

Jan. 25, 1938.

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2,106,226

COUPLING MEANS FOR PERMEABILITY TUNED CIRCUITS

Filed June 26, 1935

3 Sheets-Sheet 1

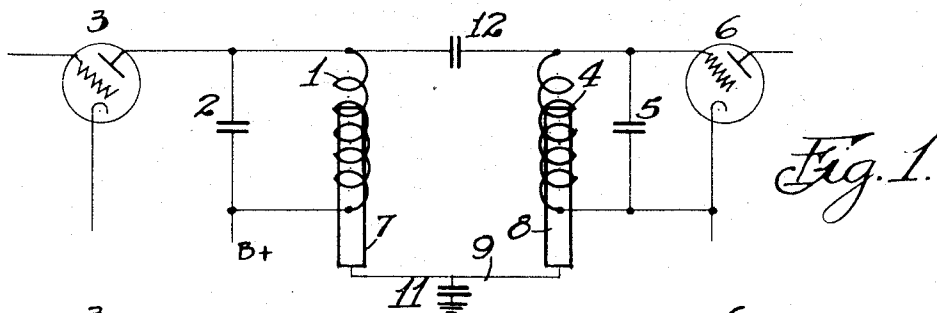


Fig. 1.

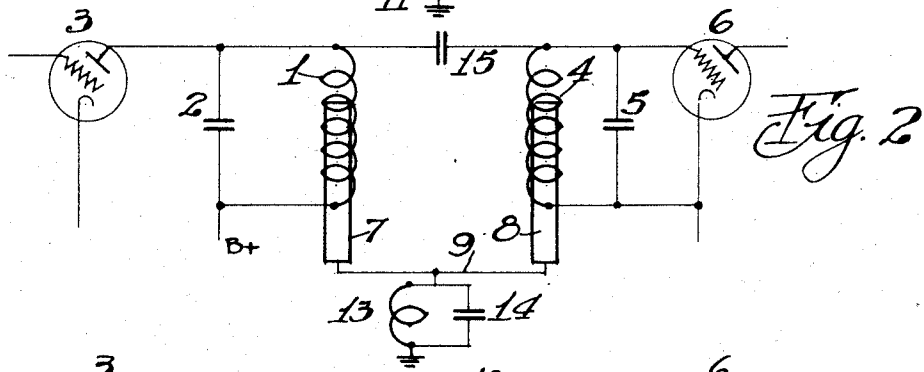


Fig. 2.

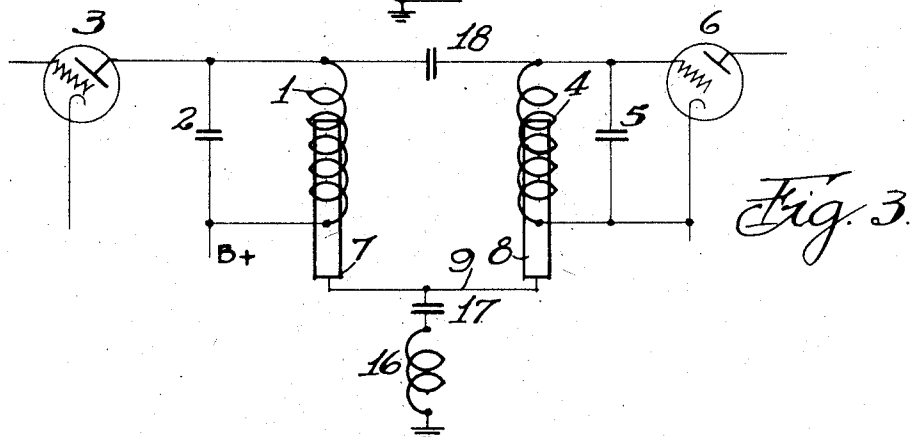


Fig. 3.

