

Feb. 6, 1940.

D. E. FOSTER

2,189,063

SIGNAL COUPLING NETWORK

Filed Nov. 17, 1937

2 Sheets-Sheet 1

Fig. 1

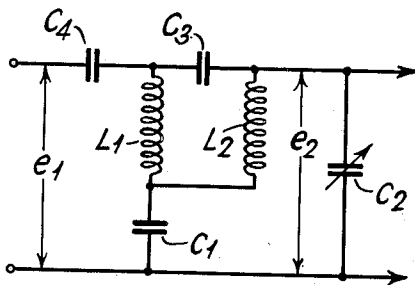


Fig. 2

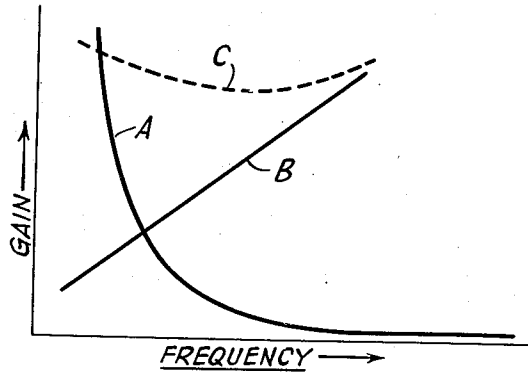


Fig. 3

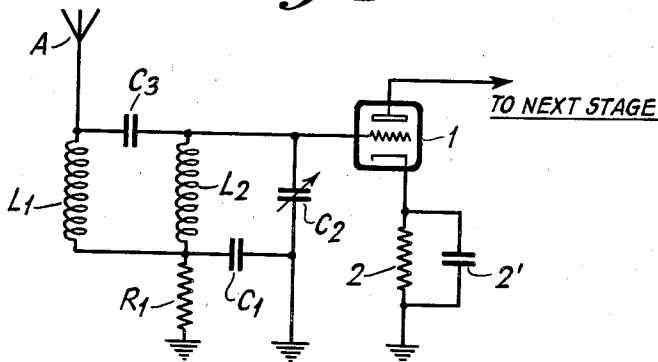
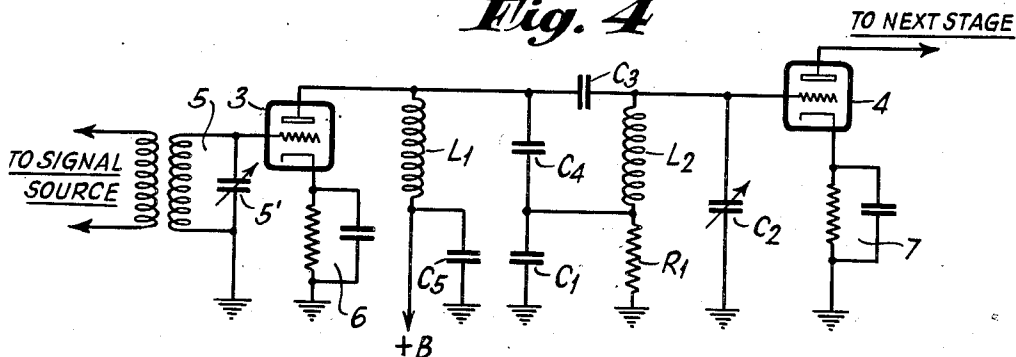


Fig. 4



INVENTOR.
DUDLEY E. FOSTER

BY

H. S. Swann
ATTORNEY.

Feb. 6, 1940.

