Dec. 12, 1933. R. A. BRADEN 1,938,620

BAND-PASS AMPLIFIER

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Fig. 1

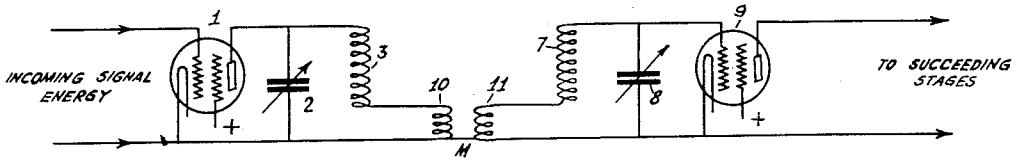


Fig. 2

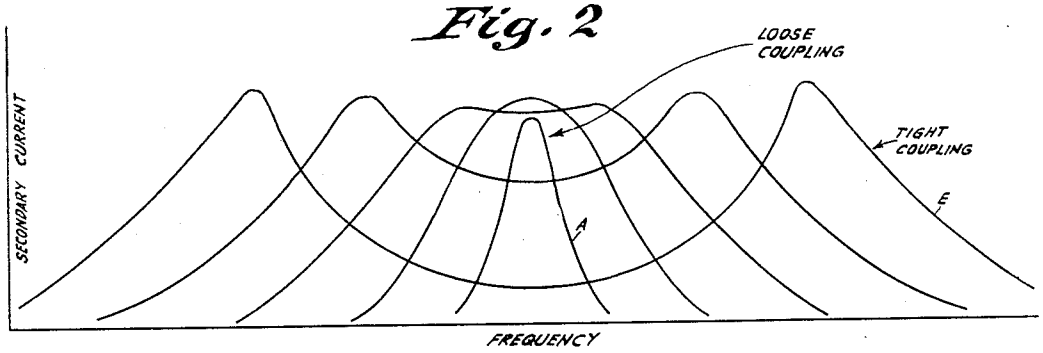


Fig. 3

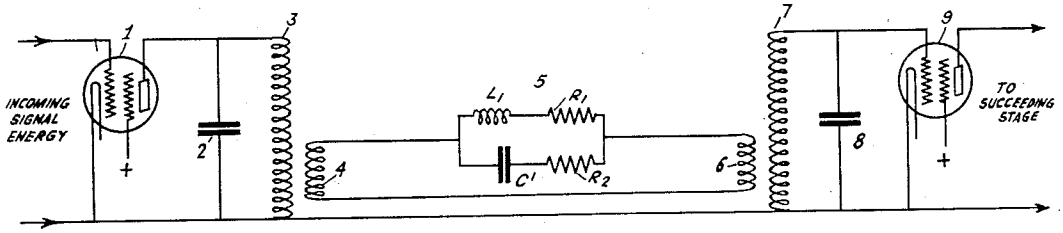
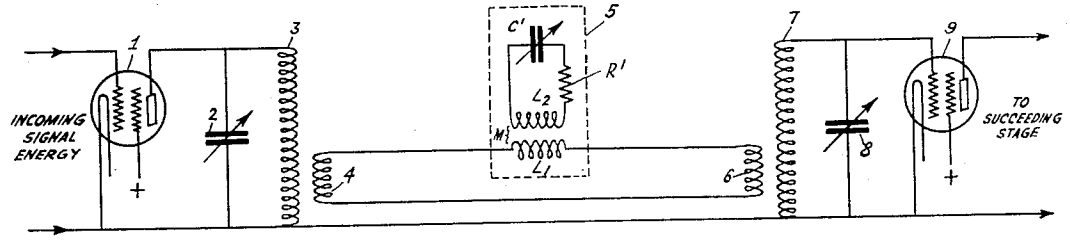