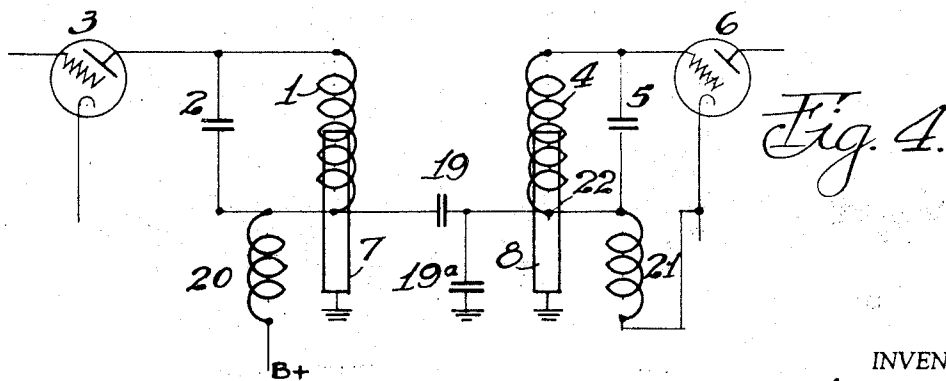


Fig. 4.

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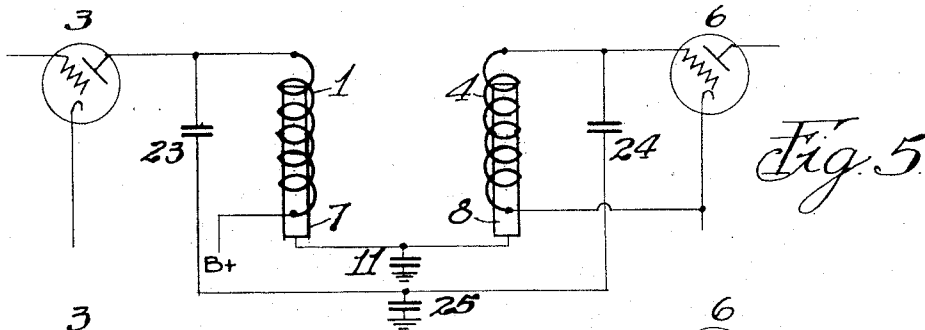
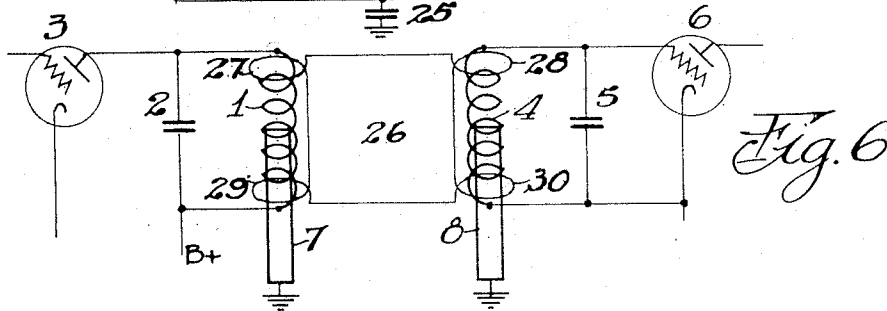
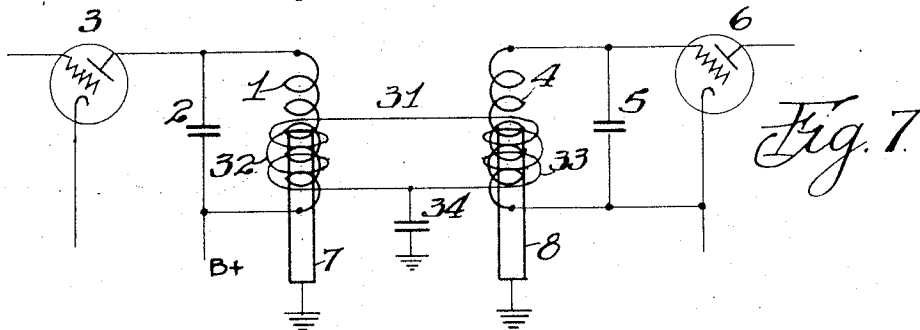
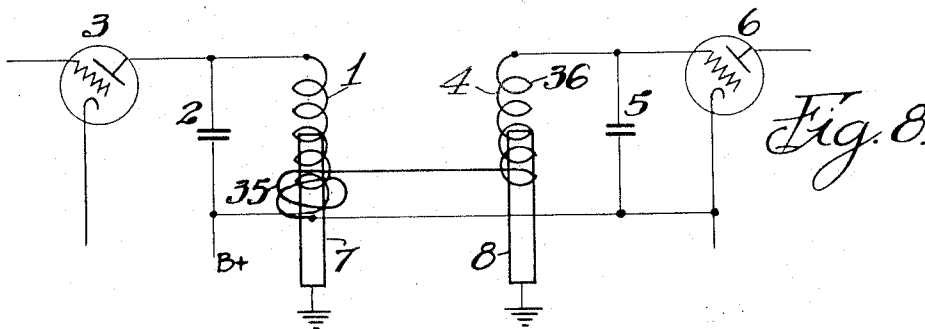
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COUPLING MEANS FOR PERMEABILITY TUNED CIRCUITS

