May 9, 1933. G. W. PICKARD 1,907,571

RADIO RECEIVING APPARATUS

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Fig. 1

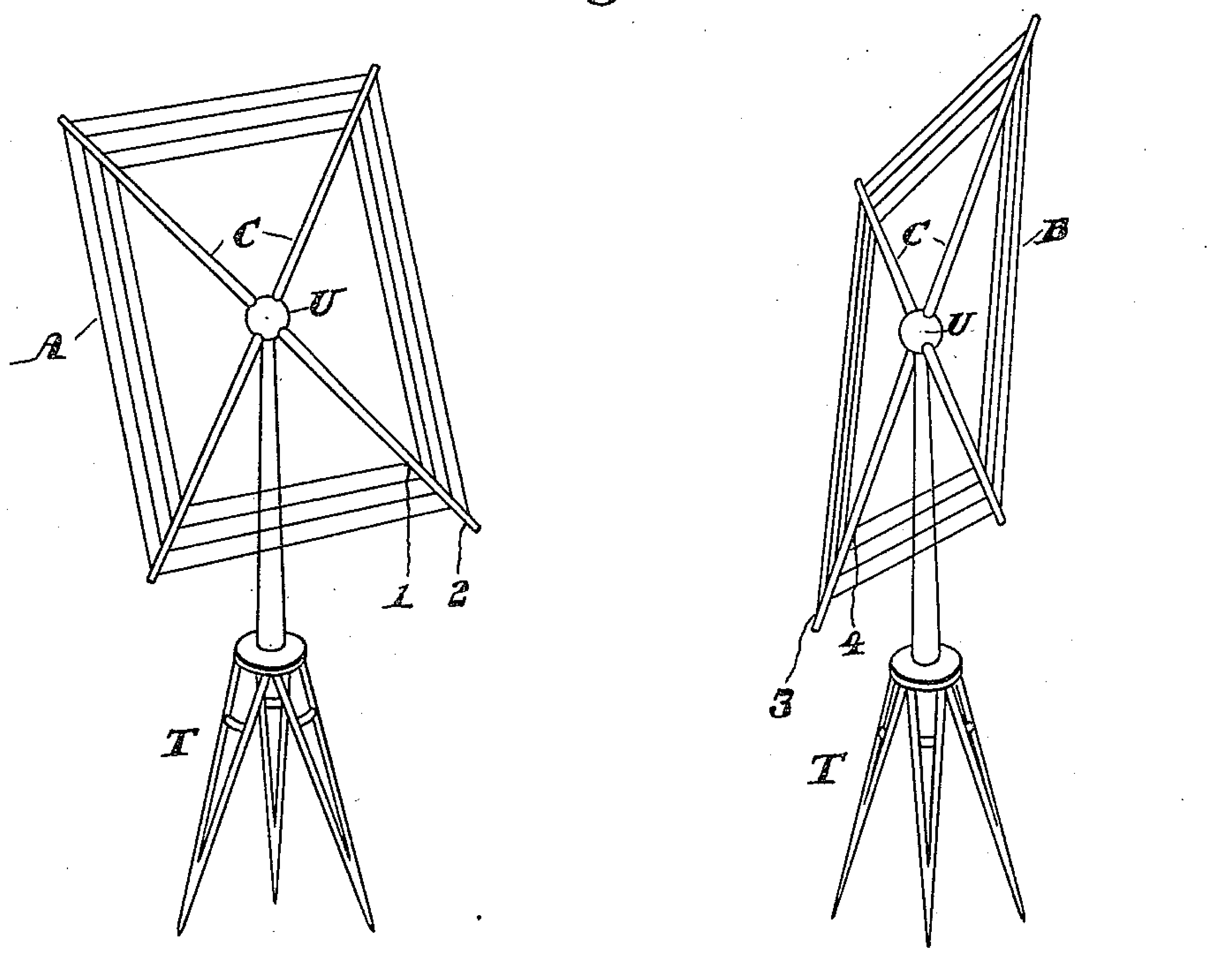
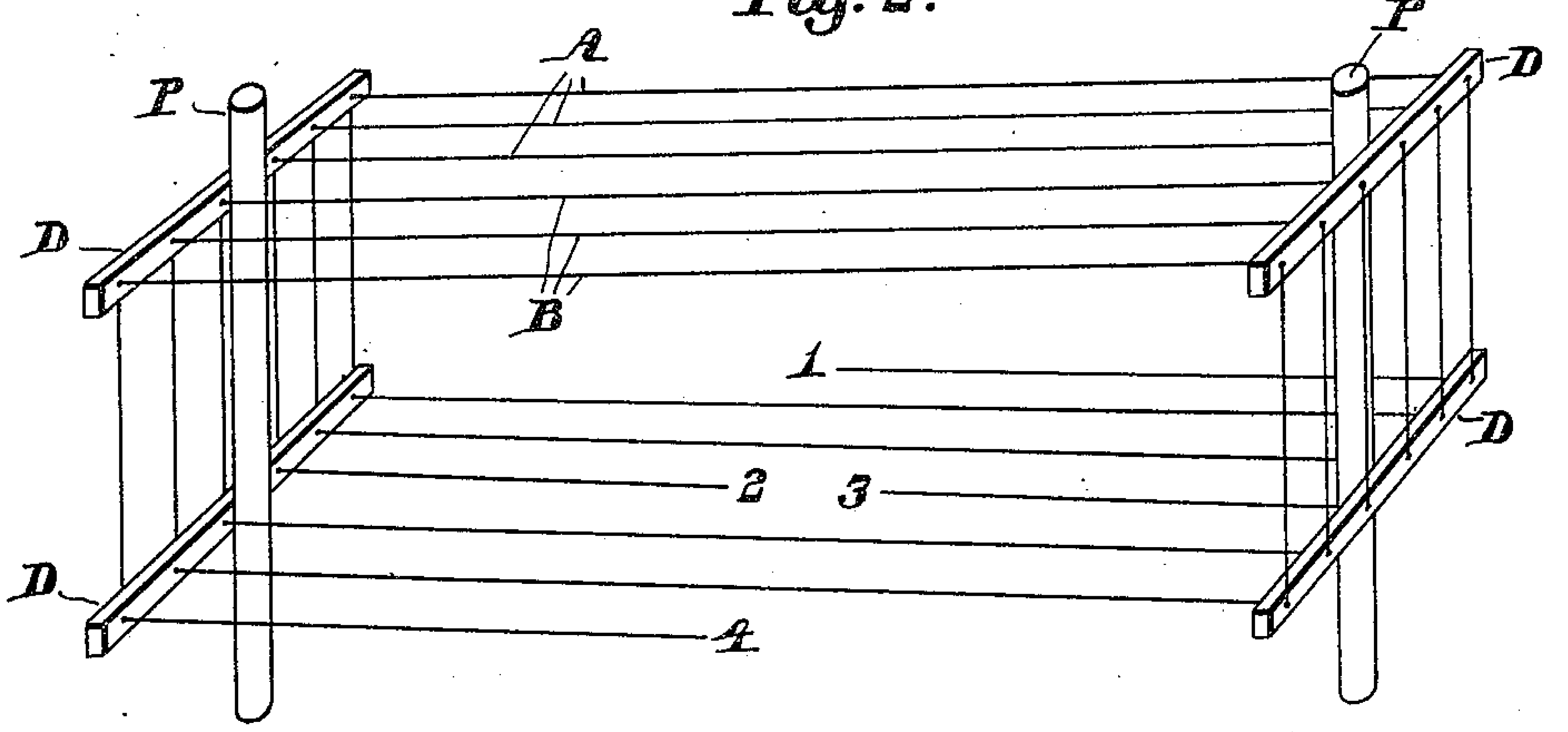


