Sept. 27, 1938. P. F. BECHBERGER ET AL 2,131,424

SELECTIVE VOICE FREQUENCY RELAY

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Fig. 1.

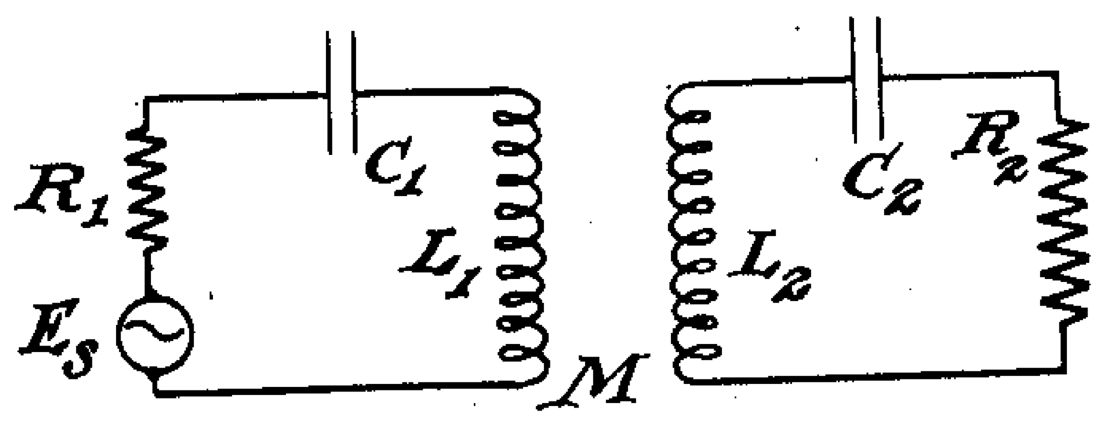
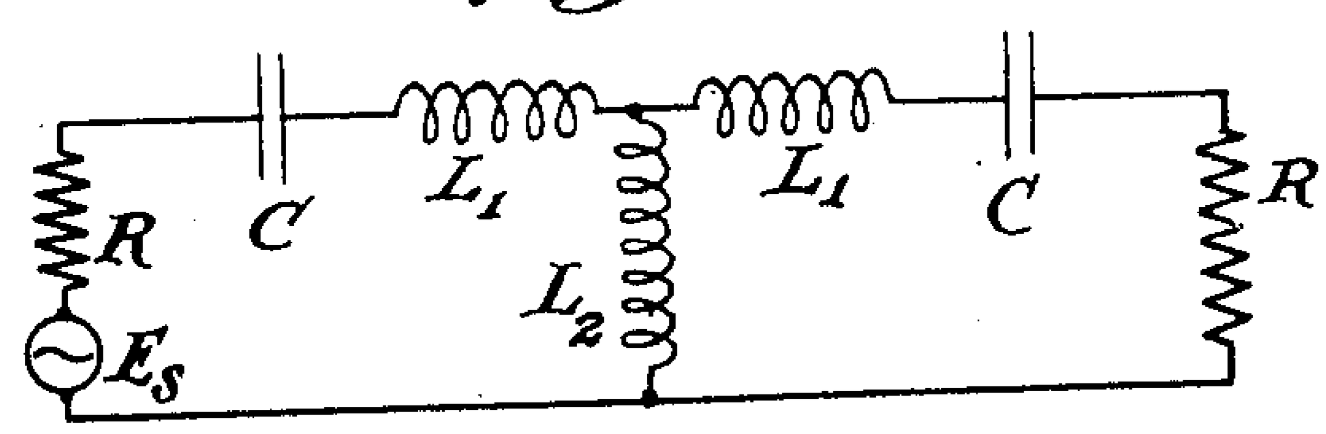
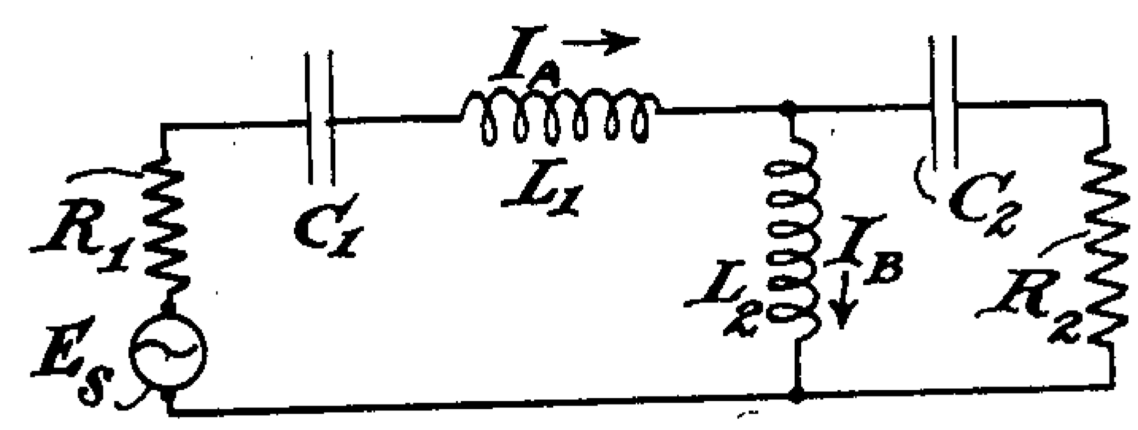


Fig. 2.