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3 Sheets-Sheet 2



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COUPLING MEANS FOR PERMEABILITY TUNED CIRCUITS

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3 Sheets-Sheet 3

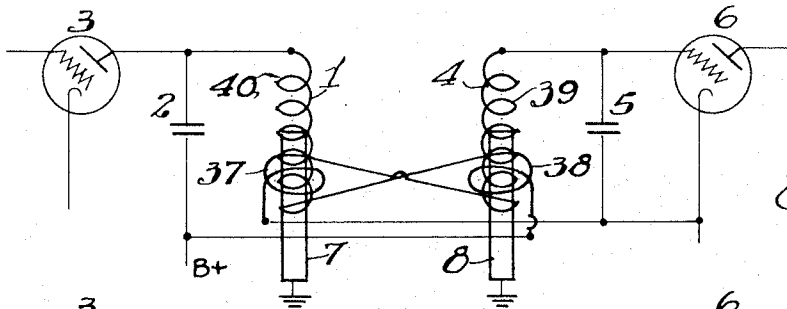


Fig. 9.

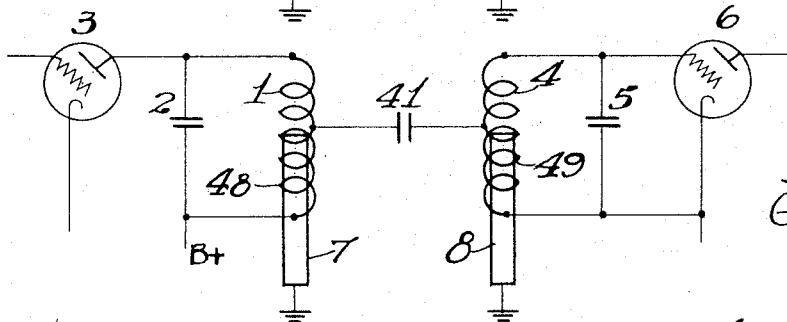


Fig. 10.

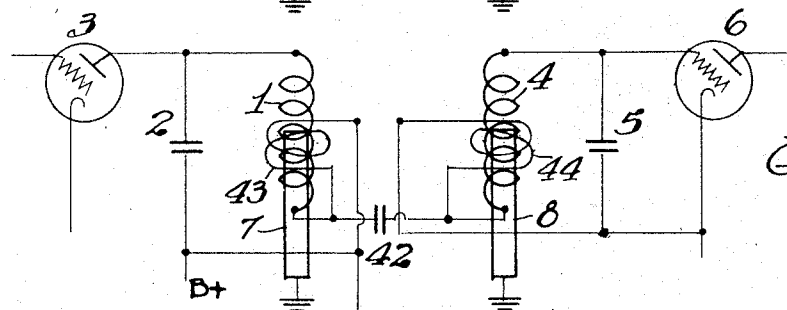


Fig. 11.