D. E. FOSTER
SIGNAL COUPLING NETWORK

2,189,063

Filed Nov. 17, 1937

2 Sheets-Sheet 2

Fig. 5

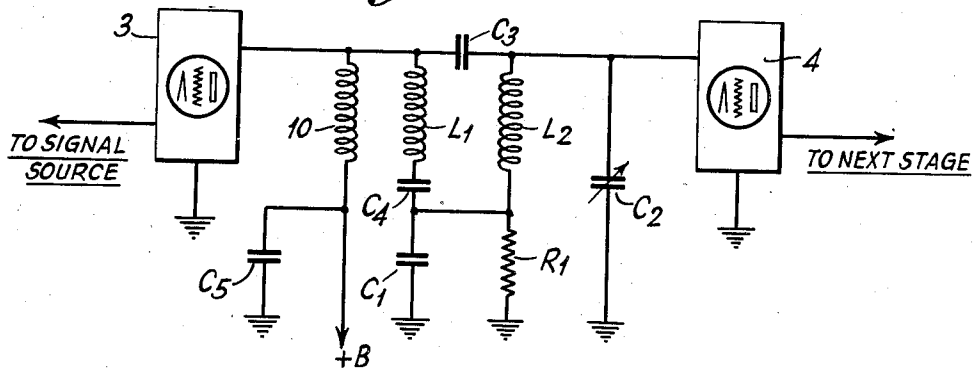


Fig. 6

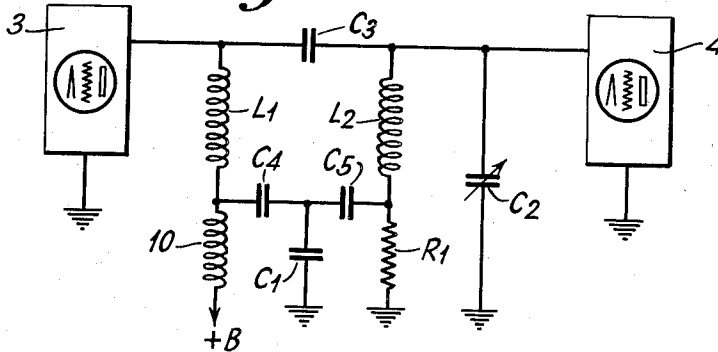
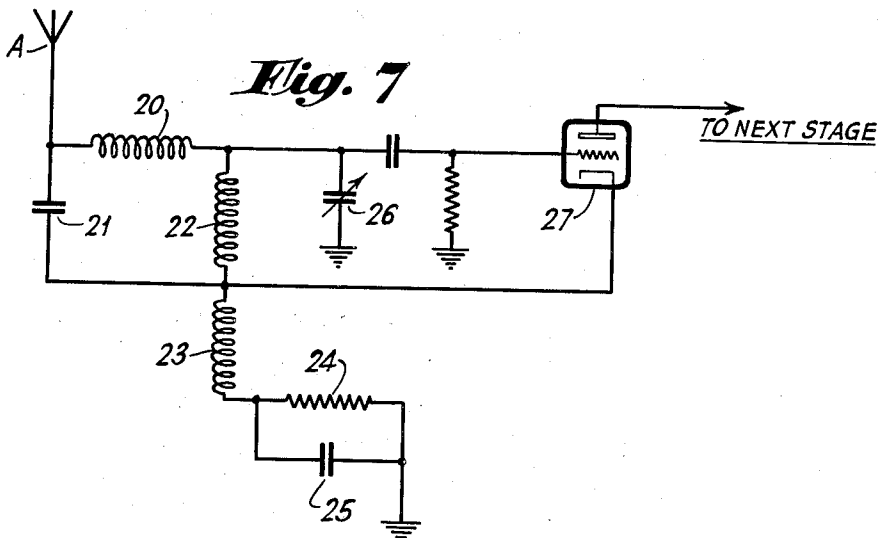


Fig. 7



BY

INVENTOR.
DUDLEY E. FOSTER
H. S. Swann
ATTORNEY.

UNITED STATES PATENT OFFICE

2,189,063

SIGNAL COUPLING NETWORK

Dudley E. Foster, South Orange, N. J., assignor to
Radio Corporation of America, a corporation of
Delaware

Application November 17, 1937, Serial No. 174,928

16 Claims. (Cl. 250—20)

My present invention relates to high frequency coupling networks, and more particularly to radio frequency coupling networks adapted for use in radio receivers.