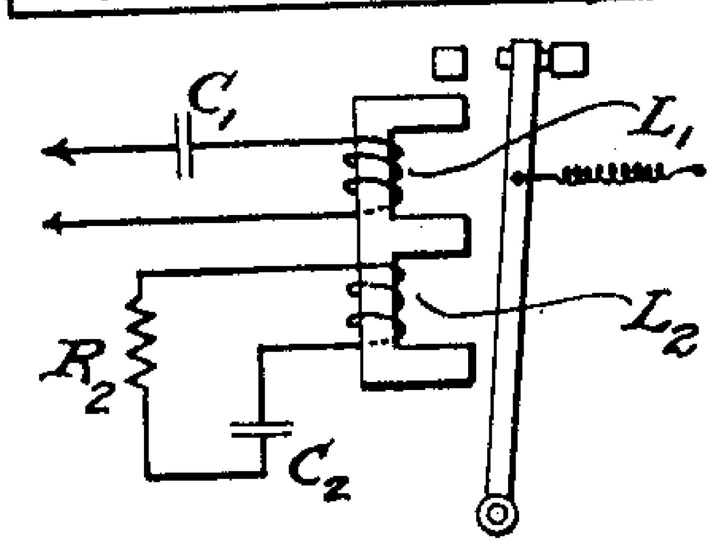
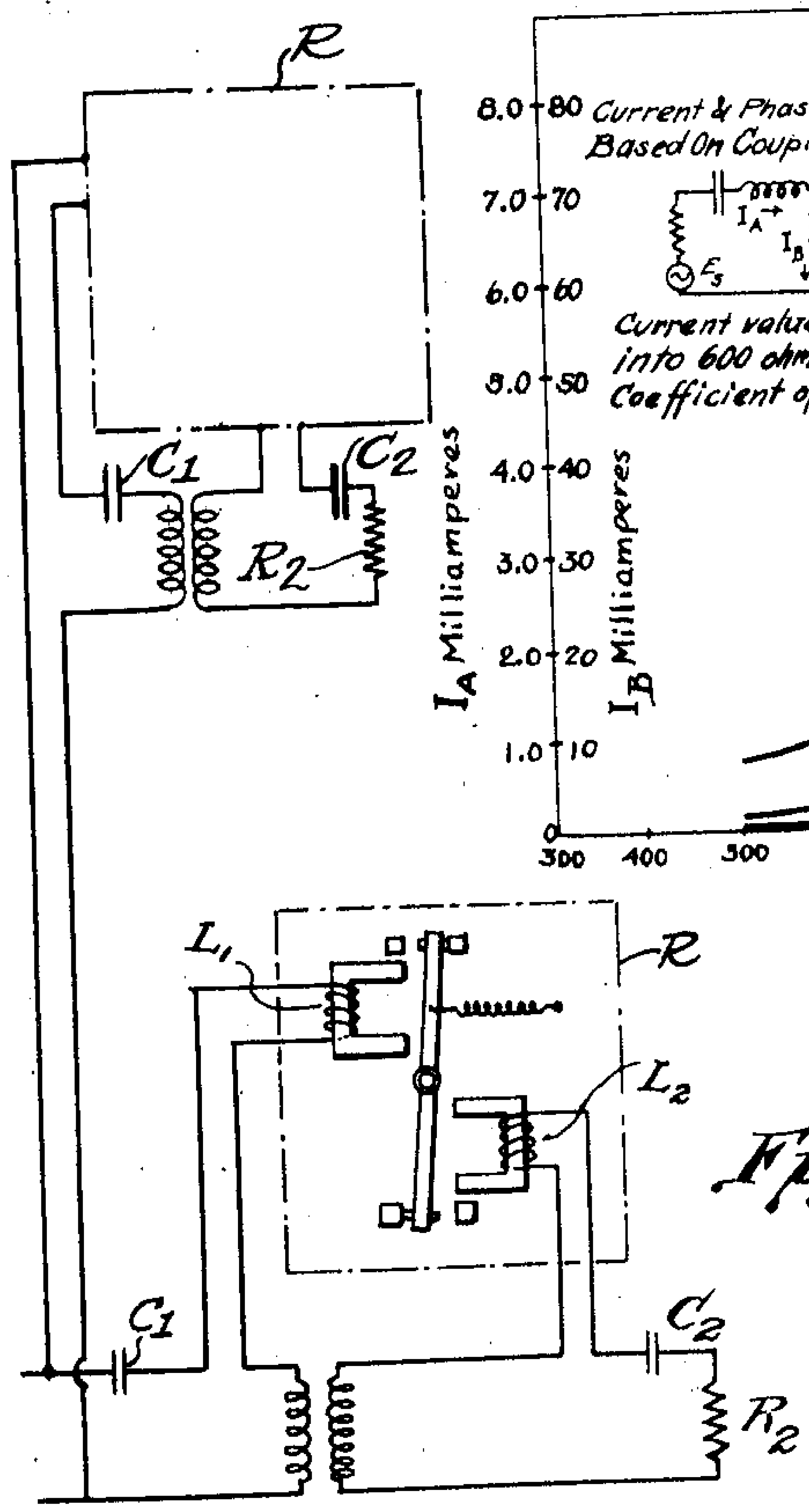


Fig. 6.

