

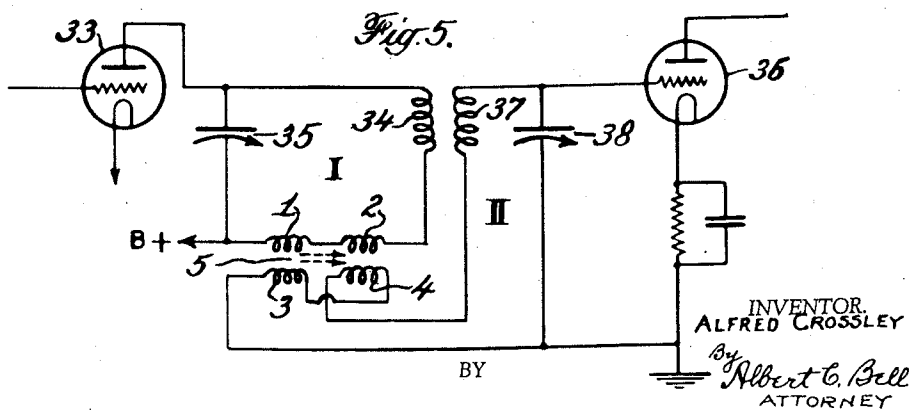
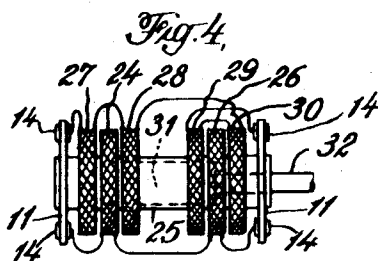
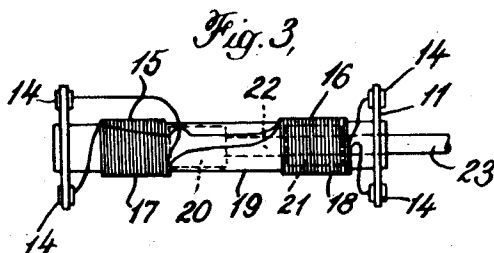
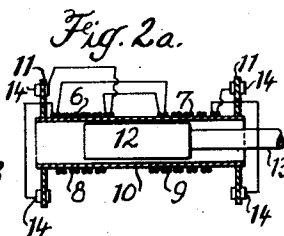
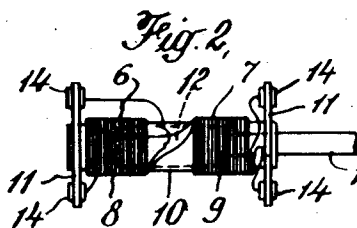
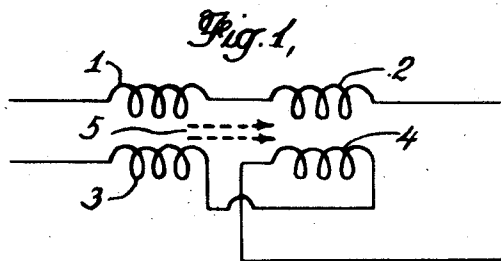
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2,354,365

COUPLING DEVICE FOR ADJUSTABLE COUPLING SYSTEMS

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UNITED STATES PATENT OFFICE

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COUPLING DEVICE FOR ADJUSTABLE
COUPLING SYSTEMS

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Continuation of application Serial No. 301,692, October 28, 1939, which is a division of application Serial No. 158,695, August 12, 1937. This application February 7, 1942, Serial No. 429,880

3 Claims. (Cl. 171-119)

This invention relates to coupling devices for electrical systems and more particularly to systems in which it is desirable or necessary to provide for varying the degree of coupling between two or more circuits or networks. The invention is especially adapted to those cases in which it is preferable to vary the coupling without producing any other appreciable change in the conditions in the system. As is well known, if the coupling between two networks is varied merely by adjusting the inductive linkage between them, there is an accompanying alteration in the inductive reactances in each of the networks which may unfavorably affect their performance. The present invention provides means by which the otherwise unavoidable alterations in the coupled networks may be avoided.