It is often desired in radio receivers, such as those employed in the broadcast band, to utilize between the antenna circuit and the first tunable radio frequency amplifier circuit, a coupling network which has a high, substantially uniform gain characteristic without undue effect on the normal tuning of the selector circuits. Again, such a characteristic is desired for inter-stage coupling networks. Particularly in the case of automobile radio receivers, where the signal collector is physically small, it is of great importance to employ, between the collector and the tunable input circuit of the first amplifier, a network which has a characteristic of the type described above. In general, it may be stated that it is desirable to employ for a high frequency coupling network, circuit elements which permit of obtaining, at the will of the designer, higher gain at the higher frequencies, or lower frequencies, of the tuning range; or substantially uniform gain throughout the receiver tuning range.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide a high frequency coupling network between two high frequency circuits, and one of which circuits is a tunable circuit, the coupling network including a capacitive reactance common to the low alternating potential ends of the coupled circuits to provide a coupling which varies inversely with frequency; whereas coupling is provided between the high alternating potential ends of the coupled circuits by a capacitive reactance which furnishes a coupling varying directly with frequency.

Another important object of my invention is to provide a coupling network between a source of radio frequency energy and a tunable radio frequency circuit, and which coupling network consists of a pair of capacities connected between the low and high alternating potential ends of the coupled circuits; and the two capacities furnishing a coupling characteristic which may be made to vary in a predetermined manner with respect to frequency.

Another object of my present invention is to provide a coupling network between a signal collector and a tunable signal selector circuit; the coupling network including two capacities for providing the sole coupling paths between the collector and selector circuit; the signal en-

ergy transfer through one of these capacities varying directly with frequency, and the signal energy transfer through the other of said capacities varying inversely with frequency.

Still other objects of my invention are to improve generally the simplicity and efficiency of high frequency coupling networks, and more especially to provide signal coupling networks for radio receivers which are not only reliable and efficient in operation, but are readily manufactured and assembled in radio receivers.

The novel features which I believe to be characteristic of my invention are set forth with 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 shows a circuit diagram of a generalized coupling network embodying the present invention;

Fig. 2 graphically illustrates the characteristics of the coupling network;

Figs. 3, 4, 5 and 6 show respectively different embodiments of the invention; and

Fig. 7 shows a modified type of signal coupling network.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 a coupling network adapted to be employed between a source of signal energy and a utilization device. For example, the source of energy may be the signal collector of an automobile radio receiver, while the utilization device can be the first signal amplifier tube of the receiver. The coupling network comprises a primary coil L_1 and a secondary coil L_2 . There is no magnetic coupling between these coils, and the junction of the coils is connected to the low alternating potential side of the network through a condenser C_1 . The high alternating potential ends of the two coils are connected by a second condenser C_3 . A condenser C_4 is arranged in series with coil L_1 , and the variable tuning condenser C_2 is connected in shunt with the series path including coil L_2 and condenser C_1 . When the source of voltage e_1 is an antenna, condenser C_4 consists of the inherent antenna capacity.

The condensers C_1 and C_3 function as the sole

coupling elements between the primary coil L_1 and the tunable circuit L_2-C_2 . The impedance of condenser C_1 varies inversely with the frequency of the signal energy impressed across coil L_1 . Hence, for a given current in the circuit $C_4-L_1-C_1$, the voltage across condenser C_1 will likewise vary inversely with the frequency of the impressed signal energy. For a given voltage across condenser C_1 , the voltage e_2 , when condensers C_1 and C_2 in series are resonant with coil L_2 , is approximately equal to the voltage across coil L_2 , which is proportional to ωL_2 ($\omega=2\pi f$). If now the current through condenser C_1 is greatest at the low frequency end of the tuning range of the tunable input circuit, then the voltage e_2 , due to current through condenser C_1 , will similarly be greatest at the low frequency end of the tuning range. This is illustrated by the full line curve A in Fig. 2.

In Fig. 2 there is plotted "Gain" against "Frequency." The component of voltage e_2 , due to the condenser C_3 , varies directly with the frequency of applied signal energy. The full line curve B in Fig. 2 shows how the network gain, i. e., the ratio

$$\frac{e_2}{e_1}$$

varies with frequency for coupling through condenser C_3 only. It will be observed that the condenser C_3 , assuming no coupling through the path including condenser C_1 , provides a rising gain-frequency characteristic over the network tuning range. The combination of coupling effects due to condensers C_1 and C_3 provides two components of voltage e_2 . One of these components varies directly with applied signal frequency, and the other component varies inversely with this frequency. The combination of the two couplings furnishes the gain-frequency characteristic illustrated by a dotted line curve C in Fig. 2. Condenser C_3 adds to the circuit minimum capacity but in auto receivers, where high gain is desired, the range extends only to 1550 kc., so that range coverage is not difficult. On household receivers, extending to 1700 or 1800 kc., antenna gain need not be as high, and in this case C_3 may be made smaller, say of the order of 5 mmf.