Fig. 3.



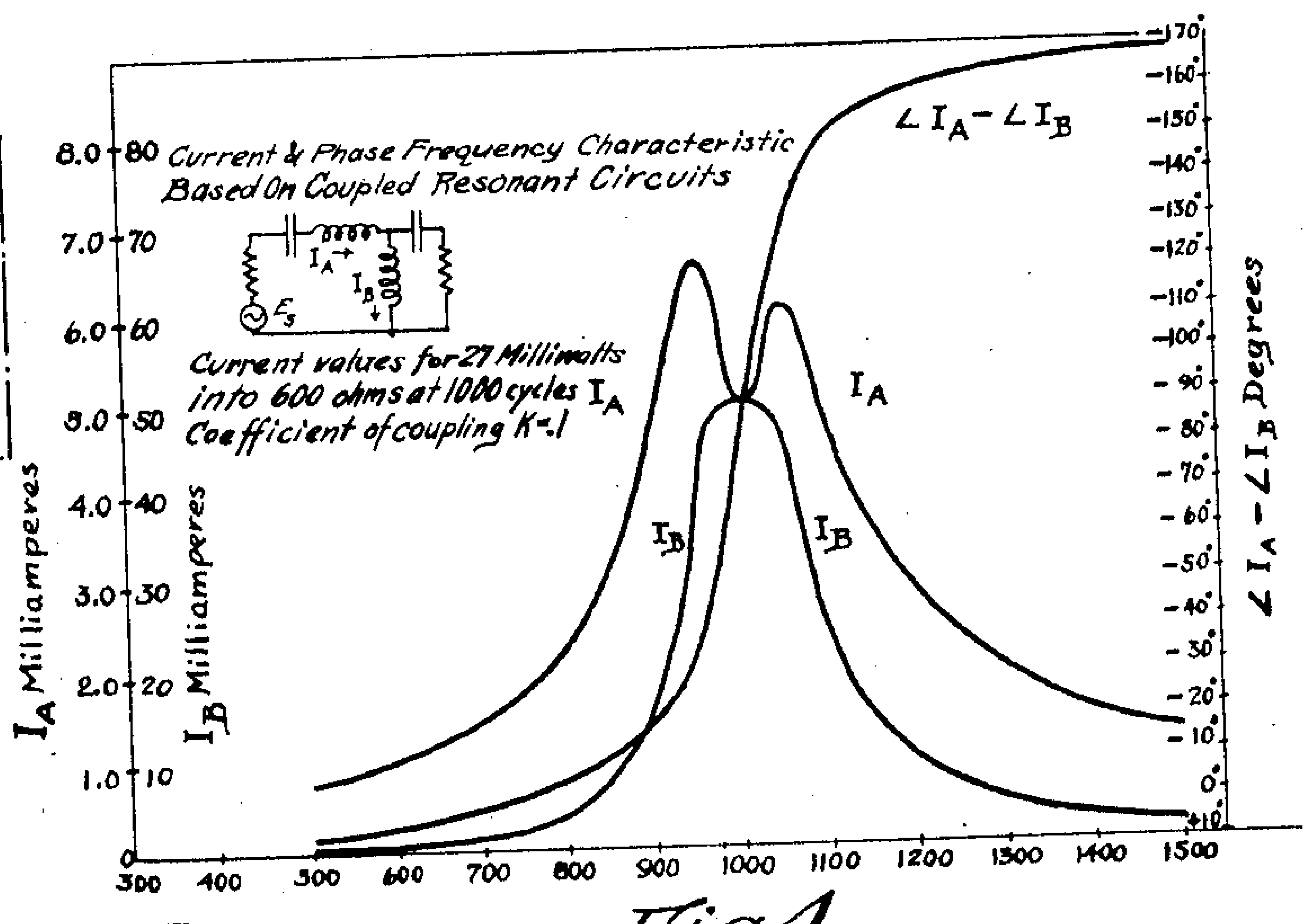


Fig. 4.

Fig. 7.

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Fig. 5.

