Jan. 11, 1938. A. CROSSLEY ET AL 2,104,792

HIGH FREQUENCY RESONANT SYSTEM

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Fig. 1,

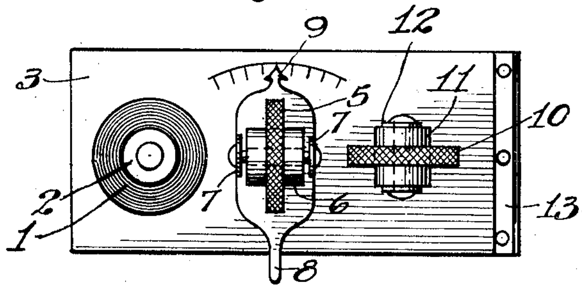


Fig. 2,

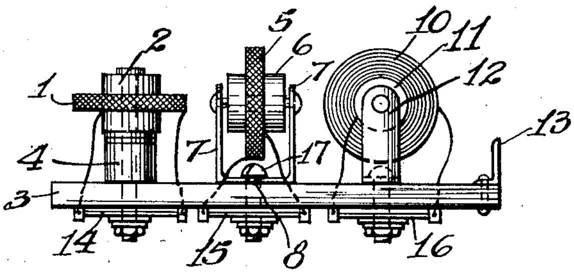
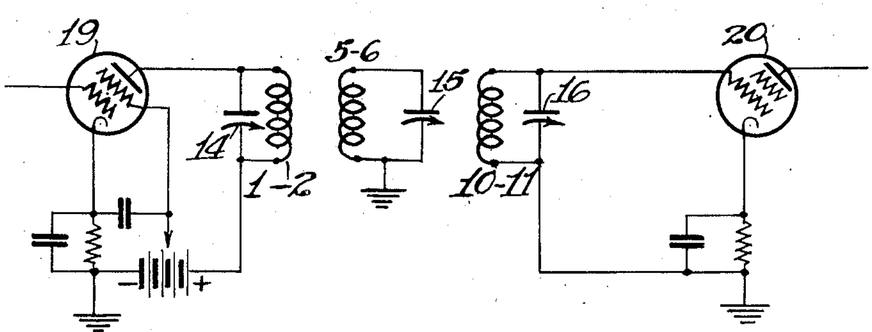


Fig. 3,



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HIGH FREQUENCY RESONANT SYSTEM

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Fig. 4,

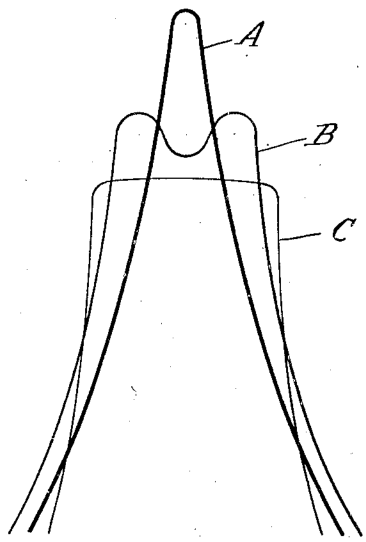
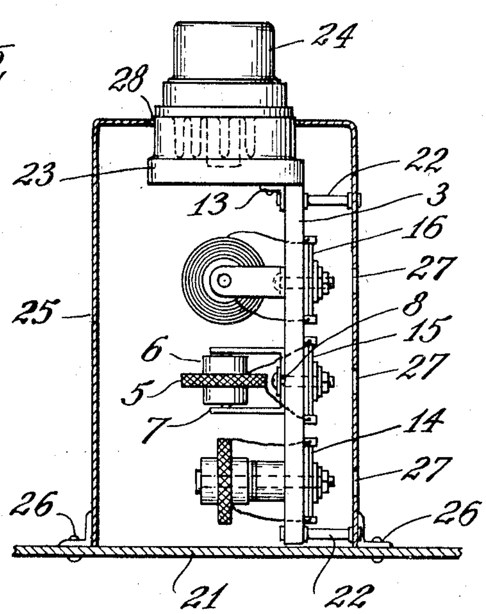


Fig. 5,



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HIGH FREQUENCY RESONANT SYSTEM