For a given resonant frequency of $L_1-C_1-C_4$, increasing the magnitude of condenser C_1 will decrease the signal energy transfer through C_1 . Since this latter capacity serves principally to transfer signal energy at the low frequency end of the network tuning range, it will primarily reduce the voltage gain at that end of the tuning range. The condenser C_3 functions principally to transfer signal energy at the high frequency end of the tuning range, and an increase in the magnitude of condenser C_3 will primarily increase the voltage gain at the high frequency end of the tuning range. Substantially uniform gain may be realized with very little coupling through C_1 if L_1 and C_4 are made resonant at, or closely adjacent to, the low frequency end of the tuning range, because under such conditions the voltage across L_1 will be maximum at such frequencies and compensate for the inefficiency of C_3 as a coupling means at those frequencies. If circuit $C_4-L_1-C_1$, be made resonant at frequencies well below the lowest frequency of the tuning range, C_1 must be made smaller in capacity to maintain coupling efficiency at the low frequency end of the tuning range.

Figs. 3 to 6 inclusive illustrate different embodiments of the fundamental coupling network

depicted in Fig. 1. Hence the following description should be considered in the light of the explanation given in connection with Figs. 1 and 2. In order clearly to relate the circuits in Figs. 3 to 6, inclusive, to the fundamental network of Fig. 1, corresponding circuit elements will be similarly designated.

Considering the circuit shown in Fig. 3, there is shown a signal collector A which is coupled to the input electrodes of the first radio frequency amplifier tube 1; the coupling network comprises the primary coil L_1 and the secondary coil L_2 . The inherent capacity of the antenna A takes the place of C_4 of Fig. 1. The junction of these two coils is connected to ground through a resistor R_1 , and this resistor may have a magnitude of the order of one-half megohm; the resistor functioning to complete the direct current path between the control grid of tube 1 and the grounded side of resistor 2 in the cathode circuit of the tube. It will be understood that the resistor 2 is the customary grid bias resistor disposed in the space current path of the amplifier, the radio frequency by-pass condenser 2' functioning in the usual manner. The variable tuning condenser C_2 has its rotors at ground potential, and the junction of coils L_1 and L_2 is connected to ground through a second path including the coupling condenser C_1 .

The condenser C_3 connects the high alternating potential ends of the primary and secondary coils. The tube 1 may have its plate circuit coupled to the usual networks of a superheterodyne receiver, or a tuned radio frequency amplifier type receiver. Furthermore, the variable tuning condenser C_2 may be considered as being adjustable through the broadcast band of approximately 500 to 1500 kc. The signal collector A may be of any desired type. The present coupling network is of particular value in cases such as in an automobile radio receiver, where the antenna must be physically small. In such case it is of great importance, since the collected signal amplitude is small, to transmit the collected signal energy to the first amplifier tube uniformly and with high gain. The network shown in Fig. 3 will function to produce such a high, and uniform, gain-frequency characteristic. In Fig. 3, L_1 resonates the combination of C_1 and the antenna capacity at, or near, the low frequency end of the tuning range. Wherever the condenser C_4 is used, the latter together with C_1 resonates L_1 , at, or near, the low frequency end of the tuning range.

