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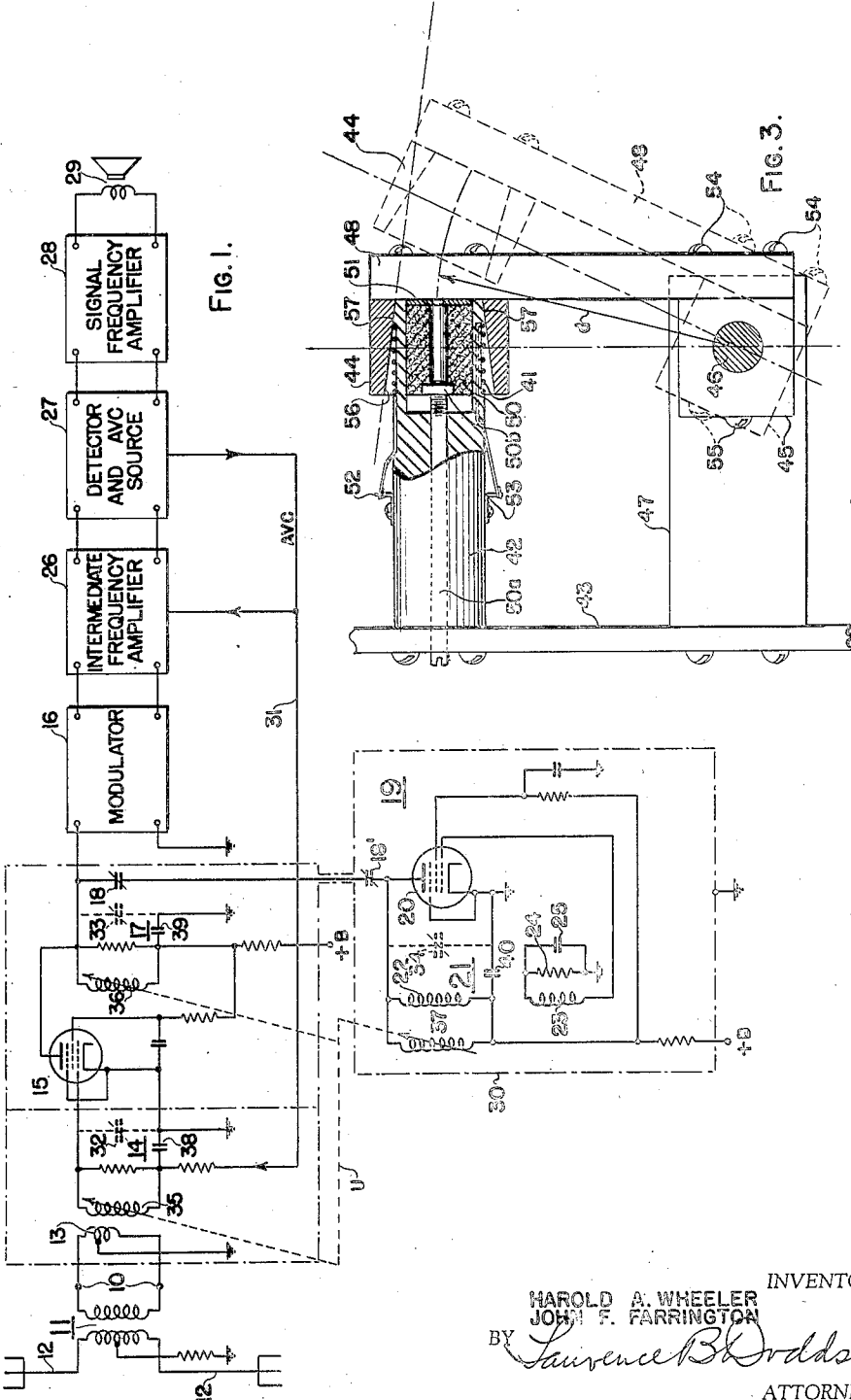
H. A. WHEELER ET AL