Fig. 2.



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RADIO RECEIVING APPARATUS

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Fig. 3.

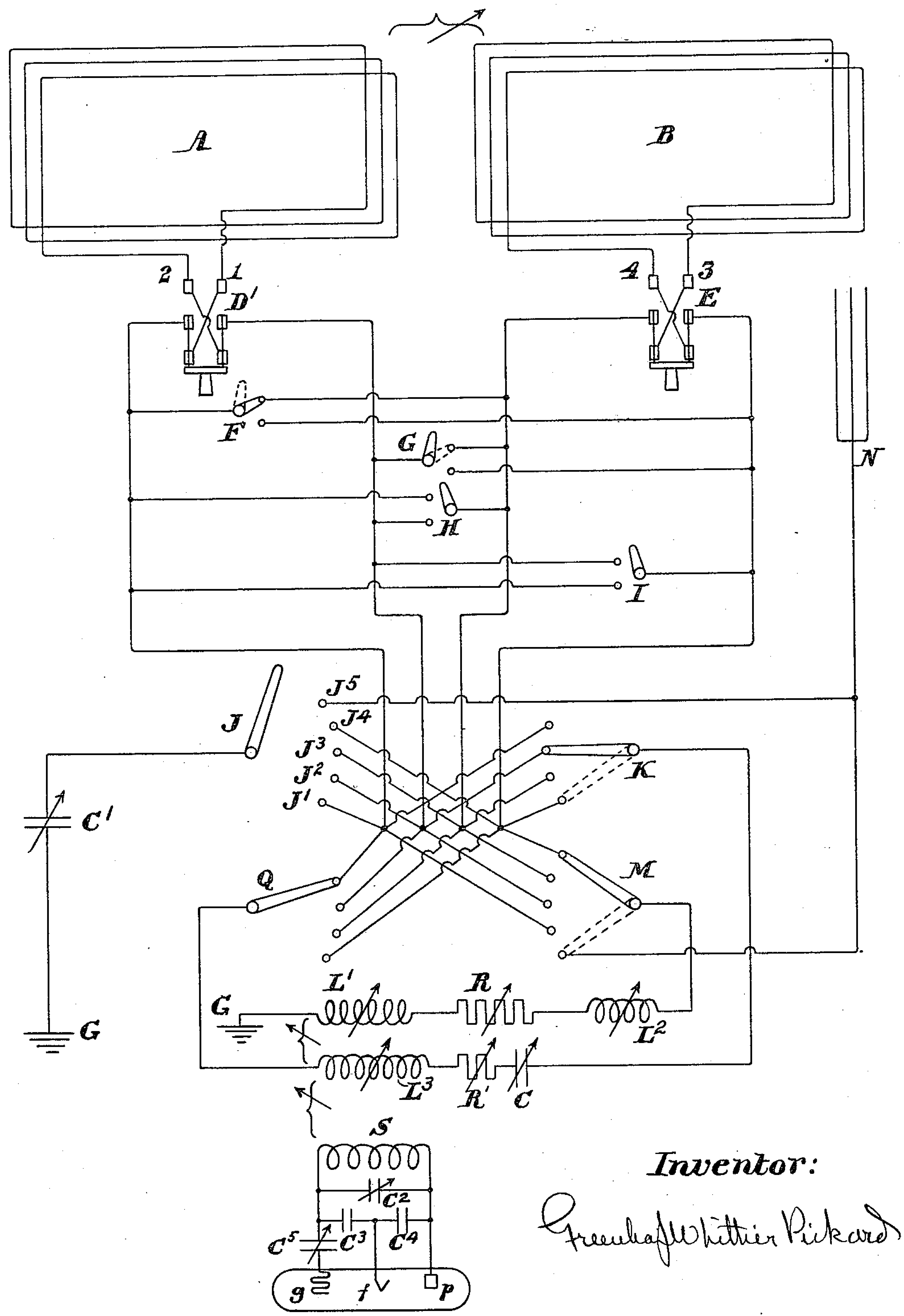

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Fig. 4.