In Fig. 4, the radio frequency amplifier tubes 3 and 4 are shown coupled by the coupling network of my invention. The tube 3 has its input electrodes coupled across the tunable input circuit 5; the latter may be coupled to any signal source, such as a signal collector device, or even a prior tunable amplifier stage. The grid bias network 6 is disposed in the grounded cathode lead of tube 3; the plate of tube 3 is connected to a positive potential source through coil L_1 . The secondary coil L_2 has its high potential end connected to the plate end of primary coil L_1 through a condenser C_3 . The condenser C_1 connects the low potential end of coil L_2 to ground; the condenser C_4 connects the plate end of coil L_1 to the junction of coil L_2 and condenser C_1 . The condenser C_5 acts as a resonating condenser for the coil L_1 . The capacity of condensers $C_4-C_1-C_5$, the effect of C_5 being negligible, resonate L_1 at, or near, the low frequency end of the tuning range. The portion of the low frequency resonated circuit which comprises C_1 is,

also, part of the tunable circuit, and acts as a coupling to the latter.

The variable condenser C_2 is shunted across coil L_2 and condenser C_1 ; the resistor R acts as the direct current path for the grid of tube 4, and it connects the low potential end of coil L to the grounded terminal of grid bias resistor 7. The condenser C acts as a carrier by-pass condenser for the low potential end of coil L_1 . As explained previously, the condensers C_3 and C_1 function to provide the gain-frequency characteristics which will result in the curve C of Fig. 2. Variable condensers 5' and C_2 will be uni-controlled, so as to tune circuits 5 and L_2 — C_2 to the same carrier frequencies of the tuning range.

In Figs. 5 and 6 are shown modifications of the coupling network in Fig. 4. Thus, in Fig. 5 the primary coil L_1 , condenser C_4 and condenser C_1 , all in series, connect the plate of amplifier tube 3 to ground; the coil 10 is a radio frequency choke coil and is located in the positive voltage lead to the amplifier plate, condenser C_5 bypassing the plate lead for radio frequencies. The secondary coil L_2 , in the succeeding tunable circuit, has its high potential end coupled to the high potential end of coil L_1 through condenser C_3 ; the low potential end of coil L_2 is connected to the junction of condensers C_4 and C_1 . The remaining elements of the network are the same as in Fig. 4.

In Fig. 6 the coupling network is varied in construction by feeding the plate current to tube 3 through the primary coil L_1 and choke coil 10 in series. The junction of these two coils is connected to ground through condensers C_4 and C_1 in series. The radio frequency bypass condenser C_5 is connected between the junction of coil L_2 and resistor R_1 and the junction of condensers C_4 and C_1 . In both Figs. 5 and 6 the condenser C_3 functions to transfer signal energy most efficiently at the high frequency end of the tuning range; the condenser C_1 transfers signal energy at the low frequency end of the tuning range.

The following values are given for an illustrative network, such as Fig. 3, and it is to be understood that the values are not restrictive:

Coil L_1 —370 microhenries

Coil L_2 —250 microhenries

Condenser C_1 —2900 mmf.

Condenser C_3 —15 mmf.

In Fig. 7, I have shown a coupling network employed between antenna A and amplifier tube 27; the network in this case acts to suppress voltage of signals other than the desired signal frequency. The network is of the bridge type, and comprises the tuning inductor 22 having one end connected to the grid side of coil 20. The antenna A is connected to the junction of coils 22 and 23 through condenser 21. The cathode of tube 27 is connected to ground through a path including coil 23 and self-biasing resistor 24, the latter being bypassed for radio frequencies by condenser 25. The variable condenser 26 tunes the coil 22 over the desired range of carrier frequencies.

It can be shown that at a frequency to be suppressed if

$$\frac{L_{20}}{L_{23}} = \frac{C_{21}}{C_{26}}$$

then no voltage at such frequency is developed between the grid and cathode of tube 27. In other words, with such relation, no voltage at the frequency to be suppressed is developed across

the input circuit of the amplifier. This frequency may be higher or lower than the desired signal frequency.

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 may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. A coupling network for transmitting energy with substantially uniform gain from a source of signal energy to a resonant input circuit, said resonant circuit including a coil and means for varying its frequency over a wide frequency range, said network including a second coil connected to said source, condensive means coupling the high potential ends of the two coils, and an additional condensive means coupling the low potential ends of said coils.

2. A coupling network as defined in claim 1, said second coil being untuned, and the signal transfer through said two condensive means being in opposed relation.