2,222,387

HIGH FREQUENCY TUNABLE SYSTEM AND APPARATUS

Filed Feb. 16, 1937

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

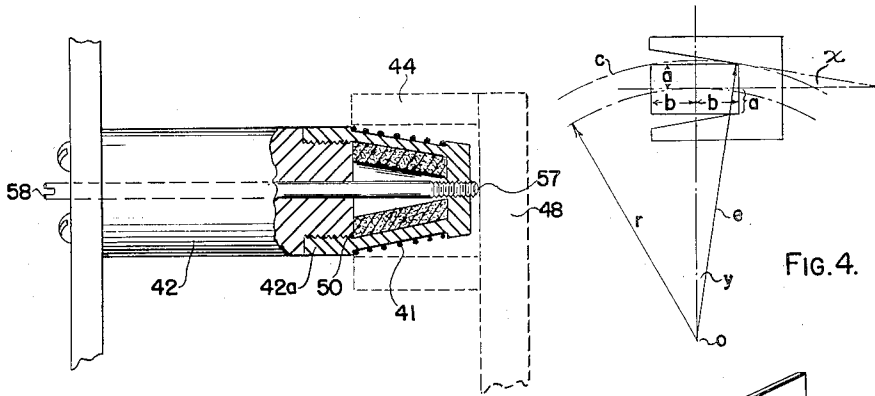


FIG. 6.

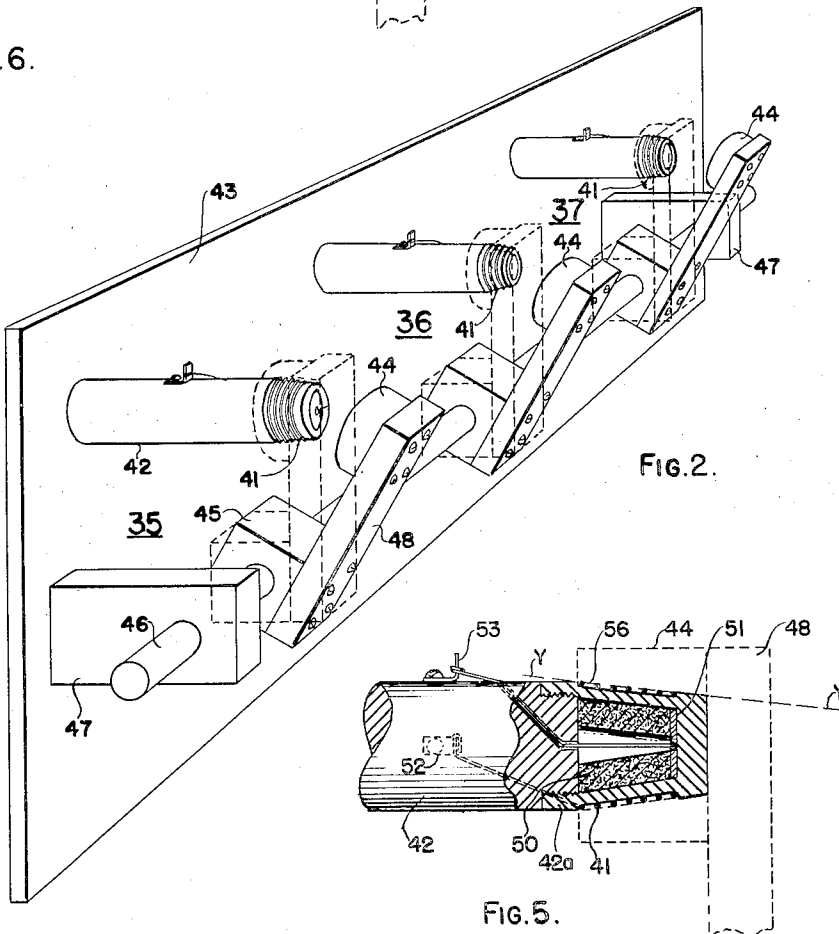


FIG. 5.

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2,222,387

HIGH-FREQUENCY TUNABLE SYSTEM AND APPARATUS

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Application February 16, 1937, Serial No. 125,968

13 Claims. (Cl. 171-242)

This invention relates to tunable systems for use in high-frequency signaling systems, and more particularly to systems or circuits which are tunable over a broad band of high frequencies, as, for example, those ordinarily encountered in radio and television transmission and reception systems.

In certain electric circuit arrangements, as, for example, in high-frequency signal-receiving systems, it is often necessary to provide selector circuits which are tunable over a broad band of frequencies. Television receivers, for example, may require selector circuits tunable over a frequency range extending from 40 to 90 megacycles, more or less. In constructing a tunable system of this type, it is advantageous to secure the highest possible resonance gain therein over the entire tuning range, and this requirement dictates that the anti-resonant impedance of the system be maintained at the highest practical value at all frequencies within the range. This requirement renders undesirable the use of an adjustable capacitor as a tuning element, for with such an element the required tuning capacitance becomes so large over a substantial portion of the band that the anti-resonant impedance and gain of the system are reduced to undesirably small values. At the same time the width of the band passed by the system becomes excessively narrow unless the circuit is loaded to the point where the gain of the system is substantially decreased. This disadvantage may be obviated by using a system comprising fixed capacitive reactance means and an adjustable inductance tuning unit for tuning over the desired broad frequency range. However, adjustable inductance tuning units heretofore devised have been unsuitable for a number of reasons. Adjustable inductance devices of the prior art have in general been of two types, one comprising a winding and an associated adjustable shield and the other, the usual variometer construction, that is, two relatively adjustable windings. The inductance units of the first type have had the drawback of a quite limited range of inductance variation, as well as being mechanically unsuited for operation by conventional tuning control devices.

