially constant frequency alignment of said circuits is effected within a relatively wide range of frequencies.

FREDERICK N. JACOB.

CERTIFICATE OF CORRECTION.

Patent No. 2,259,250. October 14, 1941.

FREDERICK N. JACOB.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, second column, line 39, claim 11, for the word "have" read --having--; page 6, first column, line 75, claim 18, for "inructance" read --inductance--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of November, A. D. 1941.

Henry Van Arsdale,
Acting Commissioner of Patents.

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