Fig. 4



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Fig. 5

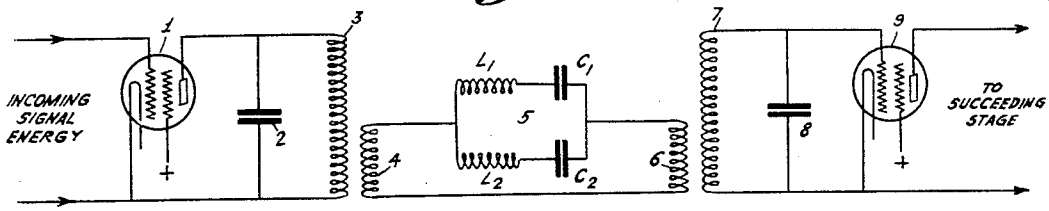


Fig. 6

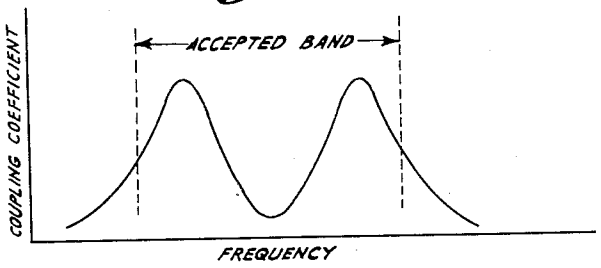


Fig. 7

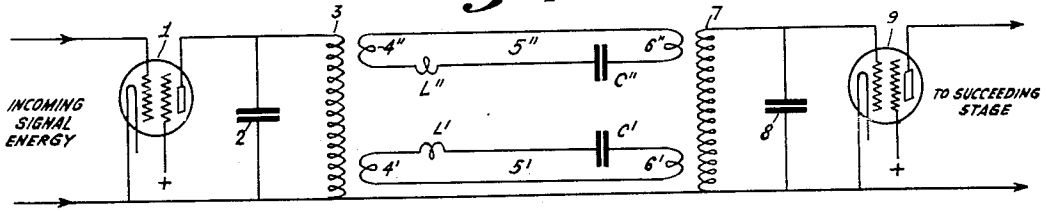
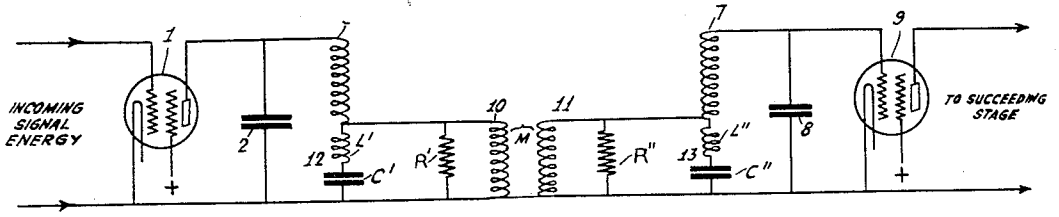


Fig. 8



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BAND-PASS AMPLIFIER

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Application August 23, 1929. Serial No. 387,836

12 Claims. (Cl. 178—44)

My present invention relates to amplifiers, and, more particularly, to band-pass amplifiers employing novel coupling means.

The typical band-pass amplifier circuit of present day practice possesses resonance curves, with various values of coupling between the tuned circuits, which have pronounced, undesirable features. One particularly disadvantageous characteristic of this type of circuit is that the width of accepted band is limited by the depression at the center of the band, which depression becomes deeper as the coupling is increased.

Again, at any frequency, either at resonance or off resonance, there is a particular value of coupling which gives to the secondary circuit the maximum current that can flow therein. Thus, the optimum coupling is small for the resonance frequency, and becomes larger as the frequency is farther from resonance. The value of coupling and band width at which the center depression begins depends, of course, on the amount of ohmic resistance in the tuned circuits.

It is, therefore, customary to insert resistance in the circuits when a greater band width than usual is desired. This has the desired result of increasing the band width. However, the amplification is reduced in proportion to the amount of resistance added.

Now, I have discovered a type of circuit in which the effective value of the coupling varies according to the frequency, being small at the resonance frequency of the tuned circuits, and relatively large for frequencies off resonance. Thus, every frequency within certain limits which is impressed in the circuit encounters the proper value of coupling to amplify it properly. All frequencies within these limits are, therefore, amplified equally. Moreover, no resistance need be added to the circuits, and the amplification obtainable from a wide-band amplifier is thereby, according to my invention, as great as that of a narrow-band amplifier.

