Feb. 6, 1945. G. B. McCLELLAN 2,368,857

HIGH-FREQUENCY INDUCTANCE UNIT

Filed June 24, 1943 2 Sheets-Sheet 1

FIG. 1.

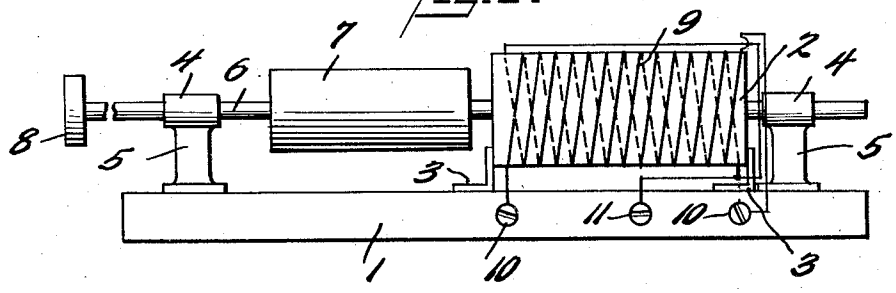


FIG. 2.

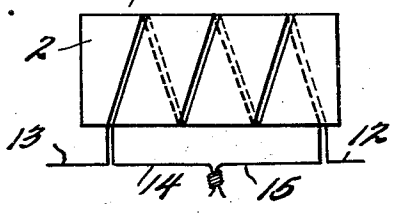


FIG. 3.

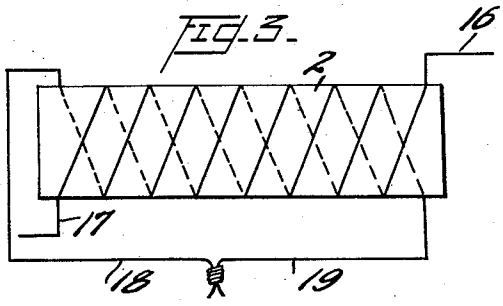


FIG. 4.

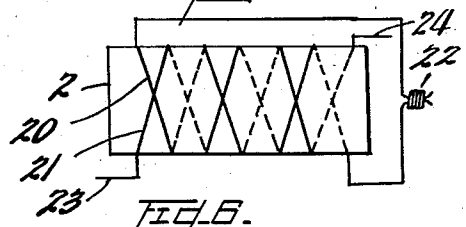


FIG. 5.

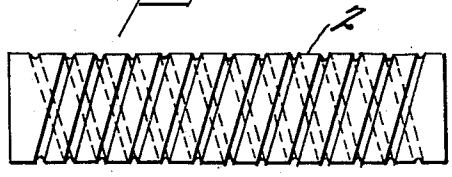


FIG. 6.

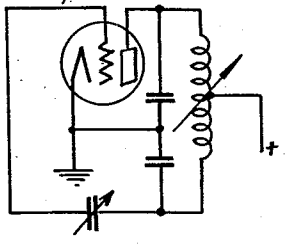
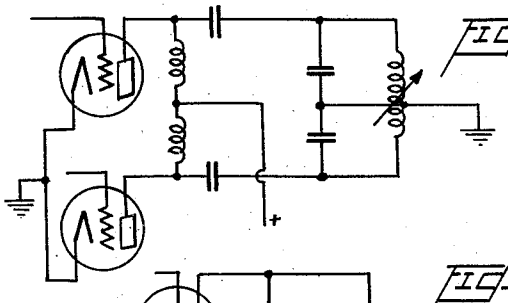


FIG. 7.



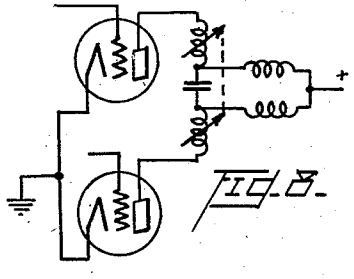
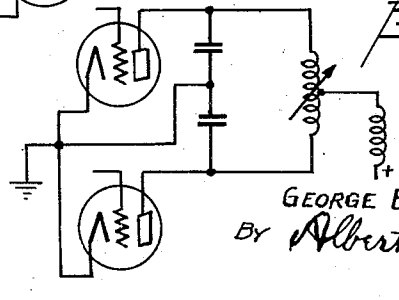


FIG. 8.