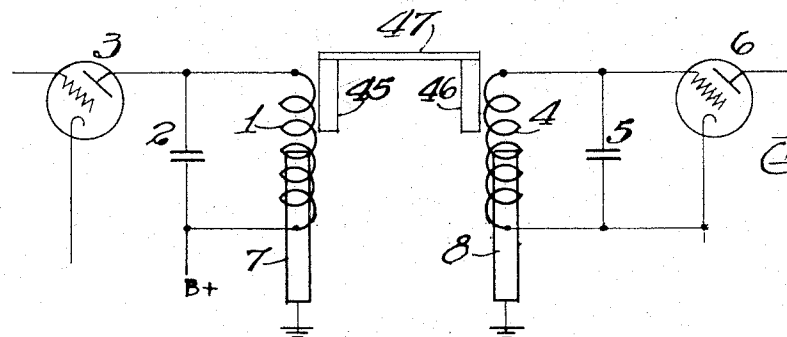


Fig. 12.

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UNITED STATES PATENT OFFICE

2,106,226

COUPLING MEANS FOR PERMEABILITY-TUNED CIRCUITS

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Application June 26, 1935, Serial No. 28,436

11 Claims. (Cl. 178-44)

The invention relates to electrical networks of the type employed in radio receiving apparatus, and more particularly to the systems of tuned high-frequency circuits which are ordinarily used to produce the selective amplification of desired frequencies in cascaded thermionic amplifiers. The invention is especially addressed to the problem of providing a suitable arrangement for coupling two tuned high-frequency circuits of the type in which the tuning is accomplished by relative movement between the inductive winding in each of the circuits and a ferro-magnetic core.

It is an object of the invention to provide coupling arrangements which, in cooperation with the inherent characteristics of the resonant circuits employed, will produce uniform amplification and uniform selectivity throughout the tuning range of the apparatus. Additionally, it is an object of the present invention to provide coupling means having the characteristics just described, in which the moving ferro-magnetic cores are utilized to secure these characteristics.

It is a further object of the present invention to provide coupling means of such nature that the voltage generated in the second circuit will have a substantially constant relation to the voltage developed in the first circuit at all frequencies throughout the tuning range.

It is well known that a resonant circuit tuned by capacitance variation is inherently incapable of uniform performance over any wide range of frequencies. It has been shown by Polydoroff in U. S. Patent 1,940,228 that the criterion for uniform performance is that the ratio of inductance to resistance shall remain constant. In systems tuned by capacitance variation the inductance remains constant but the resistance increases markedly as the frequency increases so that the ratio of inductance to resistance becomes increasingly unfavorable at the higher frequencies.

In systems tuned by inductance variation, and particularly in systems tuned by moving ferro-magnetic cores, it is possible to so design the core with relation to the winding with which it is employed that the ratio of inductance to resistance will be maintained substantially constant. This is because, as the core is inserted into the winding to increase the inductance, it also automatically increases the resistance, thus tending to maintain the inductance to resistance ratio at the same value.

My present invention is based upon the use of resonant circuits tuned by ferro-magnetic cores, and in which the cores and windings have been

so designed as to secure a constant ratio of inductance to resistance in the tuned circuit per se. It is apparent that when two such circuits are coupled together the coupling means must have such a characteristic as to automatically increase the coupling between the circuits as the resistance (and inductance) in each of the circuits increases.

In properly designed circuits of the type described, which are known as "permeability tuned" circuits, both the inductance and the resistance are inversely proportional to the square of the frequency to which the circuit is tuned. Thus, in properly designed coupling arrangements in accordance with the present invention and of the types which I shall now describe, the coupling coefficient is inversely proportional to the first power of the frequency.