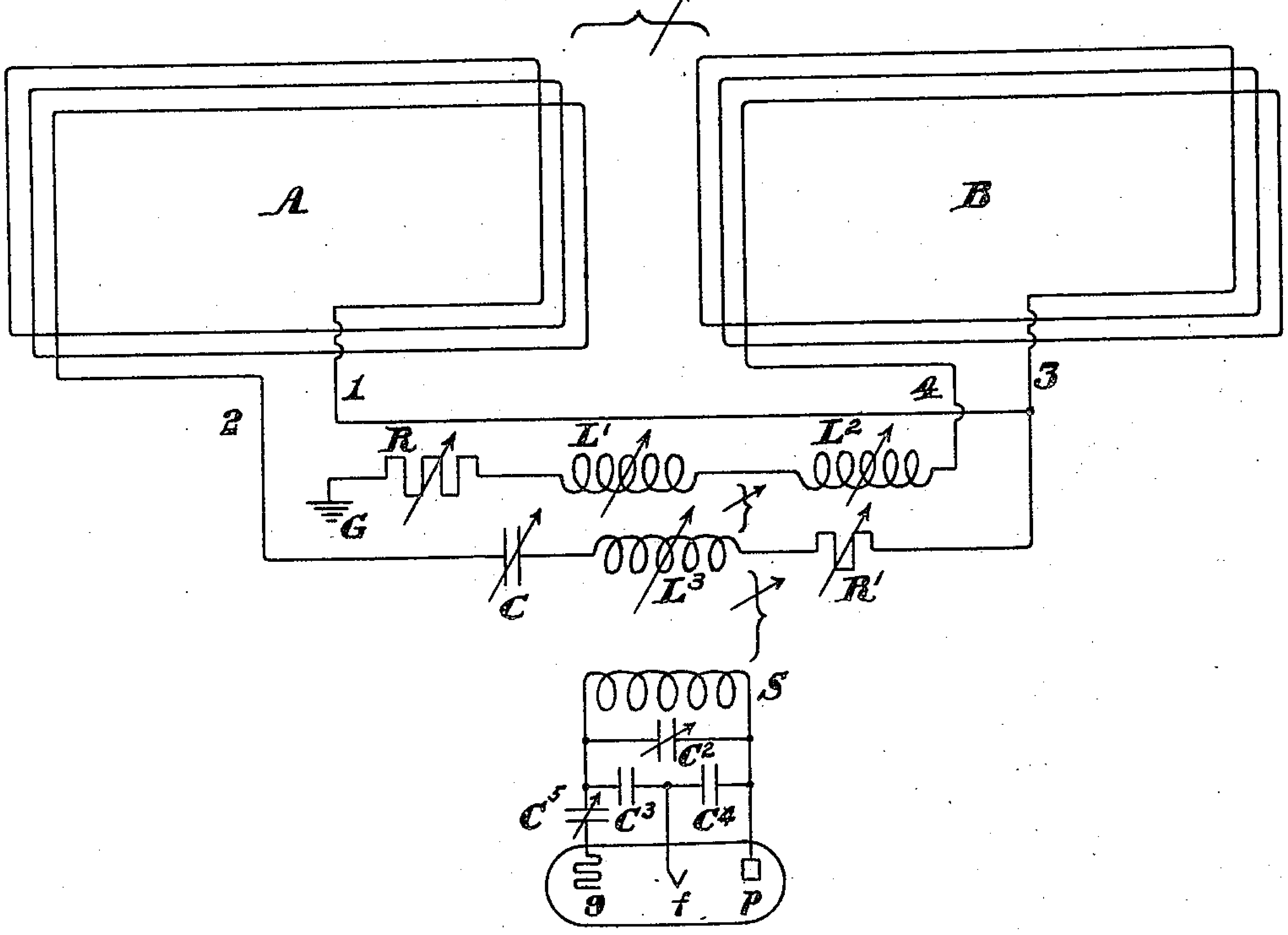
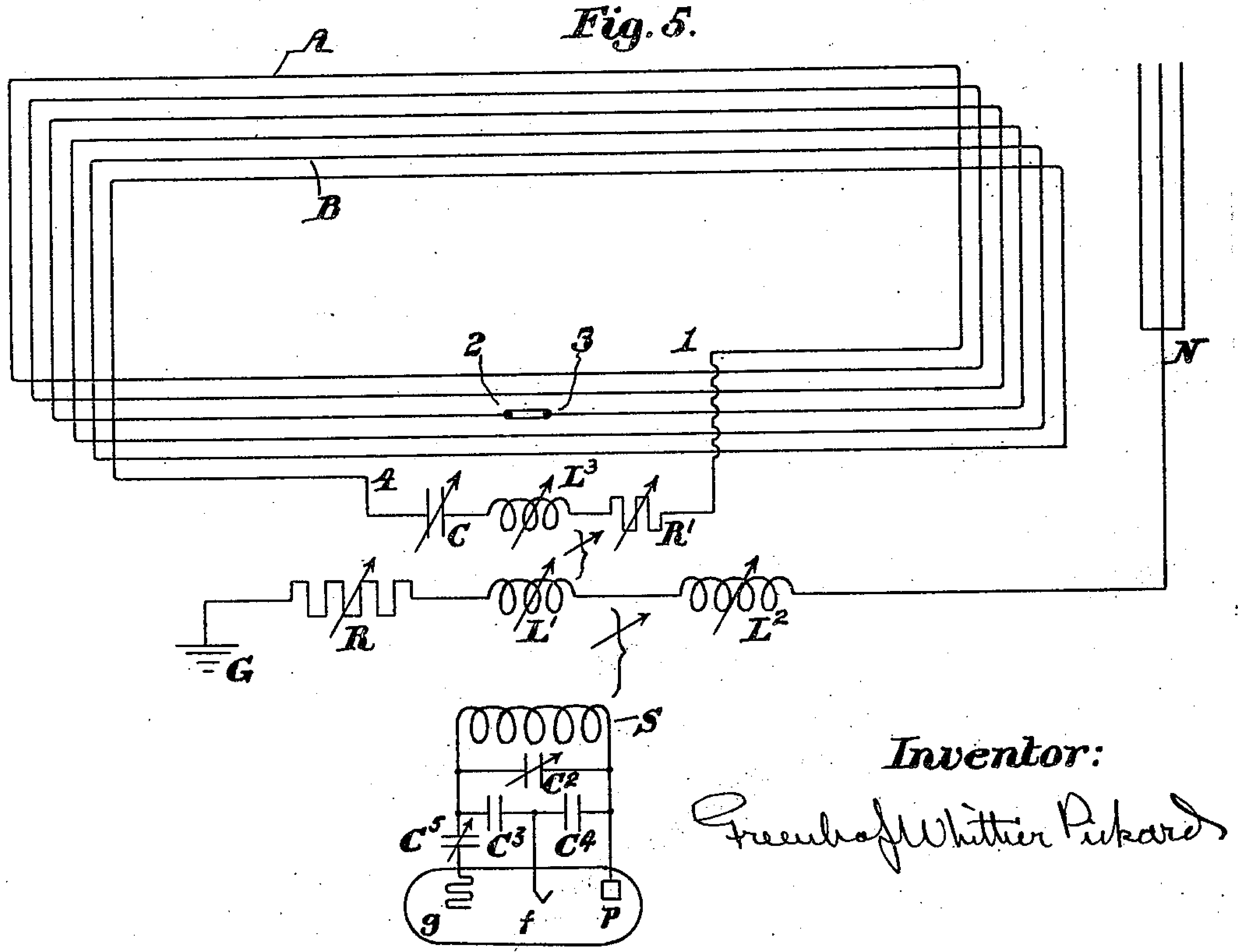


Fig. 5.



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Greenleaf Whittier Pickard

Patented May 9, 1933

1,907,571

UNITED STATES PATENT OFFICE

GREENLEAF WHITTIER PICKARD, OF NEWTON CENTER, MASSACHUSETTS, ASSIGNOR, BY MESNE ASSIGNMENTS, TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

RADIO RECEIVING APPARATUS

Application filed March 26, 1920. Serial No. 368,903.

