

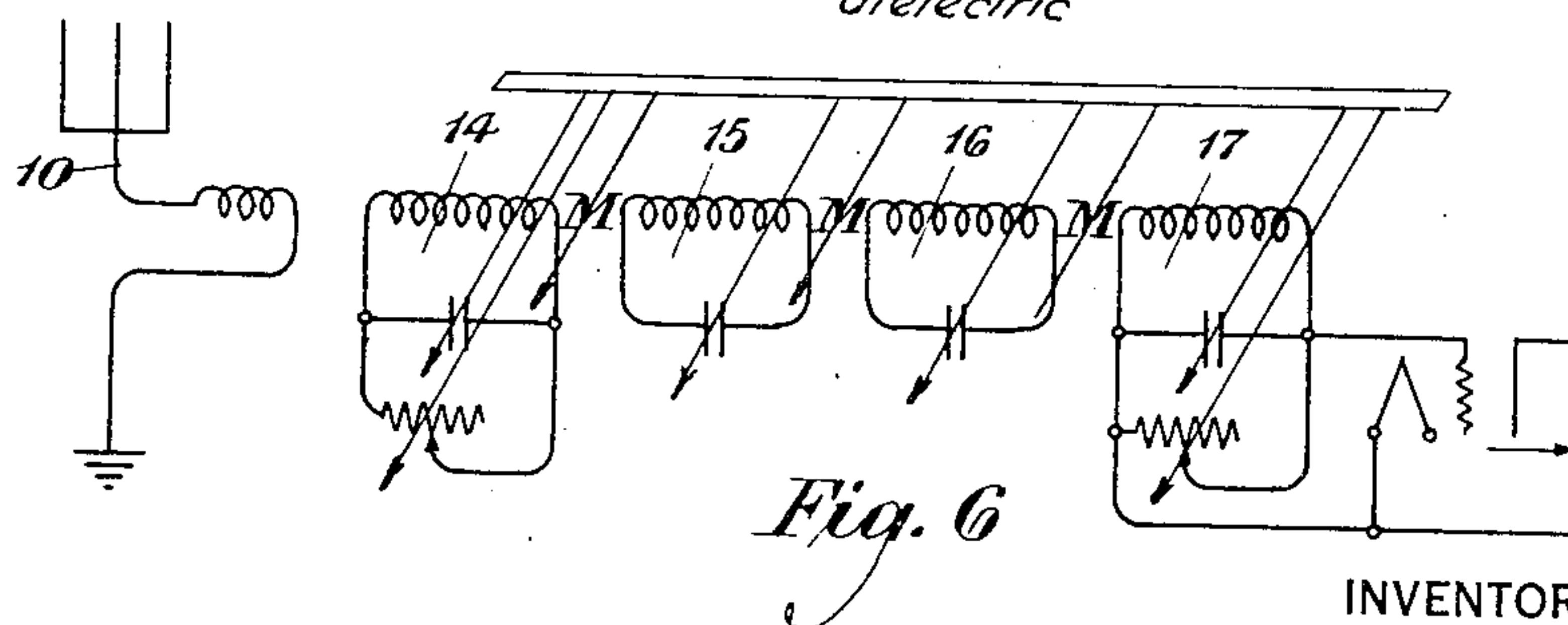
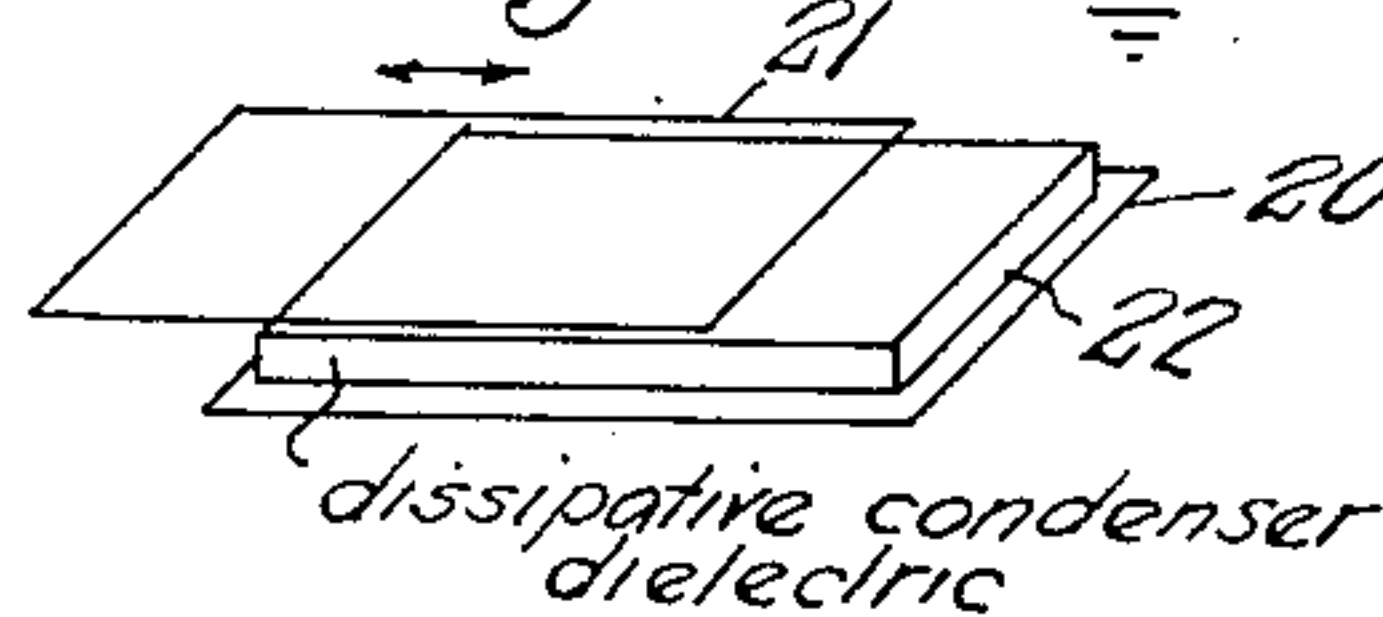