My invention will be better understood from the following description taken in connection with the accompanying drawings, in which the various figures show a number of typical arrangements embodying the principles of the invention, and in which like reference numerals refer to like parts:

Fig. 1 is an arrangement in which the magnetic cores are directly connected electrically and grounded through a capacitor;

Fig. 2 is an arrangement in which the two magnetic cores are directly connected electrically and grounded through a parallel resonant circuit;

Fig. 3 is an arrangement in which the two magnetic cores are directly connected electrically and are grounded through a series resonant circuit;

Fig. 4 is an arrangement of variable capacitive coupling later to be described;

Fig. 5 is an arrangement similar to Fig. 1, except that series coupling capacitors are employed, the junction of these two capacitors being grounded through a third capacitor.

Fig. 6 is an arrangement in which the two magnetic cores are each grounded directly and a link circuit is employed having coupling turns at both the high potential and low potential ends of the inductive windings in the tuned circuits;

Fig. 7 is an arrangement in which a simple link circuit is grounded through a capacitor;

Fig. 8 is an arrangement in which the link circuit consists of a small number of coupling turns forming a part of the second resonant circuit;

Fig. 9 is an arrangement in which a small

number of coupling turns forms a part of the inductance in each of the resonant circuits;

Fig. 10 is an arrangement in which capacitive coupling between the resonant circuits is employed;

Fig. 11 is an arrangement in which the link circuit includes a capacitor; and

Fig. 12 is an arrangement in which the coupling is obtained by small stationary core members magnetically connected.

As will be apparent from what is to follow, in certain of the embodiments of my invention, advantage is taken of the fact that there is a small but nevertheless useful capacitance between each magnetic core and the winding into which it is inserted. Additionally, advantage is taken of the fact that this capacitance between the core and the winding varies as the core is inserted into the winding.

It will be understood that while these magnetic cores consist of insulated magnetic (and conductive) particles, and while the core body has a relatively high electrical resistivity, nevertheless the core is capable of acting as one electrode of a capacitor. This property of the magnetic cores has already been pointed out by Polydoroff in U. S. Patent 1,940,228, and in technical papers by Polydoroff (see Proceedings of the Institute of Radio Engineers, May 1933, pages 690-709) and others.

Each of the circuit arrangements now to be described in connection with the drawings is capable of producing a variation of coupling more or less closely following the relations given.

Referring now to Fig. 1, inductance 1 and condenser 2 form a resonant circuit connected across the terminals of thermionic amplifier 3. Inductance 4 and condenser 5 form a resonant circuit connected across the terminals of thermionic amplifier 6. Magnetic core 7 moves into inductance 1 to increase the effective value of the inductance and to thus tune the resonant circuit 1, 2 over a desired range of frequencies. Magnetic core 8 moves into inductance 4 to increase the effective value of the inductance and thus tune resonant circuit 4, 5 over a range of frequencies.

The magnetic cores 7, 8, the inductances 1, 4 and the condensers 2, 5 are so designed and proportioned that the resonant circuits 1, 2 and 4, 5 will be tuned over the same range of frequencies by simultaneous motion of the magnetic cores 7, 8, and for any position of the cores 7, 8 will be tuned to the same frequency. Additionally, the magnetic cores 7, 8 are so proportioned as regards shape and magnetic content, with respect to the inductances 1, 4, respectively, that both the inductance and the resistance in the two resonant circuits are increased proportionately by the insertion of the cores so that the ratio of inductance to resistance in each of the resonant circuits 1, 2 and 4, 5 per se is maintained constant.

The magnetic cores 7, 8 are electrically connected by a conductor 9. It will be understood that in the arrangement shown in Fig. 1 there is no direct inductive coupling between the inductance 1 and the inductance 4, and that there is no magnetic connection between the magnetic core 7 and the magnetic core 8. Thus the only coupling between the resonant circuit 1, 2 and the resonant circuit 4, 5 is of a capacitive nature.