3. A coupling network for transmitting energy with substantially uniform gain from an antenna circuit to a resonant input circuit connected to a discharge tube, said coupling network comprising a primary coil connected in said antenna circuit, said resonant circuit including means for adjusting the tuning thereof over a desired signal frequency range, and a pair of independent capacity coupling paths between said primary coil and said resonant input circuit for transferring signal energy between the antenna circuit and the tube in opposed relation.

4. A coupling network, adapted to transfer signal energy in a desired signal frequency range, comprising an untuned primary coil upon which is impressed signal energy, a secondary coil, means for tuning said secondary coil over said range, a condenser, coupling the high potential ends of said two coils, transferring signal energy most efficiently at the high frequency end of said tuning range and a second condenser, connected between the low potential ends of said two coils, transferring signal energy most efficiently at the low frequency end of said tuning range.

5. In a network as defined in claim 4, there being zero magnetic coupling between said two coils.

6. A coupling network arranged to connect a pair of amplifier tubes in cascade, said coupling network comprising a primary coil and a secondary coil; there being zero magnetic coupling between said coils, means for resonating solely said secondary coil to a desired signal frequency, and a pair of independent condensers coupling the high potential ends of said coils and the low potential ends of said coils.

7. In a network as defined in claim 6, an additional condenser connected in series with said primary coil for resonating the latter.

8. In a network as defined in claim 4, a third condenser connected in series relation with said primary coil and said second condenser.

9. In a network as defined in claim 6, said high potential coupling condenser transferring signal energy most efficiently at the high frequency end of the tuning range.

10. A coupling network, adapted to transfer signal energy in a desired frequency range, comprising an untuned coil and a tuned coil with zero

magnetic coupling between them, the coupling between the circuits connected to the two coils comprising two condensers, one connecting the high potential ends of the coils, and the other being at the low potential ends of the coils and common to the circuits of both coils.

11. A signal coupling network, adapted to transfer energy in a desired frequency range, comprising an untuned coil and a tuned coil arranged to have zero magnetic coupling between them, a condenser connected to the high potential terminals of said coils whereby said condenser acts as the predominant coupling means at one end of the frequency range, and a second condenser connected to the low potential terminals of both coils and serially connected therewith whereby said condenser acts as the predominant coupling means at the opposite end of the frequency range.

12. A coupling network, as described in claim 10, wherein one of said coils is tuned to a frequency adjacent to the low frequency end of the desired range, and the other of the said coils includes in the circuit connected thereto means for tuning over the desired frequency range.

13. A coupling network, as defined in claim 10, wherein one of the coils is tuned to a fixed frequency within the desired range, and the other of said coils is connected in a circuit including means for tuning that circuit over the desired frequency range.

14. A signal coupling network, adapted to transfer energy in a desired frequency range, comprising a tunable circuit consisting of a pair of series connecting coils and a variable condenser, a third coil connected between the high potential terminal of said series connected coil pair and the high potential input terminal, a fixed condenser connected between the high potential input terminal and the junction between

the aforementioned series connected pair of coils, the output from the network being taken across the higher potential coil of the series pair, said third coil and said fixed condenser being so proportioned that when the network is tuned to transmit a desired frequency, the transmission through the network of an undesired frequency is less than would occur due to selective action of the tuned circuit.

15. A signal coupling network of the bridge type, adapted to tune over a frequency range and select a desired frequency within that range and to suppress an undesired frequency, comprising two coils in diagonally opposite arms of the bridge network, two condensers in the other arms of the bridge network, only one of said condensers being variable, the signal input being impressed across one diagonal of the bridge, and the signal output being taken across a third coil which is untuned and connected across the other diagonal of the bridge network.

16. A signal coupling network consisting of a fixed condenser, one coil, a variable condenser and a second coil connected in a closed mesh thereby forming the arms of a bridge type network, an untuned third coil connected between the junction of the variable condenser and one coil and the junction between the fixed condenser and the other coil, the input being across the two junctions to which the third coil is not connected, the coils and the fixed condenser forming the bridge arms being proportioned to suppress an undesired frequency, so that when the variable condenser is adjusted to obtain maximum output of a desired frequency across the said third coil, the bridge is balanced for the undesired frequency and substantially no output of the undesired frequency is obtained.

DUDLEY E. FOSTER. 40