FIG. 9.



Inventor

GEORGE B. McCLELLAN

By Albert C. Bell

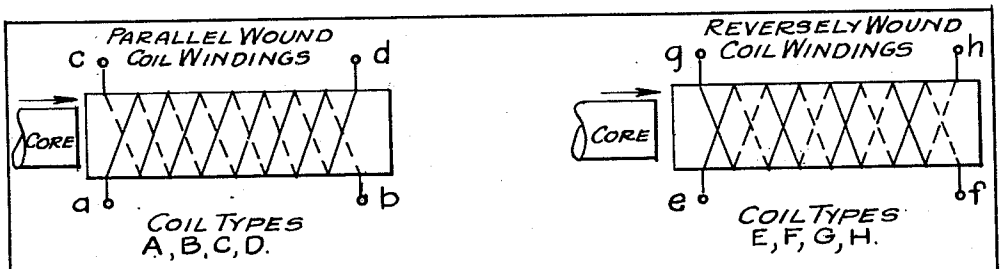
Attorney

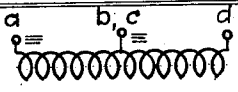
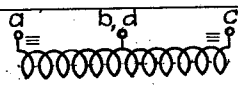
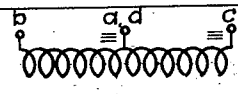
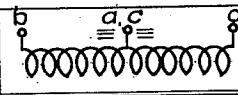
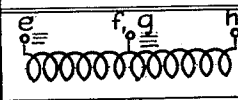
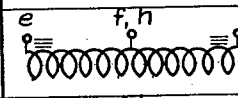
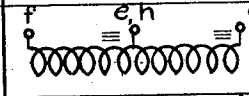
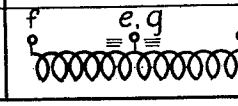
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HIGH-FREQUENCY INDUCTANCE UNIT

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FIG 10



COIL TYPE.	DIRECTION OF WINDINGS	END TERMINALS	CENTER TAP CONNECTIONS	AIDING OR BUCKING.	CORRESPONDING SOLENOID DISTRIBUTION OF INDUCTANCE, WHEN CORE IS INSERTED. INCREASED INDUCTANCE INDICATED THUS, ≡
A	PARALLEL	a, d	b AND c	AIDING	
B	PARALLEL	a, c	b AND d	BUCKING	
C	PARALLEL	b, c	a AND d	AIDING	
D	PARALLEL	b, d	a AND c	BUCKING	
E	REVERSE	e, h	f AND g	BUCKING	
F	REVERSE	e, g	f AND h	AIDING	
G	REVERSE	f, g	e AND h	BUCKING	
H	REVERSE	f, h	e AND g	AIDING	

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ATTORNEY.

Patented Feb. 6, 1945

2,368,857

UNITED STATES PATENT OFFICE

2,368,857

HIGH-FREQUENCY INDUCTANCE UNIT

George B. McClellan, Chicago, Ill., assignor to Johnson Laboratories, Inc., Chicago, Ill., a corporation of Illinois

Application June 24, 1943, Serial No. 492,086

5 Claims. (Cl. 250—40)

This invention is an inductance unit for use in regulating and/or controlling alternating current circuits, more particularly high frequency signal circuits such as used in connection with radio transmitters and receivers.