The condenser 12 is connected between the high potential end of inductance 1 and the high potential end of inductance 4. Additionally, there is an inherent capacitance between the magnetic

core 7 and the inductance 1, and a similar inherent capacitance between the magnetic core 8 and the inductance 4. These two inherent capacitances are effectively in series by virtue of the electrical connection 9 from the magnetic core 7 to the magnetic core 8. By appropriately choosing the condenser 12 in relation to the inherent capacitances between the cores and the inductances, the coupling coefficient between the resonant circuit 1, 2 and the resonant circuit 4, 5 may be made approximately inversely proportional to the frequency to which the circuits 1, 2 and 4, 5 are tuned by the magnetic cores 7, 8 respectively.

The magnetic cores 7, 8 are grounded through a capacitor 11. This reduces the effective variable capacitive coupling between the circuits 1, 2 and 4, 5, and by proper choice of the condenser 12 will produce a more nearly linear inverse relation between frequencies to which the circuits 1, 2 and 4, 5 are tuned by the cores 7, 8, and the effective mutual reactance.

Fig. 2 is a modification of Fig. 1, in which the cores 7, 8 are grounded through a parallel resonant circuit consisting of inductance 13 and condenser 14. This circuit 13, 14 may be designed to resonate at a desired frequency to increase the effective coupling coefficient between the resonant circuit 1, 2 and the resonant circuit 4, 5 for any portion of the frequency range, the condenser 15 being appropriately chosen to secure the desired relationship.

Fig. 3 is a modification of Fig. 1, similar to Fig. 2 except that the cores 7, 8 are grounded through a series resonant circuit consisting of inductance 16 and condenser 17. This combination may be arranged to decrease the effective coupling coefficient between the circuit 1, 2, and the circuit 4, 5 for any desired portion of the frequency range, the condenser 18 being appropriately chosen to secure the desired result.

In the arrangement shown in Fig. 4 the circuits 1, 2 and 4, 5 are coupled by means of a common reactance comprising condenser 19 and choke coils 20 and 21. Condenser 19a is a grounding condenser which controls the established voltage common to both circuits. The voltage drop across the common reactance 19, 20, 21 causes a current to flow from the point 22 through coil 4, and through the inherent capacitance between the coil 4 and the core 8 to ground. This current produces the initial voltage in circuit 4, 5.

The arrangement shown in Fig. 5 is similar to the arrangement shown in Fig. 1, except that the coupling capacitor 12 is eliminated and the condensers 2, 5 are replaced by condensers 23, 24, which are not connected directly to the low potential ends of the coils 1, 4 respectively, but are connected together and grounded through a condenser 25. The condenser 25 acts as a coupling capacitance between the circuit 1, 23 and the circuit 4, 24. In this figure, the varying capacitive coupling between core 7 and the coil 1, and the varying capacitive coupling between the core 8 and the coil 4, are effective to produce the desired variation in the coupling coefficient.

Fig. 6 is an arrangement in which the link circuit 26 consists of windings 27, 28 positioned at the high potential ends of inductances 1 and 4, respectively, and windings 29, 30 positioned at the low potential ends of inductances 1 and 4, respectively. The windings 27, 28 and 29, 30 are connected in series. It will be apparent that in this arrangement the coupling between the

winding 29 and the coil 1 and the coupling between the winding 30 and the coil 4, are increased as soon as the cores 7, 8 start to enter the windings 1, 4. The coupling between the winding 27 and the coil 1 and the coupling between the winding 28 and the coil 4, remain relatively low, however, until the cores 7, 8 are almost all the way into the coils 1, 4. Each of the windings 27, 28 and 29, 30 consist of a relatively small number of turns wound directly over the coils 1 and 4.

Fig. 7 is similar to Fig. 6 except that the link circuit 31, consisting of the windings 32, 33, is grounded through a condenser 34, which tends to place a load on the link circuit, which increases with frequency, and thus reduces the effect of the inductive coupling and the slight capacitances between the windings 32 and the coil 1, and between the windings 33 and coil 4 at the high-frequency end of the band.