Adjustable inductance tuning units of the other types are of more or less complicated structure and are characterized by various mechanical deficiencies which render them unsuitable for use in an application of the type specified above. More specifically, conventional units of other types are characterized either by pig-tail

connectors or by sliding contact connectors between the windings and their terminals. The stray inductances and capacitances introduced by the first-mentioned form of connector are always variable and unpredictable quantities and, consequently, are difficult to account for in exact circuit design. Similarly, the contact resistance of sliding contact connectors is an indeterminate quantity which cannot be readily and accurately accounted for, and is generally a source of background noise.

It is, therefore, an object of the present invention to provide a system tunable over a broad frequency range by means of an adjustable inductance unit so constructed and arranged as to overcome the disadvantages of the arrangements of the prior art and to be simple in construction and efficient in operation.

It is a further object of the invention to provide an adjustable inductance tuning unit suitable for the application described above having a sufficient range of inductance variation so that a wide frequency band of the order specified may readily be covered and having, in addition, one or more of the following characteristics: compactness, simplicity, adaptability to conventional tuning mechanisms, economy and ruggedness of construction, ease of duplication within reasonable manufacturing tolerances, absence of sliding or variable contacts, and freedom of backlash.

Briefly, in accordance with the present invention, the above objects are attained in a high-frequency signaling system by providing an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescopic relation with respect to the winding element, and means for moving the elements relative to each other in an arcuate path about an axis external to the winding from one limiting position in which the winding element is substantially totally shielded to another limiting position in which the winding element is substantially unshielded. The configurations of the cooperative surfaces of the elements are substantially complementary to each other so as to provide substantially the minimum clearance permitted by the location of the axis.

With such an arrangement the major portion of the inductance variation is obtained when the shield and the winding are relatively closely coupled or approach a close fitting physical relationship. Hence, to provide a unit of the above character having the required range of inductance adjustment, it is necessary so to arrange the elements that when the shield is fully telescoped

over the winding, the two elements are in as close fitting a physical relationship as the electrical requirements will permit. In order to secure a unit capable of being easily adjusted, it is also desirable to produce the desired relative movement between the shield and the winding by means of a rotatable adjusting or control element. This latter requirement may be accomplished by mounting the shield on an arm which is in turn mounted on a rotatable shaft, so that the shield traverses an arcuate path as it is moved toward and away from the winding.

For the purpose of satisfactorily meeting the requirements outlined in the preceding paragraph without undesired friction between the winding and the shield, either the inner surface of the shield or the outer surface of the winding, or both, are tapered, preferably conically tapered, and the generating angles or curves of the tapered surface or surfaces of the shield and winding are so related to their configurations, the location of the axis of the rotatable shaft, and the radius of the arcuate path of relative movement of the shield and winding, that the desired close fitting relationship between the winding and the shield is obtained without any appreciable frictional contact between the outer surface of the winding and the inner surface of the shield during relative movement therebetween. It is apparent that the winding and shield elements of such an inductance unit may take various forms; for example, the winding may be cylindrical and the shield conical; the winding conical and the shield cylindrical; or both elements may have conically cooperating surfaces; or either or both of the cooperating surfaces of the winding and shield elements may be tapered surfaces other than conical surfaces, that is, having a generatrix which is a curve rather than a straight line. Thus, the word "taper" is used herein in a broad sense to include not only the surface generated by moving a straight line, but also a surface generated by moving a curved line and the expression the "relative angle of taper" or "relative angle of conical taper" refers to the angle between the generating curves or lines, respectively, of the two cooperating surfaces when in a position of maximum coupling, the generating angle or curve of either of the surfaces being considered zero when the surface is cylindrical.