Considerable difficulty has been experienced in the past in simultaneously tuning matched or balanced branch circuits of a radio frequency network connected between the end terminals and the center tap connection of a straight or conventionally wound solenoid having a movable core member, due to the shifting of the electrical center of the solenoid relatively to the center tap connection as the core member is entered and moved within the coil from one end. This relative shifting of the electrical center of the solenoid under the conditions noted manifests itself in several ways, namely: by a relative change in the grid currents of the tubes included in the respective branch circuits; by unequal ratios of loaded to unloaded plate currents for the respective tubes in push-pull systems; and in uneven heating of the tube electrodes. Furthermore, the relative shifting of the electrical center of the solenoid may be verified by measuring the inductances of the respective coil sections on opposite sides of the center tap under the conditions noted, whereby it can be shown that the inductance values of the two coil sections differ appreciably. These conditions are seriously objectionable in that they prevent that uniformity of intensity of oscillation of the tubes which is essential to efficient operation and control. Numerous attempts have been made to avoid these difficulties, such as by employing separate core members movable into the coil from opposite ends, but so far as is known these prior attempts have all required more or less complicated electrical or mechanical devices for relatively moving the core members with respect to the coil sections to insure symmetrical tuning of the branch circuits simultaneously.

The object of the invention therefore, is to provide an inductance unit having plural coil sections so positioned that a single core member may be moved axially of the unit to simultaneously vary the inductance values of the coil sections.

Another object of the invention is to provide an inductance unit which may be symmetrically connected in respect to substantially identical branch circuits in networks where it is desirable to simultaneously tune two branch circuits to the same, or substantially the same resonant frequency while maintaining the mid-point or center tap connection between said unit and circuits substantially coincident with the electrical center of the inductance unit.

Another object of the invention is to provide an inductance unit in which are provided plural coil sections arranged to provide coincident magnetic fields so that a single core member may be moved by simple mechanical means, in said fields to simultaneously vary the inductances of the coil sections to thereby simultaneously vary the electrical characteristics of the branch circuits connected to said coil sections.

Another object of the invention is to provide an inductance unit in the form of a bifilar winding, the two strands or wires forming said bifilar winding having their ends connected so as to form a continuous winding having a center tap connection, the coil sections on opposite sides of said center tap being disposed to provide coincident magnetic fields.

Another object of the invention is to provide an inductance unit of the character described in which a powdered iron core member may be moved in the coincident magnetic fields provided by the coil sections of the unit, whereby the unit may be used in what is generally known as permeability tuning systems for radio frequency signal circuits.

A further and important object of the invention is to accomplish the previously recited objectives without materially changing the distributed capacity of the unit.

These and other objects of the invention will become apparent from reading the following specification in connection with the accompanying drawings wherein I have described and illustrated preferred embodiments of my invention. It will be understood, however, that I may make such changes in size and proportion of parts and in the relative arrangements thereof as are within the scope of the appended claims without departing from the spirit of my invention.

Referring to the accompany drawings

Fig. 1 shows in front elevation one form of the inductance unit.

Figs. 2, 3 and 4 are diagrammatic views illustrating the manner in which the coil sections of the inductance units may be mounted upon or wound on the coil forms.

Fig. 5 is a detail view of one form of the coil form or support.

Figs. 6, 7, 8 and 9 are circuit diagrams illustrating representative forms of networks including tunable branch circuits in which the present invention may be employed.

Fig. 10 is a chart showing effects produced by differently connecting the sections of a two section inductance unit in accordance with the invention.

Referring more particularly to the drawings in which like reference numerals are used to designate like parts throughout, the inductance unit forming the subject-matter of the present invention is shown in Fig. 1 as comprising a suitable base member 1 on which is mounted a coil form or support 2. The coil support 2 may be mounted upon the base in any convenient manner such as by bracket members 3—3. Preferably, but not necessarily, the coil form or support 2 is mounted upon the base 1 in a position such that the longitudinal axis of the member 2 lies substantially parallel to the plane of the base member 1.