In one common type of high-frequency coupling device for example, in which a pair of resonant circuits is employed, the inductive coupling between the circuits is varied by changing the relative positions of the coils. In the case of highly efficient coils, to attain the required very low degrees of inductive coupling, it is customary to place the coils exactly at right angles, with their axes intersecting at the geometrical center of one of the coils. Additionally, the capacitive coupling between the coils and their connecting leads has a definite minimum value which must be taken into account. Thus the attainment of the desired degree of coupling between the circuits in such a coupling device is difficult, and variation of the coupling over a desired range of values is almost impossible of realization in a commercially practical device.

Coupling devices of the type associated with pairs of resonant circuits are usually operated at or somewhat above critical coupling. If the individual resonant circuits are highly efficient, the degree of coupling is relatively low and a small change in it produces a marked change in the performance of the device. Previously known devices of this type have not been capable of providing a smooth variation of coupling over the desired narrow but highly important range.

In previous devices intended to overcome these difficulties, the means for varying the coupling between the circuits, for example to broaden the selectivity characteristic, frequently produced at the same time undesired changes in the individual circuit inductances. This in turn altered the resonant frequency of each of the resonant circuits, with the result that the selectivity characteristic of the device was asymmetrical over at least a portion of the range of coupling variation.

In the intermediate-frequency amplifiers of receivers of the superheterodyne type, the problem of adjusting the coupling without disturbing the conditions in the individual circuits is of particular importance because such a variation in coupling may be utilized to adjust the band width of the amplifier, that is, the range of musical or voice modulation frequencies which will be passed through to the loud speaker. Several methods of altering the band width of such amplifiers have already been proposed, but the present invention provides a new, simple and highly effective solution of the problem.

It is an object of this invention to provide a coupling means which is capable of precise coupling adjustment without affecting the total effective inductance of the circuits with which it may be employed.

It is an additional object of the invention to provide means whereby both the sense and the degree of inductive coupling between two circuits or networks may be varied without influencing the effective inductance values in either of the circuits or networks.

In accordance with the invention, these and other objects are attained by providing means comprising small inductors which are coupled together and respectively connected in series in pairs. These small inductors are so arranged that the degree of coupling between them may be varied without altering the effective inductance value of each pair. In this manner, the inductive coupling between two circuits respectively including the pairs of small inductors may be varied without changing the individual circuit inductances and without the necessity for critical mechanical adjustments.

This is a continuing application of my co-pending application Serial No. 301,692 filed October 28, 1939, the latter application in turn being a divisional application of my original application Serial No. 158,695 filed August 12, 1937, which latter application has become Patent No. 2,182,071 dated December 5, 1939, the present application being addressed particularly to specific aspects of the coupling devices disclosed in said original application.

The invention will be better understood by reference to the accompanying drawing, in which:

Fig. 1 is a schematic circuit diagram of coupling means in accordance with the invention;

Fig. 2 is an elevation of one embodiment of the coupling means shown schematically in Fig. 1;

Fig. 2a shows in vertical, longitudinal, sectional view, the coupling means illustrated in Fig. 2;

Fig. 3 is an elevation of a modified embodiment of the coupling means shown schematically in Fig. 1;

Fig. 4 is an elevation of a third embodiment of the coupling means shown schematically in Fig. 1; and

Fig. 5 is a schematic circuit diagram of a vacuum-tube amplifier employing coupling means in accordance with the invention.

Referring to Fig. 1 of the drawing, which schematically depicts the basic principle of the invention, coils 1 and 2 are connected in series and are coupled to coils 3 and 4 respectively, which are also connected in series. Coils 1 and 3 are so wound as to have a relatively high degree of coupling between them, and coils 2 and 4 are similarly wound. The high degree of coupling may be secured, for example, by winding coils 1 and 3, and similarly coils 2 and 4, in a bifilar manner, that is, with the conductors of the two coils side by side in successive turns. Coils 1 and 2 are connected in aiding relation, and coils 3 and 4 are connected in opposing relation. A ferromagnetic core 5 is positioned within and is preferably coaxial with coils 1, 2, 3 and 4, and is arranged to be axially movable relatively to the coils.