The range of inductance variation of such an inductance unit may be substantially increased by providing the winding with a magnetic core element, preferably of comminuted iron mixed with a suitable insulating binder, which is effective very materially to increase the maximum inductance of the unit without substantially affecting its minimum inductance, when the shield and winding elements are closely coupled. In accordance with this feature of the invention, there is provided in a high-frequency signaling system an adjustable inductance tuning unit comprising a winding element, a shielding element, and means for relatively moving the elements into and out of coupling relationship, the winding element being provided with an adjustably-fixed magnetic core element effective upon adjustment substantially to increase the maximum inductance of the unit without appreciably affecting its minimum inductance. When several such inductances are associated with tunable systems adapted for unicontrol, the magnetic core element may be made adjustable to facilitate alignment of the tunable systems at the low-frequency

end of the tuning range without substantially affecting their alignment at the high-frequency end.

The novel features believed to be characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings, in which Fig. 1 schematically illustrates the invention as applied to a high-frequency signal-receiving system of the superheterodyne type; Fig. 2 is a perspective view of a plurality of adjustable tuning units constructed in accordance with the present invention and suitable for use in the circuit of Fig. 1; Fig. 3 is a detailed view, partially in section, of one of the tuning units shown in Fig. 2; Fig. 4 schematically illustrates certain features of the invention; while Figs. 5 and 6 illustrate modifications of one of the elements of the tuning units shown in Figs. 2 and 3.

Referring now more particularly to Fig. 1 of the drawings, there is illustrated a high-frequency signal-receiving system of the superheterodyne type having embodied therein a plurality of tunable systems constructed and arranged in accordance with the present invention. While the receiver shown is described more particularly with reference to its use in the reception of sound signal-modulated carriers, it will be understood that it may be used for the reception of television signal-modulated carriers by modification of conventional elements thereof. Briefly described, the receiver comprises input terminals 10 which may be coupled through a balanced transmission line and an impedance-matching transformer 11 to an antenna circuit 12, the antenna being of the doublet type suitable for use in the reception of a wide high-frequency band. The input terminals 10 are coupled by means comprising an inductance element 13 to the high-potential end of an inductance element incorporated in the tunable input circuit 14, which circuit is coupled to the input electrodes of a shielded pentode amplifier tube 15, preferably of a type having minimum capacitance between its electrodes and so disposed as to have a minimum inductance in, and a minimum capacitance between its internal and external connectors. The output electrodes of this tube are coupled to the input circuit of a modulator or frequency changer 16 by means comprising a tunable selector system 17 identical with the system 14. Also coupled to the input circuit of the modulator 16 by means including condensers 18 and 18', is the output circuit of a local oscillator indicated generally at 19. This oscillator comprises a shielded pentode tube 20, also preferably of a low interelectrode capacitance type, having its input and output electrodes coupled to a tunable system 21. As will be pointed out in greater detail hereinafter, adjustment of the resonant frequency of the system 21 over the desired tuning range is accomplished by varying the inductance of the circuit, rather than the capacitance. In order to prevent such inductance variations of the main tuning inductance from affecting detrimentally the amount of feedback from the output to the input electrodes of the tube 20 there is included in the system 21 a fixed inductance element 22 which is coupled to the input electrodes of the tube through a cir-

cuit comprising an inductance element 23 and a grid-leak resistor 24 shunted by a condenser 25. As is pointed out in greater detail in Patent No. 2,165,468, granted July 11, 1939, on an application of John F. Farrington, this arrangement of the oscillator circuit insures a sufficient output voltage for all adjustments of the main inductance element to tune the system over the entire band.

10 Coupled in cascade with the modulator stage 16, in the order named, are an intermediate-frequency amplifier 26, a detector and source of automatic amplification control bias 27, a signal-frequency amplifier 28, and a translating device 15 indicated as a loud-speaker 29. Additional features of the circuit arrangement include: the complete shielding of the radio-frequency amplifier and selector circuits and the local oscillator 19 as indicated by the dash lines 30; the application of operating voltages of appropriate value to the screen and anode electrodes of the tubes shown through the +B terminals and appropriate voltage dropping resistors; the connection of the tuning units of the several circuits 14, 17 and 21 for unicontrol adjustment as indicated by the dotted line U; and the provision of an automatic amplification control circuit including the connection 31 for deriving from the detector 27 a bias voltage variable with the signal carrier amplitude and applying the same negatively to the input electrodes of the tube 15 and one or more of the tubes included in the intermediate-frequency amplifier 26 to maintain the signal output within a narrow range for a wide range of received signal amplitudes.