Filed Aug. 10, 1935 3 Sheets-Sheet 3

Fig. 6,

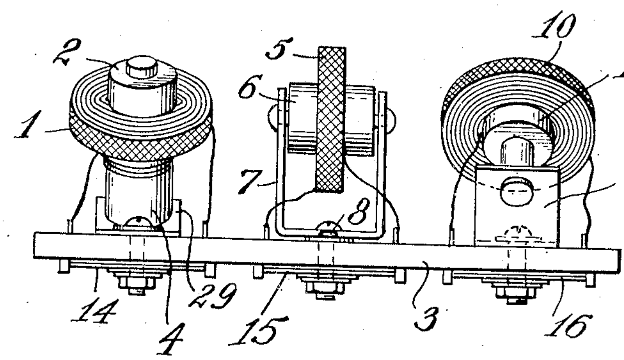


Fig. 7,

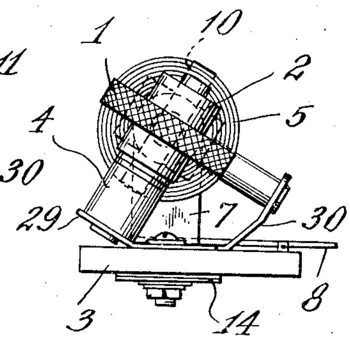


Fig. 8,

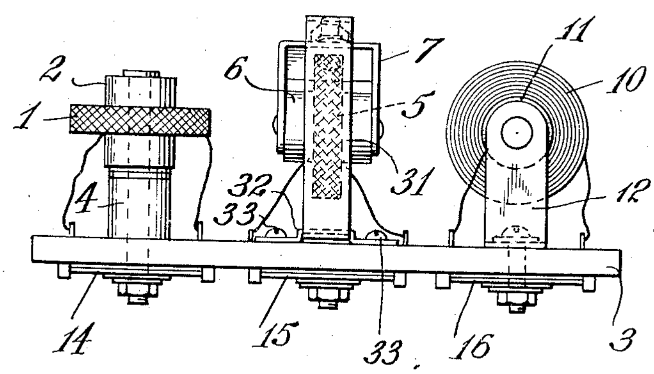
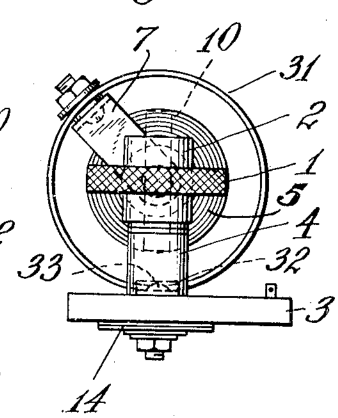


Fig. 9.



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UNITED STATES PATENT OFFICE

2,104,792

HIGH-FREQUENCY RESONANT SYSTEM

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Application August 10, 1935, Serial No. 35,634

14 Claims. (Cl. 178—44)

This invention relates to improvements in high-frequency systems, and more specifically to improvements in high-frequency resonant systems. Resonant systems of the type herein contemplated are generally employed to link the output circuit of a first vacuum tube to the input circuit of a second vacuum tube, are usually intended for operation over a limited range of frequencies, and are commonly employed in the intermediate-frequency amplifier of a radio receiver of the superheterodyne type.

An object of this invention is to provide an improved type of resonant system which may be adjusted to give a desired relation between selectivity and gain when used in conjunction with amplifying vacuum tubes.

Another object of the invention is to provide an improved type of high-frequency resonant system having a band-pass selectivity characteristic, with broad response to the desired signal accompanied by increased discrimination against undesired signals on nearby and adjacent channels.

An additional object of the invention is to provide improved means for coupling two vacuum tubes, capable of producing a wide range of selectivity characteristics.

Still a further object of the invention is to provide a high-frequency resonant system which employs an improved type of inductor with very advantageous results.

Although resonant systems of the type herein contemplated may be employed in any type of high-frequency apparatus, they are particularly useful in the intermediate-frequency amplifiers of superheterodyne radio receivers.

