

A. W. HULL.
WIRELESS RECEIVING SYSTEM.
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1,291,527.

Patented Jan. 14, 1919.

Fig. 1.

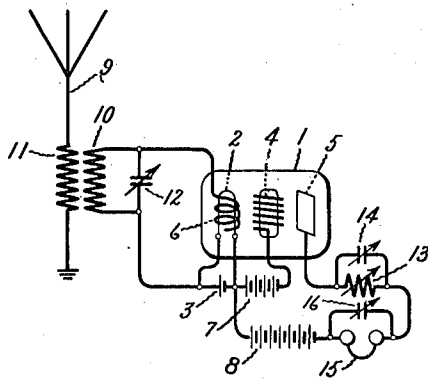
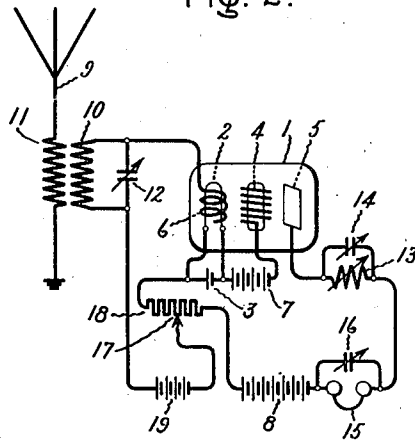


Fig. 2.



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UNITED STATES PATENT OFFICE.

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WIRELESS RECEIVING SYSTEM.

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Specification of Letters Patent.

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Application filed March 10, 1917. Serial No. 154,025.

To all whom it may concern:

Be it known that I, ALBERT W. HULL, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Wireless Receiving Systems, of which the following is a specification.

My present invention relates to means for amplifying variable currents, and more particularly to means for amplifying and detecting currents produced by wireless signals in a receiving antenna.

In a paper published in the *Physical Review* of January, 1916, I have described an electron discharge device in which a negative resistance characteristic is obtained by producing, from an incandescent cathode, an emission of primary electrons, and from a cooperating electrode, an emission of secondary electrons of such a magnitude that the current between the two electrodes in an external circuit varies inversely as the potential between the electrodes. With this device the value of the negative resistance may be varied by varying the temperature of the cathode and thereby varying the number of primary electrons produced, since a variation in the number of primary electrons which reach the third electrode will cause a corresponding variation in the number of secondary electrons emitted. This device is described and claimed in my prior application Serial No. 47,938, filed August 30, 1915. In a prior application, S. N. 101,729, filed June 5, 1916, I have described and claimed a modification of this device in which the value of the negative resistance may be varied by varying the potential of a discharge controlling member in proximity to the cathode. I have also shown in the above mentioned application how this device may be utilized for receiving wireless signals.

The object of my present invention is to provide an improved circuit arrangement in which the device described in the application referred to may be utilized for receiving wireless signals whereby the sensitiveness and selectivity of the receiving circuit may be greatly increased.

A second object of my invention is to provide a receiving circuit which will be especially adapted for the reception of continuous wave signals by the so-called "heterodyne" method.

In carrying out the first object of my invention I provide inductance and capacity in circuit with the negative resistance, of such values that the circuit is resonant to the radio frequency of the waves to be received. The circuit is so arranged that oscillations will not be produced unless the value of the negative resistance is greater or less than a certain critical value. When the circuit is arranged in this way and received oscillations are impressed upon a controlling grid, the value of the negative resistance will be altered in such a way that oscillations will be produced in the circuit. As a result the selectivity and sensitiveness of the device or the degree of amplification of the received signals will be greatly increased. I also provide in conjunction with the telephone receiver a capacity of such value with respect to the inductance of the telephone receiver that the circuit will be resonant to a desired audio frequency which may be equal to the group frequency of the received signals. In order to provide a still further increase in the degree of amplification I provide means for transferring from the circuit containing the negative resistance to the circuit of the discharge controlling member an amount of energy sufficient to make up the losses in that circuit and in the antenna circuit to which it is coupled.

