May 16, 1939. W. J. POLYDOROFF 2,158,252

INDUCTIVE TUNING SYSTEM

Filed April 22, 1933 2 Sheets-Sheet 1

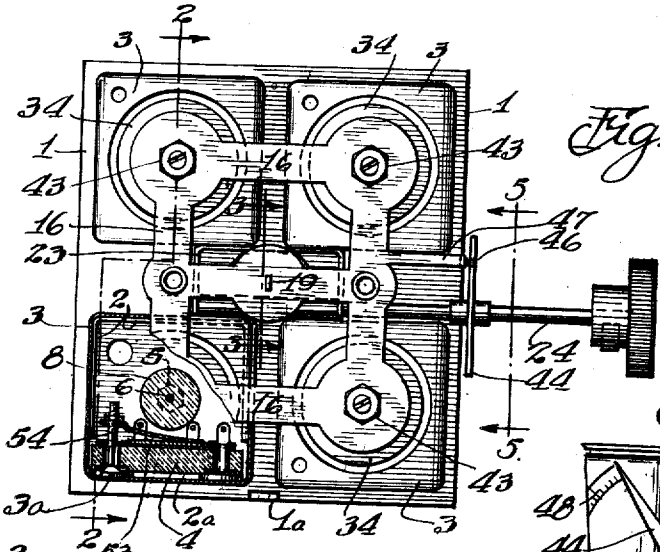


Fig. 1.

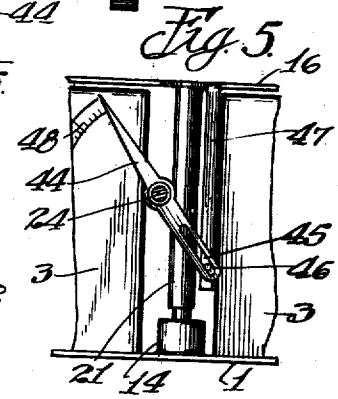


Fig. 5.

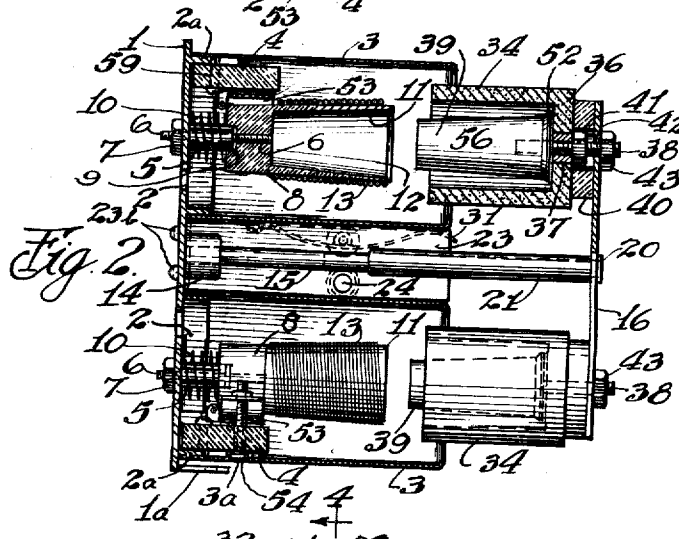


Fig. 2.

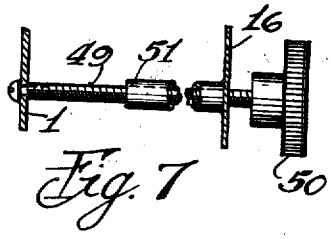


Fig. 7

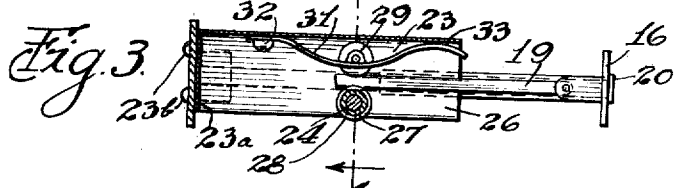


Fig. 3.