The overall selectivity characteristic of a superheterodyne radio receiver depends almost entirely upon the selectivity characteristic of the intermediate-frequency amplifier. This depends, in turn, upon the arrangement of the resonant circuits which are employed between the vacuum tubes. In coupling devices of the prior art, consisting of two tuned circuits which have a fixed or adjustable degree of inductive coupling between them, if the degree of coupling is at a value designated as the optimum value, and the two tuned circuits have been adusted to resonate at the intermediate frequency, the resultant selectivity characteristic will have a pronounced single peak and gradually sloping sides. This peak indicates that the receiver will attenuate the higher modulation frequencies, so that the output of the receiver will sound muted. The gradually sloping sides of the selectivity characteristic indicate that the receiver will not discriminate satisfactorily against undesired signals on nearby channels.

If the receiver is to provide high fidelity of reproduction without sacrifice in ability to discriminate against stations on adjacent or nearby channels, the selectivity characteristic must have a broad and substantially flat top and steeply sloping sides. When the coupling of a conventional two-circuit coupling device is increased beyond the optimum point, a double-peaked selectivity characteristic is obtained, but the top has a pronounced central depression and the sides of the characteristic are gradually sloped. Thus the characteristic obtainable from an overcoupled two-circuit coupling device is, at best, only a rough approximation of the desired broad flat-topped and steep-sided selectivity characteristic.

In accordance with the present invention, in order to make the sides of the selectivity characteristic sufficiently steep, three highly efficient resonant circuits are employed. When all three mutual couplings are adjusted below the optimum point, the resultant selectivity characteristic has steep sides and a very high and narrow peak. Such an adjustment is not satisfactory for use in a radio receiver intended for high-fidelity reproduction of voice and music. It is necessary that the steep sides of the characteristic be retained, but that the peak be widened sufficiently to avoid attenuation of the higher modulation frequencies, if the resultant characteristic is to be of the form required for high fidelity of reproduction.

Previous attempts to attain a reasonably satisfactory selectivity characteristic have involved the use of complicated and expensive circuits, with accompanying difficulty in obtaining initial alignment. As against this, the present invention solves the problem of providing a broad flat-topped steep-sided selectivity characteristic by an arrangement which is compact and inexpensive, and in which the initial alignment is readily obtained in a simple and definite manner. The resonant system of the present invention provides the proper amount of coupling between its three tuned circuits to produce a selectivity characteristic which closely approaches the ideal response, and means are provided to alter the characteristic if desired.

The resonant system of the present invention includes three tuned circuits and employs adjustable coupling between at least one pair of inductors. In a preferred embodiment, adjustable coupling is obtained by movement of the middle one of the three inductors, the positions of the other two inductors being such that this movement produces the desired variation in coupling between the two outer inductors. By proper adjustment of the tuned circuits and their mutual couplings, it is readily possible to attain in practice a close approach to the theoretically ideal broad flat-topped and steep-sided selectivity characteristic.

The inductors are preferably of the type having ferro-magnetic cores, in order to concentrate the magnetic fields and thereby facilitate the design of a compact and readily shielded device. The low losses of this type of inductor are of material assistance in obtaining the desired selectivity characteristic. It will be understood that other types of inductor may be employed within the scope of the present invention, but not without some sacrifice in the compactness and efficiency of the resonant system.

The resonant system of the present invention is readily adjustable, however, to a condition of maximum selectivity, that is, to a condition in which the selectivity characteristic has a narrow top and steeply sloping sides. This adjustment may be desirable under certain conditions of operation of a radio receiver, in which selectivity is more important than high fidelity of reproduction. The selectivity per stage with the resonant system of the present invention is superior to that obtained with the conventional coupling device employing only two tuned circuits.

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

Figure 1 is a plan view of an illustrative embodiment of the invention;

Figure 2 is an elevation of the device shown in Figure 1;

Figure 3 is a schematic diagram of a resonant system in accordance with the invention associated with appropriate auxiliary apparatus;

Figure 4 is a graph showing various selectivity characteristics;

Figure 5 is an elevation, partly in section, of the device of Figures 1 and 2 assembled on the chassis of a radio receiver;

Figure 6 is an elevation of a modified embodiment in which two of the inductors are mounted at an angle to the base;

Figure 7 is an end view of the modification of Figure 6;

Figure 8 is an elevation of a second modified embodiment in which the rotatable inductor is mounted so that the angle which its axis of rotation makes with the base may be adjusted; and

Figure 9 is an end view of the modification of Figure 8.

