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HIGH-FREQUENCY COUPLING DEVICE

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Fig. 1,

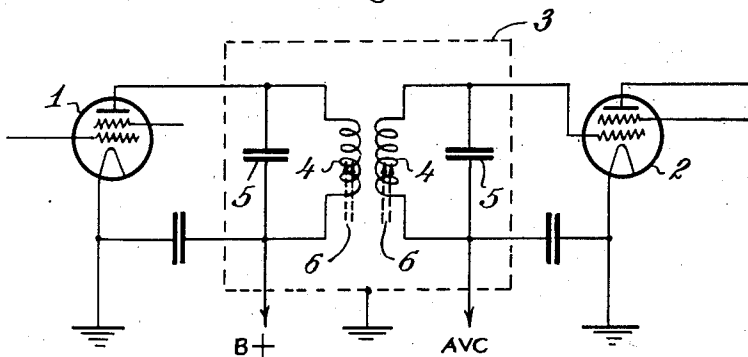
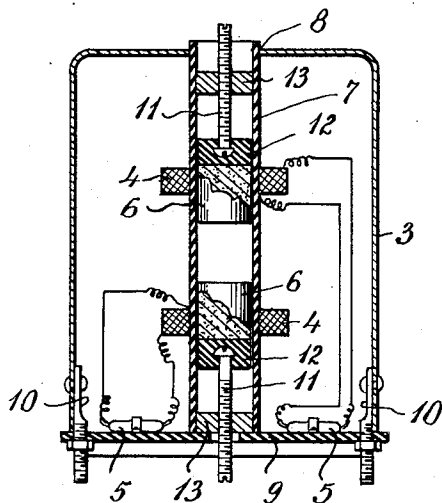


Fig. 2,



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HIGH-FREQUENCY COUPLING DEVICE

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Application June 3, 1937, Serial No. 146,241

7 Claims. (Cl. 178-44)

This invention relates to improvements in high-frequency systems, and more specifically to improvements in high-frequency resonant systems, such, for example, as those which are generally employed between the output terminals of a first vacuum tube and the input terminals of a second vacuum tube, and which are intended for operation at a particular frequency, or over a limited range of frequencies, for example, in the intermediate-frequency amplifiers of radio receivers of the superheterodyne type.

Resonant systems of the above-mentioned type are of two general forms, one employing a single resonant circuit and the other employing two or more coupled resonant circuits, each circuit having an inductor and a capacitor, one or both of which elements is adjustable to align the circuits at a particular frequency or to permit varying the resonant frequency of each circuit over a limited range. The present invention is particularly addressed to the second form.

Fixed air-core inductors shunted by adjustable tuning capacitors have been in common use in coupled resonant-circuit devices, the two inductors being so positioned with respect to each other as to provide, at some chosen frequency, a desired degree of inductive coupling between the two resonant circuits. The usual type of adjustable "trimmer" capacitor, however, is appreciably affected by changes in temperature, and is also subject to changes in capacitance value with time, thus making it difficult if not impossible to maintain the desired performance characteristics in capacitively tuned fixed-inductance coupled resonant-circuit devices of the types now commonly employed.

The difficulty just described may be eliminated by employing fixed capacitors and accomplishing tuning by the use of variable inductors, preferably of the type employing movable ferromagnetic cores for inductance adjustment. In such a device, the resonant circuits may be tuned by inductance variation to secure alignment at a desired frequency, and, once established, this alignment is substantially permanent.

In the design of devices of the class here under consideration, it is necessary to first determine the frequency at which they are to be operated, or the range of frequencies over which they are to be adjustable. A particular device will, in general, be designed for use at a particular frequency, but will be adjustable and operative over a small range of frequencies. When the device is adjusted to operate at the particular frequency for which it was designed, either

the capacitance or the inductance will be varied to compensate for deviations in the capacitances and inductances in the circuits with which the device is associated, in such a way as to bring the product of the total effective capacitance and the total effective inductance to the correct value for the particular frequency. Thus, if the inductance value in a particular case is high, the capacitance value must be correspondingly lower, and vice versa.

Under the circumstances just described, it is possible to design the device in accordance with the invention so that, for any adjustment of its variable elements, it will produce the same resonant gain or the same selectivity characteristic, as may be desired. Since modern radio receiving apparatus usually has adequate gain and in addition has automatic gain control to compensate for any changes in gain or in the strength of the received signal, and since, on the other hand, variations in the selectivity characteristic result in variations in fidelity and may produce serious distortion, it is preferable to design the device so that it will maintain the selectivity constant at the desired value regardless of the settings of its adjustable elements.

In general, there are two methods by which the over-all selectivity of such a device may be kept substantially constant. In the first method, each of the circuits is so designed that its individual selectivity will remain constant, and the coupling between the two circuits is so arranged that it remains constant, regardless of adjustments in either of the circuits. In the second method, the individual selectivities of the circuits are allowed to vary but the coupling between the two circuits is arranged to also vary in such a manner as to substantially compensate for the individual circuit variations. The first method, and devices which enable it to be carried out, constitute the subject matter of my co-pending application Serial Number 146,239, filed June 3, 1937, and which issued as United States Patent No. 2,144,029 dated January 17, 1939. The present application is addressed to the second method.

It is an object of this invention to provide a high-frequency coupling device in which the variation of the coupling between the resonant circuits is appropriately related to the adjustments of the individual resonant-circuit inductance values.

Another object of the invention is to provide a high-frequency coupling device in which substantially uniform selectivity regardless of inductance adjustment may be secured, without

resort to expensive or complicated arrangements.