This invention relates to receiving systems for radio signals and particularly to such systems in which a loop or coil aerial is used in combination with an open aerial, in the manner disclosed in Fig. 3 of my U. S. Patent No. 876,996. In such systems there is a combination of loop action and open antenna action, and the combined effects of the currents flowing in the loop and in the open antenna, in proper phase relation, are brought to bear on the secondary or detector circuit. Such systems have great value in their capacity to eliminate both the effect of static and other atmospheric disturbances and the effect of interference from other stations than the one from which it is desired to receive signals, apparently because of their unilateral directional reception.

This application is a continuation in part of an application Serial No. 256,978, filed by me October 5, 1918.

The object of this invention is to modify or improve upon such systems in a manner to increase their elimination of undesired disturbances or signals, my present theory of this improved action being that it is a result of an improved or sharpened directional reception resulting from the novel methods and apparatus employed.

To this end I employ a plurality of loops, placed in various relations to each other and to the open antenna or ground circuit, together with means for adjusting the received current values in the system and also for preventing complex wave formations in the network as a result of impact excitation by static or other disturbances, as will be hereafter more particularly described.

In the accompanying drawings, Fig. 1 shows a pair of loop antennæ of a type which I have found particularly useful in carrying out my invention. Fig. 2 shows another arrangement of loops suitable for use in carrying out my invention. Fig. 3 shows diagrammatically two loops which may be used in carrying out my invention, and an arrangement of switches and connections whereby they may be connected together in various desirable relations, and may be coupled with a detector circuit. Fig. 4 shows diagrammatically the circuits of the arrangement shown in Fig. 3, when the switches shown in Fig. 3 are in their full line position as indicated in said figure. Fig. 5 shows the circuits resulting in the arrangement of Fig. 3 when the switches are thrown into the dotted line positions indicated in said figure.

Fig. 1 shows a pair of loop antennæ supported on movable tripods in such a manner that the two loops may be placed in a wide variety of relative positions. The two loops A and B are carried on radial frames C, C, supported on universal joints U, U, which are in turn supported on tripods or other suitable bases T, so that the loops A and B may be disposed in any desired angular relation to each other and to the signal and static waves. The coupling between the loops A and B may also be varied by moving the tripods T so as to alter the distance between the loops. The terminals 1, 2 of loop A and 3, 4 of loop B may be connected in the manner hereinafter set forth.

The arrangement of loops shown in Fig. 2 is suitable for an installation receiving signals from fixed directions, as, for example, for the receipt of trans-Atlantic signals in this country. Poles P support cross-arms D, forming a sort of rectangular frame, on which the loops A and B are wound. In this arrangement of loops their position and coupling is usually determined by the installer, although by providing movable supports for the poles P, and sliding extensions on the cross-arms D, the loop positions and couplings may be varied at will.

In general, the loops will be so placed that their planes are normal to the signal wavefront, that is, the turns should lie in a vertical plane including the line of propagation. This is the condition for maximum signal reception, as I have pointed out in my above mentioned Patent No. 876,996. However, as it is usually more important to annul the disturbances than to have a strong signal, the loops may be placed in such position as will give the minimum disturbance, even if by so doing they depart considerably from the position of maximum signal reception. The dimensions of the loops employed will of course be determined by considerations of available space, and by the wave-length to be received. For loops of the type shown in Fig. 1, I have found that excellent trans-Atlantic reception may be obtained with frames about twenty feet on a side, and wound with about thirty turns of wire. For loops of the type shown in Fig. 2, equally good trans-Atlantic reception and elimination of disturbances was obtained by me with a frame one hundred feet long, twenty feet high, and wound with three or four turns in each loop, the turns being spaced apart about six inches. While these dimensions are given merely by way of illustration and may be very considerably departed from without detriment to their operation, it should be noted that in general the loops should be small as compared with a wave-length, so that reception on the various collectors is substantially simultaneous. Inasmuch as the use of audion amplifiers is now well known and utilized, and as the object of my invention is to produce the best signal-static ratio in the detector circuit, the various loop and other collectors employed herein are not in general made of such dimensions as will collect and transmit to the detector circuit the maximum amount of signal energy. Instead, the collectors are usually made small, to the end that they may be concentrated at substantially one point in space (with reference, of course, to the wave-lengths employed) for the purpose, as explained above, of being substantially simultaneously affected by the waves, and also to avoid the use of long connecting leads, which, acting as collectors themselves, injuriously complicate the action.