Referring to Figs. 1 and 2, an inductor consisting of winding 1 and magnetic core 2 is fixedly mounted upon insulating base 3 and its distance from base 3 is determined by the length of spacer 4. Winding 5 and core 6 form the second inductor, which is pivotally mounted on base 3 by means of a yoke 7 having an adjusting handle 8 and an indicating pointer 9. A third inductor, consisting of winding 10 and core 11, is fixedly mounted on base 3 by means of yoke 12. Bracket 13, riveted or otherwise suitably secured to base 3, may be employed to secure the device to the chassis or baseboard of the complete apparatus in which the device is to be used. The three inductors are so mounted relatively to the base 3 that their magnetic centers (but not their axes) lie approximately in a straight line parallel to the longitudinal axis of the base 3.

The three inductors 1—2, 5—6, and 10—11 are so positioned upon the base 3 that, when inductor 5—6 is in the position shown, the magnetic axes of the three inductors are substantially mutually at right angles, the axes of inductors 5—6 and 10—11 being in a plane perpendicular to the axis of inductor 1—2, and the axis of rotation of yoke 7 being parallel to the axis of inductor 1—2.

Referring to Fig. 2, the base 3, in addition to supporting windings 1, 5 and 10 with their associated magnetic cores 2, 6 and 11, also carries adjustable tuning capacitors 14, 15 and 16, which may be of any suitable type using either mica or air as a dielectric. Capacitor 14 is connected across inductor 1—2; capacitor 15 is connected across inductor 5—6; and capacitor 16 is connected across inductor 10—11. Each inductor with its associated capacitor forms a resonant circuit whose frequency may be adjusted by means of the adjustable capacitor.

This view also shows the pivot 17 by which yoke 7 is secured to base 3, and spacer 4 which suitably spaces inductor 1—2 from base 3.

In Fig. 3, a resonant system in accordance with, for example, the type shown in Figs. 1 and 2, is shown schematically as being connected between a first vacuum tube 19 and a second vacuum tube 20, either or both or which may operate otherwise than as an amplifier. For example, vacuum tube 19 may be the modulator, or vacuum tube 20 may be the demodulator of a superheterodyne receiver. Inductor 1—2 is tuned by capacitor 14 to form a parallel resonant circuit inserted in the plate circuit of vacuum tube 19. Inductor 5—6 is tuned by capacitor 15 to form a link circuit between inductors 1—2 and 10—11. Inductor 10—11 together with its tuning capacitor 16 forms a parallel resonant circuit and is inserted in the grid circuit of vacuum tube 20.

Referring to Fig. 4, a curve A is representative of the selectivity characteristic of a conventional two-circuit coupling device with the coupling adjusted to the optimum point. Curve B indicates the performance of the same device when the coupling is increased to a value substantially greater than optimum. Curve A has an undesirable high and narrow peak, and its sides have a gradual slope. The sides of curve B are somewhat steeper, but there is an undesired central depression in the top of the curve.

Curve C is the selectivity characteristic of a resonant system in accordance with this invention. It will be observed that curve C differs from curves A and B because it has not only a broad substantially flat top, but also increased steepness of the sides, thus closely approaching the theoretically ideal curve having vertical sides and a horizontal top.

Still referring to Figure 4, curves A and B are typical of all cases in which two resonant systems are coupled together, whether the systems be mechanical, acoustic or electrical in nature. Each of the resonant systems must first be tuned accurately to the desired mean frequency, with substantially zero coupling between the two systems. As the coupling is then gradually increased, the mutual reactance tends to lower the resonant frequency of one system and raise the resonant frequency of the other system, thus inevitably producing an undesired depression in the curve at the mean frequency.