The receiver, as generally described above, is of the conventional superheterodyne type, the operation of which is well understood in the art. Briefly, a desired signal-modulated carrier intercepted in the antenna circuit 12 is selected and amplified in the radio-frequency amplifier stage including the tube 15, is further selected and converted into a modulated intermediate-frequency signal in the selector system 17 and the modulator stage 16, respectively, is further selected and amplified in the intermediate-frequency amplifier 26 and is supplied to the detector 27 for rectification. The modulation-frequency components derived from the detector 27 are amplified in the signal-frequency amplifier 28 and supplied to the translating device 29 for reproduction. The amplitude of the input voltage to the detector 27 is maintained within narrow limits through the action of the automatic amplification control circuit in a manner well understood in the art.

As pointed out above, in order to tune a receiver of the above type over an exceedingly broad range of high frequencies without a substantial sacrifice in the resonance gain thereof over at least a substantial portion of the tuning range, it is necessary to employ variable inductance units as the tuning elements of the various tunable systems embodied in the receiver. Accordingly, the tunable systems 14, 17, and 21 comprise, respectively, fixed capacitance means 32, 33 and 34, which capacitance means may comprise in whole or in part the inherent capacitance of the individual circuits and tubes with which they are associated individually shunted by adjustable inductive reactance means in the form of adjustable inductance tuning units 35, 36, and 37. It is, of course, desirable to maintain the capacitance of each of these sys-

tems effectively in parallel with the tuning inductance as small as possible in order to maintain the anti-resonant impedance thereof as high as possible over all portions of the operating range. Hence, in the arrangement described above, only the inter-electrode capacitances of the tubes into which the individual systems operate, the stray lead capacitances, and small padding or capacitance equalizing condensers, all in parallel and the total effectively in series with the direct current blocking condensers 38, 39 and 40, are included in the respective circuits. Tubes 15 and 20 as specified above, have a very small interelectrode capacitance, so that the total capacitance in each of the enumerated circuits effectively in parallel with the tuning inductance is extremely low, being of the order of 10 micro-microfarads. This low value of total capacitance insures a high anti-resonant impedance for each of the circuits 14, 17, and 21. The load resistors connected across the tuned circuits 14 and 17 preferably have resistance values which are low compared with the anti-resonant impedances of the circuits so that, by the use of variable inductance tuning, the gain and selectivity characteristics of the circuits remain approximately uniform throughout the tuning range.

Referring now more particularly to Fig. 2 of the drawings, there is illustrated the general mechanical arrangement of the inductance tuning units 35, 36 and 37, whereby unicontrol adjustment is obtained. As shown in this figure, each of the units comprises a winding 41, on a coil form comprising one end of a supporting member 42 rigidly secured at its other end to a panel or base 43 which may comprise one wall of a shielding container. The member 42 may be constructed of Bakelite or other insulating non-magnetic material.

In order to vary the value of the inductance of each of the windings 41, there are provided non-magnetic shields 44 of low resistance material such as aluminum, brass or copper each movable in telescoping relationship relative to its associated winding 41 by means of a shaft 46 rotatable in bearing surfaces provided in members 47, the shields 44 being supported on the shaft 46 by arms 48 mounted on block member 45 adjustable about the shaft 46. By this construction, the shielding elements 44 are moved relative to the winding elements 41 in arcuate paths about a common axis external to the windings. Preferably, the members 47 are rigidly mounted on the panel 43 to provide a unitary structure. In Fig. 2, the shields of the inductance units are shown in full lines in their limiting positions for maximum inductance, in which the winding elements are substantially unshielded, and in dotted lines in their limiting positions for minimum inductance, in which the winding element is substantially totally shielded.

The three units shown in Fig. 2 are of identical construction, the details thereof being illustrated in Fig. 3. As shown in the latter figure, the winding element 41 is cylindrical while the complementary cooperating surface of the shield 44 is slightly conical or tapered. The end of the member 42 comprising the form for the winding 41 is provided with a cylindrical recess or bore in which is disposed a magnetic core 50 consisting of comminuted magnetic material intermixed with a suitable binder. The end of the recess is closed by means of a plug 51 to retain the core 50 within the recess. The ends of the winding 41