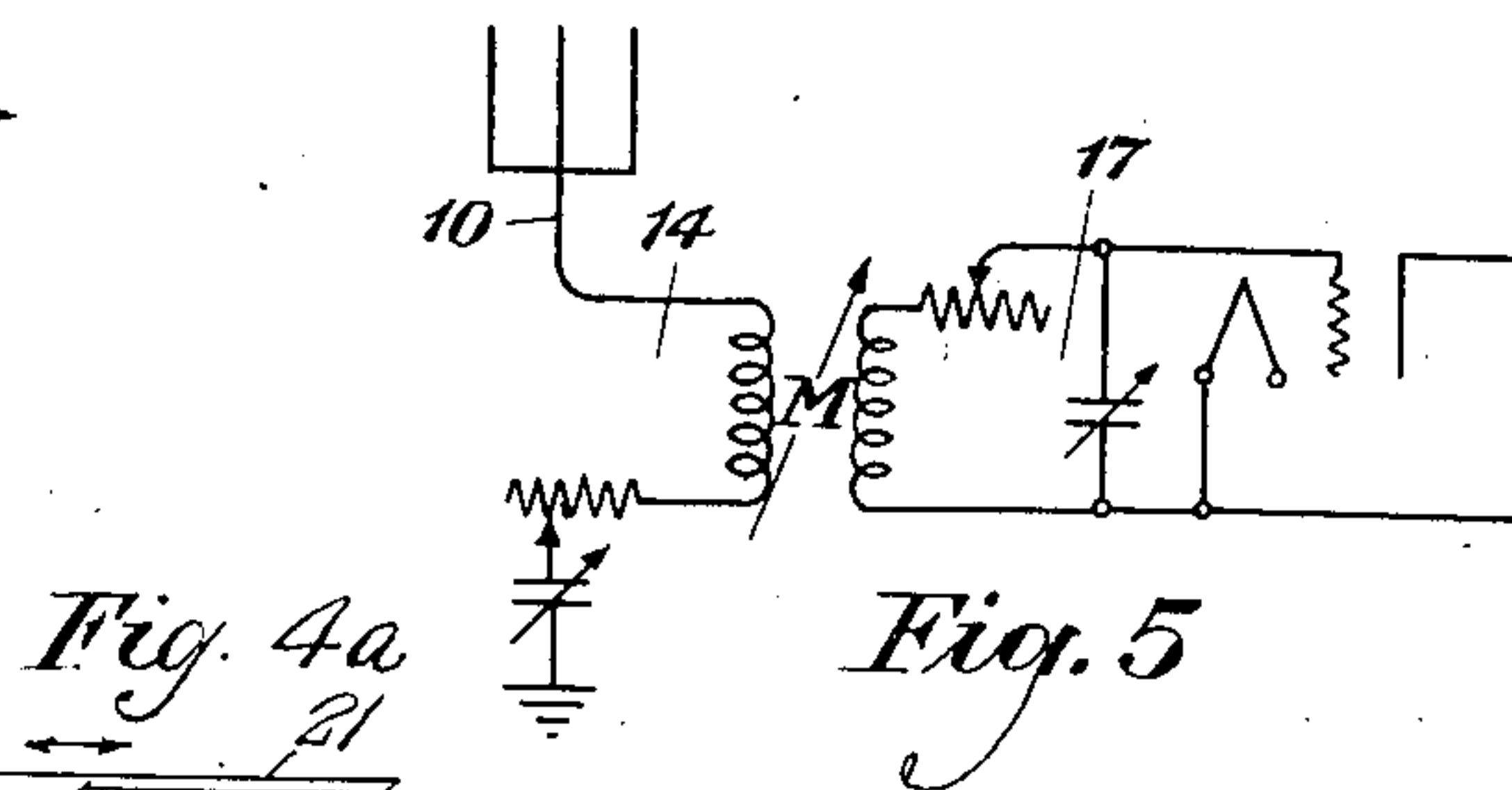
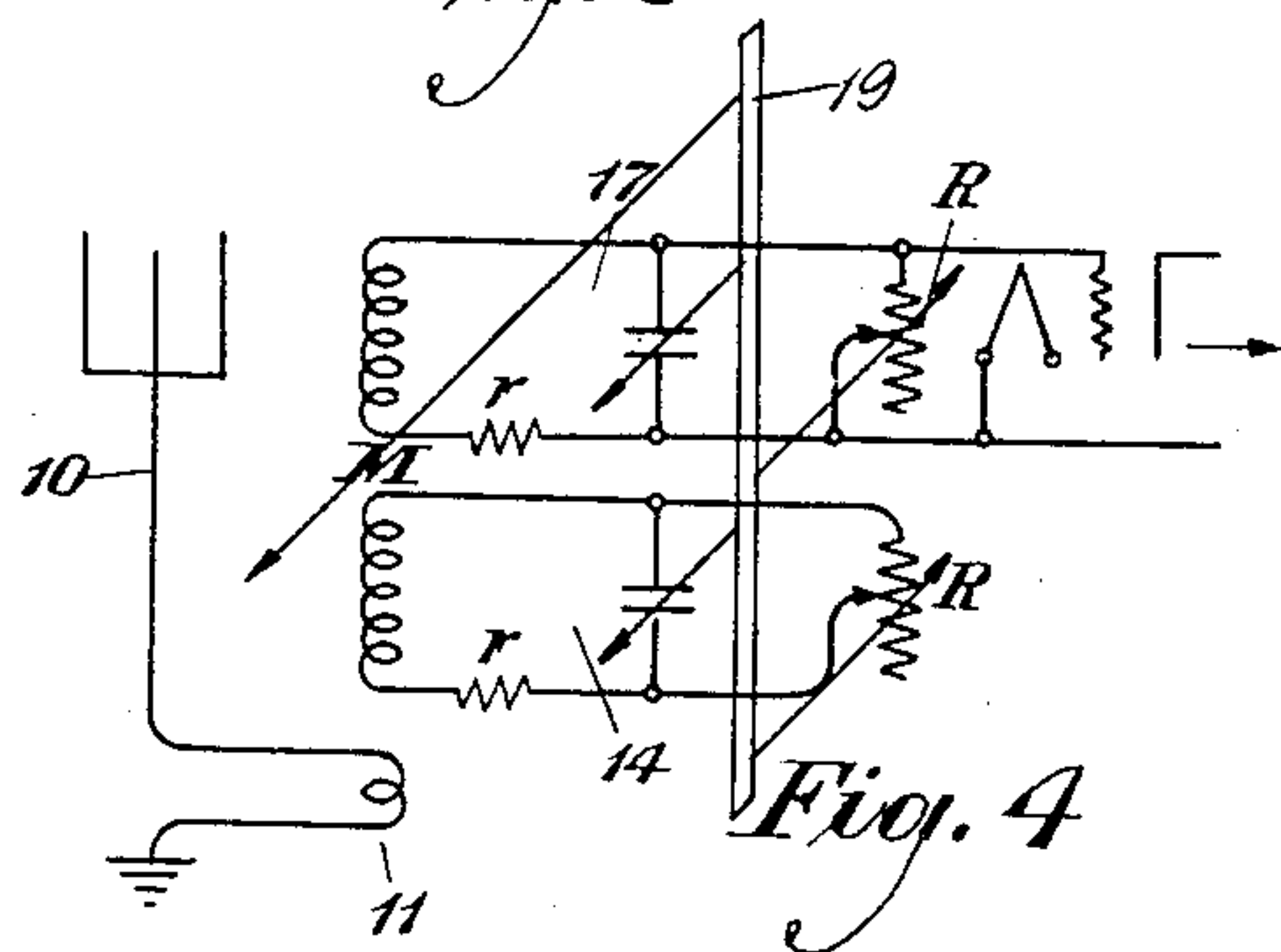