The three-circuit arrangement of the present invention, when properly constructed and adjusted, overcomes this difficulty without material sacrifice in gain and with substantial increase in useful selectivity. In this case, there is provided means whereby the coupling between inductor 1—2 and inductor 5—6 is maintained substantially at an optimum value, while the coupling between inductor 5—6 and inductor 10—11 is varied from zero to maximum overcoupled condition. As the coupling between inductor 5—6 and inductor 10—11 is increased, there is reflected back into inductor 1—2 a load which increases with the increase in coupling, and means are provided, as shown in the drawings, whereby as the load is increased, the coupling between inductor 1—2 and inductor 5—6 is also increased to compensate for the load, and at the same time maintain optimum coupling between inductor 1—2 and inductor 5—6. Having optimum coupling between inductor 1—2 and inductor 5—6, we obtain a selectivity curve between these circuits, which under minimum coupling between inductor 5—6 and inductor 10—11, produces a normal shaped selectivity curve, but as the coupling between inductor 5—6 and inductor 10—11 increases, the selectivity characteristic between the circuits of inductor 1—2 and inductor 5—6 is such that the resonant curve becomes broader at the peak, and this coupled with the selectivity characteristics obtainable due to the circuits including inductors 5—6 and 10—11, which vary from extreme selectivity to the double-peaked condition shown in curves A and B of Figure 4, combined, produces an effect which is shown in curve C of this figure. In other words, for the extreme overcoupled condition, the circuits including inductors 5—6 and 10—11 produce the double-peaked characteristic common to two-circuit transformer characteristics, but when these circuits are associated with the other circuit including inductor 1—2 and means are provided to increase the coupling, we produce the effect wherein the selectivity characteristics of the circuits including inductors 1—2 and 5—6 fill in the gap, and as previously stated, combine to produce the flat top characteristic. The devices shown in Figures 6, 7, 8 and 9 produce the ideal conditions, wherein means are provided for increasing the coupling between inductor 1—2 and inductor 5—6 automatically as inductor 5—6 is rotated, thus always providing optimum coupling between these two units.

Fig. 5 shows a modified embodiment in which the base 3 is secured to a shield 25 by means of tubular rivets 22. Bracket 13, at the upper end of base 3, is utilized to support a vacuum tube socket 23, which receives vacuum tube 24. Shield can 25 is attached to the chassis 21 by any suitable means, as for example by angle brackets 26, and has holes 27 to provide access to adjustable capacitors 14, 15 and 16. The shield 25 is also provided with a large hole 28 to clear the base of vacuum tube 24, and with a slot, not shown, to permit adjustment of the position of inductor 5—6 relative to the other two inductors by means of handle 8.

The arrangement of Fig. 5 is especially satisfactory when vacuum tube 24 is of the compact twin diode type having a metal shell, since this combination provides a very efficient and fully shielded assembly. Other types of vacuum tubes may be employed, however, with very satisfactory results.

In the arrangement shown in Figs. 1 and 2, the inductor 5—6 rotates about a vertical axis parallel to the magnetic axis of inductor 1—2. It is obvious that the inductor 5—6 could alternatively be arranged to rotate around a horizontal axis parallel to the axis of inductor 10—11. If this were done, then the coupling between inductor 5—6 and inductor 10—11 would change in the same manner as the coupling between inductor 5—6 and inductor 1—2 in the original arrangement. It is apparent that in either case the rate of change of coupling of inductor 5—6 would be much more rapid with respect to one of the outside inductors than with respect to the other outside inductor.

Figs. 6, 7, 8 and 9 show modifications in which it is possible to vary the rate at which the coupling between the center inductor and each of the outside inductors changes, as the center inductor is rotated upon its axis. This is attained by arranging to rotate the center inductor on an axis which is not parallel to the axes of either of the outside inductors. These arrangements are advantageous when it is desired to maintain the coupling between the first and second inductors at substantially optimum value while the coupling between the second and third inductors is increased to the maximum permissible overcoupled condition, to produce the desired flat-topped steep-sided selectivity characteristic.

Figs. 6 and 7 show a side elevation and an end view, respectively, of an embodiment of the invention which has been found to be particularly satisfactory with vacuum tubes of the 6A7 and 6D6 types. In this embodiment the inductor 1—2 is supported on a bracket 29 so that its axis is at an angle of 60° with the base 3. The inductor 5—6 is rotatably mounted in the same manner as in Figs. 1 and 2. The inductor 10—11 is positioned on a bracket 30 so that its axis makes an angle of 30° with the base 3. It will be understood that these angles may be varied to adapt the design to the specific conditions under which it is to be used and to secure the desired performance. In this arrangement, the coupling between inductor 1—2 and inductor 5—6 changes more rapidly than is the case in Figs. 1 and 2, but still not so rapidly as the coupling between inductor 5—6 and inductor 10—11.

