June 15, 1937. P. O. FARNHAM 2,083,901

SELECTIVE COUPLING CIRCUITS

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Fig. 1.

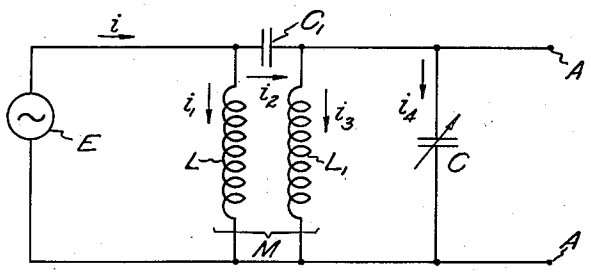
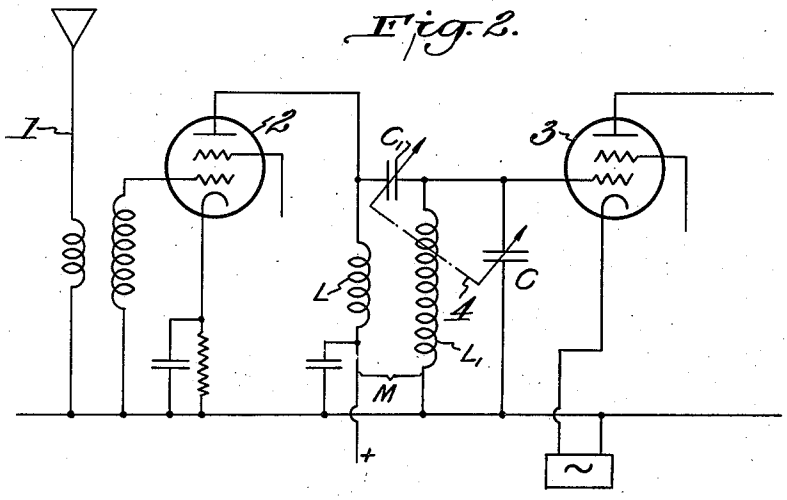


Fig. 2.



Inventor:

Paul O. Farnham,

By Byrnes Townsend & Potter,

Attorneys.

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SELECTIVE COUPLING CIRCUITS

Paul O. Farnham, Boonton, N. J., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

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5 Claims. (Cl. 250—20)

This invention relates to selective coupling circuits, and more particularly to coupling circuits which have the property of attenuating a disturbing frequency to a degree greater than that obtainable by tuning the known coupling circuits to the frequency which it is desired to transmit.

While not limited thereto, the invention will be described as applied to a superheterodyne receiver, in which type of receiver it operates as an "image" suppressor. In the operation of a superheterodyne receiver, two beat frequencies are produced when the local oscillation is combined with a received signal and, conversely, two signal frequencies may beat with the local oscillations to produce the same intermediate frequency. When a signal of a given frequency produces the required intermediate frequency, a signal of a frequency differing from the desired frequency by twice the intermediate frequency will also give rise to an intermediate frequency signal. This second frequency is commonly known as the "image" frequency since it produces an undesired intermediate frequency signal superposed upon the desired signal.

Selectivity effective to suppress the image frequency may be obtained by cascaded stages of tuned radio frequency in advance of the first detector, but, since adequate selectivity against signals other than one at the image frequency is provided in the intermediate frequency amplifier, it is not economical to include a large number of radio frequency stages in a superheterodyne receiver. The requirements for satisfactory operation in the broadcast band call for a minimum of two tuned radio frequency stages in advance of the first detector and, for nearly complete suppression of image frequencies, three tuned stages should be employed to secure the necessary selectivity.

In accordance with the present invention, the coupling system between two radio frequency amplifier tubes is so designed as to obtain an image frequency suppression that, with the known circuits, could be obtained only by the use of an additional tuned carrier wave amplifier stage.