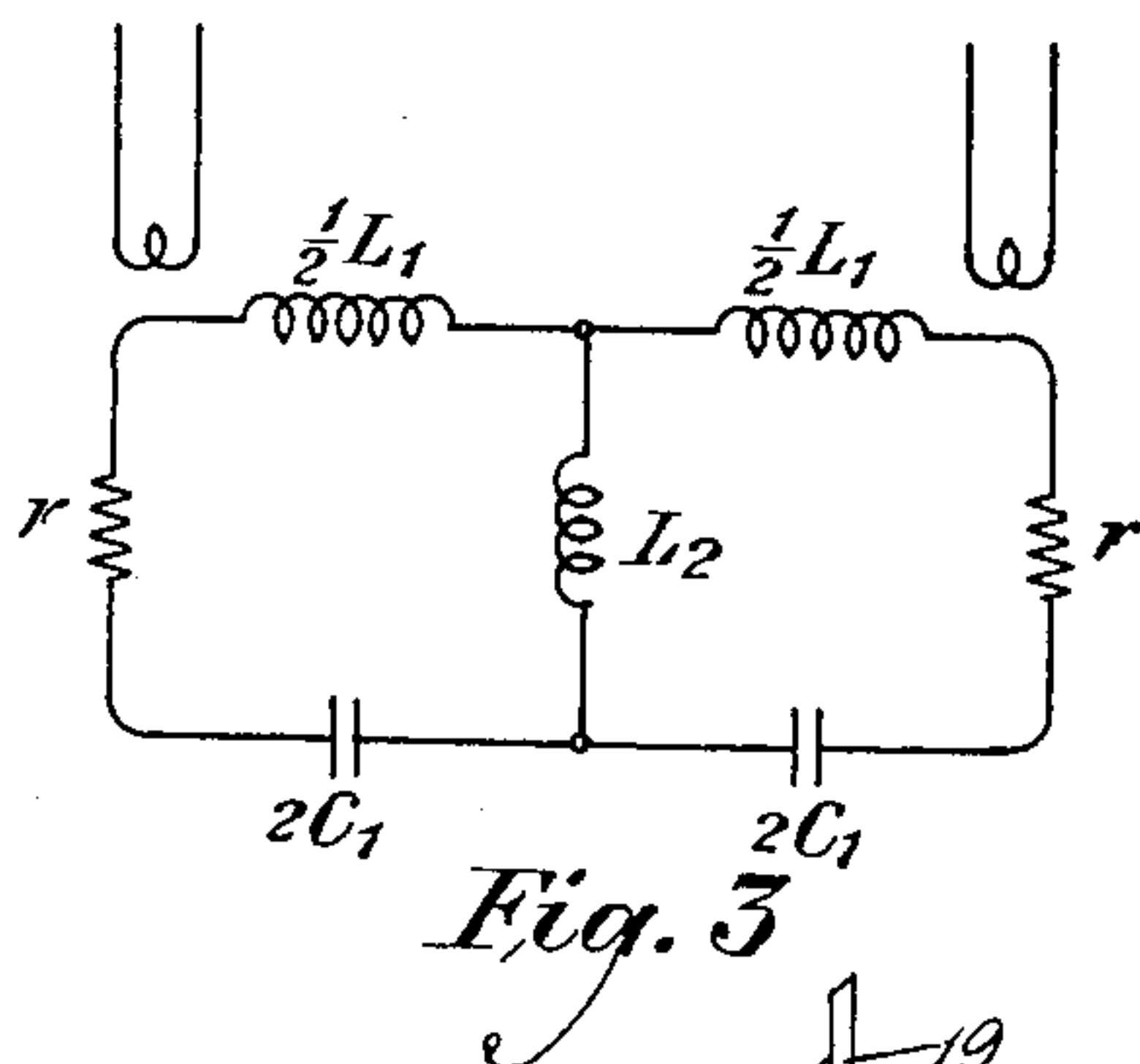
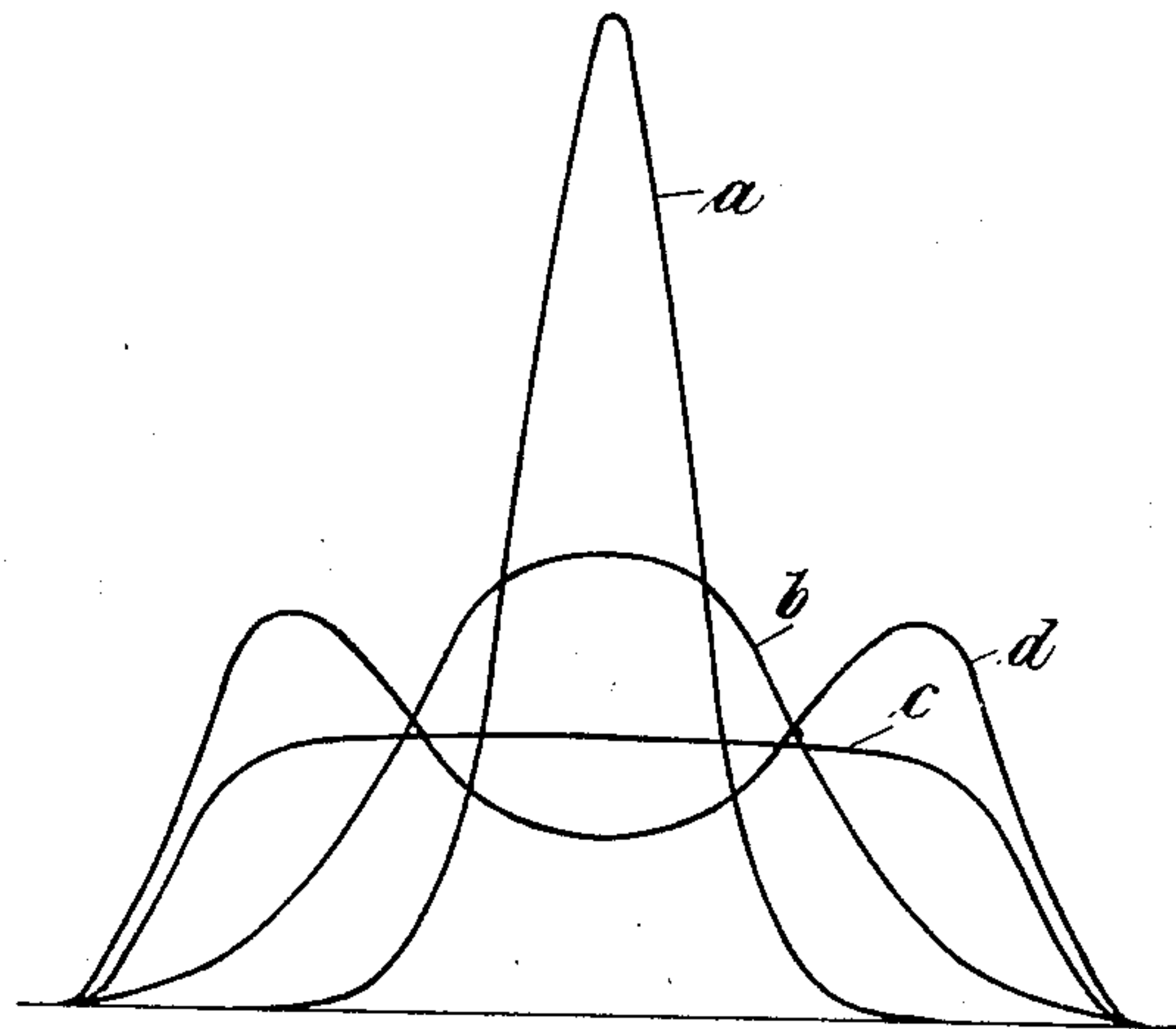