Figs. 8 and 9 show a side elevation and an end view, respectively, of another modified embodiment of the invention in which center inductor 5—6 is so mounted that the angle which its axis of rotation makes with the base 3 may be adjusted after the device has been assembled. In this modification the yoke 7 supporting the inductor 5—6, instead of being mounted directly on base 3, is pivoted from an insulating ring 31, the ring in turn being secured to the base 3 by a clamp 32 held by screws 33. By slightly loosening the screws 33, the ring 31 may be rotated, thus changing the angular relation between the axis of rotation of inductor 5—6 and the magnetic axes of inductors 1—2 and 10—11, inductors 1—2 and 10—11 being mounted as in Figures 1 and 2.

This modification is advantageous in a design which is intended to be adaptable to a variety of different conditions in the amplifiers with which it is to be employed. Depending upon the vacuum tubes used and the particular form of selectivity characteristic desired, the angle at which the axis of rotation of the inductor 5—6 is positioned may be determined experimentally so as to produce any desired relation between the rate of change of coupling between inductor 1—2 and inductor 5—6, and between inductor 5—6 and inductor 10—11.

In operation, the coupling between inductor 1—2 and inductor 10—11 is substantially zero because of their positions relative to each other (and relative to the shield in Fig. 5). The link circuit consisting of inductor 5—6 and capacitor 15, however, provides a path by which a desired degree of induction between inductors 1—2 and 10—11 may be established. In Figs. 1 and 2 when the inductor 5—6 is in the position shown, the coupling is at a minimum between inductors 1—2 and 5—6 and between inductors 5—6 and 10—11, and the effective total coupling between inductors 1—2 and 10—11 is therefore at a minimum.

Still referring to Figs. 1 and 2, as inductor 5—6 is rotated from the position shown, its coupling to inductor 1—2 remains substantially unchanged, while its coupling to inductor 10—11 substantially increases. The coupling between inductors 5—6 and 1—2 is initially established by positioning inductor 1—2 slightly above (or below) the magnetic axis of inductor 5—6. The amount of coupling required will depend upon the parallel impedance across inductor 1—2. The necessary displacement of inductor 1—2 is obtained by using a spacer 4 of suitable length in mounting the inductor upon its spindle.

Referring now to Figs. 8 and 9, it will be apparent that if the ring 31 be turned until the axis of rotation of inductor 5—6 is vertical, then the arrangement of Figs. 8 and 9 will correspond to the arrangement of Figs. 1 and 2. It will also be apparent that if the ring 31 be turned until the axis of rotation of inductor 5—6 makes an angle of 60° with the base, then the arrangement will be the same as that shown in Figs. 6 and 7. It will also be apparent that by adjusting the ring 31 to other angular positions, any desired relation may be secured. When ring 31 is adjusted so that the axis of rotation of inductor 5—6 is parallel to the magnetic axis of inductor 1—2 (and at right angles to the magnetic axis of inductor 10—11), the minimum rate of change of coupling occurs between inductor 5—6 and inductor 1—2 (and the maximum rate of change between inductor 5—6 and inductor 10—11). By rotating ring 31 90° from this position, the minimum rate of change of coupling is secured between inductors 5—6 and 10—11 (and the maximum rate of change between inductors 5—6 and 1—2).

In embodiments in accordance with Figs. 1 and 2, there will usually be a certain amount of capacitive coupling between inductor 1—2 and inductor 5—6. This capacitive coupling may be sufficient so that with the slightly increased coupling produced by the rotation of the inductor 5—6 substantially optimum coupling between inductor 1—2 and inductor 5—6 is maintained, while the coupling between inductor 5—6 and inductor 10—11 is being increased. On the other hand, in embodiments in which precautions are taken to reduce the capacitive coupling to a very small or negligible value, arrangements similar to Figs. 6 and 7 or Figs. 8 and 9 will be found advantageous in order to secure a more rapid increase in the coupling between inductor 1—2 and inductor 5—6 as inductor 5—6 is rotated to increase its coupling with inductor 10—11.