Accordingly, it is one of the main objects of my present invention to provide an improved coupling means for band-pass amplifiers by means of which it is possible to construct a band-pass amplifier passing a wider band than is passed by an amplifier employing the usual, present day circuit, without the use of a large number of tuned circuits in each amplifier stage, and without damping the tuned circuits.

Another important object of the invention is to provide a method of, and means for, coupling two tuned circuits so that the coupling is relatively small at the resonant frequency of the circuits, and larger at frequencies, higher and lower than the resonant frequency.

Another object of the invention is to provide a band-pass amplifier consisting of two tuned circuits, and means for coupling the two circuits in such a way that the co-efficient of coupling is substantially proportional at any frequency to the difference between that frequency and the resonant frequency of the tuned circuits.

Still other objects of the invention are to improve generally the efficiency of band-pass amplifier couplings.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings,

Fig. 1 schematically shows a typical band-pass amplifier circuit employed in present practice,

Fig. 2 shows resonance curves for the circuit in Fig. 1 with various values of coupling,

Fig. 3 shows a circuit embodying my novel form of coupling,

Figs. 4 and 5 show modified forms of the invention,

Fig. 6 graphically shows the coupling coefficient of the circuit in Fig. 5,

Figs. 7 and 8 show additional modified forms of the invention.

Referring to the accompanying drawings in which like characters of reference indicate the same elements in the different views, Fig. 1 illustrates an amplifier circuit which is typical of all band-pass circuits which have been used heretofore. The incoming signal energy is impressed across the input terminals of the tube 1, the latter being of the screen grid type. The output circuit of the tube is tuned by the variable capacity 2 and inductance 3.

The input circuit of the screen grid tube 9 is tuned by the inductance 7 and variable capacity 8, the input circuit being coupled to the output circuit 2, 3 by coupling coils 10, 11, as at M. The output from the tube 9 is then impressed upon a succeeding stage and utilized in any well known manner.

In Fig. 2, I have shown resonance curves for

the circuit in Fig. 1, with various values of coupling M between the two tuned circuits. The abscissa is "Frequency", and the ordinate "Secondary current", curve A illustrating the effect of loose coupling, while curve E portrays the result of tight coupling, the curves between designating increasing values of coupling.

The particular feature of this circuit, which it is desired to illustrate by means of the resonant curves of the Fig. 2, is that the width of the accepted band is limited by the depression at the centre of the band, which depression becomes deeper as the value of the coupling M is increased. It will, additionally, be noted that at any frequency, either at resonance or off resonance, there is a particular value of coupling which gives to the secondary circuit the maximum current that can flow therein; and that the optimum coupling is small for the resonance frequency and becomes larger as the frequency is farther from resonance.

The value of coupling and band width at which the depression begins depends upon the amount of resistance in the tuned circuits. It is customary, therefore, to insert resistance in the tuned circuits when a greater band width than usual is desired. This allows the coupling to be increased, thus increasing the band width, but the amplification is reduced in proportion to the amount of resistance which is inserted into the tuned circuits.

My invention, as explained heretofore, and as illustrated in Figs. 3 to 8 inclusive, involves a circuit in which the effective value of the coupling varies according to the frequency, being small at the resonance frequency of the tuned circuits, and relatively large for frequencies off resonance, Every frequency within said limits, which is impressed on the circuit, encounters the proper value of coupling to amplify it properly, and all frequencies within these limits are therefore amplified equally. Moreover, no resistance need be added to the circuits, and the amplification obtainable from a wide-band amplifier is therefore as great as that of a narrow-band amplifier.

In Fig. 3, there is shown an amplifier circuit embodying a coupling designed according to my invention. The incoming signal energy is impressed across the input terminals of the screen grid tube 1, the output circuit of the tube being shown as fixedly tuned by the capacity 2 and the inductance 3. It is to be understood that a vacuum tube of the triode or tetrode type may be employed in the circuit. The output circuit of the tube 1 is coupled to the tuned input circuit of the screen grid tube 9 by a coupling circuit to be shortly described in detail.