In Fig. 3 is shown a circuit arrangement wherein the two loops shown in Fig. 1 or in Fig. 2 may be employed in accordance with my invention. The loops indicated, A and B, preferably with variable coupling, may be connected to each other and to the coupling coils L^1 and L^2, and other apparatus and circuits, in a number of different relations by means of the switches D^1. E, F, G, H, I, J, K, M and Q. The object of having so many switches is to enable the operator to make various combinations of circuits, according to the character and point of origin of the disturbance which he wishes to eliminate from the detector circuit. I have found that when a plurality of loops or other types of aerials are placed together at a receiving station, there are formed both magnetic and electrostatic couplings between these aerials, and that a reversal or interchange of connections will often reverse one coupling, as the electrostatic, without materially affecting the magnetic coupling, and vice versa. Inasmuch as the effect on the detector circuit is due to the total of the various current additions in the network, both by the various couplings between the coils in the receiving station and in the complex of magnetic and electrostatic in the aerial system itself, it is important that these aerial couplings be under complete control, as well as those between the coils in the station. To this end, the switches D^1 and E enable the loops A and B to be reversed in their connections, either with respect to each other or to the rest of the circuit. Switches F, G, H and I enable the four terminals of the two loops to be interconnected in any desired way, either in series or in parallel, or by leaving these switches open the loops may be employed without interconnection. Switches Q and K allow a circuit consisting of inductance L^3, a variable condenser C, and a variable resistance R, to be connected in series with either or both of the loops A and B. Switch M may be used to connect a circuit containing an inductance L^1, a variable resistance R, a second inductance L^2 and a ground or counterpoise connection G, to any of the four terminals of the two loops A and B, or to a separate open antenna N. Finally, switch J is for the purpose of connecting a variable condenser C^1 to any of the four terminals of the loops A and B, this condenser being for the purpose of varying the capacity of the entire system, or any part of it, to ground, and thereby effecting a tuning of the open circuit, similar to that which may be effected by variable inductances L^1 and L^2. Although the use of a shunt condenser for tuning an open antenna is now well known, and is generally considered to be an equivalent of the tuning which may be accomplished by variable series elements in the open circuit, I have found that under certain conditions it is advantageous to use the shunt condenser, apparently because it increases the capacity of the open aerial, and so reduces the potential developed across the open aerial by the waves. This reduction of potential seems to be useful in that it decreases the amount of energy transferred across the network by the electrostatic couplings, and hence leaves the various magnetic couplings predominant, to the useful simplification of the action.

I have also provided a separate open antenna N, which may be used in combination with either or both of the loops A and B. When the open antenna is employed, the loops A and B may be left without attachment to ground, thereby obtaining pure loop action, without addition of open antenna current in out-of-phase relation to the loop current. This enables a sharper directional action of the system.

Any of the well known forms of secondary or detector circuit may be employed in connection with my invention. I have shown in the drawings, Figs. 3, 4 and 5, one of the forms of oscillating audion detector, suitable for use in receiving undamped or continuous waves, in which S is the secondary variably coupled with L^1 and L^3; C^2, C^3, C^4 and C^5 are condensers, and *f*, *g* and *p* are respectively the filament, grid and plate. The telephone or other indicator, or the amplifier if used, is connected between the filament *f* and the plate *p* in the usual manner. A crystal or other form of detector might also be used, particularly when damped or spark signals are to be received.

Although inspection of Fig. 3 will show that a number of possible combinations may be made, for simplicity I have shown but two of these combinations, namely, the ones which result, respectively, when the switches are thrown to the positions shown in full line, or to the dotted line positions of Fig. 3. In Fig. 4, I have shown a simplified diagram of the circuit resulting from the full line position of the switches in Fig. 3. The terminals 1, 2, of the loop A are connected in series with a variable condenser C, a coupling coil L^3, and if desired a variable resistance R^1. This circuit forms a magnetic loop antenna, and is tuned to the desired wave-length by variation of C or L^3 or both. Terminal 1 of loop A, in addition to its connection to R^1, L^3 and C, is connected to terminal 3 of loop B, and terminal 4 of loop B connects with L^2, L^1, R and G, L^2 being a variable inductance, L^1 a coupling coil and R a resistance variable over wide limits. The circuit A, B, L^2, L^1, R, G, forms an open antenna, and is tuned to the desired wave-length by variation of L^2 or L^1 or both. In the circuit as shown in Fig. 4, the capacity of the open antenna is simply the capacity of the loops A and B to ground or counterpoise. However, as shown in Fig. 3, a variable condenser C^1 may be provided, and by throwing the switch J of this figure on to any one of the points J^1, J^2, J^3, J^4, the open antenna is shunted by C^1, and its capacity may be increased to any desired extent, thereby tuning the circuit A, B, L^2, L^1, R, G, to the desired wave-length.

In Fig. 5 is shown the circuit resulting from moving the switches to the dotted line position shown in Fig. 3. The two loops A and B are connected in series by the connection of their terminals 2, 3, and the outer terminal 1 of loop A is connected to the variable condenser C, thence to the coupling inductance L^3, the resistance R^1 and then to the terminal 4 of loop B. This makes the loops A and B in effect a single loop, which is tuned to the desired wave-length by varying C or C and L^3. The open antenna N in this circuit is separate from the loops A and B, and in this arrangement the conductors of the loops A and B do not form a part of an open antenna system, but act only as a magnetic loop antenna. The open antenna is tuned to the desired wave-length by variation of L^2 or L^1 or both. As in the circuit shown in Fig. 4, the open antenna of Fig. 5 may be tuned by the variable condenser C^1 shown in Fig. 3, which for this purpose must be connected by throwing switch J (Fig. 3) to point J^5, thereby adding a variable capacity to the antenna N.