It will be understood that while the coil support 2 is generally cylindrical in form and hollow, it may have any convenient form which will permit movement of the core within the coil, and may be made of any suitable insulation material such as Mycalex. A pair of bearing members 4—4 are supported by bracket members 5—5 from the base 1, said bearing members 4—4 being preferably axially aligned with the axis of the coil form 2. A core supporting rod 6 is slidably mounted in the bearing members 4—4, said rod 6 having fixedly mounted thereon a core member 7. The core member 7 is dimensioned to be received within the hollow center of the coil support 2, the rod 6 being of a length sufficient to move the core 7 from the position shown in Fig. 1, to a position in which it is fully inserted into the coil support 2. The rod 6 may be provided at one end with a suitable knob 8 to facilitate movement of the core member into and out of the confines of the coil form 2.

The inductance winding 9 is wound upon the coil support 2 in a manner to be hereinafter more particularly described, said winding being provided with end terminals 10 and a center or mid-tap connection 11.

It will be understood that the particular form of the coil support 2, the core member 7, and the particular means for shifting the core member into and out of the coil support 2, may be varied within wide limits without sacrificing any of the advantages accruing from the invention, and for this reason it will be appreciated that I do not limit myself to the particular form of these elements shown in Fig. 1, but reserve the right to employ other forms of said parts and various mechanical expedients for shifting the core member longitudinally into and out of the inductance winding.

As previously indicated, I propose to provide an inductance winding in which plural coil sections are disposed to provide coincident magnetic fields in which a core member may be moved. I have illustrated in Figs. 2, 3 and 4, some approved forms of the inductance winding. Thus in Fig. 2 I show the winding in the form of a bifilar winding or helix comprising wires 12 and 13 wound side by side and in the same direction around the coil support indicated at 2. One end 14 of the wire or strand 12 is connected to one end 15 of the wire or strand 13 to form a center tap for a continuous winding comprising plural coil sections formed respectively by the wires or strands 12 and 13. The opposite ends of the respective wires or strands 12 and 13 form the end connections for the inductance unit and in practice will be connected to the end terminals 10 of the unit as shown in Fig. 1, while the connected ends 14 and 15 are connected to the center or mid-tap connection 11 of said unit. A consideration of this form of the winding will show that the coil sections formed by the wires 12 and 13 respectively are positioned upon the coil form or support 2 in a manner to provide coincident magnetic fields in which a core member such as 7, may be moved to simultaneously vary the inductances of said coil sections in the same amount.

In Fig. 3 I have shown a slightly different modification of the arrangement of the coil sections on the coil support. In the arrangement shown in Fig. 3 the wires or strands 16 and 17 are started at points on the periphery of the coil form 2 angularly displaced 180 degrees. The two wires 16 and 17 however, are wound in the same direction about the support 2 and the end 18 of the wire 16 is connected to the end 19 of the wire 17 in a manner previously described to form a center tap connection, whereas the opposite end portions of the wires 16 and 17 are utilized for the end connections of the unit as previously described in connection with the form of winding shown in Fig. 2. It will be realized that by arranging the windings in this form, there is absolute symmetry between the two windings and the core 7 in all positions of overlap between the core and the coil sections.

In both forms of windings as shown in Figs. 2 and 3, the coil sections on opposite sides of the center tap are connected in series aiding relation. This is desirable in certain types of control, and is essential where permeability tuning is employed. It is to be noted, however, that the same advantages in respect to simultaneously varying the inductances of the two coil sections in equal amounts may be realized even though the two coil sections are connected in series bucking relation. This form of the inductance winding is shown in Fig. 4 where the two strands 20 and 21 are wound in opposite directions about the form 2 and wherein the opposite ends of the respective strands are connected as at 22 to form the center tap connection of the unit whereas the terminal portions 23 and 24 provide the end connections for the unit when made in this form.

It will be appreciated that by arranging the coils in the manner suggested in Figs. 2 and 3, namely, in series aiding relation, the inductance L of the unit is greater than that of the helix wound with the same length of wire, whereas the quantity

$$Q=\frac{(WL)}{R}$$

is approximately the same. In order that the degree of this increase in the value of L might be realized, I give below specific examples of these values as measured on a Leeds and Northrup Bridge, for different coils, the complete physical characteristics of which are set forth below, namely:

COIL COMPARISON DATA

Bifilar coil as per Fig. 3

Winding—11 T.P.I.