Ferromagnetic core 5 may be made in accordance with United States Patent No. 1,982,689 to Polydoroff, or in a similar manner. It consists of compressed comminuted ferromagnetic material, and is substantially homogeneous throughout its length, the only departure from homogeneity being that which is inherent in the molding process.

In operation, the inductive coupling provided by the coupling means may be adjusted by varying the inductive coupling between coils 1 and 3 and between coils 2 and 4. These couplings are dependent upon the position of core 5, since the presence of the core within coils 1, 3 increases the inductive coupling between these coils, and a similar result occurs when core 5 is within coils 2, 4. The minimum inductive coupling occurs when core 5 is midway between coils 1, 3 and coils 2, 4, and the maximum inductive coupling is realized when core 5 is concentric with either coils 1, 3 or coils 2, 4. Core 5 is preferably slightly longer than either of coils 1, 3 or coils 2, 4 and is also preferably slightly longer than the space between coils 1, 3 and coils 2, 4.

As core 5 is moved into coils 1, 3, the individual inductances of coils 1 and 3 are increased simultaneously with the increase in inductive coupling between them. At the same time, however, core 5 is withdrawn from coils 2, 4. This in turn decreases the individual inductances of coils 2 and 4, by an amount which substantially compensates for the increase in the inductances of coils 1 and 3. Similar compensation occurs if core 5 is moved into coils 2, 4 instead of coils 1, 3, but in this case the sense of the inductive coupling provided by the coupling means is reversed.

It will be understood that the desired coupling variation without change in the effective inductance of coils 1 and 2 in series, or coils 3 and 4, also in series, is realized in accordance with the invention by the cooperation of the coils 1, 3 and 2, 4 with magnetic core 5, as described above. The use of the movable core makes possible the achievement of the new result by simultaneously providing a change in the coupling between, and in the inductance of, coils 1 and 3 and coils 2

and 4, while maintaining substantially constant the total inductance of coils 1 and 2 in series and the total inductance of coils 3 and 4 in series.

Reference is now made to Figs. 2 and 2a, which show one embodiment of the adjustable coupling means of Fig. 1. Coils 6, 8 and 7, 9 are wound on insulating tube 10, which is supported by members 11. Core 12 moves freely within tube 10 and may be actuated by handle 13, which is attached to core 12 by cementing or in other suitable manner. Connections to coils 6 and 7 in series-aiding relation, and to coils 8 and 9 in series-opposing relation, are made to lugs 14, which are secured to members 11. This embodiment is characterized by compactness and low cost of manufacture.

In the modified embodiment of Fig. 3, coils 15, 17 and 16, 18 are wound on an insulating tube 19 which is somewhat longer than tube 10 of Fig. 2. Coils 15 and 16 are connected in series-aiding relation, and coils 17 and 18 are connected in series-opposing relation. Instead of a single core as in Fig. 2, two shorter cores 20, 21 are employed and they are joined by means of rod 22 in such a manner that they may be simultaneously moved by handle 23. When core 20 is centered in coils 15, 17, core 21 is entirely withdrawn from coils 16, 18, and vice versa. Thus as the inductive coupling between coils 15, 17 is increased by axial movement of cores 20, 21 the inductive coupling between coils 16, 18 is simultaneously decreased, and vice versa. When the cores are midway of their travel, the inductive coupling provided by the coupling means is substantially zero, since the individual inductive couplings of coils 15, 17 and coils 16, 18 are equal in degree and opposite in sense. The inductive coupling provided by the coupling means is a maximum when one of the cores 20, 21 is centered in coils 15, 17 or in coils 16, 18. Furthermore, since the inductance of one coil in each pair of series-connected coils is increased due to one of the cores 20, 21 by the same amount that the inductance of the other coil in the pair is decreased by the other of the cores 20, 21, the total effective inductance of coils 15, 16 in series and of coils 17, 18 in series remains substantially unchanged.