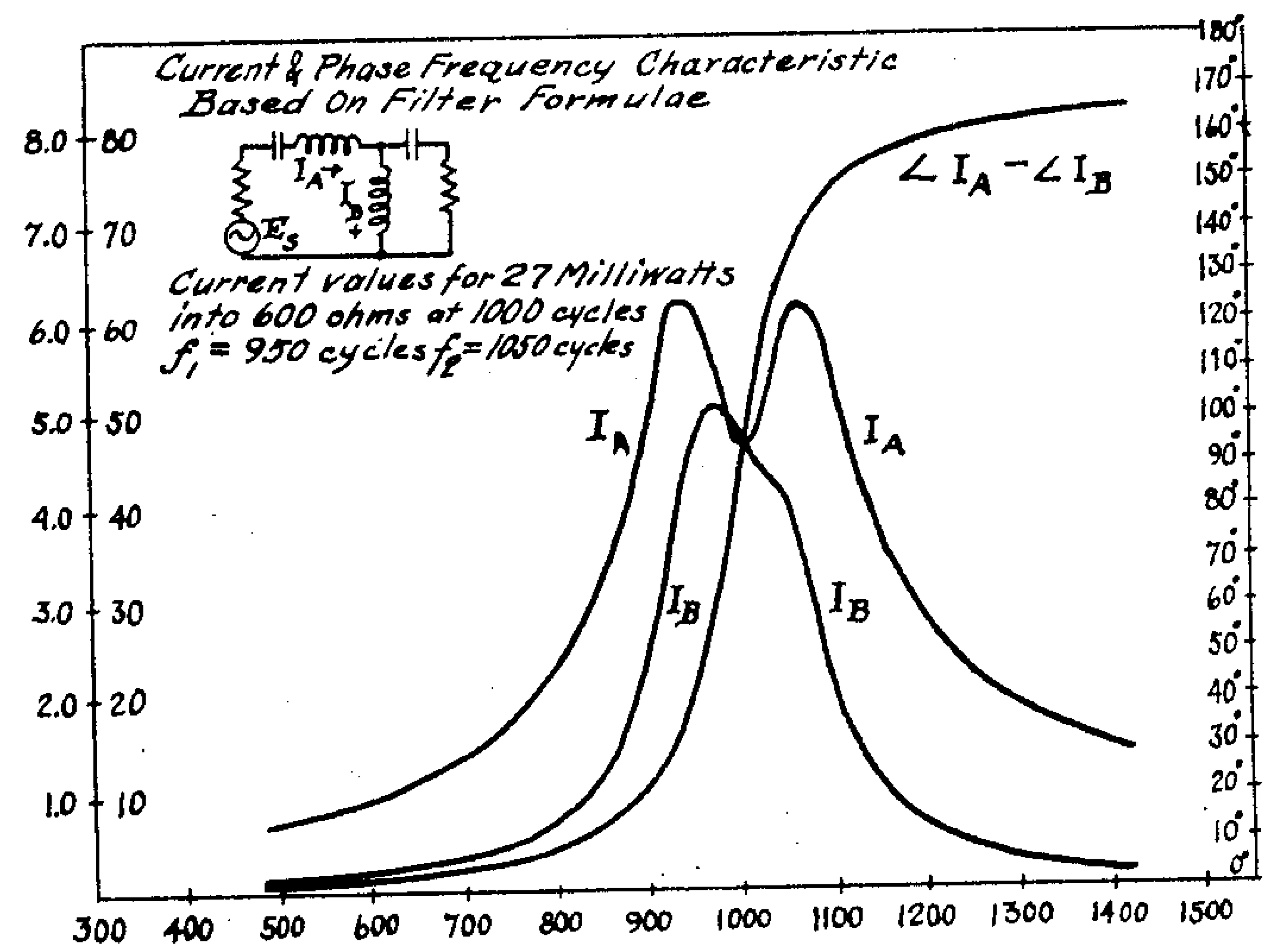


Fig. 8.

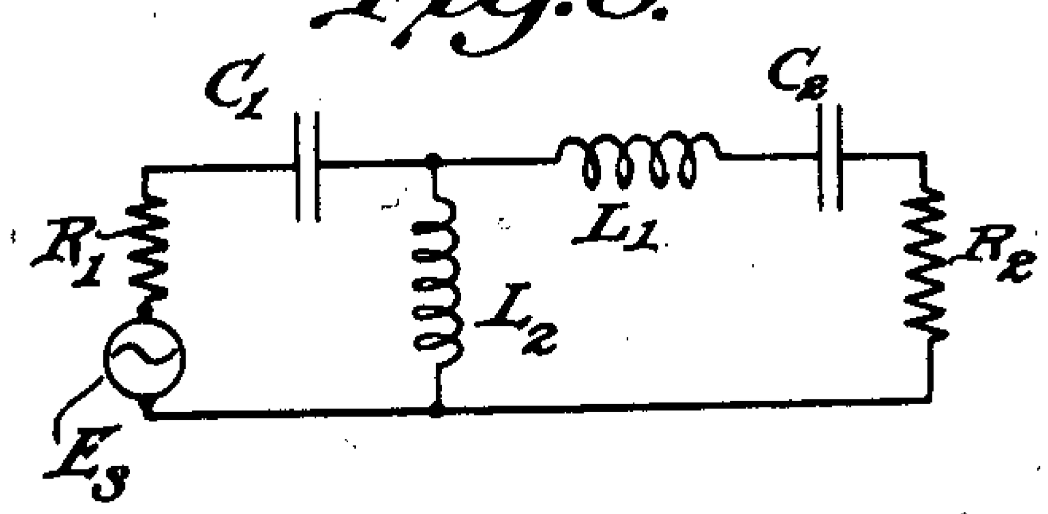


Fig. 9.