Double pitch thread
19 turns total
Winding length=1⅝"
Wire=#26 tinned copper wire

Core outside of coil.

L_t=1.4μh	L_1=.5μh L_2=.5μh	M=.2μh

Core ½ inserted.

L_t=2.4μh	L_1=.8μh L_2=.8μh	M=.4μh

Standard solenoid

Winding—22 T. P. I.

Single pitch thread
19 turns total
Winding length=1⅛"
Wire=#26 tinned copper wire

Core outside of coil.

L_t=1.1μh	L_1=.5μh L_2=.5μh	M=.05μh

Core inserted to center of coil.

L_t=2.1μh	L_1=1.4μh L_2= .6μh	M=.05μh

A comparison of inductance values of coils formed in accordance with Figs. 2 and 3, shows that the two coil sections may be wound with any degree of angular displacement between the starting points of the respective strands, the maximum displacement being that shown in Fig. 3, wherein the displacement is substantially 180 degrees, and the minimum being that shown in Fig. 2, where the strands start from substantially the same point on the surface of the form 2.

In order to show that the inductance values of the two coil sections of the unit formed as shown in Fig. 2 are substantially identical, even though the two strands start at substantially the same point on the periphery of the coil form 2, I give below two sets of data pertaining to two different coils made in accordance with the winding of Fig. 2. In both of these instances the two strands are started at substantially the same point on the periphery of the coil form, the strands lying side by side and being wound in the same direction. The strands of coil No. 1 were slightly spaced axially of the coil, whereas the strands in coil No. 2 were disposed in contiguous relation.

Coil No. 1

Winding length=⅞"
Number of turns=19
Wire is #26 tinned copper
Form: Threaded @ 11 T. P. I. double pitch

Core outside of coil.

L_t=2.9μh L_R=1.6μh L_E=1.3μh	L_1=L_2=2.1μh L_R=1.6μh L_E= .5μh	M=.18μh

Core ½ inserted.

L_t=3.9μh L_R=1.6μh L_E=2.3μh	L_1=L_2=2.3μh L_R=1.6μh L_E= .7μh	M=.35μh

Coil No. 2

Winding length=⅞"
Number of turns=19
Wire is #26 plain enamel
Form: .255" I. D. x .270" O. D.
Wound 22 turns per inch

Core outside of coil.

L_t=2.8μh L_R=1.6μh L_E=1.2μh	L_1=L_2=2.1μh L_R=1.6μh L_E= .5μh	M=.1μh

Core ½ inserted.

L_t=3.7μh L_R=1.6μh L_E=2.1μh	L_1=L_2=2.4μh L_R=1.6μh L_E= .8μh	M=.25μh

Definition of terms used:

L_t=total inductance.
L_R=Bridge residual inductance.
L_E=Measured inductance minus the residual.
L_1=inductance of one section of the coil from an open end to center tap.
L_2=inductance of other coil section from opposite open end to center tap.

Some discrepancies appear in the measurements as shown, due to the impossibility of operating the measuring apparatus with perfect accuracy.

The foregoing figures show clearly the relatively fixed point electrically, of the center tap in respect to the two coil sections disposed on opposite sides thereof. This is evident from the same inductance values for each coil section when the core member is inserted within the coil from one end into the coincident magnetic fields. The data above set forth shows that the coil sections have identical inductance values for the same position of the core whether the core member is within the coil form or completely outside thereof. The data also shows clearly the advantage in respect to the increased values of mutual inductance to be realized by arranging the coils in series aiding relation with the respective magnetic fields thereof coincident. It is apparent that due to the series aiding relation of the coil sections the mutual inductance adds to the total inductance and therefore results in a higher inductance for a given number of turns. Thus the coils may have fewer turns for a given inductance, and a smaller and more compact unit results.