An object of the invention is to provide a coupling circuit which will suppress an undesired signal frequency to a greater extent than a coupling circuit of the previously known types. An object of the invention is to provide an image frequency suppressor which will attenuate an undesired frequency to a degree not obtainable by tuning a conventional coupling circuit to resonance at the desired signal frequency. More specifically, an object is to provide a tuned coupling circuit which includes a tuned suppressor circuit for by-passing undesired signals. A further specific object is to provide a superheterodyne receiver system in which the particular image frequency corresponding to a desired signal will be substantially attenuated when the coupling system is tuned to the desired frequency.

These and other objects of the invention will be apparent from the following specification, when taken with the accompanying drawing, in which,

Fig. 1 is a circuit diagram of a coupling system embodying the invention, and

Fig. 2 is a fragmentary circuit diagram of a superheterodyne receiver embodying the invention.

In the circuit diagram of Fig. 1, the reference characters L, L_1 identify two inductances which are coupled magnetically by a mutual inductance M, the inductance L being included in circuit with an alternating current source E, and the inductance L_1 being shunted by a tuning condenser C. If the high potential terminals of the inductances are coupled by a capacity C_1, it will be apparent that two main paths are provided for the current i from source E. A part i_1 will flow through coil L, and a second part i_2 will flow through C_1. The current i_2 then takes two paths, a part i_3 flowing through coil L_1 as the remainder i_4 returns to source E through condenser C.

If, however, the magnetic coupling M is so chosen that the voltage induced across L_1 by the flow of current i_1 through L is equal and opposite to the voltage drop across L_1 due to the flow of current i_3, the net voltage drop across L_1 due to current flow from source E is zero, and current flow from source E does not affect the voltage across the terminals A of the coupled circuits. It should be pointed out that the sign of the mutual inductance for this condition is that given by having the coils L, L_1 wound and connected in the same sense.

A mathematical analysis of the circuit will show that the frequency for which the circuit has a maximum attenuation is:

$$\omega'^2=\frac{1}{MC_1}\times\frac{k^2}{1-k^2} \qquad (1)$$

where

$$k=\frac{M}{\sqrt{L_1L_2}}=\text{ coefficient of magnetic coupling.}$$

It is to be noted that this equation does not include the capacity of condenser C, and there-

fore the attenuation due to the opposing actions of the capacitive and the inductive couplings is not a function of the magnitude of the tuning capacity C. In other words, as condenser C is adjusted to tune the coupling system to a desired frequency, the undesired frequency most effectively suppressed by the capacitive coupling C_1 remains constant and the attenuation of all other undesired signals is only that due to the tuning of L_1 C to a particular frequency.

In the operation of a superheterodyne receiver, the image frequency varies with the tuning and is spaced from the desired frequency by a definite finite value equal to twice the intermediate frequency. It is therefore apparent that, to suppress the image frequency, some factor appearing in Equation (1) must be varied as the magnitude of condenser C is varied to tune to the desired signal within a frequency band.

An inspection of Equation (1) indicates that the coefficient of coupling between inductances L, L_1, or the values of the inductances may be varied to effect a maximum attenuation at a frequency which varies with the magnitude of capacity C, but the most convenient method is to vary the magnitude of the coupling condenser C_1. A mathematical analysis of the problem presented will show that, to effect a maximum suppression at a frequency ω' (equal to the signal frequency, ω, plus twice the intermediate frequency), the conditions obtaining are:

$$C_1 = C\left\{\left(\frac{\omega}{\omega'}\right)^2 \cdot \frac{L_1}{M} \cdot \frac{k^2}{1-k^2}\right\} \qquad (2)$$

In accordance with the invention, the adjustable elements of the condensers C and C_1 are related by Equation (2) thus showing that to provide maximum attenuation at the image frequency, the condenser C_1 varies in the same direction as the tuning condenser C, but at a somewhat slower rate.

In the fragmentary superheterodyne circuit shown in Fig. 2, the coupling from the collecting structure **1** to the first carrier frequency amplifier **2** may be of any desired form. The novel features are to be found in the coupling system between tubes **2** and **3**, the tube **3** being either an additional carrier wave amplifier or a first detector. The coupling system is substantially identical with that shown in Fig. 1, but the coupling condenser C_1 is mechanically connected to the tuning condenser C as is indicated by the dotted line **4**.