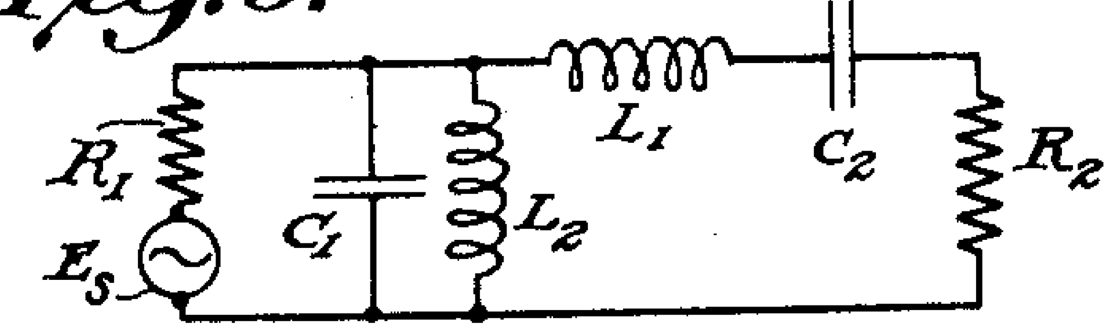


Fig. 10.

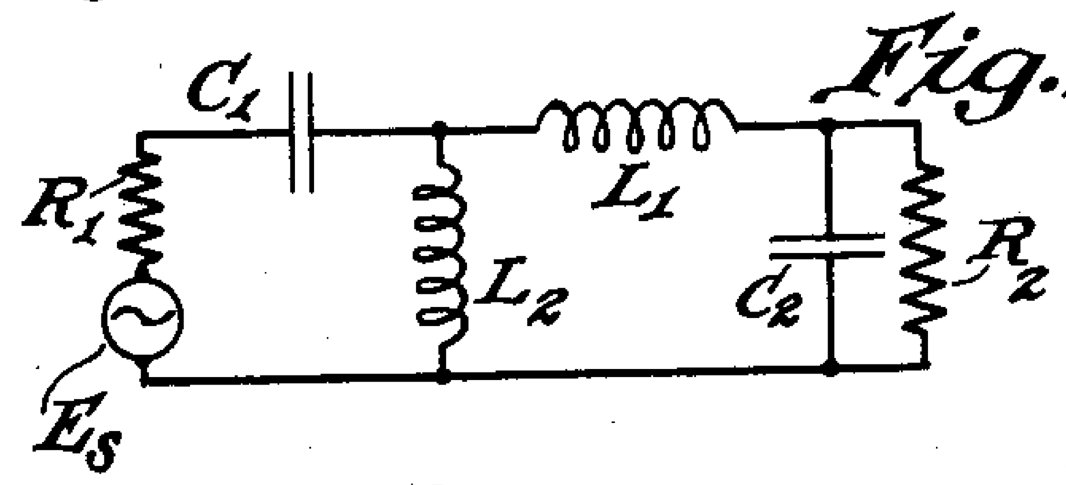
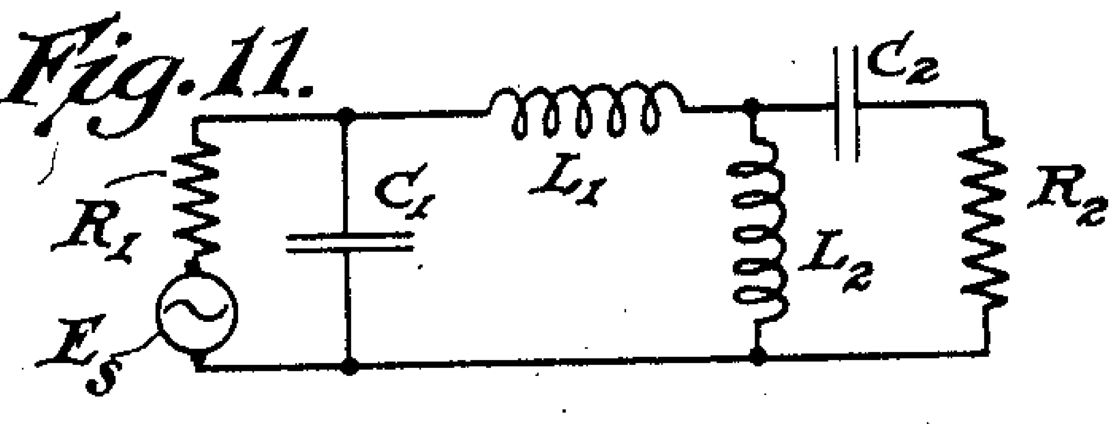


Fig. 11.