The coil sections may be mounted upon the coil form in any convenient manner. Inasmuch as it has been found that the most effective form of the inductance unit for use in permeability tuning is that form in which the respective strands lie parallel to one another throughout the length of the winding, I find it convenient to provide the coil form with a double spiral groove as shown in Fig. 5. The spiral groove may have any convenient or desirable pitch and it serves to maintain the respective strands in the desired parallel relationship throughout the winding without any other means or device for anchoring the convolutions of the winding. While I have referred to this form of coil support as a desirable form, it is of course to be understood that it is not necessary to provide spiral grooves in the coil support, and that the full advantages accruing from the invention may be realized by merely winding the strands on a conventional cylindrical form and anchoring them in position by any known means such as by liquid insulating coating applied to the windings while in place on the support.

It will be understood that the invention described is advantageous in any case where it is

desired to simultaneously change the inductances of branch circuits, by the movement of a single core member in the magnetic field of a tapped winding, and that said core member may either be ferromagnetic, for example a powdered iron core, or non-magnetic and electrically conductive, for example a core of copper or brass, depending upon the nature of inductance change desired to be produced by movement of the core member relatively to the windings of the inductance device.

In Figs. 6 to 9 inclusive, I have set forth representative forms of networks including balanced branch circuits wherein the inductance unit of the present invention may be used to great advantage. In each of the circuit diagrams I have shown the inductance units as a straight wound helix or inductance having a center tap and end connections, but it will be understood that in each instance the inductance unit is in substance one of the forms previously described as shown in Figs. 1 to 4 inclusive.

In Fig. 6 I have shown a typical plate neutralized single ended amplifier wherein the inductance unit of the present invention has the center tap connected to the source of B-battery potential, and the opposite end terminals of the unit are connected respectively to the plate and grid electrodes of a vacuum tube.

In Fig. 7 I have shown a typical example of a shunt fed push-pull amplifier or oscillator wherein the inductance unit of the invention has its mid-point grounded and the opposite end terminals thereof connected to the respective plate electrodes of the vacuum tubes.

In Fig. 8 I have shown a series tuned amplifier or oscillator in which the center tap of the inductance unit of the present invention is shown connected to the source of B-battery potential through a pair of radio frequency coils interconnected with a condenser. The opposite ends of the inductance unit are connected to the respective plate electrodes of a pair of vacuum tubes.

In Fig. 9 there is shown a conventional form of series fed amplifier or oscillator in which the inductance unit of the present invention is shown with its mid-point connected to the source of B-battery potential and its opposite end terminals connected to the plate electrodes of a pair of vacuum tubes.

It should be noted that while the circuit diagrams of Figs. 7 to 9 inclusive, show the inductance unit of the present invention connected to the plate electrodes of the respective tubes, the inductance unit may be connected to the grid circuits of the tubes if desired.

In Fig. 10 I present a chart showing possible connections and results with inductance devices as described above in connection with Figs. 2, 3 and 4. Two conditions of winding are illustrated, first the condition of winding in which the coil sections are parallel wound, and second, the condition of winding in which the coil sections are reversely wound. In the first vertical column of the chart, the coil type is designated, each different connection of the windings of the inductance device being considered to be a different type for the considerations of the chart. The second vertical column indicates whether the coil sections or windings of the inductance device are parallel wound or reversely wound. The third vertical column indicates the end terminals of the inductance device by reference to the appropriate diagrammatic drawings of the device at the top of the chart, and the fourth vertical column indicates the manner of forming the center tap connection by reference to said diagrammatic drawings. The fifth vertical column indicates whether the relation of the coil sections or windings is aiding or bucking for each of the coil types, and the sixth vertical column illustrates schematically the corresponding effect of inductance change for a single layer solenoid, resulting from the insertion of a core into the windings of the inductance device of the corresponding type coil, together with the locations in the solenoid at which said inductance changes take place, if it were possible to produce such inductance changes in connection with single layer solenoids.