As will be clear from what is to follow, it is by virtue of these novel arrangements, and the highly efficient design of the inductors themselves, that the new and advantageous results of the present invention are secured.

In practice, each resonant circuit is first adjusted to resonate at the mean frequency at which the resonant system is to operate, care being taken to have all couplings at their minimum value. The position of inductor 5—6 is altered until the desired selectivity characteristic is attained. The adjustment may be arranged to be made by the user of a radio receiver, by employing one or more resonant systems of the type herein disclosed, for the purpose of varying the selectivity and hence the fidelity of the receiver in accordance with conditions existing at any given time, during the operation of the receiver.

Although any suitable type of inductor may be employed in the resonant system of the invention, we prefer to employ inductors of the type described in U. S. Patent No. 1,978,568 issued to Crossley and Neighbors. Inductors of this type include magnetic cores made in accordance with U. S. Patent No. 1,982,689 issued to Polydoroff. Various coupling relationships between two inductors of this type are shown and described in pending U. S. application for Letters Patent No. 719,906 of Neighbors and Meinema patented June 1, 1937 as U. S. Patent Number 2,082,589.

It will be understood that the mechanical methods of mounting the inductors may be varied, and that, where more than one resonant system is employed, the coupling adjustments may be ganged in any suitable manner for operation by means of a single control. It is also within the scope of the invention to fixedly mount the middle inductor at a desired position relative to the other inductors.

In a preferred embodiment of the present invention, it is possible to obtain a selectivity characteristic having a band width at one hundred times resonant voltage about half that of the conventional type of two-coil intermediate-frequency transformer. In a resonant system designed to operate at a mean frequency of 456 kilocycles, the measured band width at one hundred times resonant voltage is only 30 kilocycles.

The use of three loosely coupled circuits instead of the usual two would, in general, result in a reduction in the gain obtainable. This loss in gain, however, may be avoided and the gain maintained at substantially the same value as obtainable with conventional two-circuit coupling devices by designing the inductor 1—2, which is included in the plate circuit of the first tube, with greater inductance, so that its resonant impedance is much higher. This construction maintains the gain at normal values without noticeably decreasing the selectivity advantages obtainable in the three-circuit coupling device. It is apparent that the selectivity of the first resonant circuit is in any case materially impaired by the parallel load imposed upon it by the plate circuit of the associated vacuum tube.

The desirable steepness of the sides of the selectivity characteristic which is obtained with a resonant system in accordance with the invention may be substantially retained, while at the same time increasing the width of the top of the characteristic by adjusting the inductor 5—6 to a position beyond the optimum coupling. Operation in the overcoupled condition is especially satisfactory in the case of radio receivers intended for high-fidelity reproduction of the received signal. The fact that the coupling can also be readily varied to a value giving high selectivity greatly enhances the usefulness of the receiver by permitting its satisfactory use under conditions of severe interference or noise.

It will be understood that the middle tuned circuit, which functions as a link between the two outer circuits, may be utilized for additional purposes. For example, the voltage across the link circuit may be supplied to an additional vacuum tube which operates to regulate the amplification of one or more of the amplifying vacuum tubes of the receiver. Other additional uses of the link circuit will occur to those skilled in the art, and in certain cases it may be desirable to adjust one or more of the circuits to resonate at a different frequency.

Having thus described our invention, what we claim is:

1. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being initially so mounted that their magnetic axes are mutually at right angles, one of said inductors being adjustable from its intial position to vary its coupling with the other two inductors, said other two inductors being so positioned that the direct inductive coupling between them is substantially zero.

2. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with their magnetic axes mutually at right angles, and means for moving one of said inductors to a position at which its magnetic axis is oblique to the magnetic axis of one of the other two inductors to adjust the selectivity of said resonant system.

3. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with the magnetic center of a first of said inductors slightly displaced from said line to provide a desired degree of coupling between said first and a second of said inductors, said second inductor being rotatively adjustable to vary the coupling between said second and the third of said inductors and thereby control the selectivity of said resonant system.

4. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatable to a position at which its magnetic axis is oblique to the magnetic axis of one of the other two inductors for adjusting the selectivity of said resonant system.