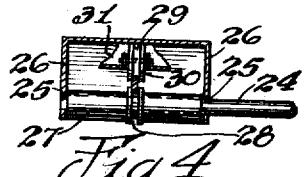


Fig. 4.

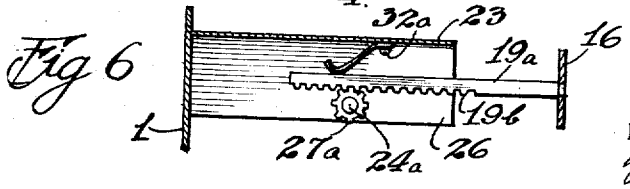


Fig 6

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INDUCTIVE TUNING SYSTEM

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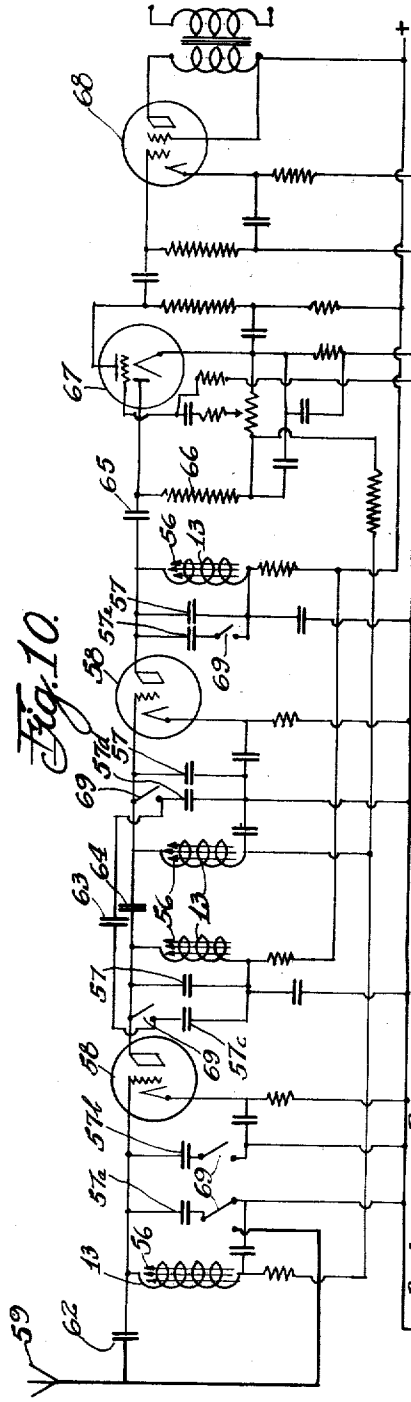


Fig. 10.

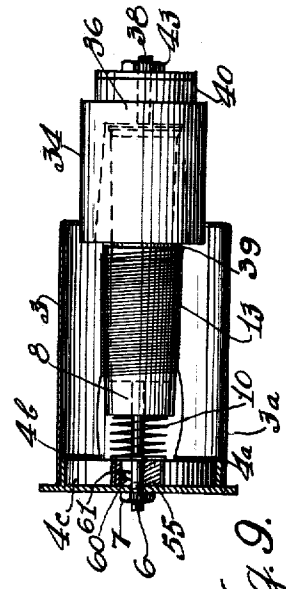


Fig. 9.

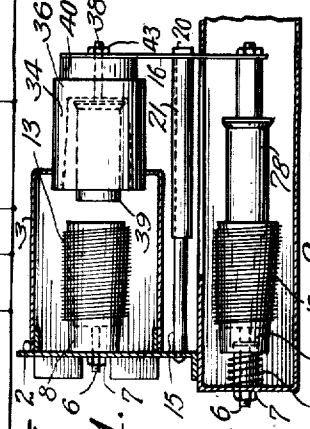


Fig. 11.

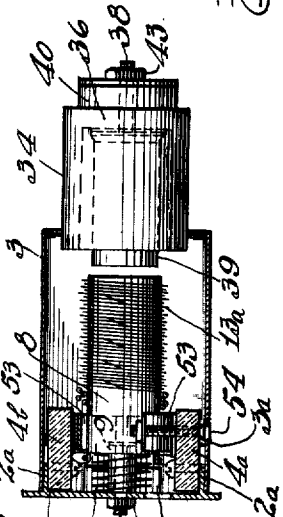


Fig. 8.