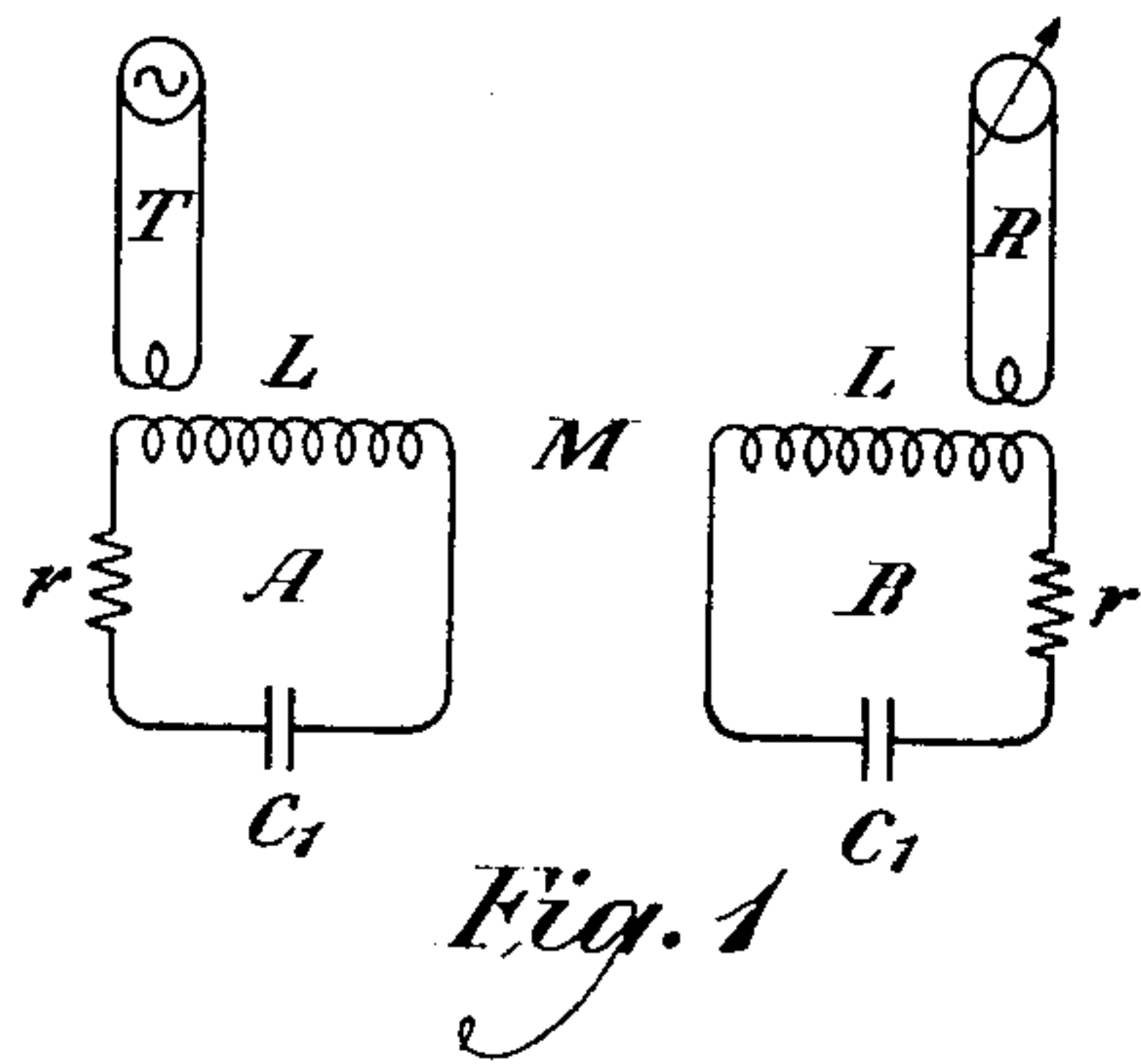
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CARRIER FREQUENCY RECEIVING CIRCUITS