are brought out to terminals 52 and 53 through suitable passageways cut in the member 42 upon which the terminals are mounted. The arm 48 is secured to the member 45 by screws 54 threaded into the latter member and extending through holes cut in the arm 48 of appreciably greater diameter than the screw shanks, in order to permit adjustment of the shield 44 radially and axially with respect to the shaft 46 and thus permit proper alignment of the shield 44 with respect to the winding 41. A third adjustment may be secured by loosening the set screws 55 to permit relative movement between the shaft 46 and the members 45. Further, the iron core 50 may be axially adjusted by a screw 50a threaded into an insert 50b in the core 50. Axial adjustment of the core 50 is effective substantially to increase the maximum inductance of the unit without appreciably altering its minimum inductance, thus increasing the range of inductance variation. These several adjustments are useful when two or more of the units are ganged for unicontrol, as shown in Figs. 1 and 2, in adjusting the individual units to provide the correct frequency alignment of the associated tunable systems in which they are individually connected, as for example, the circuits 14, 17 and 21 included in the circuit of Fig. 1. A shoulder 57 formed on the end of the member 42 cooperates with the inner surface 56 of the shield accurately to align the winding and shield, and the end of the member 42 forms a stop for limiting the movement of the shield relative to the winding. The high alternating potential end of the winding is preferably disposed to have the greatest clearance to the shield when in position of maximum coupling, thereby minimizing the effective capacitance between the shield and the winding and minimizing the capacitance added to the tuned system of which the inductance unit forms a part and the variation of such capacitance with movement of the shield.

The advantage of providing an adjustable inductance tuning unit in which there is obtained a close-fitting relationship between the associated shield and winding, without any appreciable friction therebetween, has been mentioned above. In the unit described above, this desirable feature is attained by making the configuration of the inner surface of the shield 44 substantially complementary to the configuration of the associated windings 41 and by properly relating such configurations, the radius d of the arcuate path described by the center of the shield 44 as it is moved relative to the winding 41, and the position of the shaft 46 so as to provide substantially the minimum clearance permitted by the location of the axis of shaft 46. In the arrangement illustrated in Fig. 3, for example, which is shown in the drawings to scale, maximum coupling between the shield and the winding with the shield fully telescoped over the winding is obtained without any appreciable frictional engagement between these elements during any portion of the relative movement therebetween by positioning the axis of the shaft 46 in a plane substantially perpendicular to the axis of the winding 41 and passing through its longitudinal center and by making the radius d of the arcuate path approximately four times the diameter of the winding 41. However, the clearance between the winding 41 and the shield should not be reduced to such a small value that the capacitance between winding and the shield materially increases

the total capacitance of the circuit, of which the inductance unit is a part, effectively in parallel with the inductance unit.

The inductance element 22 forms a portion of the aligning means for maintaining frequency alignment between the frequency-determining circuit 21 of the oscillator 19 and the tunable systems 14 and 17. Thus, the tunable input circuit 15 (and also 17) and the frequency-determining circuit 21 comprise a pair of circuits tunable to different frequencies and over different frequency ranges, and it is conventional practice to align these circuits so that the frequency difference thereof is maintained approximately constant over their respective tuning ranges. This is usually accomplished in conventional arrangements employing variable capacitance tuning by using series and parallel padding condensers in one or more of the circuits. In an arrangement of the form described, however, wherein inductance tuning is employed, alignment may be secured by adjusting the inductances of the circuits. The inductance element 22 may conveniently be used for this purpose by properly proportioning the inductance thereof relative to the inductance of the tunable circuits with which the circuit 21 is to be aligned and constructing the element so that its inductance may be adjusted within sufficiently wide limits to permit alignment of this circuit with the other circuits. In the arrangement described, also, the parallel capacitance is preferably given a value different than that of the other tunable circuits with which the oscillator is to be aligned, by analogy to the use of inductance elements of different inductance value in conventional variable capacitance tuning arrangements.

Referring now more particularly to Fig. 4 of the drawings, the arrangement of Fig. 3 is illustrated schematically with suitable legends for determining in more general terms the relations whereby the desired characteristics stated above are obtained. It can be shown that the smallest generating angle x of the conical surface 56 which may be used without engagement of the winding and shield during any position of relative movement therebetween is fixed by the line tangent at the upper right hand corner of the winding to the arc c having as its center o the axis of rotation of the shield, its radius being indicated by $r+a$. The generating angle x is equal to the angle y between the radius passing through the longitudinal center of the winding and the radius e extending to the upper right hand corner of the winding. Neglecting any extensions of the form beyond the end of the coil and assuming that the axis of rotation of the shield lies in a plane perpendicular to the winding axis and passing through its longitudinal center, this angle may be determined from the equation:

$$x = y = \tan^{-1} \frac{b}{r+a}$$

where a =radius of the winding
and b =half-length of the winding

It will be understood that the circuit and tuning unit specifications may vary according to the design of a particular application and that certain approximations and compromises with respect to the relations given above may be made. The following specifications for the tunable systems 14, 17 and 21 of Fig. 1, and the tuning units used therein and constructed as shown in Figs. 75