The input circuit of the tube 9 is shown as fixedly tuned by the capacity 8 and the inductance 7, and the output from the tube 9 is impressed upon a succeeding stage and utilized in any well-known fashion. The coupling circuit comprises an inductance coil 4 coupled inductively to the coil 3, and an inductance coil 6 coupled inductively to the inductance 7, the coils 4 and 6 being connected in series with each other.

A net-work 5 of resistances and reactances is inserted in series with the coils 4 and 6, the network including an inductance L_1 and a resistance R_1 in series with each other, and a capacity C' in series with a resistance R_2, the latter two elements being in shunt with the series connection of resistance and inductance. It is to be noted that coils 6 and 4 are similar to each other, coil 7 is similar to coil 3, and capacity 8 is similar to the capacity 2.

In operation, the net-work 5, consisting of the inductance L_1, the capacity C', and the resistances R_1 and R_2, is tuned to the mid-band frequency of the band of frequencies which is to be amplified, the output circuit of tube 1 and the input circuit of tube 9 being maintained fixedly tuned to the same mid-band frequency. It is to be observed that the last named two circuits correspond to the primary and secondary circuits of Fig. 1, and that they are coupled by the circuit 4, 5 and 6,

The effective coupling between the circuits 2, 3, and 7, 8 depends upon the coupling between the coils 3 and 4, and the coupling between the coils 6 and 7, and also on the impedance of the circuit 4, 5, 6, the coupling being diminished as the impedance of this latter circuit is increased. The net-work circuit 5, being resonant to the frequency to which the primary and secondary circuits are tuned, puts a high impedance in the coupling circuit at that frequency, and reduces the coupling to a small value. At frequencies which are higher and lower than the resonant frequency, the impedance of the net-work 5, is smaller, and the coupling is greater.

Adjustment of the circuit may be effected by first adjusting the coupling between coils 3 and 4 and between 6 and 7, so that with the net-work 5 short circuited, the two peaks of the resonance curve are far enough apart to give the desired band width. Then, the net-work 5 is inserted, and the circuit elements L_1, C', R_1 and R_2 are adjusted so that the impedance at parallel resonance has the value which gives the proper degree of coupling at the mid-band frequency of the accepted band, and so that the impedance of net-work 5 changes at the proper rate with increasing or decreasing frequency.

In Fig. 4, I have shown a modification of the circuit shown in Fig. 3. It is to be pointed out at this time that the reference numerals in this figure and the following figures denote the same circuit elements as in Figs. 1 and 3. In Fig. 4, the coupling circuit impedance 5 consists of the coupled inductances L_1 and L_2 (the inductances being coupled as at M), the condenser C' and the resistance R', the condenser, resistance and inductance L_2 being in series with one another.

The circuit is otherwise exactly the same as shown in Fig. 3, but is a more convenient circuit than that shown in Fig. 3 from the standpoint of ease of adjustment, it being pointed out that its operation is exactly the same as in the case of Fig. 3. The capacities 2, 8 and C' are variable in this modification. In Fig. 5 the coupling circuit impedance 5 consists of two series resonant circuits L_1, C_1, and L_2, C_2, the series resonant circuits being connected in shunt. These series resonant circuits are adjusted so that one is resonant at approximately the upper frequency limit of the band, and the other is resonant at the lower frequency limit, while the two in combination are in parallel resonance at the mid-band frequency of the accepted band. In this modification, the capacities 2 and 8 are fixed.

In Fig. 6 I have graphically shown the coupling coefficient produced by the coupling circuit in Fig. 5. In this figure frequencies, as abcissae, are plotted against coupling coefficients, as ordinates, the accepted band being shown as pos-

sessing a width denoted between the dotted vertical lines.