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CARRIER FREQUENCY RECEIVING
CIRCUITS

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8 Claims. (Cl. 178—44)

This invention relates to radio tuning circuits, and more particularly to a method and means whereby the distortion commonly present in sharply tuned circuits is reduced without corresponding loss of selectivity against frequencies outside the desired band. The invention is applicable to radio circuits or to other carrier frequency circuits.

In radio signaling it has usually been considered good practice to reduce the resistance of a tuned circuit to the lowest possible value in order to obtain high selectivity but this has resulted in a narrowness of the received band with accompanying loss of suitable intensity away from the center of the band and corresponding signal distortion. Efforts to overcome this have been made by using band wave filters with their accompanying useful properties but with certain limitations. In this invention, I make use of a plurality of successively coupled tuned circuits of such characteristics that they behave like a wave filter and still permit ready adjustment to different carrier frequencies. In order to obtain the desired results, I find it necessary to have present or to definitely introduce a certain amount of resistance in the circuits in a manner and for a purpose to be hereinafter described.

The invention will be better understood by reference to the following specification taken in connection with the accompanying drawing, in which Figure 1 shows two coupled tuned circuits; Fig. 2 shows the transmission characteristics of such a combination; Fig. 3 shows the electrical equivalent of this circuit, taking on the form of one section of a three-element wave filter, Figs. 4, 5 and 6 show various radio circuits in which my invention is embodied; and Fig. 4a is a detailed view of one form which the condensers in certain of the circuits may take.

Referring to Fig. 1, there are shown two identical tuned circuits A and B coupled to each other through a certain amount of mutual inductance M. Such a combination of two circuits may readily be studied by impressing alternating currents from a loosely coupled transmitter T and receiving them on a loosely coupled receiving circuit R. Such a study would show that if the mutual inductance M is very small, the response characteristics is that of the well-known resonance curve with a single peak or maximum, the width of the resonance curve being determined by the resistance in the tuned circuits. Thus, if the resistance is small, the resonance curve may be that of the curve *a* in Fig. 2; whereas, if the resistance is increased, the resonance curve will be

much less sharp and might be indicated by curve *b*. If, now, the coupling between the two circuits is increased considerably, it is found that the resonance curve possesses two peaks, as shown in curve *d*, the separation of the two peaks and the depth of the depression between them depending upon the relative inductances, capacities, coupling and resistances. There is one value of coupling for given resistances and inductances which is critical and in which the curve is a flat top curve, as indicated by the *c* of Fig. 2 and this corresponds to the condition which exists when

$$2\pi fM = \sqrt{r_1 r_2} = r \quad (1)$$

where *f* is an intermediate frequency in this band, corresponding to the natural frequency of the circuits taken separately and *r*₁, *r*₂ are the resistances of the circuits A and B, taken as of the same value *r*. While *f* is the frequency, it will be convenient to refer to the quantity $2\pi f$ as the angular frequency. This condition of critical coupling is defined as the condition for maximum transfer of energy from the one circuit to the other. Thus this circuit acts like a band filter.