In the embodiment of Fig. 4, coil 24 consists of a universal-wound coil mounted on insulating tube 25, and is connected in series-aiding relation with a similar coil 26. Coils 27 and 28, mounted on either side of coil 24, are connected in series-aiding relation to form the equivalent of coil 3 of Fig. 1. Coils 29 and 30 are similarly located with respect to coil 26, and are connected in series-aiding relation to form the equivalent of coil 4 of Fig. 1. Coils 27, 28 are connected in series-opposing relation with coils 29, 30. Core 31 is axially movable to increase the inductive coupling between coils 27, 24, 28 or between coils 29, 26, 30, without appreciably altering the inductance values of coils 24, 26 in series or of coils 27, 28, 29, 30 in series, as explained above in connection with Figs. 2 and 3 of the drawing. Core 31 may be actuated by a handle 32 attached thereto.

I shall now describe an application of my invention in the intermediate-frequency amplifier of a superheterodyne receiver. It will be understood, however, that I do this merely to provide a further illustrative embodiment of the invention, in a system well known to workers in the communication art, and that in so doing I do not limit myself to this or any other particular

application of the invention, which, as to its scope and utility, is to be taken as limited only as set forth in the appended claims.

Fig. 5 of the drawing shows an application of my coupling device to a vacuum-tube amplifier. The output circuit of vacuum tube 33 includes main inductor 34, coils 1 and 2 connected in series-aiding relation, and tuning capacitor 35 to form resonant circuit I. The input circuit of vacuum tube 36 includes main inductor 37, coils 3 and 4 connected in series-opposing relation, and tuning capacitor 38 to form resonant circuit II. Inductors 34 and 37 may employ ferromagnetic cores, and may be so disposed with respect to each other that there is a desired degree of inductive coupling between them, or, alternatively, so that there is substantially zero inductive coupling between them. Core 5 is arranged to move axially within coils 1, 2, 3, 4 as in Fig. 1.

In operation, the inductive coupling between resonant circuits I and II may be adjusted by varying the inductive couplings between coils 1, 3 and coils 2, 4, respectively. These couplings are dependent upon the position of core 5 with respect to coils 1, 3 and 2, 4, since the presence of the core within one or the other of coils 1, 3 and 2, 4 greatly increases the inductive coupling between them. In addition to the inductive coupling between circuits I and II due to coils 1, 3 and 2, 4, there may be inductive coupling between circuits I and II due to the relative positions of inductors 34 and 37. Whether the inductive coupling due to coils 1, 3 and 2, 4 aids or opposes the inductive coupling due to inductors 34 and 37 depends upon which one of coils 1, 3 and 2, 4 is more strongly influenced by core 5. Thus not only the degree but also the sense of the inductive coupling between circuits I and II may be varied by axial adjustment of core 5.

The following data is given by way of illustrative example of one successful embodiment of the invention in the intermediate-frequency amplifier of a superheterodyne receiver, according to Fig. 5. A 0.34-inch diameter tube is wound with two bifilar windings, each consisting of 21 turns of No. 36 enamelled silk-covered copper wire, the windings being spaced by about two-thirds the length of a winding. The core is 0.3125 inch in diameter and 0.812 inch long, and is of the described type. With the core centered in coils 1, 3, the inductance of the coils 1 and 2 in series is 17.0 microhenries, the inductance of coils 3 and 4 in series is 19.2 microhenries, and the mutual inductance between coils 1 and 2 in series and coils 3 and 4 in series is 11.3 microhenries. With the core centered in coils 2, 4, the inductance of coils 1 and 2 in series is 16.0 microhenries, the inductance of coils 3 and 4 in series is 19.5 microhenries, and the mutual inductance between coils 1 and 2 in series and coils 3 and 4 in series is 10.0 microhenries.

Inductors 34 and 37 are each 1.0 millihenry, and the change in the total inductance of either circuit, due to motion of the core to adjust the coupling between the circuits, is therefore only 0.1 percent, which is negligible. The change in inductance may be made even less, however, by a slight change in the number of turns in one or more of the coils.