2, 3 and 4, are included by way of example only.		
Radio-frequency tuning range-----		
Intermediate frequency-----		
5	Condensers 38, 39 and 40	.002 microfarad each
Total shunt capacitance of each of circuits 15 and 17-----		
Total shunt capacitance of circuit 21-----		
10	Windings 41-----	each 7 double turns No. 26DSC in a bifilar single layer close wound on a cylindrical form $\frac{1}{8}$ inch diameter over a comminuted iron core. Maximum inductance—1.4 microhenries
15		
20	Inductance element 22--	16 turns No. 26DSC single layer close wound on $\frac{1}{2}$ inch diameter Bakelite rod. Inductance 3.8 microhenries
25	Inductance element 23--	23 $\frac{1}{4}$ turns No. 26DSC single layer close wound on the same Bakelite rod as inductance element 22 with the adjacent low potential ends of the two elements spaced one turn apart
30		
35		
	r-----	inches-- 1.65
	b-----	do----- 0.1875
	a-----	do----- 0.2345
40	x-----	degrees-- 5.7

In the operation of the unit, the primary magnetic field produced by current in the winding 41 causes eddy currents to flow in the shield 44, which currents produce a secondary magnetic field. This secondary magnetic field is opposite in phase to the primary field and effectively reduces the latter thus decreasing the inductance of the winding. Rotation of the shaft 46 causes relative movement between the winding 41 and the shield 44 to change the coupling therebetween and the relative strength of the two magnetic fields noted, thereby to produce variations in the inductance of the winding 41.

The function of the comminuted iron core 50 is to obtain an inductance unit having a maximum value of inductance with a minimum number of turns without at the same time materially increasing the minimum inductance, when the shield is in the position of maximum coupling. For example, in the case of the inductance unit the specifications of which are given above, the ratio maximum to minimum inductance without the iron core was approximately 3 to 1 and with the iron core, approximately 5 to 1. As mentioned above, by axially adjusting the core 50, the maximum inductance of the unit may be adjusted to facilitate alignment of the tunable system of which it is a part with other tunable systems without appreciably affecting the minimum inductance of the unit.

Although the invention has been described with reference to the particular structural arrangement of the tuning unit illustrated in Figs. 2 and 3, it will be understood that various structural

modifications may be devised for securing the desired characteristics set forth above. Thus, in Fig. 5 there is illustrated a modification of certain of the elements embodied in the unit of Fig. 3, the difference residing principally in the shape of the winding 41. The winding of Fig. 5 is shown as a single layer coil conically shaped to conform to the inner conical surface of the shield 44. In this construction the core 50 is also conical in form and the coil form 42 is divided, being provided with a cap 42a threaded onto the shank portion and retaining the core 50 in position. With this relative configuration of the winding and the inner surface of the shield, extremely close coupling between the two may be obtained, such that an extremely rapid variation in the inductance of the winding is obtained during relative movement between the two elements, particularly during the portion of the movement when maximum coupling between the two elements is approached. The structure of Fig. 5 is particularly suitable for applications in which the winding and shield are moved linearly and axially with respect to each other, although it can be used also in cases where they are relatively angularly movable as in the arrangement of Fig. 3, by providing a slight clearance between the conical winding and its associated shield or by modifying the generating angle α of the conical shield in accordance with the dimensions of the structure. In the operation of this last described modification of the invention, due to the extremely close coupling between the shield and the winding 41, the minimum inductance is substantially reduced over that of the arrangement of Fig. 3 without materially altering its maximum inductance, so that the ratio of maximum to minimum inductance, and thus the tuning range of the system including the inductance unit, is materially increased.

In Fig. 6 there is illustrated a second modification of the structure of Fig. 3 in which the winding element 41 has a conical outer surface cooperating with a shield 44 having a cylindrical inner surface. In this construction, also, the coil form 42 is provided with a stop member 57 adapted to be axially adjusted by a screw 53 and cooperating with the shield 44 to limit the movement of the shield towards the position of maximum coupling. Such an arrangement provides an adjustment of the minimum inductance of the tuning unit without materially affecting its maximum inductance, thereby serving to align the circuit with which the unit is associated with other tunable circuits at the high frequency end of its tuning range without materially affecting such alignment at the low frequency end of the tuning range.

While there have been described what are at present considered to be the preferred embodiments of the invention, it will be understood that various changes and modifications may be made therein without departing from the invention and it is contemplated in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding from one limiting position in which said

winding element is substantially totally shielded to another limiting position in which said winding element is substantially unshielded, at least one of the cooperating surfaces of said elements being tapered, and the tapering of said one of said surfaces being so related to the configuration of the other cooperating surface that for a given location of said axis, a minimum clearance between said elements may be obtained, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement therebetween.

2. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding from one limiting position in which said winding element is substantially totally shielded to another limiting position in which said winding element is substantially unshielded, the cooperating surfaces of said elements being relatively tapered and the angle of relative taper of said surfaces being such that for a given location of said axis, a minimum clearance between said elements may be obtained, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement therebetween.

3. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding from one limiting position in which said winding element is substantially totally shielded to another limiting position in which said winding element is substantially unshielded, said shielding element having a tapered inner surface, concave toward the winding, the angle of taper of said surface being so related to the configuration of said winding element and the radius of said arcuate path that a minimum clearance between said elements may be obtained, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement therebetween.

4. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a cylindrical winding element, a conductive shielding element relatively movable in telescoping relation with respect to said cylindrical winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding, said shielding element having a conical inner surface concave toward the winding element, the generating angle of said conical surface being so related to the dimensions of said winding element and the radius of said arcuate path that a minimum clearance between said elements may be obtained, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement therebetween.

5. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other and

in an arcuate path about an axis external to said winding, the cooperating surfaces of said elements being relatively conically tapered and the difference in the generating angles of said surfaces being so related to the dimensions of said winding element and the radius of said arcuate path that a minimum clearance between said elements may be obtained, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement therebetween.

6. In a high-frequency signaling system an adjustable inductance tuning unit comprising a cylindrical winding element having a length of $2b$ and a diameter of $2a$, a conductive shielding element relatively movable with respect to said winding element and having a conical inner surface concave toward the winding element, and means for moving said elements relative to each other in an arcuate path having a radius r , the generating angle of said surface being of the order of magnitude of an angle whose tangent is

$$\frac{b}{r+a}$$

whereby a minimum clearance is obtained between said elements, when maximum coupling exists therebetween, without any appreciable frictional contact between said elements during relative movement thereof.

7. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding, and said elements having cooperating abutting surfaces for determining their relative position of minimum inductance.

8. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding, and said elements having relatively adjustable cooperating abutting surfaces for adjusting the minimum inductance of the unit without appreciably affecting its maximum inductance.

9. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a shielding element, and means for relatively moving said elements from relative positions of negligible coupling to relative positions of very close coupling relationship, said winding element being provided with an adjustably fixed magnetic core element effective upon adjustment substantially to increase the maximum inductance of the unit without appreciably affecting its minimum inductance.

10. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, an external shielding element, and means for relatively moving said elements from relative positions of negligible coupling to relative positions of very close coupling relationship, said winding element being provided with an internal adjustably fixed magnetic core element effective upon adjustment substantially to increase the maximum inductance of the unit without appreciably affecting its minimum inductance.

11. In a high-frequency signaling system, an

adjustable inductance tuning unit comprising a winding element, a shielding element, and means for relatively moving said elements from relative positions of negligible coupling to relative positions of very close coupling relationship, said winding element being provided with an adjustably fixed magnetic core element effective upon adjustment substantially to adjust the maximum inductance of the unit without appreciably affecting its minimum inductance.

12. In a high-frequency signaling system, an adjustable inductance tuning unit comprising a winding element, a conductive shielding element relatively movable in telescoping relation with respect to said winding element from relative positions of negligible coupling to relative positions of very close coupling, and means for moving said elements relative to each other in an arcuate path about an axis external to said winding, said winding element being provided with an adjustably fixed magnetic core element effective substantially to increase the maximum inductance of the unit without appreciably affecting its minimum inductance, the relative configurations of the cooperating surfaces of said elements being substantially complementary to each other so as to provide the minimum clearance between said elements, when maximum coupling exists therebetween, without any appreciably frictional

contact between said elements during relative movement therebetween.

13. In a high-frequency signaling system including a tunable circuit having an extremely low capacitance effectively in parallel, an adjustable inductance tuning unit comprising a winding element, one end of said winding element being adapted to operate at a higher alternating potential than the other end thereof, a conductive shielding element relatively movable in telescoping relation with respect to said winding element from one limiting position in which said winding element is substantially totally shielded to another limiting position in which said winding element is substantially unshielded, the cooperating surfaces of said elements being relatively tapered and substantially complementary to each other so as to provide substantially the minimum clearance permitted therebetween during relative movement, the end of said winding element of higher alternating potential being disposed to have the greater clearance with respect to said shielding element, thereby minimizing the effective capacitance between said elements and the effect of relative movement between said elements on the total effective capacitance of the circuit.

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