When a ferromagnetic core of the usual type is introduced into a coil, the inductance of the coil is increased and the resistance is increased, but with cores of good quality the respective rates of increase are such that the ratio of inductance to resistance, or L/R of the coil, becomes greater. When such a coil and core combination is employed in a resonant circuit and the movable core is used to tune the circuit, the selectivity of the circuit improves as the inductance is increased. Since an inductance variation as great as 25 percent is usually necessary, the variation in circuit selectivity becomes appreciable and must be taken into account.

Devices of the type here contemplated are normally operated somewhat above critical coupling, in order to provide reasonably uniform response over a narrow range of frequencies.

A coupling device in accordance with the invention, comprising two such resonant circuits, provides substantially constant over-all selectivity as the individual inductances are varied, the arrangement being such that the mutual inductance of the two circuits decreases as the inductance values are increased, so that the coupling decreases at the proper rate to compensate for the improved performance of the individual circuits.

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

Fig. 1 shows a schematic diagram of one form of coupling device embodying the invention; and

Fig. 2 shows, partly in section, a preferred embodiment of a coupling device of the form of the invention shown in Fig. 1.

Referring to Fig. 1 of the drawing, vacuum tubes 1 and 2 are shown coupled by a coupling device contained within shield 3. The output circuit of vacuum tube 1 includes an input resonant circuit comprising coil 4 and shunt capacitor 5. Input coil 4 is adjustable in its inductance value by means of movable ferromagnetic core 6. Similarly, an output resonant circuit comprising coil 4 and shunt capacitor 5 is connected in the input circuit of vacuum tube 2. Output coil 4 is provided with an adjustable ferromagnetic core 6. By adjustment of cores 6 relatively to coils 4, the resonant frequencies of the input and output resonant circuits, respectively, may be varied. Input coil 4 is inductively coupled to output coil 4.

A preferred embodiment of the coupling device of Fig. 1 is shown in Fig. 2, in which coils 4 are mounted coaxially on insulating tube 7 vertically disposed in shield can 3. Tube 7 protrudes slightly through hole 8 in shield can 3, and is secured to assembly plate 9, which is secured to the open end of shield can 3 by means of mounting spade bolts 10. Cores 6 slide freely within tube 7, and are retained in proper position by means of adjusting screws 11 secured to them by rubber washers 12 and engaging internally threaded plugs 13. Capacitors 5 are secured to member 9, and are connected in shunt respectively with coils 4 to form the input and output resonant circuits, respectively.

In the embodiment shown in Fig. 2, the coils 4 are so spaced that desired minimum inductance values and a desired degree of coupling are secured when the cores 6 are inserted towards each other to a position in which their outer end surfaces are approximately in line with the inner side surfaces of coils 4. As either core 6 is adjusted in a direction away from the other

coil and core, the inductance of its associated coil is increased. The positions of the cores with respect to the coils, however, affect not only the inductance values of the individual coils but also vary the reluctance of the path traversed by the flux linking the two coils and hence the mutual inductance of the two circuits in which the coils are employed.

Since cores 6 are increasingly separated as they are moved into coils 4 to increase the effective inductances of the latter, the reluctance of the flux path between the inductors increases, and thus the mutual inductance of the circuits decreases due to this cause, as the individual inductances are increased. By properly spacing the coils 4 and by proper choice of the dimensions of cores 6 with respect to those of coils 4, therefore, a desired relation between the increase of inductance in the individual circuits and the decrease of inductive coupling between them is readily secured.

By way of illustrative example, one successful embodiment of the invention employs coils of 15/41 Litz wire and having inductances of 1150 microhenries and Q or $2\pi/L$ values of about 160 at 460 kilocycles per second with the cores fully withdrawn. These coils are so placed that the over-all selectivity of the device is such as to provide a band width at one-tenth amplitude of about 15.5 kilocycles. When the cores are fully inserted, the individual inductances increase to 1500 microhenries, the Q values become about 200 at the same frequency, and the band width at one-tenth amplitude becomes 14 kilocycles. Thus, although the L/R ratios are increased by 25 percent, the selectivity increases less than 10 percent. Inserting the cores raises the gain of the device in conjunction with a vacuum tube from about 210 to 230, or a little more than 9 percent.

Having thus described my invention, what I claim is:

1. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits.

2. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling be-

tween said circuits by an amount sufficient to maintain the over-all selectivity of said device substantially constant.

3. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, said cores and said coils being coaxially arranged, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits.

4. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, said cores and said coils being coaxially arranged, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits by an amount sufficient to maintain the over-all selectivity of said device substantially constant.

5. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, said coils being universal windings wound in spaced relation upon an insulating tube, said cores being of plug type and being positioned within said tube adjacent said coils, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum induct-

ance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits.

6. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, said coils being universal windings wound in spaced relation upon an insulating tube, said cores being of plug type and being positioned within said tube adjacent said coils, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits by an amount sufficient to maintain the over-all selectivity of said device substantially constant.

7. A high-frequency coupling device for operation at a predetermined frequency comprising a pair of coupled resonant circuits each including a fixed capacitor and an inductance coil adjustable as to its inductance value by a movable ferromagnetic core, the selectivity of each of said circuits at said predetermined frequency varying with adjustment of the inductance therein, said coils being universal windings wound in spaced relation upon an insulating tube, said cores being of plug type and being positioned within said tube adjacent said coils, screw-threaded members attached to said cores and cooperating screw-threaded members at either end of said tube for adjusting the positions of said cores relatively to said coils, the spacing between said inductance coils being such that when said cores are adjusted each to produce minimum inductance in its associated circuit the coupling between said circuits has a desired maximum value, the adjustment of either of said cores away from the other of said cores increasing the inductance value in the associated circuit and simultaneously decreasing the coupling between said circuits by an amount sufficient to maintain the over-all selectivity of said device substantially constant.

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