The measured Q of resonant circuit I or II by itself is 160, and becomes 153 upon introducing coils 1 and 2 or coils 3 and 4 into the circuit being measured. This is a decrease of less than 9 percent. The value of critical coupling in this

case is about 0.65 percent. The relative positions of inductors 34 and 37 are chosen to provide a mutual inductance value between them of 6.5 microhenries, so that critical coupling between circuits I and II is realized when the coupling between coils 1 and 2 in series and coils 3 and 4 in series is zero. The maximum coupling which is available between circuits I and II is 1.78 percent under these conditions. The coupling between circuits I and II may be brought to zero by suitable adjustment of the core. It will be understood that the value of critical coupling will be somewhat greater than above stated when the coupling device is associated with vacuum tubes in an amplifier.

Thus in the example above described, it is possible to increase the inductive coupling considerably beyond the critical value to obtain a desired overcoupled condition. This is sufficient to provide the necessary broadening of the selectivity characteristic of the coupling device in most instances. If still higher degrees of inductive coupling are required, they are readily obtained by providing coils 1, 3 and 2, 4 with additional turns.

As will be apparent to those skilled in the electrical arts, my invention has advantageous application to numerous problems in electrical circuit design. Its applications in the communication art, and particularly in the high-frequency and radio branches of that art, are of especial importance, since it is in this field that alterations in the performance of networks between which it is desired to utilize a variable coupling become most troublesome. By way of additional illustrative examples of particular systems in this field to the improvement of which my invention is particularly adapted may be mentioned the signal-frequency resonant-circuit networks of radio receivers, and the resonant-circuit networks of transmitters, oscillators and signal generators. In the signal-frequency portions of radio receivers, my invention may be employed to vary the coupling between pairs of coupled circuits either or both of which are variably tunable over a range of frequencies, and by suitable mechanical arrangements the variation of the coupling may be actuated by the tuning control in such a way as to produce any desired relation between the resonant frequencies of the circuits and the coupling between them. The invention may also be advantageously utilized to provide a variable regenerative or degenerative coupling between the plate circuit and the grid circuit of a thermionic tube, or between an antenna or pick-up system and the first resonant circuit in a radio receiver. In oscillators, signal generators and the like, my invention may be employed to provide a variable attenuation between wide limits of the oscillation or signal delivered to the output terminals or the load circuit.

Other advantageous applications of the invention will readily occur to those skilled in the art, as well as various modifications of the structures here shown and described by way of illustrative example of successful embodiments. Such applications and modifications are within the scope of the invention, as set forth in the appended claims.

Having thus described my invention, what I claim is:

1. A coupling device including in combination, an insulating tube, first, second, third and fourth coils, said first and second coils being serially connected in aiding relation, said third and fourth

coils being serially connected in opposing relation, said first and third coils being wound in closely coupled relation adjacent one end of said tube, said second and fourth coils being wound in closely coupled relation but spaced from said first and third coils adjacent the other end of said tube, and a ferromagnetic core structure positioned within said tube and movable relatively to said coils, said core structure being continuous magnetically and having an over-all length substantially equal to the distance between the center of the closely coupled coils on one end of said tube and the center of the closely coupled coils on the other end of said tube.

2. A coupling device including in combination an insulating tube, first, second, third and fourth coils, said first and second coils being serially connected in aiding relation, said third and fourth coils being serially connected in opposing relation, said first and third coils being wound in closely coupled relation adjacent one end of said tube, said second and fourth coils being wound in closely coupled relation but spaced from said first and third coils adjacent the other end of said tube, and a ferromagnetic core structure positioned within said tube and movable relatively to said coils, said core structure being continuous

magnetically and having a relation to said windings increasing by its movement the inductance of two said closely coupled windings at the same time it proportionately decreases the inductance of the other two said closely coupled windings.

3. A coupling device including in combination an insulating tube, a first winding comprising two aidingly related series-connected coils, a second winding comprising two opposingly related series-connected coils, the coils of each of said windings being wound spaced from each other but closely related to the corresponding coils of the other of said windings adjacent the ends of said tube, and a ferromagnetic core structure positioned within said tube and movable relatively to said windings to alter the coupling between said windings while maintaining the total effective inductance of each of said windings substantially constant, said core structure being continuous magnetically and having a relation to said windings increasing by its movement the inductance of two said closely related windings at the same time it proportionately decreases the inductance of the other two said closely related windings.

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