The equivalent band filter is shown in Fig. 3 in which *L*₂ corresponds to the mutual inductance between the circuits of Fig. 1. It is seen that Fig. 3 represents one section terminated mid-series of a three-element wave filter in which the series element corresponds to a series connection of inductance *L*₁ and capacity *C*₁, while the shunt element consists of the inductance *L*₂. In accordance with the theory of wave filters in which the sections are of the form indicated, it may be found that for a given transmission band

$$L_2 = \frac{(f_1 + f_2)r}{4\pi f_1 f_2} = \frac{r}{2\pi f} \quad (2)$$

where $\frac{1}{f}$ is equal to

$$\frac{f_1 + f_2}{2f_1 f_2} \quad (3)$$

Such formulas, for instance, may be found in an article by O. J. Zobel on the "Theory and Design of Uniform and Composite Electric Wave Filters" in the Bell System Technical Journal for January, 1923. The relation given for *L*₂ corresponds to the case where the filter is terminated into its proper impedance and it is seen that this is identical to the relation (1) since *L*₂ corresponds to *M*. The establishment of critical coupling in Fig. 1, then, corresponds to the termination of the equivalent band filter in its proper impedance. If the coupling is less than

critical, the response band is narrowed. This corresponds to the termination of the equivalent band filter in an impedance greater than its characteristic impedance, resulting in attenuation near the edges of the band. If the coupling is greater than critical, the two distinct response peaks appear and this corresponds to the termination of the equivalent band filter in an impedance less than its characteristic impedance, causing losses at the center of the band and reflection gains at the edges. In neither case is there an appreciable change in the attenuation at frequencies remote from the pass band, so that improper coupling always results in distortion without compensating gain in selectivity. Thus it is seen that the adjustment of tuned circuits of given constants and given dissipation to critical coupling yields a circuit which is equivalent in characteristics to a band filter with fixed series elements connected to a given line impedance r , the shunt element of which is varied to cause the filter impedance to match its termination.

The design of the tuned circuits for good quality in radio reception should therefore aim to make r of such value with respect to the other constants of the circuits that the resulting band width, when $2\pi fM$ is made equal to r , will be just sufficient for good quality. The selectivity of frequencies outside of the band may then be obtained conveniently from the appropriate filter formulas.

The matter of relationship of band width to the signaling message is of prime importance in radio communication, and for the best application of my invention, it is necessary to have formulas by means of which to calculate the necessary inductances, capacities and resistances to give the desired band width. These may be developed from the following filter formula:

$$L_1 = \frac{f_1 r}{\pi f_2 (f_2 - f_1)} \quad (4)$$

where L_1 is twice the inductance in one of the circuits A of Fig. 1 and where f_2 and f_1 are, respectively, the upper and lower limiting frequencies of the band to be transmitted. There is also the relation for critical coupling given by

$$r = 2\pi fM = 2\pi f k L, \quad (5)$$

where k is the coupling coefficient. From these relations it is seen that

$$\frac{f_2 - f_1}{f} = \frac{f_1}{f_2} k \quad (6)$$

This shows, incidentally, that when the carrier frequency is relatively high, the band width $f_2 - f_1$ is approximately equal to the coupling coefficient multiplied by the carrier frequency. The approximation is close for a small percentage band width but is departed from as the band width is increased.

It will be seen from (6) that in order to obtain a constant width at different carrier frequencies, the coefficient of coupling should be inversely proportional to the carrier frequency and, assuming fixed inductances, the resistance should remain constant.

Fig. 4 shows a circuit embodying my invention. In this figure, the antenna 10, in series with the coil 11, is loosely coupled to two tuned circuits 14 and 17 of the kind described above. It will be noted that provision is made for a variable inductive coupling between the circuits 14 and 17 and each of these circuits contains a small re-

sistance r by which to bring about the relations noted above. The detecting circuit or the high frequency amplifier into which the circuit 17 is to feed may be coupled inductively to the circuit 17 or, in accordance with well established practice in radio, may be connected across the terminals of the tuning condenser as shown in the figure. This corresponds in the equivalent filter section to deriving the output voltage across the series capacity $2C_1$ or the series inductance $L_1/2$. For a relatively narrow band, the wave form of the voltage obtained in this way is very nearly the same as that obtained across the termination resistance r .

In tuning to a second carrier frequency, it will be necessary to change the natural frequency of each of the individual circuits and this may most readily be accomplished by varying the capacities C . But, in accordance with my invention and in order to maintain the most favorable relations for band width, it will now be necessary to either change r or to change M . It will be more convenient to keep r constant and to change M . The desired adjustment may be readily realized by mechanical gearing of the coupling coil with the tuning condensers as indicated in Fig. 4.

In general, it will be found that the natural dissipation resistance of the circuit components increases with the frequency of the carrier and it will be desirable to provide means to counteract this. Two methods suggest themselves: one is to slightly modify the value of r , but I find that a preferable and more delicate control can be obtained by other means. For example, the condensers may be built with dissipative dielectric between the plates so that the loss increases as the plates mesh. Thus, as the condensers are adjusted for lower frequencies, the natural decrease in dissipation is compensated by the increase in dissipation in the dielectric. This change I have indicated in Fig. 4 by resistances R which are shown as adjustable, it being understood that such dissipation is included in the condenser. One manner in which this may be accomplished is indicated in Fig. 4a in which 20 and 21 indicate the two plates of a condenser, one of which may slide with respect to the other, thus forming a variable condenser. To one of these plates is secured a slab of dielectric 22 of some material which shows appreciable dissipation loss. As the capacity of the condenser is changed by sliding the plate 21, a larger or smaller amount of dielectric is subjected to loss. It is obvious that instead of using this particular form of condenser, any other variable form would be appropriate, such as the very common semi-circular plates which mesh one with the other. Obviously, another method for obtaining the same results would be to have a contact element attached to the condenser or to the coupling coil which through a slider bearing on a resistance wire or element, adjusts the resistance in the proper direction and proper amount, thus keeping the total effective resistance constant at all frequencies. This is indicated in certain of the figures by showing a rod passing from the variable contacts on the resistances R to the shift bar 19, thus adjusting these resistances simultaneously with the adjusting of the tuning condensers and the coupling of the coils.