In one particular circuit arrangement, the several elements had the following values:

L=approximately 5.8 millihenries

L_1=approximately 200 microhenries

C=maximum, approximately 400 micromicrofarads

C_1=from about 8 micromicrofarads at 550 kilocycles to about 1.5 micromicrofarads at 1500 kilocycles.

By thus varying the value of the coupling condenser C_1 as the circuit is tuned over a frequency band by adjustment of condenser C, signals of all frequencies other than the resonant frequency are attenuated and a further suppression of the image frequency is obtained.

The invention provides an additional suppression of image frequencies which is comparable to that obtained by the use of an additional tuned carrier amplifier stage. It has, however, the great advantage of low cost since, for equal suppression of the image frequency, an amplifier constructed in accordance with the invention requires but one small variable condenser instead of a complete tuned amplifier stage.

While I have illustrated the embodiment of the invention which now seems most practical, it will be apparent that, without departing from the invention as set forth in the following claims, one or more of the other factors which control the relationship between the desired and image frequency may be varied in addition to, or in place of, the described variation of the capacitive coupling.

I claim:

1. In a transmission system adapted for the selective transmission of alternating currents and having a pair of input and a pair of output terminals, one input terminal being in common with one output terminal, the combination with a coil and a tuning condenser connected in parallel across one of said pairs of terminals and forming a tunable circuit adjustable to provide maximum transmission for currents of a desired frequency and comprising the only tunable circuit connected across said terminals, and a second coil connected between the other pair of terminals and having mutual electromagnetic coupling to said first coil, of additional means coupling said coils to effect a maximum attenuation at a frequency differing from said desired frequency, said means comprising a capacity connected between points on said coils of substantially different alternating current potential, said capacity having such a value that the voltage induced in said second coil due to its inductive coupling with the first coil for currents of the undesired frequency is neutralized by the voltage induced therein by currents of the undesired frequency transmitted through said capacity.

2. A transmission system as claimed in claim 1, in combination with means operable simultaneously with adjustments of said tuning condenser for varying one of the said couplings between said coils at that rate which maintains a substantially constant interval between the frequencies of maximum attenuation and maximum transmission throughout the tuning range of said tuning condenser.

3. Means for transferring currents of a desired frequency between a pair of input and a pair of output terminals while preventing the transfer of currents of an undesired frequency therebetween comprising in combination, a coil connected across said input terminals, a second coil connected across said output terminals and inductively coupled to said first coil, a variable tuning condenser connected across said output terminals and a variable condenser having its opposite sides connected to points of said coils of substantially different alternating current potential, said coils and condensers having the relationship

$$C_1 = C\left\{\left(\frac{\omega}{\omega'}\right)^2 \times \frac{L_1}{M} \times \frac{k^2}{1-k^2}\right\}$$

wherein,

C_1 is the capacity of the second named condenser,

C is the capacity of the tuning condenser,

ω is the desired frequency,

ω' is the undesired frequency

M is the mutual inductance of the two coils, and

k is the coefficient of magnetic coupling between the coils and L_1 is the inductance of said second coil.

4. In a transmission system adapted for the selective transmission of alternating currents and having a pair of input and a pair of output termi-

nals, a direct connection between the low potential pair of terminals, a coil and a tuning condenser connected in parallel across said output terminals and forming a tunable circuit adjustable to provide maximum transmission for currents of a desired frequency and comprising the only tunable circuit across said output terminals, a second coil connected across said input terminals and having mutual electromagnetic coupling to said first coil and a variable condenser having its opposite sides directly connected to the high potential terminals of said coils, the maximum capacity of said variable condenser having a value of the order of two per cent of the maximum value of said tuning condenser.

5. A transmission system according to claim 4 in which a uni-control operating means is connected to said tuning and variable condensers and said variable condenser is so constructed that its capacity increases at a slower rate than that of said tuning condenser.

PAUL O. FARNHAM.