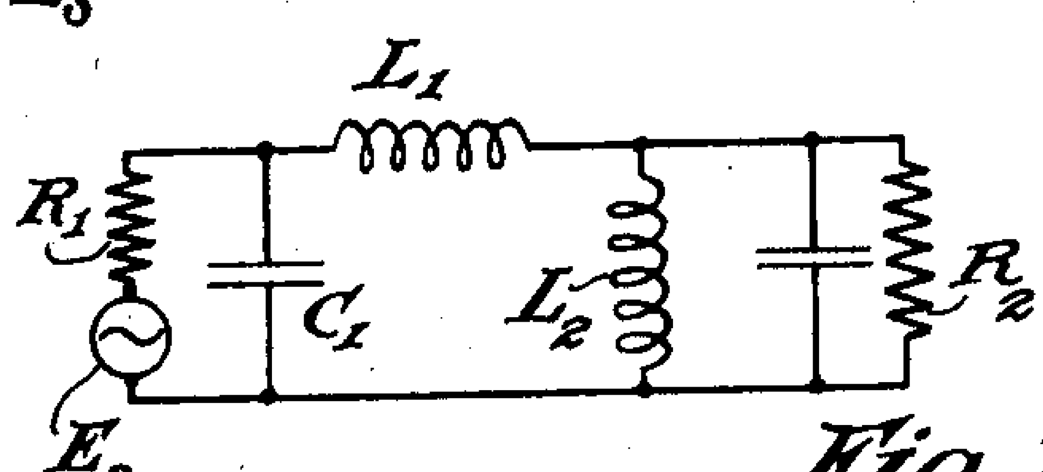


Fig. 12.

Fig. 13.

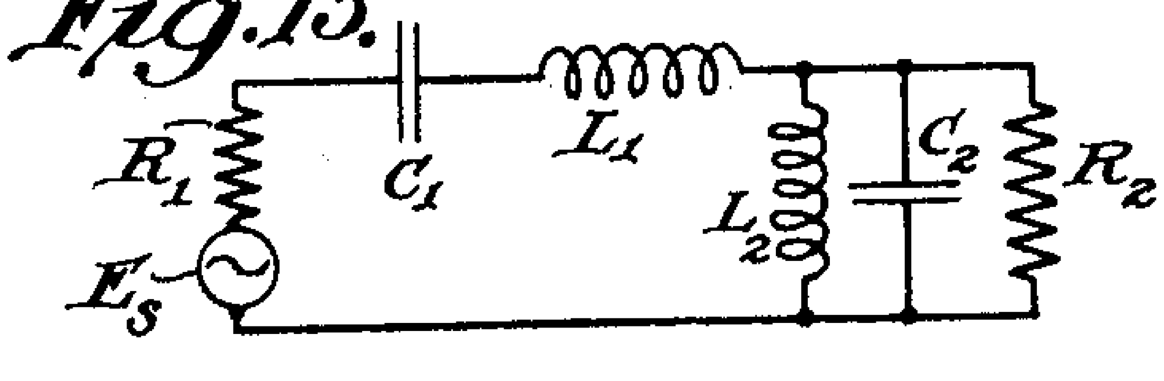


Fig. 14.

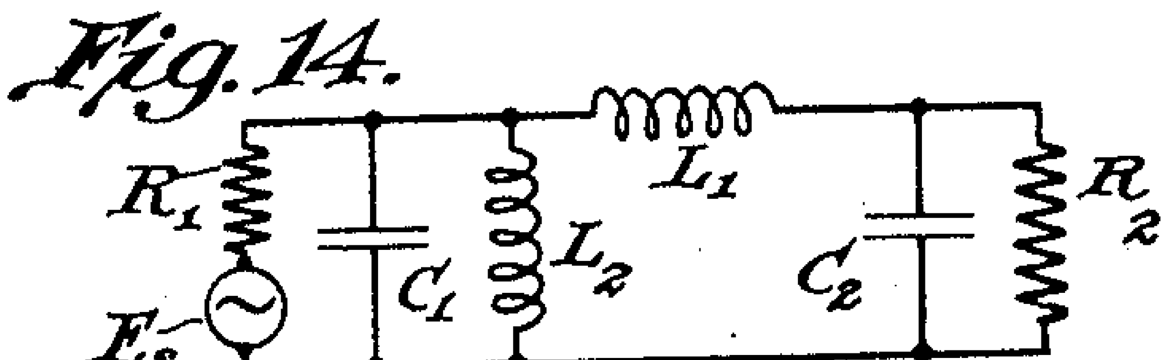
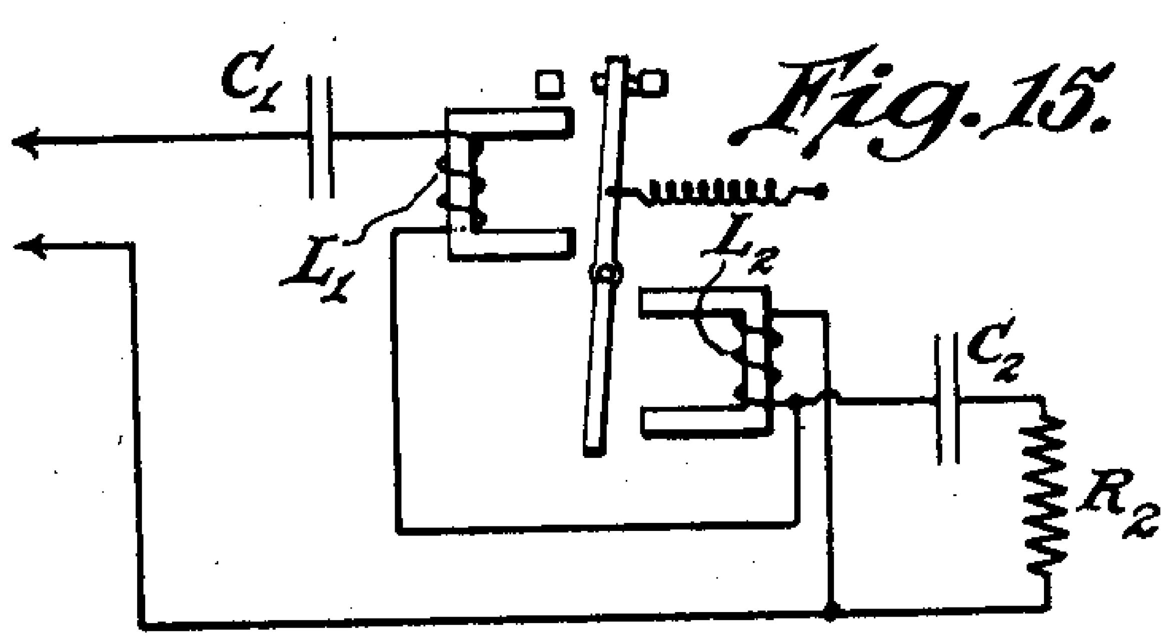