Fig. 5 shows a modification of Fig. 4 in that one of the tuned circuits is the antenna itself.

Fig. 6 shows a further modification in which a greater number of tuned circuits are introduced, giving the equivalent of a wave filter of a larger number of sections with corresponding improve-

ment in the form of the transmission band. In this case the dissipating resistance of each of the intermediate tuned circuits should preferably be small and all the circuits would be adjusted to critical coupling and proper terminal impedance by the inclusion of appropriate resistance in the terminating tuned circuits. Here also, by suitable gearing, the coupling would be controlled by the change in the setting of the condensers to tune to different carrier frequencies.

An application of the relations above, as ordinarily employed in radio receivers, will illustrate more fully the manner of carrying out my invention. Assume, for example, that the inductances and the capacities of the circuits A and B of Fig. 1 have the values of .15 millihenries and 250 micromicrofarads at 800 kilocycles. These values correspond to a half-series section of the equivalent band filter. Let us assume, for the purpose of illustration, that the two coupled circuits are identical and that a band width of 10,000 cycles is desired. Then, from the filter formula, it will be seen that

$$r = \frac{\pi f_2(f_2 - f_1)L_1}{f_1} = 9.54 \text{ ohms} \quad (7)$$

Since $2\pi f(L_1/2)$ equals about 750 ohms, this corresponds to a Q of 79 at this frequency, where Q equals

$$\frac{2\pi f L_1}{r}$$

The corresponding value of $L_2 (=M)$ is 1.9×10^{-6} , whence

$$\frac{f_2 - f_1}{f_1} = .0127. \quad (8)$$

Such a structure would be fairly flat over a range of about 4,000 cycles on each side of the center of the band and has an attenuation of about 26 transmission units at 750 and 850 kilocycles. It is evident that, other things being equal, the band width is directly proportional to r .

What is claimed is:

1. In a radio receiving circuit, two tuned circuits coupled to each other and containing a resistance element, means for tuning the two circuits in accordance with the carrier frequency to be received, and means for simultaneously changing the coupling between the two circuits in accordance with the value of the resistance elements and the change in tuning in order to maintain a constant width of receiving band.

2. In a radio receiving circuit, an antenna, two tuned circuits inductively connected and each containing a resistance element one of the circuits being associated with the antenna and the other with a detector, means for tuning the two circuits

in accordance with the carrier frequency to be received and for simultaneously changing the coupling between the two circuits in accordance with the value of the resistance elements and the change in tuning in order to maintain a constant width of receiving band.

3. In a radio receiving circuit comprising two tuned circuits inductively coupled and each containing a resistance element, the method of maintaining constant width of receiving band for different carrier frequency which consists in changing the coupling coefficient simultaneously with the change of tuning and in such magnitude that the coupling coefficient times the angular frequency of the carrier is maintained constant.

4. In a radio receiving circuit comprising two tuned circuits inductively coupled and each containing a resistance element, the method of maintaining constant width of receiving band for different carrier frequency which consists in changing the coupling coefficient simultaneously with the change of tuning and in such magnitude that the coupling coefficient times the angular frequency of the carrier is maintained constant and equal to the resistance in the tuned circuits.

5. In a radio receiving circuit, two tuned circuits inductively connected and each comprising an inductance and a condenser each condenser containing a dissipative dielectric, and means for controlling the amount of dissipation loss as the circuits are tuned to different carrier frequencies.

6. In a radio receiving circuit, two tuned circuits the effective resistance of which is a function of the frequency and each comprising an inductance and a condenser each condenser containing a dissipative dielectric, and means for controlling the amount of dissipation loss as the circuits are tuned to different carrier frequencies such that the total effective resistance is constant.

7. In a radio receiving circuit comprising two tuned circuits inductively coupled and each containing a resistance element, the method of maintaining a flat top reception band and controlling the band width which consists in keeping the angular frequency multiplied by the coefficient of coupling equal to the resistance and changing the band width by changing the resistance.

8. In a radio receiving circuit comprising two tuned circuits effectively coupled and each containing a resistance element and in which the angular frequency of the carrier wave multiplied by the coefficient of coupling is equal to the resistance, the method of changing the band width which consists in changing the resistance of the circuits in proportion to the desired change in the band width.

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