The function of the resistance R, or the resistance R^1 if used, is to prevent the impact excitation of static or other disturbances from setting up complex or coupling waves in the system as a whole. Such complex oscillations result from the successive transfer and retransfer of energy between coupled circuits of feeble damping, and are objectionable in my invention because they tend to destroy or impair the directional reception of the system, on which the elimination of disturbances depends. By increasing the damping of either or both of the antenna systems, which is most readily done by the insertion of the resistance R or R^1 or both, such transfer and retransfer of energy is prevented, and no coupling waves are formed. The preferred place for the insertion of the resistance is in the open antenna, because in general this circuit collects more energy from the waves than does the loop, and the resistance may therefore perform two functions,—first, the damping of the system to prevent complex wave formation, and second, the reduction of the current in the open circuit to approximate equality with that in the closed circuit. In case the loop receives more energy than the open circuit, the resistance R^1 is used in place of R, and performs the same functions.

In using the circuit of Fig. 4 for neutralization of static or other disturbance, the operator first opens the open antenna circuit A, B, L^2, L^1, R, G, as by opening the switch M in Fig. 3. He then tunes the circuit A, R^1, L^3, C, to the desired distant station, by first coupling coil L^3 with the secondary circuit S, and noting the signal strength as the inductance L^3 or the capacity C is varied. During this tuning, it is advantageous to reduce the resistance R^1 to zero, in order to note the effect of the tuning more readily. When the maximum response is obtained in the secondary circuit, as evidenced by the response of the detector, the magnetic loop circuit A, R^1, L^3, C, is opened, as by opening either switch Q or switch K, Fig. 3, and the open antenna circuit A, B, L^2, L^1, R, G, is connected by closing the switch M to the full line position, Fig. 3. This open antenna circuit is next tuned to the same distant station by first reducing the resistance R to zero, and varying L^1 or L^2 until the maximum response is obtained in the secondary circuit S. If desired, the condenser C^1 (Fig. 3) may be used for this tuning, by connecting switch J to any one of the points J^1, J^2, J^3 or J^4, and varying the capacity until tune is reached. When both open antenna and magnetic loop circuit are thus in tune, the switches are closed as shown in full line in Fig. 3, and resistance R is increased from zero until the maximum static elimination is obtained. Then the operator varies the couplings between the coils L^1 and L^3 until a further reduction in disturbance is reached, and, finally, slightly retunes the loop and the open antenna circuit. These steps may obviously be performed in any desired order, and may be repeated until the best reduction of disturbance is noted. The effect of these various adjustments seems to be to produce in the two aerials currents due to the disturbance which are equal and opposite in their effect upon the secondary, so that when they are added their effect is nil. The signal waves, however, owing to the directional properties of the system, are not in general equal and opposite in their effect upon the secondary, and add to produce a useful signal. It is important that the currents due to static or disturbance in the two aerials be opposed in their effect upon the secondary, for otherwise they would add to produce a strong disturbance. To insure this, the operator may reverse one aerial with respect to the other, as by throwing reversing switch D^1, or by reversing simultaneously switches Q and K, Fig. 3. The static will increase if the aerials are wrongly connected to the circuit, and decrease when the aerials are properly connected.

It will be observed that in the circuit shown in Fig. 4 the current in the open antenna circuit A, B, L^2, R, L^1, G, is led through the loop B, which is coupled in opposition to loop A, that is, the circuit through A and B is noninductive to open antenna circuit currents. Whatever the true theory of the improved action resulting from such opposed loops may be, I have found that in general the best effect is produced when the loops are connected in opposition with respect to open antenna currents.

In the circuit shown in Fig. 5, the operator adjusts in the same way as in circuit of Fig. 4, that is, he tunes the open and the closed circuits separately to the desired station, couples them both to the secondary, adjusts the resistance R, and then the couplings, until the best result is obtained. In Fig. 5 the two loops A and B are not opposed, but in effect form one loop, entirely insulated from ground.

The circuit arrangements of both Figs. 4 and 5 avoid the undesirable effects of out-of-phase current in the system. In the Fig. 4 circuit, out-of-phase current appears to be prevented or neutralized by opposition, while in the circuit shown in Fig. 5 out-of-phase current is prevented by the expedient of not connecting the magnetic loop to earth at all, but employing a separate open antenna which forms no part of the loop.

In order that currents in the magnetic loop circuit can be properly added, in their effect upon the secondary or detector circuit, to the currents due to the same waves acting upon the open antenna circuit, it is desirable that the phase of these currents—the loop and the open—be made the same, the currents in the system due to open antenna action being 90° out of phase with the loop current, as explained in my U. S. Patent No. 876,996 referred to above. In the system illustrated in the accompanying figures, the means for bringing into phase both sets of currents in their action on the common receiving apparatus consists of the coupling between coils L^1 and L^3 and S. When two tuned circuits are coupled together and energy in the form of oscillating or alternating currents in the one circuit is transferred to the other by means of such a coupling, in the transfer the phase is changed by 90°, so that in this system the currents flowing in the open circuit (normally 90° out of phase with currents flowing in the loop circuit) when transferred by way of the coupling between coils L^1 and L^3 to the loop circuit are changed in phase by 90° and are so made equal in phase to the currents already existing in the loop circuit.