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2,158,252

UNITED STATES PATENT OFFICE

2,158,252

INDUCTIVE TUNING SYSTEM

Wladimir J. Polydoroff, Chicago, Ill., assignor to Johnson Laboratories, Inc., Chicago, Ill., a corporation of Illinois

Application April 22, 1933, Serial No. 667,368

15 Claims. (Cl. 250—40)

The invention relates to radio receiving apparatus in which compressed ferromagnetic cores are utilized as the tuning means. In such apparatus, the ferromagnetic cores are arranged to be movable with respect to the inductance coils, and the variation of the inductance, which produces the variable tuning, is brought about by varying the effective permeability of the space surrounding the coils. This method is therefore conveniently called "permeability tuning" to distinguish it from other methods of inductance variation, and from methods in which the capacitance is varied.

The several comminuted compressed ferromagnetic cores and inductance devices which are described in this specification are disclosed in my United States Patents No. 1,982,689, for Magnetic core material; No. 2,113,603, for High-frequency inductance device; and No. 2,005,203, for Variable inductance device; and hence no claims covering such improvements per se are herein included.

In permeability-tuned systems containing several tuned circuits and intended to be tuned by a single control handle, there arises the problem of so designing and constructing the tuning unit that all of the circuits will be tuned very closely to the same frequency for each setting of the single control. This is accomplished partly by designing and constructing the ferromagnetic cores and the inductance coils so that they will be closely alike, partly by providing a mechanism which will insure that the cores (or the coils) will move in unison, and partly by providing adjusting means so that any unavoidable discrepancies in the cores, the coils, or the operating mechanism can be compensated for.

It is an object of this invention, therefore, not only to provide suitable gang or multiple tuning means for permeability-tuned systems, but also to provide, as a part of the complete mechanism, those essential adjustments by which the ganged units may be definitely aligned, so that they will be in substantial agreement throughout the range of adjustability.

As will be better understood from what is to follow, other and further objects of the invention include the provision of alternate driving means which may have advantage in specific embodiments, and the provision of a suitable indicator to show the position of the cores (or the coils) at any adjustment of the main control handle. Still other objects of the invention, and advantages secured by its employment, will also appear in what follows.

As has been indicated, the first essential in a multiple tuning unit of the permeability-tuned type is that the inductance coils shall be closely alike. This same requirement has existed in other and earlier multiple tuning units, and it is well known that by properly choosing the materials used and by adopting a suitable technic in the manufacture of such coils, they may be made closely alike. It is recognized, however, that even with all reasonable precautions the coils will not be exactly alike, and that, in general, some means for compensating for those slight unavoidable differences which will exist must be employed.

It is equally desirable to so design and produce the ferromagnetic cores that they also will be closely alike. Here again, however, in spite of every reasonable precaution, slight differences will remain and adjustments must be provided by which these differences can be compensated. Methods which may be employed to make the cores closely alike are described in United States Patent No. 1,982,689 above referred to, and additional means are disclosed in this specification.

In mechanisms for permeability tuning, the cores move in a straight line into and out of the coils, and the requirement that they shall move in unison and shall be actuated by the single driving means is met by mounting the several cores on a rigid gang-plate and by providing suitable guide means so that the only motion which the gang-plate can have is one of pure translation. There are, of course, many ways of arranging mechanically for this single translatory motion of the gang-plate and its associated cores. There are also many ways of arranging to produce this translatory motion by simple driving means.

The tuning function is accomplished by the relative motion of the cores and the coils, and it is essential that each coil shall be placed in a correct position with respect to its cooperating core, in order that the effect of its core may be the same on each of the coils, so that all the circuits will be tuned to the same frequency for each setting of the cores. Because of the difficulty of establishing this precise relation by merely mounting the coils on an appropriately designed rigid foundation plate, it is advisable to provide adjusting means by which the position of each coil may be adjusted with respect to its cooperating core independently of the relation established by the common means.