A consideration of the results secured by differently connecting the coil sections or windings of the inductance device, to produce the different coil types illustrated in the chart of Fig. 10, shows that the portions of the coil sections or windings directly affected by the insertion of a core, are determined by the manner of connecting the terminals of the coil sections; and it also appears that the aiding or bucking relationship of the coil sections or windings to each other is determined by whether said sections or windings are parallel wound or reversely wound, in conjunction with the manner in which the connections of the coil sections or windings are made, it being possible to obtain the same inductance distribution with either an aiding or a bucking relationship of the coil sections or windings, in any case.

From the foregoing examples of the manner in which the inductance unit of the present invention may be employed, it is apparent that the unit lends itself admirably to instances in which permeability tuning is desirable or necessary for simultaneously tuning balanced branch circuits of a network. It is of course to be understood that condensers connected in shunt relation across the units as shown, may be employed to assist in control of the branch circuits if desired without in any way interfering with the effectiveness of operaton of the respective inductance units.

The center tapped bifilar inductance unit of the present invention has been designed especially for use in permeability tuning systems employed in radio transmitters and receivers, and has been used effectively within a wide range of frequencies, including frequencies as low as 2.9 megacycles up to frequencies as high as 200 megacycles.

It will be understood from the foregoing description that the present invention differs from known inductance units including conventional center tapped solenoids and/or bifilar windings, in that the present inductance unit is characterized by coil sections disposed to provide coincident aiding magnetic fields within which a single core member may be moved to simultaneously vary the inductances of the coil sections. While I have referred herein to a core member of powdered iron, it is of course to be understood that the invention is not limited to a core of this form, and that any known or convenient means may be employed for shifting the core with respect to the coil form.

While the invention is described in connection with the particular embodiments above set forth, it will be understood that the invention includes equivalent structures involving the principles of

operation described, which are included within the scope of the appended claims.

Having thus described my invention what I claim is:

1. In a network including a pair of tunable branch circuits, an inductance unit comprising a winding defining two coil sections having substantially identical electrical characteristics and disposed to provide substantially coincident fields, means connecting one of said coil sections in each branch circuit with the coil sections in series relation, an inductance-changing core member common to both coil sections, and means for adjusting said member with respect to said coil sections to simultaneously tune said branch circuits to the same resonant frequency.

2. In a network including a pair of tunable branch circuits and a pair of electron tubes connected in push-pull relation by said branch circuits, an inductance unit comprising a winding defining two coil sections having substantially identical electrical characteristics and disposed to provide substantially coincident fields, means for connecting one of said coil sections in each branch circuit with the coil sections in series aiding relation, an inductance-changing core member movable in said coincident fields, and means for adjusting said core member within said fields to simultaneously tune said branch circuits to the same resonant frequency.

3. In a network including a pair of tunable branch circuits and a pair of electron tubes connected in push-pull relation by said branch circuits, an inductance unit comprising a bifilar winding defining two coil sections constituting the inductive portion of said unit, said sections having substantially identical electrical characterstics, means connecting one of said coil sections in each branch circuit with the coil sections in series aiding relation, a capacity unit in shunt relation to said coil sections, an inductance-changng core member common to both coil sections, and means for adjusting said core member axially with respect to said coil sections to simultaneously tune said branch circuits to the same resonant frequency.

4. In a network including a pair of tunable branch circuits and a pair of electron tubes connected in parallel relation by said branch circuits, an inductance unit comprising a winding defining two coil sections having substantially identical electrical characteristics and disposed to provide substantially coincident fields, means connecting one of said coil sections in each branch circuit with the coil sections in series aiding relation, an inductance-changing core member common to both coil sections, and means for adjusting said core member axially of said coils to simultaneously tune said branch circuits to the same resonant frequency.

5. In a network including a pair of tunable branch circuits and a pair of electron tubes connected in push-pull relation by said branch circuits, an inductance unit comprising a winding constituted by helical coil sections connected respectively with said branch circuits and disposed to provide substantially coincident fields, said coil sections being connected to form a tap connection of said winding, the turns of one coil section being adjacent throughout to the turns of the other of said coil sections, and an inductance-changing core member common to said coil sections and adjustable relatively thereto to simultaneously tune said branch circuits to the same resonant frequency.

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