5. A selective high-frequency resonant system including cooperating first, second and third resonant circuits, each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with their magnetic axes substantially mutually at right angles, the inductor in said first circuit having its magnetic center slightly displaced from said line to provide a desired degree of coupling between said first and second circuits, the inductor in said second circuit being rotatable to vary the coupling between said second and third circuits for adjusting the selectivity of said resonant system.

6. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, the inductor in one of said circuits having a materially higher inductance than the inductors in the other two circuits, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatively adjustable to a position at which its magnetic axis is oblique to the magnetic axis of one of the other two inductors for varying the selectivity of said resonant system.

7. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with the magnetic center of a first of said inductors slightly displaced from said line to provide a desired degree of coupling between said first and a second of said inductors, said second inductor being rotatively adjustable on an axis parallel to the magnetic axis of said first inductor to establish a desired over-all selectivity characteristic in said resonant system.

8. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with the magnetic center of a first of said inductors slightly displaced from said line to provide a desired degree of coupling between said first and a second of said inductors, said second inductor being rotatively adjustable on an axis which is perpendicular to a line through the magnetic centers of said second and the third inductors and oblique to the magnetic axes of said first and third inductors to establish a desired over-all selectivity characteristic in said resonant system.

9. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatively adjustable on an axis parallel to the magnetic axis of a second of said inductors to a position at which its magnetic axis is oblique to the magnetic axis of the third of said inductors to establish a desired over-all selectivity characteristic in said resonant system.

10. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatively adjustable on an axis which is perpendicular to a line through the magnetic centers of said inductors and oblique to the magnetic axes of the other two of said inductors, to a position at which its magnetic axis is oblique to the magnetic axes of said other two inductors to establish a desired over-all selectivity characteristic in said resonant system.

11. A selective high-frequency resonant system including cooperating first, second and third resonant circuits, each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with their magnetic axes substantially mutually at right angles, the inductor in said first circuit having its magnetic center slightly displaced from said line to provide a desired degree of coupling between said first and second circuits, the inductor in said second circuit being rotatively adjustable on an axis parallel to the magnetic axis of the inductor in said first circuit to establish a desired over-all selectivity characteristic in said resonant system.

12. A selective high-frequency resonant system including cooperating first, second and third resonant circuits, each having a capacitor and an inductor, said inductors being positioned with their magnetic centers approximately in line and with their magnetic axes substantially mutually

at right angles, the inductor in said first circuit having its magnetic center slightly displaced from said line to provide a desired degree of coupling between said first and second circuits, the conductor in said second circuit being rotatively adjustable on an axis which is perpendicular to a line through the magnetic centers of the inductors in said second and third circuits and oblique to the axes of the inductors in said first and third circuits to establish a desired over-all selectivity characteristic in said resonant system.

13. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, the inductor in one of said circuits having a materially higher inductance than the inductors in the other two circuits, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatively adjustable on an axis parallel to the magnetic axis of a second of said inductors to a position at which its magnetic axis is oblique to the magnetic axis of the third of said inductors to establish a desired over-all selectivity characteristic in said resonant system.

14. A selective high-frequency resonant system including three cooperating resonant circuits each having a capacitor and an inductor, the inductor in one of said circuits having a materially higher inductance than the inductors in the other two circuits, said inductors being positioned with their magnetic axes mutually at right angles, one of said inductors being rotatively adjustable on an axis which is perpendicular to a line through the magnetic centers of said inductors and oblique to the axes of the other two of said inductors, to a position at which its magnetic axis is oblique to the magnetic axes of said other two inductors to establish a desired over-all selectivity characteristic in said resonant system.

ALFRED CROSSLEY.
HERBERT E. MEINEMA.

CERTIFICATE OF CORRECTION.

Patent No. 2,104,792. January 11, 1938.

ALFRED CROSSLEY, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 28, for "or" second occurrence, read of; line 40, for "a curve A" read curve A; page 4, second column, line 63, strike out the article "the"; page 5, first column, line 16, claim 1, for "intial" read initial; page 6, first column, line 4-5, claim 12, for "conductor" read inductor; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 1st day of March, A. D. 1938.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.