Each resonant circuit consists of a coil with its cooperating core and a capacitor which, in so far as the tuning operation is concerned, is fixed in value but which, for the purpose of establishing

the initial conditions in the several tuned circuits, is preferably made so that its capacitance is adjustable over a limited range.

In order to establish a sufficient uniformity of performance of the cores themselves, it is desirable to arrange in the design of the core bodies an adjustment by which slight differences in the effective permeability of the core can be compensated. This adjustment is available after the cores have been completely fabricated and is preferably carried out before they are assembled on the gang-plate. It avoids the necessity for selecting a group of cores which are sufficiently alike without adjustment, and insures exact agreement of the several circuits at the low-frequency end of the tuning range.

In order to secure the full advantage of the several adjustments which have been described, and in order to secure the best possible agreement of the several circuits over the tuning range, it is preferable to carry out the adjustments in a prescribed order so that each adjustment will be made at that portion of the tuning range where it is most effective, and so that one adjustment will not affect another. Thus, assuming that the cores have already been adjusted to have identical effective permeability, it is preferable to adjust the capacitances in the several tuned circuits with the cores at the position of their minimum effect on the inductance of the coils. This adjustment is conveniently carried out at or near the highest frequency in the range for which the receiver is designed, and consists in tuning each of the several circuits to that frequency by the adjustment of the capacitors. This takes care of any differences which may exist in the capacitances in the wiring of the several circuits.

To the extent to which the self-inductances of the coils themselves are precisely alike, the capacitors need only to be adjusted to make the capacitance values in the several circuits also alike. However, to the extent to which the inductance values are not alike, the adjustment of the capacitors will also compensate for the inductance differences, so that at the starting point, corresponding to the minimum inductance and the highest frequency, the several circuits will be in exact alignment.

The relatively movable ferromagnetic cores act only upon the inductances themselves. However, each core acts to multiply the inductance value of its associated coil by a definite factor, no matter what the inductance value may be. If, therefore, the inductance value in a particular circuit is low, and if that circuit has been brought into alignment with the others by adjusting its capacitor to a slightly higher value, at an initial setting corresponding to the highest frequency, then the core will operate to tune that circuit over the same range of frequencies, and finally to the same minimum frequency, as the other circuits.

It remains only to adjust the positions of the coils with respect to their cooperating cores, so that each coil is equally affected by its core. This adjustment is preferably carried out at a frequency intermediate the two ends of the tuning range, in order to establish exact agreement of the several circuits at this third or intermediate point.

To summarize, therefore, agreement at the highest frequency is secured by adjustment of the capacitors, agreement at the lowest frequency is secured by adjustment of the cores, and agreement at a frequency approximately midway between the highest and the lowest frequencies is secured by adjustment of the position of the coils. With exact agreement established at these three frequencies, substantial agreement is secured throughout the tuning range.

My present invention, therefore, contemplates that reasonable care will be taken to make the inductance coils alike, and that the cores, manufactured in accordance with the above-mentioned United States patents, will also be closely alike. I then provide, in the present invention, the independent adjustments just described, in addition to mechanism for producing the necessary motion in unison of the several cores (or coils).

The invention will be better understood if reference is made to the accompanying drawings, which are illustrative of preferred embodiments, and wherein—

Figure 1 is a plan view of an assembly of several high-frequency devices, in one unit, parts being broken away to reveal subjacent elements;

Figure 2 is a sectional view of said unit taken on the line 2—2 of Figure 1;

Figure 3 is a view, partly in section, showing means for moving the cores of said unit;

Figure 4 is a sectional view taken on the line 4—4 of Figure 3;

Figure 5 is a sectional view taken on the line 5—5 of Figure 1, showing an indicator and other parts in elevation;

Figures 6 and 7 are views showing core-actuating devices either of which may be substituted for the device shown in Figures 3 and 4;

Figures 8 and 9 show certain modifications of the tuning elements;

Figure 10 shows diagrammatically a receiving circuit employing one of the new high-frequency units; and

Figure 11 shows a modification of the high-frequency device.