Fig. 7 shows an amplifier circuit including fixedly tuned circuits 2, 3 and 7, 8, in which there are provided coupling link circuits, denoted by 5' and 5'', respectively. Circuit 5' is tuned to one frequency limit, and coupling circuit 5'' to the other limit of the accepted band. Link circuit 5' contains an inductance L' and a capacity C' in series, while link circuit 5'' contains an inductance L'' and a capacity C'' in series. The circuit operates in a manner similar to the circuits already described, this particular modification producing low coupling at mid-band frequency, and increasing coupling with increasing or decreasing frequency.

In Fig. 8, the output circuit of screen grid tube 1 is fixedly tuned by the capacity 2 and the inductance 3, while the input circuit of the screen grid tube 9 is fixedly tuned by the capacity 8 and the inductance 7. The tuned circuits are coupled by the coils 10 and 11 as at M, the impedances 12 and 13 being utilized to cause the coupling M to vary with frequency. Each impedance comprises a series resonant circuit tuned to the same frequency as the two tuned circuits 2, 3 and 7, 8, that is to say, to the mid-band frequency. The impedance 12 is made up of an inductance L' in series with a capacity C', while the impedance 13 comprises an inductance L'' in series with the capacity C''.

At the mid-band frequency, the coupling coils 10 and 11 are shunted effectively by resistances R' and R'', and the effective coupling is reduced to a small value, the amount of reduction being determined by the magnitudes of R' and R''. At other frequencies above or below the mid-band frequency, the series resonant circuits 12 and 13 have higher impedances, and the effective coupling is increased. The rate at which the coupling increases as the frequency departs from the mid-band value, is determined by the ratio of L': C' and L'': C''.

The coupling systems disclosed herein are particularly applicable to a superheterodyne receiver, or to a transmitter, in which the circuits are left fixedly tuned to one frequency. The coupling circuits must be tuned, as well the stage input and output circuits, and there are, therefore, actually three or four tuned circuits in each stage. Obviously, in the case of a tuned radio frequency receiver, this might prove cumbersome. However, in the case of a superheterodyne, or a transmitter for television purposes, the present arrangement might prove to be very desirable because of the extremely wide band which is utilized in a television system.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications in the circuit arrangements, as well as in the apparatus employed, may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. A band-pass amplifier comprising two oscillatory circuits resonant to the same frequency, and a network resonant to said frequency for coupling the two circuits, said network comprising inductive and capacitative reactances of such relative magnitudes; that the coefficient of coupling between said circuits is substantially proportional at any frequency to the difference between that frequency and the resonant frequency of the tuned circuits whereby the coupling between the circuits is a minimum at said resonant frequency.

2. A band-pass amplifier stage comprising input and output circuits, two tuned circuits resonant to a desired frequency, a link circuit coupling the tuned circuits, and a parallel resonant circuit inserted in series with the link circuit, tuned to the same frequency as the tuned circuits, said coupling link circuit consisting of inductive and capacitative reactances of such relative magnitudes as to provide minimum coupling between the two tuned circuits at the desired frequency and maximum coupling at frequencies off resonance.

3. A band-pass amplifier stage comprising two tuned circuits, two link circuits, each independently coupling the tuned circuits, each link circuit tuned by series inductance and capacity to one end of the frequency band which is accepted by the circuits, both said link circuits being in parallel resonance at the mid-band frequency.

4. A band-pass amplifier comprising two tuned circuits resonant to a mid-band frequency, a link circuit coupling the two tuned circuits, an inductance coil in series with the link circuit, and a series resonant circuit coupled to the coil in the link circuit and being tuned to said mid-band frequency of the accepted frequency band whereby the coupling between the two tuned circuits is a minimum at said mid-band frequency.

5. A band-pass amplifier circuit comprising a pair of tuned circuits resonant to the same frequency, a network resonant to the said frequency for coupling said circuits, said coupling network including inductive and capacitative impedances of such relative magnitudes that the effective value of the coupling varies according to the frequency, the value of the coupling being small at the resonance frequency of the tuned circuits and relatively large for frequencies off resonance.