Fig. 15.



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UNITED STATES PATENT OFFICE

2,131,424

SELECTIVE VOICE FREQUENCY RELAY

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Application May 8, 1934, Serial No. 724,540

7 Claims. (Cl. 175—320)

This invention relates to alternating current electro-magnetic devices, such as relays, which are selective to a particular frequency band and are especially adapted for multi-channel carrier current telegraph systems, although their use is not confined thereto.

It is known that electro-magnets, relays and similar devices, having only one magnetic circuit will not operate smoothly from an alternating current source because the alternating flux becomes zero twice in each cycle. To overcome this difficulty such devices have been made with two magnetic circuits energized by currents supplied at the same frequency but differing in phase so that the magnetic torque applied to the armature will never become zero. It is desirable to obtain the two currents from the same source and to obtain the phase difference by some phase shifting device. This has been accomplished in various ways, the shaded pole alternating current relay being a common application.

It is often desirable to have a relay respond more readily to one frequency or band of frequencies than to other frequencies. The object of our invention is to provide a relay of this character in which the energizing windings will embody the inductance of the frequency discriminating circuit and to obtain both desirable characteristics, viz;—frequency selection and smooth operation over the responsive band.

In explaining the principles underlying our invention and the manner of applying the same to relays, we shall refer to the accompanying drawings, in which—

Figures 1 to 3, and 8 to 14 are diagrams explanatory of the underlying principles;

Figures 4 and 5 are plotted curves showing the current and phase frequency characteristics of the coupled resonant circuits of relays embodying our invention and operating under certain stated conditions.

Figures 8 to 14 are diagrams illustrating various modified arrangements of the elements in the resonant circuits of the relay.

Figures 6, 7 and 15 are schematic diagrams of relays constructed in accordance with this invention.

In constructing an alternating current relay responsive to and operating smoothly over a band of frequencies, we provide the relay with two windings which are arranged as elements of resonant circuits. By properly tuning and coupling these two circuits we obtain the desired characteristics above mentioned.

By proper use of resonant circuits the currents I_A and I_B flowing in the respective windings of the relay, may be built up to several times the value that could ordinarily be obtained. To make this clear, we shall now refer to the principles underlying our relay construction.

Referring to Fig. 1, let the following relations in the two inductively coupled resonant circuits hold among the circuit constants:

$$L_1C_1=L_2C_2=\frac{1}{\omega_o^2} \qquad (1)$$

$$R_1=\omega_oL_1K \text{ and } R_2=\omega_oL_2K \qquad (2)$$

where

$$K=\frac{M}{\sqrt{L_1L_2}} \qquad (3)$$

$\mu_o=2\pi$ times the resonant frequency. (4)

K=the coefficient of coupling between the two inductances L_1 and L_2. (5)

M=the mutual inductance between the two inductances L_1 and L_2. (6)

Substituting for the loose coupled transformer L_1 and L_2 its equivalent transformer and multiplying $1/C_2$ and R_2 by

$$\frac{L_1}{L_2}$$

we have a circuit as in Fig. 2.

Here the relations are as follows:

$$(L_1+L_2)C=\frac{1}{\omega_o^2} \qquad (7)$$

$$R=\omega_o(L_1+L_2)K \qquad (8)$$

$$L_2=(L_1+L_2)K \qquad (9)$$

Now, if we refer both the "leakage" inductances (L_1) of the equivalent transformer of Fig. 2 to the left side, making a dissymmetrical equivalent transformer of only two inductances, and changing the circuit constants to suit, we have the circuit shown in Fig. 3.

The circuit relations now become—

$$R_1=\omega_o(L_1+L_2)K \qquad (10)$$

$$R_2=\omega_oL_2K \qquad (11)$$

$$(L_1+L_2)C_1=L_2C_2=\frac{1}{\omega_o^2} \qquad (12)$$

$$L_2=(L_1+L_2)K^2 \qquad (13)$$

Assuming a practical value of K=.1, and frequency f_o=1000, and determining how the currents I_A and I_B and their phase difference vary with frequency, we have the curves shown in Fig. 4. It will be observed that this circuit has marked phase shifting and frequency discriminating properties.