The unit disclosed in Figures 1 and 2 has four shielded variable inductance devices arranged to operate simultaneously. This unit has a foundation plate 1 that is provided with flanges 2 to which rectangular shields 3 are removably secured by friction or by other means, and with ribs 2a which serve as mountings for the semi-adjustable capacitors 4. A perforated lug 1a rising from an edge of the plate 1, enables the unit to be connected with a suitable support.

The foundation plate 1 also is provided with hexagonal tubular thimbles 5 through each of which extends a longitudinally movable screw-threaded rod 6 which terminates outside of the foundation plate 1, where it is provided with an adjusting nut 7. Fixed to the inner end of each of the rods 6, is a coil form 8 having a hexagonal cavity 9 into which the hexagonal thimble 5 extends, the depth of this cavity being such as to permit the coil form to move longitudinally relatively to said thimble, but without disengagement therewith, the coil form, while thus moving, being prevented from rotating by its hexagonal engagement with the thimble. A helical spring 10 is disposed between the foundation plate 1 and each of the coil forms 8, in order to maintain the coil forms in their adjusted positions. Each of the coil forms 8 has a flared wall 11 and is open at the end 12, and carries an inductance coil 13. The mechanism just described constitutes means for adjusting the positions of each of the coils 13 individually with reference to the core portions 34, 39.

The foundation plate 1, furthermore, is provided with tubular sockets 14 for guide rods 15

which are parts of the mechanism for relative motion in unison between the several coils and cores of the unit.

The flanges 2, the hexagonal tubular thimble 5, and the tubular sockets 14 may be made integral with the plate 1, as by die casting, or may be separately produced and secured to the plate in any suitable manner.

Associated with and movable toward and from the foundation plate 1, is a preferably integral rectangular gang-plate 16, to which a jointed actuating rod 19 is attached. The gang-plate 16 has holes 20 in which the ends of guide tubes 21 are fixedly secured. The guide rods 15, carried by the foundation plate 1, telescope with and accurately fit these guide tubes.

As detailed in Figs. 3 and 4, mounted on the foundation plate 1 is a three-sided housing 23 having a flange 23a secured to the plate by screws 23b and containing the devices for reciprocating the actuating rod 19 and the gang-plate 16 to which the rod 9 is attached, these devices being a driving shaft 24 having bearings 25 in the sides 26 of the housing and fixedly carrying a sleeve 27 which is provided with a guide groove 28 for the actuating rod 19, and an idler 29 pivoted on and extending through the slot 30 of a curved pressure-producing spring 31, which spring is attached at one end 32 to the rear wall of the housing 23, and, at its other and free end 33, bears against the rear wall.

Carried by the gang-plate 16, are compressed ferromagnetic cores 56, preferably of the type having variable magnetic density along the magnetic path, and all closely alike. These magnetic cores cooperate with the inductance coils 13 in such a way as to vary the effective permeability of the space surrounding the coils. Each ferromagnetic core has a cup-shaped shell 34 open at one end to receive the coil 13 and has, in its head 36, an internally threaded bushing 37 through which a screw-threaded rod 38 extends, and in which the rod 38 is longitudinally adjustable.

Each core 56 also includes a plug 39 which is tapered so as to conform with the inner wall 11 of the coil form 8, and into which is moulded the inner end of the rod 38. The cup-shaped shell 34 may be spaced from the rectangular gang-plate 16 by an insulating washer 40 to exclude undesired influences of the metal gang-plate on the core, and to leave room for a lock nut 41 which engages the screw threads of the rod 38 and, by contact with the head 36 of the shell 34, locks the plug 39 in any chosen position.

The aforesaid construction allows both the plug 39 and the shell 34 to be made separately and assembled by simply screwing the rod 38 into the bushing 37 of the outer shell, and then tightening the nut 41 until it locks these parts together. The core may thus be matched with other cores of the same unit so as to insure uniform maximum values of inductance in all of the variable inductance devices. This is accomplished by appropriately regulating the air gap 52 between the plug 39 and the head 36 of the shell 34, and then locking these parts together by the nut 41. The arrangement just described constitutes means whereby the core portions 34, 39 may be adjusted so that the cores will have the same effective permeability value.