In attaining the second object of my invention I arrange the circuit containing the negative resistance in such a way that oscillations will be produced therein of a frequency slightly different from the frequency of the received oscillations. As a result the two sets of oscillations will combine to produce beats in the telephone receiver in accordance with the usual "heterodyne" method.

The novel features which I believe to be characteristic of my invention are pointed out with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figures 1 and 2 show diagrammatically two different modifications.

As indicated diagrammatically in the drawing, an evacuated receptacle 1 is provided with a cathode 2, which is preferably

a filament of tungsten and which may be heated to incandescence by means of the battery 3, an anode 4 and a third electrode 5. A discharge controlling member 6 is also located in proximity to the cathode. The receptacle 1 is preferably exhausted to such a degree that with any operating voltage which may be employed, the flow of current between the electrodes is not accompanied by any visible manifestation of gas ionization, such for example, as blue glow. In the operation of this device a definite positive potential is applied to the anode 4 by means of the battery 7, the cathode 5 being considered as at zero or earth potential. If the cathode is heated to incandescence there will be a flow of electrons from cathode to anode. If the third electrode 5 is at the same potential as the cathode no electrons will be received thereby. If, however, a small positive potential less than that of the anode is applied to the third electrode a portion of the electrons will pass through the anode and reach the third electrode. The velocity with which these electrons will strike the third electrode will depend upon the potential between it and the cathode. If this potential is increased the velocity will increase until the electrons, striking the third electrode, are able, by their impact, to liberate secondary electrons. These secondary electrons leaving the third electrode will be attracted to the more positive anode. As the potential is increased, a point will be reached at which the number of secondary electrons leaving the third electrode increases faster than the number of primary electrons received, and the current which will flow in the external circuit between the cathode and third electrode will begin to decrease. As the potential of the third electrode is increased beyond this point, the current will continue to decrease and may even reverse in direction up to a point where the potential of the third electrode approaches that of the anode. Thus it will be apparent that the device has a working range through which it has a negative resistance characteristic; that is, over which the current in the external circuit between the cathode and the third electrode varies inversely as the potential between the electrodes. If now a constant potential is applied to the third electrode, by means of the battery 8, of such value that the device will operate as a negative resistance, there will be a constant flow of current in the external circuit. If, however, a variable potential is applied between the cathode and the discharge controlling member 6, the number of electrons which leave the cathode and reach the third electrode will be varied, and the current in the external circuit will be varied accordingly, that is, if the member 6 is made more positive, the

flow of electrons to the third electrode will increase and if the member 6 is made more negative, the flow of electrons will decrease and a small change in the potential of the member 6 will be capable of producing a large change in the current between the cathode and the third electrode.

In utilizing this device for the reception of wireless signals, waves which are received upon the antenna 9 are impressed upon the discharge controlling member 6 by means of an oscillating circuit comprising an inductance 10 which is coupled to the antenna inductance 11 and a variable condenser 12. I also provide in the external circuit between cathode and third electrode a variable inductance 13 and a variable capacity 14 in parallel. This circuit may include the usual telephone receiver 15 shunted by a variable condenser 16. In receiving signals, by this system, the inductance 13 and capacity 14 may be so adjusted that the circuit is capable of oscillating at a frequency equal to that of the received signals. The value of the negative resistance is adjusted to such a point that the circuit is near a point of instability or a point where oscillations will begin. When the potential of the member 6 is varied by received oscillations, the value of the negative resistance will be changed sufficiently so that the circuit will start oscillating. Under these conditions the amplification of the received signals will be asymmetric and the resulting current will operate the telephone receiver to give the desired indication. Without the condenser 16 the circuit would tend to produce oscillations of an undesirable audio frequency. This condenser 16, however, may be so adjusted as to prevent the setting up of audio frequency oscillations or may be so adjusted as to produce audio frequency oscillations of a frequency equal to the group frequency of the incoming waves. The final adjustments of the system may conveniently be made by varying the value of the negative resistance by varying the temperature of the cathode 2.

In case the system described is used for receiving continuous waves, it may be so adjusted that continuous oscillations will be produced of a frequency slightly different from that of the received waves. The two sets of oscillations will then combine to produce beats in the telephone receiver 15. In order to secure the highest degree of amplification in the system above described, the positive resistance of the circuit should be approximately equal in value to the negative resistance.