What I claim and desire to secure by Letters Patent is:—

1. A receiving system for wireless signals comprising a closed loop aerial, a vertical aerial including a grounded conductor and an open loop aerial in series therewith, said closed loop aerial being rotatable relative to said open loop aerial, said open loop aerial being magnetically coupled to said closed loop aerial, and means coupled to said aerials for detecting currents set up in said aerials.

2. A receiving system for wireless signals including two loops, a loop closing line including an inductance coil, means whereby either terminal of either loop may be connected to either terminal of the other loop and to either terminal of said loop closing line, and a secondary circuit in inductive relation to said inductance coil and operating a detector.

3. A receiving system for wireless signals including a plurality of loops, a loop closing line including an inductance coil, a circuit to ground including an inductance coil, means whereby either terminal of either loop may be connected to either terminal of the other loop, to either terminal of said loop closing line or to said circuit to ground, and a secondary circuit in inductive relation to said inductance coils and operating a detector.

4. A unilateral receiving system for wireless signals comprising relatively rotatable and variably coupled open and closed loop aerials, said open loop aerial being connected to ground by way of a variable impedance and said closed loop aerial including a variable tuning reactance and a lumped in-

ductance, and a detector coupled with said loop aerials.

5. A receiving system for wireless signals including a plurality of independent and complete loop aerials, means whereby said loop aerials may be used as such and alternately connected in series and included in a closed circuit to form a closed magnetic aerial, an open aerial, and common means for detecting currents in said aerials.

6. A receiving system for wireless signals comprising a closed loop aerial, an open aerial having a loop coupled to and opposing the closed loop aerial, phase changing means for adding the signal currents in phase, and detecting means for said added currents.

7. Means for receiving wireless signals comprising an aerial system having unilateral directional properties, said system including a vertical aerial and a frame aerial, means for tuning said vertical aerial, means for minimizing out-of-phase currents in said system comprising a resistance in one of said aerials to damp the out-of-phase currents flowing therein, and detecting means associated with said aerial system.

8. A receiving system for wireless signals comprising a closed loop aerial having means for tuning it, a connection from said loop forming an open aerial and having a loop in series therewith and coupled to said closed loop aerial, means for tuning the open aerial, and detecting means for said aerials.

9. A unilateral receiving system for wireless signals comprising a closed loop aerial, a tuning condenser in series therewith, a vertical aerial, said vertical aerial being coupled with said closed aerial in a manner to minimize out-of-phase currents in the loop, means for tuning the open aerial, a lumped resistance connected with said vertical aerial to damp out out-of-phase currents therein, and means coupling said aerials to a detector circuit.

10. A receiving system for wireless signals comprising signal absorbing means including a closed loop aerial, an open aerial having a second loop separate and distinct from said first loop, means for coupling said last named loop to the first loop, a detector circuit coupled to said aerials and acted upon by currents in said aerials, and means in one of said aerials for regulating the amplitude of the signal absorbed thereby, whereby the effect on the detector circuit of currents in said aerials may be made substantially equal.

11. A receiving system for wireless signals comprising a closed loop aerial, a conductor forming with said closed loop an open aerial, a second loop aerial separate and distinct from said first named closed loop aerial, said last named loop aerial being in coupled relation to the first loop, inductances in each of said aerials, said inductances providing additional coupling between said aerials, and detecting means coupled with said inductances.

12. A receiving system for wireless signals comprising a closed loop aerial, means for tuning said loop aerial, a conductor forming with said loop an open aerial, a second loop in series with said conductor, said second loop being physically separated and distinct from the first named closed loop aerial but coupled thereto, tuning means connected with said open aerial, a detector circuit, and means for causing the currents set up in said closed loop aerial and the currents set up in said open aerial to act conjunctively and equally upon said detector circuit.

13. A receiving system for wireless signals comprising a closed loop aerial, means for tuning said loop aerial, a vertical aerial including in series a second loop independent of the loop of the closed aerial and placed in coupled relation to the first loop, a variable inductance in said vertical aerial, means for damping out out-of-phase currents in said system comprising a damping resistance in one of said aerials, means for equalizing the amplitude of the currents in said aerials comprising a resistance in the other of said aerials, and detecting means arranged to be operated by the conjoint action of currents in said aerials.

14. A receiving system for wireless signals comprising a closed loop aerial having a variable capacity and an inductance coil; a conductor from said loop forming therewith an open aerial and including in series a second loop in variable coupled relation with the first loop, an inductance coil in said open aerial in coupled relation with said first-mentioned inductance coil, a variable tuning inductance in said open aerial, a resistance associated with said aerials; and a detector circuit having an inductance coil in variable coupled relation with said two first-mentioned inductance coils.

In witness whereof, I have hereunto set my name this 24th day of March, 1920.

GREENLEAF WHITTIER PICKARD.