The rectangular gang-plate 16 is provided with holes 42 through which the outer ends of the screw-threaded rods 38 may be passed when the core portions 34, 39 are placed in position, nuts 43 being screwed onto those ends to thereby firmly unite the gang-plate 16, the core portions 34, 39 and the insulating washer 40.

When cores and coils are assembled, as hereinbefore described, it is necessary to so adjust their relative positions that all the cores and coils, however positioned, will produce substantially the same inductance variations. These uniform results may be secured by the adjustment of the nuts 7 and consequent linear movement of each coil form 8 with its coil 13.

Referring to Fig. 5, the movement of the cores 56 relatively to the coil forms 8 and the coils 13 may be indicated by a pointer 44 rotating on the drive shaft 24 and having a slot 45 through which extends a pin 46 that is carried by a downwardly bent finger 47 with which the rectangular gang-plate 16 is provided. A scale 48 indicates various positions of the pointer, and, consequently, of the gang-plate 16 and the cores 56. Many other types of indicator, of course, may be satisfactorily employed.

Modifications of the actuating devices shown in Figures 1, 2, 3 and 4 are revealed in Figures 6 and 7.

Figure 6 shows a rack 19a secured at one end to the gang-plate 16, and having teeth 19b which are held engaged with a pinion 27a carried by a driving shaft 24a, by a spring secured to the rear wall of said housing 23, by a screw 32a. The rotation of this shaft 24a and its pinion 27a imparts a linear movement to the rack 19a, and moves the gang-plate 16 and the parts mounted thereon relatively to the other parts of the device.

Figure 7 shows a screw-threaded rotary shaft 49 extending at one end through the plate 1 and provided at the other end with a knob 50. An internally screw-threaded sleeve 51, fixed to the gang-plate 16, surrounds and engages the screw-threads of the shaft. Hence, the rotation of the shaft will effectuate the desired motion of the gang-plate 16. Many other forms of driving mechanism may be employed. The three forms above described are preferred for simplicity and effectiveness.

The capacitors 4 may be of the semi-adjustable type, each having at least two plates 53 spaced by an insulator and resiliently held at any desired separation by a screw 54. The adjustable capacitors constitute the means whereby the several tuned circuits may be tuned to the same frequency at the high-frequency end of the tuning range.

Each of these capacitors is desirably disposed within one of the shields 3, whereby individual circuits are shielded from external influences and from each other. Hence, the problem of shielding inter-connecting wires between component parts of the same circuit is eliminated. The shields have holes 3a affording access to the adjusting screws 54.

In some cases it is desirable to have two values of capacitance in each circuit, as shown in Figures 8 and 9.

Figure 8 shows two capacitors 4a, 4b having different capacitance values, which capacitors are of the same design as the capacitor 4, already described, and are similarly mounted on ribs 2a; Figure 9 also reveals two capacitors 4a, 4b having either the same or different capacitance values, both mounted on a common insulating base 4c. The plug of the ferromagnetic core and the coil 13a may, as shown in Figure 8, be cylindrical, and the coil may be bank-wound, with several layers of wire.

Figure 9 illustrates means which may be substituted for the devices shown in Figure 2 for preventing the coil forms 8 from rotating while being adjusted, the hexagonal thimble 5 and the hexagonal cavity 9 being superseded by a bushing 55 fixed within the base 4c and having an internal longitudinal groove 60 with which a pin 61, on the screw-threaded rod 6, engages. Any other suitable means for preventing rotation of the coil during adjustment may be employed.