6. In combination, an amplifier having a tuned output circuit, a second amplifier having a tuned input circuit, both said tuned circuits being resonant to a desired mid-band frequency, and a network coupling said tuned circuits, said network being resonant to the said frequency and including capacitative and inductive reactances of such relative values that its impedance at mid-band frequency and the rate of change of its impedance for frequencies off the mid-band frequency is such that all frequencies within the band are substantially uniformly amplified.

7. In combination, an amplifier having a tuned output circuit, a second amplifier having a tuned input circuit, both said tuned circuits being resonant to a desired mid-band frequency, and a network coupling said tuned circuits, said network being resonant to the said frequency and including capacitative and inductive reactances of such relative values that its impedance at mid-band frequency and the rate of change of its impedance for frequencies off the mid-band frequency is such that all frequencies within the band are substantially uniformly amplified, said network including a series resonant path tuned to the upper frequency limit of the band including said mid-band frequency, and a second series resonant path tuned to the lower frequency limit of the said band.

8. In combination, a source of alternating cur-

rent energy to be amplified, a tuned circuit coupled thereto, an amplifier having a tuned output circuit, a second amplifier having a tuned input circuit, both said tuned circuits being resonant to a desired mid-band frequency, and a network coupling said tuned circuits, said network being resonant to the said frequency and including condensers and inductances of such values that its impedance at mid-band frequency and the rate of change of its impedance for frequencies off the mid-band frequency is such that all frequencies within the band are substantially uniformly amplified.

9. In combination, a source of alternating current energy to be amplified, a tuned circuit coupled thereto, an amplifier having a tuned output circuit, a second amplifier having a tuned input circuit, both said tuned circuits being resonant to a desired mid-band frequency, and a network coupling said tuned circuits, said network being resonant to the said frequency and including condensers and inductances of such values that its impedance at mid-band frequency and the rate of change of its impedance for frequencies off the mid-band frequency is such that all frequencies within the band are substantially uniformly amplified, said network including a series resonant path tuned to the upper frequency limit of the band including said mid-band frequency, and a second series resonant path tuned to the lower frequency limit of the said band.

10. In combination, a source of alternating current energy of a wide band of frequencies to be amplified, a tuned circuit coupled thereto, an amplifier tube having a tuned input circuit, both said tuned circuits being resonant to the mid-band frequency of said wide band of frequencies, and an impedance path coupling said tuned circuits, said impedance path being resonant to said mid-band frequency and including capacities and inductances of magnitudes such that the coupling between said tuned circuits is a minimum at said mid-band frequency, and is increasingly greater for frequencies within said band but off the mid-band frequency whereby all frequencies within the said side band are substantially uniformly amplified.

11. In combination, a source of alternating current energy of a wide band of frequencies to be amplified, a tuned circuit coupled thereto, an amplifier tube having a tuned input circuit, both said tuned circuits being resonant to the mid-band frequency of said wide band of frequencies, and an impedance path coupling said tuned circuits, said impedance path being resonant to said mid-band frequency and including capacities and inductances of magnitudes such that the coupling between said tuned circuits is a minimum at said mid-band frequency, and is increasingly greater for frequencies within said band but off the mid-band frequency whereby all frequencies within the said side band are substantially uniformly amplified, said impedance path including a series resonant circuit tuned to the upper frequency limit of said band and a second series resonant circuit tuned to the lower frequency limit of said band.

12. In combination with a source of side band modulated radio frequency energy, a pair of successive screen grid amplifier tubes, means for coupling said source to the input electrodes of the first tube, means for connecting the output electrodes of the second tube to a succeeding stage, a coil connected across the output electrodes of the first tube, and a coil connected across the input electrodes of the second tube, a condenser across each of said coils for resonating the coils to the mid-band frequency of a desired frequency band to be amplified, a coupling network coupled between said coils, said network including a plurality of inductances and condensers having relative magnitudes sufficient to resonate said network to said mid-band frequency and to cause the coupling coefficient between said coils to be a minimum at said mid-band frequency and to be increasingly greater for frequencies within said desired band but off the mid-band frequency.

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