Let us now take another example, namely, a band pass filter. Starting with a constant K type of band pass filter as shown in Fig. 2, f_1 and f_2 being the lower and upper frequency limits respectively, the circuit relations are as follows:—

$$L_1=\frac{f_1R}{2\pi f_2(f_2-f_1)} \tag{14}$$

$$C_1=\frac{f_2-f_1}{2\pi f_1f_2R} \tag{15}$$

$$L_2=\frac{(f_1+f_2)R}{4\pi f_1f_2} \tag{16}$$

Replacing the symmetrical equivalent transformer composed of two L_1's and L_2 in Fig. 2 by a dissymmetrical equivalent transformer of two inductances, we have a circuit as in Fig. 3.

Now the circuit relations are—

$$L_1=\frac{R_1f_1f_2}{\pi(f_2-f_1)(f_2^2+f_1^2)} \tag{17}$$

$$L_2=\frac{R_1(f_2+f_1)(f_2^2-f_1^2)}{4\pi f_1f_2(f_2^2+f_1^2)} \tag{18}$$

$$C_1=\frac{f_2-f_1}{2\pi f_1f_2R_1} \tag{19}$$

$$C_2=\frac{(f_2^2+f_1^2)^2}{2\pi R_1f_1f_2(f_2+f_1)(f_2^2-f_1^2)} \tag{20}$$

$$R_2=R_1\frac{(f_2^2-f_1^2)^2}{(f_2^2+f_1^2)^2} \tag{21}$$

Choosing practical values of $f_1=950$ and $f_2=1050$ cycles and plotting the currents and their phase difference against frequency, we have Fig. 5. This circuit is also seen to be satisfactory.

The example shown in Fig. 3 is but one of many satisfactory circuits and is merely representative of resonant circuits and band pass filters. Diagrams of some other circuits which may be used are given in Figs. 8 to 14, inclusive.

In all of the various modifications, the series and shunt impedances of the selective network constitute the two energizing windings of the relay, as shown in Fig. 15. In the cases illustrated, each winding is associated with a condenser.

It is sometimes desirable to design the two magnetic circuits with part of their paths in common, as shown in Fig. 6, thereby giving the desired coupling between the two frequency discriminating circuits.

In a multi-channel carrier telegraph system, relays of this type operating over the same band width, and from the same value of impedance, would have the same value of L_1. However, L_2 will be different for each channel frequency. If now both windings on relays for all the channels are made to have the same inductance value, and the two circuits in each case are connected by a transformer as illustrated in Fig. 7, having a turn ratio of

$$\sqrt{\frac{L_1}{L_2}}$$

then the relays are interchangeable in the several channels insofar as the windings, magnetic circuits and moving parts are concerned. The interchangeable relay apparatus is embraced within the dotted line rectangles R in Fig. 7. In relays receiving a constant band width and employing the type of circuit exemplified by Figs. 3 and 13, the turn ratio of the associated transformers is approximately directly proportional to the frequency to be received. In cases such as Figs. 8 and 10 a similar but inverse proportion is involved.

We have illustrated a number of circuit arrangements embodying our invention but it will be evident to engineers that other modifications can be made within the scope of our invention and within the purview of the appended claims.

We claim:

1. A relay adapted to be operated by current of a definite band of frequencies, comprising a network selective to said band of frequencies and having series and shunt branches, each branch including an inductive element and a condenser, said relay having energizing windings constituting respectively the inductive elements of the series and shunt branches of said network.

2. In a relay device as set forth in claim 1, means for increasing the flow of current in the relay windings by making the elements of each branch of the network resonant at approximately the frequency to be received.

3. An electromagnetic device responsive to a definite band of frequencies, comprising energizing windings arranged in series and shunt relation, condensers connected in circuit with each of said windings, said windings and condensers jointly constituting a network selective to said band of frequencies and excluding frequencies outside of said band.

4. An electromagnetic device responsive to a definite band of frequencies, comprising energizing windings arranged in series and shunt relation, condensers connected in circuit with each of said windings to form circuits resonant at approximately the desired frequency, said resonant circuits jointly constituting a network selective to said band of frequencies and excluding frequencies outside of said band.

5. An electromagnetic device responsive to a definite band of frequencies, comprising two magnetic circuits having a common path forming a portion of each circuit, energizing windings for said circuits and condensers connected in circuit with each of said windings to form resonant circuits at a given frequency, said windings and condensers jointly constituting a network selective to said band of frequencies and excluding frequencies outside of said band, said common magnetic portion forming a coupling between said two circuits.

6. An electromagnetic device responsive to a definite range of frequencies comprising energizing windings, condensers connected to said windings, said windings and condensers jointly constituting a network selective to said range of frequencies.

7. An alternating current relay having a plurality of flux producing elements, auxiliary impedance elements connected to said first named elements and causing the relay to respond to an exclusive range of frequencies.

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