Figure 10 shows a circuit arrangement having a plurality of resonant circuits tuned by variable inductance devices such for example as those of Figs. 1 and 2, and having the three adjustments above described for securing alignment between the several circuits. The cores 56 will have provision for adjustment of their effective permeabilities, the capacitors 57 will have means for the adjustment of their capacitance values, and means will be provided for the adjustment of the relative position of each core 56, with respect to its coil 13. In a preferred embodiment of the circuit of Fig. 10, these adjustments will have the form described in connection with Figs. 1, 2 and 9. The motion of the several cores 56 relatively to the coils 13, to tune the system over a range of frequencies, will be secured by employing the drive arrangements described in connection with Figs. 1, 2, 3, 4, 6 and 7, and an indicator will be provided as described in connection with Fig. 5. It will be understood that equivalent arrangements for the adjustments, the drive and the indicator may be employed without departing from the scope of my invention.

In certain cases, as for example in superheterodyne circuits, it is necessary to have one tuned circuit cover a different range of frequencies from the other tuned circuits, although the two ranges may overlap to some extent. In such a superheterodyne circuit, the preselector may be designed to cover the range from 550 to 1500 kilocycles, and this will require an inductance variation of $(1500)^2/(550)^2$, or 7.45. If the intermediate-frequency amplifier is designed for a frequency of 175 kilocycles, the oscillator circuit will require to be tuned from 1500+175 kilocycles to 550+175 kilocycles, which requires an inductance variation of only 5.35. To obtain this range with a variable inductance device of the same type as used in the preselector, an additional fixed inductance coil, not acted upon by the moving core, may be inserted in the circuit in series with the coil of the variable inductance device.

When a sufficiently high intermediate frequency is employed in superheterodyne circuits, such for example as 450 or 500 kilocycles, the inductance variation necessary in the oscillator is only of the order of 4 and may easily be accomplished by the use of the inner plug alone. In this case, similar coils may be employed for the preselector and for the oscillator, as shown in Figure 11, the plug 78, which is used to tune the oscillator circuit, being given a suitable shape to produce the desired variations throughout the range of frequencies to be covered by the oscillator.

Having thus described my invention, what I claim is:

1. A plurality of resonant circuits tunable over a range of frequencies by a tuning means which simultaneously varies the effective value of the inductance in each of said circuits, electrical means for adjusting all of said circuits to substantially the same maximum frequency, magnetic means for adjusting all of said circuits to substantially the same minimum frequency, and mechanical means for adjusting all of said circuits to substantially the same frequency intermediate said maximum and said minimum frequencies.

2. A tuning unit for a radio receiver including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said resonant circuits, said tuning means including inductance coils and cooperating ferromagnetic cores and means for effecting relative motion in unison therebetween, means for adjusting the relative position of each cooperating coil and core, means for adjusting the capacitance value in each of said resonant circuits, and means for adjusting the effective permeability of each of said cores.

3. A tuning unit for a radio receiver, including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said resonant circuits, said tuning means including a ferromagnetic core for each of said resonant circuits, said cores each having an adjustable air gap by which said cores may be adjusted to be effectively alike.

4. A tuning unit for a radio receiver, including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said resonant circuits, said tuning means including a foundation plate and an inductance coil for each of said resonant circuits, said coils each including a form, an adjusting screw and guide means, and being adjustably mounted upon said foundation plate.

5. A tuning unit for a radio receiver, including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said circuits, said tuning means including plural inductance coils each having a form, a winding, a guiding means, a spring member and a screw-threaded member for adjustably securing said coil, against the action of said spring member, to a foundation plate.

6. A tuning unit for a radio receiver, including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said circuits, said tuning means including a carrier, plural ferromagnetic cores each having a screw-threaded member in two portions thereof to adjustably establish an air gap between said members and to mount said core upon said carrier, and additional screw-threaded members to lock said air gap at its adjusted dimension and to secure said core to said carrier.

7. In a plurality of resonant circuits each having a capacitor, an inductance coil and a ferromagnetic core cooperating with said coil, said cores being arranged for motion in unison relatively to said coils to tune said circuits from a minimum frequency to a maximum frequency, the method of correcting inaccuracies of alignment between said circuits which consists in adjusting the capacitance value in each of said circuits, adjusting the effective permeability of each of said cores and adjusting the relative position of each cooperating coil and core, to secure substantial alignment at said maximum frequency, at said minimum frequency and at a frequency intermediate said minimum and maximum frequencies.