The arrangement shown in Fig. 8 is similar to the arrangement of Fig. 6, except that the link circuit 26 of Fig. 6 is replaced by coupling turns 35 wound over the inductance 1, but connected in series with the inductance 36. Coupling turns 35 and inductance 26 in series constitute the inductance of the second tuned circuit. The coupling between the coupling turns 35 and the coil 1, which is relatively low before the core 7 is inserted, is increased by the presence of the core 7.

The arrangement shown in Fig. 9 is similar to the arrangement in Fig. 8, except that coupling turns 37 and 38 respectively are in series with coils 39 and 40 and respectively wound over said coils 40 and 39. It will be understood that the coupling between turns 37 and coil 40, and also the coupling between turns 38 and coil 39, are increased when the cores 7, 8 are advanced into the coils 40, 39.

In the arrangement shown in Fig. 10 the cores 7, 8 are grounded and the capacitor 41 is connected between intermediate points on inductances 1 and 4, these points being chosen with relation to the size of capacitor 41.

The arrangement shown in Fig. 11 has a coupling capacitor 42. The windings 43, 44 are portions of the inductances 1, 4 respectively, and are wound over the turns thereof, the position of 43 on 1 and the position of 44 on 4 determining the inductance of the windings 43, 44 for any position of the cores 7, 8. The condenser 42 couples the circuits 1, 43, 2 and 4, 44, 5 in proportion to the coupling coefficient determined by the mutual inductance between 43 and 1, and between 44 and 4.

In the arrangement of Fig. 12 the coupling is produced by a magnetic link consisting of small stationary cores 45, 46, secured near the high potential ends of inductances 1, 4 and joined by a magnetic yoke 47. This magnetic yoke provides a small inductive coupling between the circuits 1, 2 and 4, 5, which is increased as the cores 7, 8 are advanced into the coils 1, 4 respectively.

As illustrative of the constants to be employed in any of the circuit arrangements shown in Figs. 1 to 12 inclusive, the following data are given for the circuit of Fig. 5. In a particular embodiment of the arrangement of Fig. 5, the coils 1, 4 each have an inductance of 113 microhenries and consist of two-layer bank wound coils $2\frac{1}{4}$ " long by $\frac{1}{2}$ " internal diameter. The capacitors 23 and 24 each has a capacitance of 90 micromicrofarads. The capacitance of capacitor 11 is .0115 microfarad, and that of capacitor 25 is 0.015 microfarad.

It will be understood that the constants just given are illustrative of a practical embodiment and are not to be taken as in any way limiting the scope of my invention.

The arrangements of Figs. 4, 6, 7, 8, 9, 10, 11 and 12, possess the advantage that the cores may be directly grounded, thus eliminating the necessity for magnetically and electrically insulating them from the mechanism employed to produce the relative motion between the cores and the coils.

The position of the link circuit winding shown in Figs. 6, 7, 8 and 9 is somewhat critical. Referring to Fig. 6, for example, the coils 29, 30 are preferably mounted approximately at the low potential ends of the coils 1, 4 and are preferably wound on insulating tubing having $\frac{1}{2}$ " wall thickness and an internal diameter equal to or slightly greater than the external diameter of the coils 1, 4. The remaining coils 27 and 28 are preferably mounted approximately $\frac{1}{8}$ inch from the high potential ends of the coils 1 and 4.

It will be observed that in the arrangements shown in Figs. 10 and 11, the circuits 1, 2 and 4, 5 are coupled not only by the condenser 41 in Fig. 10 and the condenser 42 in Fig. 11, but also by the portion 43 of the coil 1 and the portion 49 of the coil 4 in Fig. 10 and similarly by the portion 43 of the coil 1 and the portion 44 of the coil 4 in Fig. 11. The effective inductance of these portions of the coils is varied by the insertion of the cores 7, 8. The effectiveness of the coupling secured by virtue of these portions of the windings may be adjusted by selecting the position at which the taps for the connection of condenser 41 in Fig. 10, or of condenser 42 in Fig. 11, are brought out.