In the arrangement shown in Fig. 1 the negative resistance compensates for the losses in the positive resistance of the circuit between cathode and third electrode. In the modification shown in Fig. 2 I have indicated means for compensating also for the

losses in the resonant receiving circuit and the antenna. In this case the discharge controlling member 6, instead of being connected directly to the cathode 3, is connected to a suitably selected point 17 in the resistance 18 which is in series with the negative resistance. The voltage supplied to the device by the battery 8 is of such a value that the current in the circuit is negative, that is, positive electricity or its equivalent flows from cathode 2 to third electrode 5 across the evacuated space and thence through the battery 8 and resistance 18 back to the cathode. If the potential of member 6 is made more positive, the current through the resistance 18 will increase and thus the potential of the point 17 and of the member 6 will be still further increased. By means of this resistance coupling energy is fed back from the negative resistance circuit to the resonant receiving circuit and by properly adjusting the point 17, the amount of energy thus transferred may be made sufficient to compensate for the losses in the receiving circuit and in the antenna without producing oscillations. A battery 19 may be included in this circuit in order to adjust the normal potential of the member 6 to a value at which it will operate most efficiently. Under these circumstances, the antenna coupling may be as close and its resistance as large as desired.

While I have illustrated and described only two modifications of my invention, it is by no means limited to the precise circuit arrangements shown as many modifications in the connections may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The combination in a wireless receiving system of an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, and means for applying received waves to the discharge controlling member.

2. The combination in a wireless receiving system of an electron discharge device comprising an electron emitting cathode, an anode, a third electrode, and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, means for ap-

plying received waves to the discharge controlling member and capacity and inductance connected in said external circuit and so adjusted that the circuit is resonant to a desired radio frequency.

3. The combination in a wireless receiving system of an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, means for applying received waves to the discharge controlling member, a telephone receiver in said external circuit and a capacity shunting said receiver and having a value so related to the inductance of the receiver that the circuit is resonant to a desired audio frequency.

4. The combination in a wireless receiving system of an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, means for applying received waves to the discharge controlling member, a telephone receiver in said external circuit and a capacity shunting said receiver and having a value so related to the inductance of the receiver that the circuit is resonant to a desired audio frequency, and capacity and inductance connected in said external circuit and so adjusted that the circuit is resonant to a desired radio frequency.

5. The combination in a wireless receiving system of an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, means for applying received waves to the discharge controlling member and capacity and inductance connected in said external circuit and so adjusted that radio frequency oscillations of a frequency slightly different from that of the received oscillations will be generated in said circuit during the operation of the system.

6. The combination in a wireless receiving system of an antenna, an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a dis-

charge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, a resonant circuit associated with said antenna and with said discharge controlling member for impressing received waves upon said member, and means for transferring from the first mentioned circuit to the resonant circuit a sufficient amount of energy to compensate for the losses in that circuit and in the antenna.

7. The combination in a wireless receiving system of an antenna, an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, a resonant circuit associated with said antenna and with said discharge controlling member for impressing received waves upon said member, and a resistance coupling between the two

circuits for transferring energy from the negative resistance circuit to the resonant circuit to compensate for the losses in that circuit and in the antenna.

8. The combination in a wireless receiving system of an antenna, an electron discharge device comprising an electron emitting cathode, an anode, a third electrode and a discharge controlling member inclosed in an evacuated receptacle, sources of potential applied to said electrodes of such values that the device has a negative resistance between cathode and third electrode which varies inversely as the potential applied to the discharge controlling member, a resonant circuit associated with said antenna and with said discharge controlling member for impressing received waves upon said member, a positive resistance in series with the negative resistance and a connection from said resonant circuit to a point in said resistance, said point being so chosen that energy will be transferred from the negative resistance circuit to the resonant circuit to compensate for the losses in that circuit and in the antenna.

In witness whereof, I have hereunto set my hand this 9th day of March, 1917.

ALBERT W. HULL.