8. In a plurality of resonant circuits each hav-

ing a capacitor, an inductance coil and a ferromagnetic core cooperating with said coil, said cores being arranged for motion in unison relatively to said coils to tune said circuits from a minimum frequency to a maximum frequency, the method of correcting inaccuracies of alignment between said circuits which consists in adjusting the capacitance value in each of said circuits at said maximum frequency, adjusting the effective permeability of each of said cores at said minimum frequency and adjusting the relative position of each cooperating coil and core at a frequency intermediate said minimum and maximum frequencies.

9. A high-frequency network including plural units each having inductance and capacitance, tunable over a range of frequencies by tuning means which simultaneously varies the effective values of said inductances, electrical means for adjusting at least one of said units to have a desired maximum frequency, magnetic means for adjusting at least one of said units to have a desired minimum frequency, and mechanical means for adjusting at least one of said units to have a desired frequency at a point intermediate said maximum and minimum frequencies.

10. A high-frequency network including plural units each having capacitance and inductance, responsive to a relatively narrow band of frequencies but tunable over a wide range of frequencies by simultaneous variation of the effective values of said inductances, electrical means for adjusting at least one of said units to have a desired maximum frequency, magnetic means for adjusting at least one of said units to have a desired minimum frequency, and mechanical means for adjusting at least one of said units to have a desired frequency at a point intermediate said minimum and maximum frequencies.

11. A tuning unit for a radio receiver, including a high-frequency network comprising capacitances and inductances, tunable over a range of frequencies by ferromagnetic cores which vary the effective values of said inductances, means for adjusting the relative position of each cooperating coil and core, means for adjusting the values of the capacitances, and means for adjusting the effective permeability of each of said cores.

12. A tuning unit for a radio receiver, including a high-frequency network comprising capacitances and inductances, responsive to a relatively narrow band of frequencies but tunable over a wide range of frequencies by ferromagnetic cores which simultaneously vary the effective values of said inductances, means for adjusting the relative position of each cooperating coil and core, means for adjusting the values of the capacitances, and means for adjusting the effective permeability of each of said cores.

13. A tuning unit for a radio receiver, comprising a plurality of resonant circuits each including an adjustable capacitor and an inductance coil, a plate supporting said capacitors and said inductance coils, means for adjusting the position of said inductance coils relatively to said plate, inductance-varying ferromagnetic cores associated with and movable relatively to each of said inductance coils, said cores including an adjustment of their inductance-varying effect, a carrier to which said cores are secured, guides to limit the motion of said carrier to a direction parallel to the axes of said inductance coils, and means for producing said motion.

14. A tuning unit for a radio receiver, comprising a plurality of resonant circuits each including an adjustable capacitor and an inductance coil, a plate supporting said capacitors and said inductance coils, means for adjusting the position of at least one of said inductance coils relatively to said plate, an inductance-varying element for each of said inductance coils, at least one of said elements having an adjustment to establish its inductance-varying effect, means for moving said elements in unison relatively to said inductance coils including a carrier to which said elements are secured, and a driving member which engages a portion of said carrier.

15. A tuning unit for a radio receiver, including a plurality of resonant circuits tunable over a range of frequencies by tuning means which simultaneously varies the effective value of the inductance in each of said circuits, electrical means for adjusting said circuits to a maximum frequency, magnetic means for adjusting said circuits to a minimum frequency and mechanical means for adjusting said circuits to a frequency intermediate said maximum and minimum frequencies.

WLADIMIR J. POLYDOROFF.

CERTIFICATE OF CORRECTION.

Patent No. 2,158,252. May 16, 1939.

WLADIMIR J. POLYDOROFF.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 20, strike out the word "and"; and second column, line 51, before "means" insert mounting; page 2, second column, line 49, strike out the comma after "plate 1"; page 3, first column, line 22, for "rod 9" read rod 19; and second column, line 68, after "2a" strike out the semicolon and insert instead a period; 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 4th day of July, A. D. 1939.

(Seal)

Henry Van Arsdale
Acting Commissioner of Patents.