As has already been pointed out, it is highly desirable that the resonant circuits 1, 2 and 4, 5 of Figs. 1 to 12 inclusive, should be so designed that the resonant circuits in themselves possess the characteristic of constant inductance to resistance ratio. However, to the extent to which the resonant circuits deviate from this preferred relation, it is possible, in accordance with my invention, to make such adjustment of the rate at which the coupling coefficient between the two circuits decreases, as the frequency to which the circuits are tuned increases, as to effectively compensate for the deviations in the circuits themselves.

It will be understood, therefore, that while my invention provides coupling arrangements in which the effective coupling coefficient between two resonant circuits may be made substantially inversely proportional to the frequency to which the resonant circuits are tuned, I do not wish to be limited to this precise relationship, but include within the scope of my invention means by which the coupling may be adjusted to automatically compensate for slight deviations of the circuits themselves from the ideally constant ratio of inductance to resistance.

Having thus described my invention, what I claim is:

1. A high-frequency system, having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a variable coupling between said two circuits which increases as the frequency of the system is decreased, and means including said cores to so regulate said coupling

as to maintain substantially constant performance throughout the tuned frequency band.

2. A high-frequency system having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a variable coupling between said two circuits which increases as the frequency of the system is decreased, said coupling including a variable capacitance between each core and coil, and a capacitor between said cores and the ground to so regulate said coupling as to maintain substantially constant amplification throughout the tuned frequency band.

3. A high-frequency system having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a variable coupling between said two circuits which increases as the frequency of the system is decreased, said coupling including a variable capacitance between each core and coil, and a parallel circuit through which the cores are grounded to so regulate said coupling as to control the amplification throughout the tuned frequency band.

4. A high-frequency system having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a variable coupling between said two circuits which increases as the frequency of the system is decreased, said coupling including a variable capacitance between each core and coil, and a series circuit through which the cores are grounded to regulate said coupling and thereby control the amplification throughout the tuned frequency band.

5. A high-frequency system having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a variable coupling between said two circuits which increases as the frequency of the system is decreased, said coupling including a variable capacitance between each core and coil, and a capacitive reactance common to said resonant circuits to so modify said coupling as to maintain substantially constant amplification throughout the tuned frequency band.

6. A high-frequency system having two resonant circuits each including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substan-

tially constant, and a link circuit inductively coupled to the ends of said coils, the couplings between said link circuit and said coils being so varied by said cores as to maintain substantially constant amplification throughout the tuned frequency band.

7. A high-frequency system, having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, and a link circuit coupled with said coils and connected through a capacitor to ground, the coupling between said link circuit and said coils being so varied by said cores as to maintain substantially constant amplification throughout the tuned frequency band.

8. A high-frequency system having two resonant circuits each including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, and a link circuit coupled with and including part of the inductance of said coils, the coupling between said link circuit and said coils being so varied by said cores as to maintain substantially constant amplification throughout the tuned frequency band.

9. A high-frequency system having two resonant circuits, each circuit including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, a link circuit coupled with and including part of the inductance of said coils, and a common capacitive reactance, the coupling between said link circuit and said coils being so varied by said cores as to maintain substantially constant amplification throughout the tuned frequency band.

10. A high-frequency system having two resonant circuits each including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, and a magnetic yoke cooperating with said cores to so regulate the coupling between said coils as to maintain substantially constant amplification throughout the tuned frequency band.

11. A high-frequency system having two resonant circuits each including a capacitor and an inductance coil, a magnetic core movable relatively to each of said inductance coils for tuning said circuits in such a manner that the ratio of inductance to resistance is maintained substantially constant, and means including said cores to so regulate the coupling between said circuits as to maintain substantially constant amplification throughout the tuned frequency band.

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