E. F. W. ALEXANDERSON.
SELECTIVE TUNING SYSTEM.
APPLICATION FILED OCT. 29, 1913.

1,173,079. Patented Feb. 22, 1916.

2 SHEETS—SHEET 1.

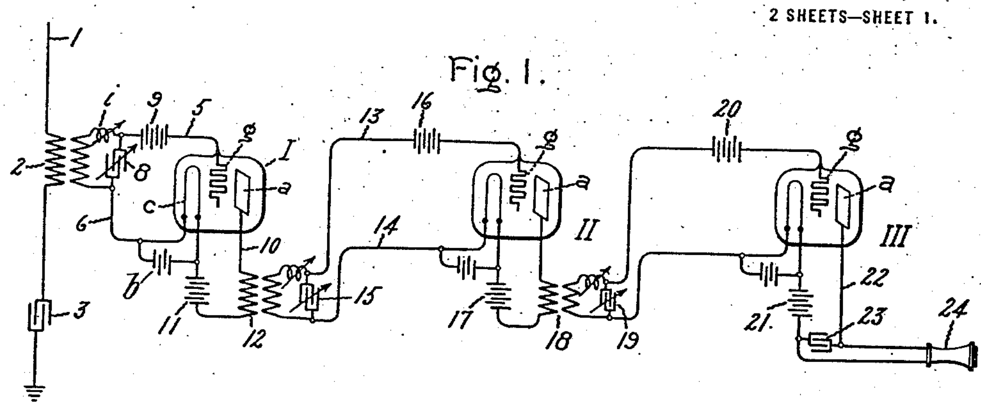

Fig. 1.

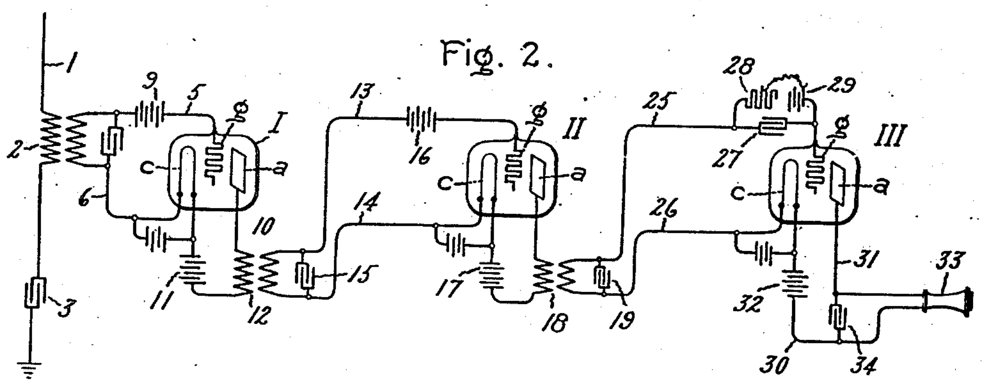

Fig. 2.

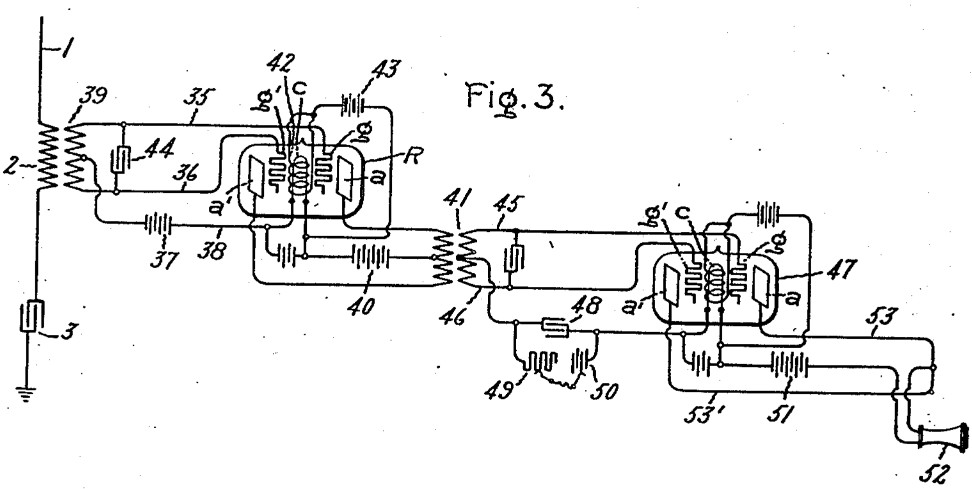

Fig. 3.

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2 SHEETS—SHEET 2.

Fig. 4.

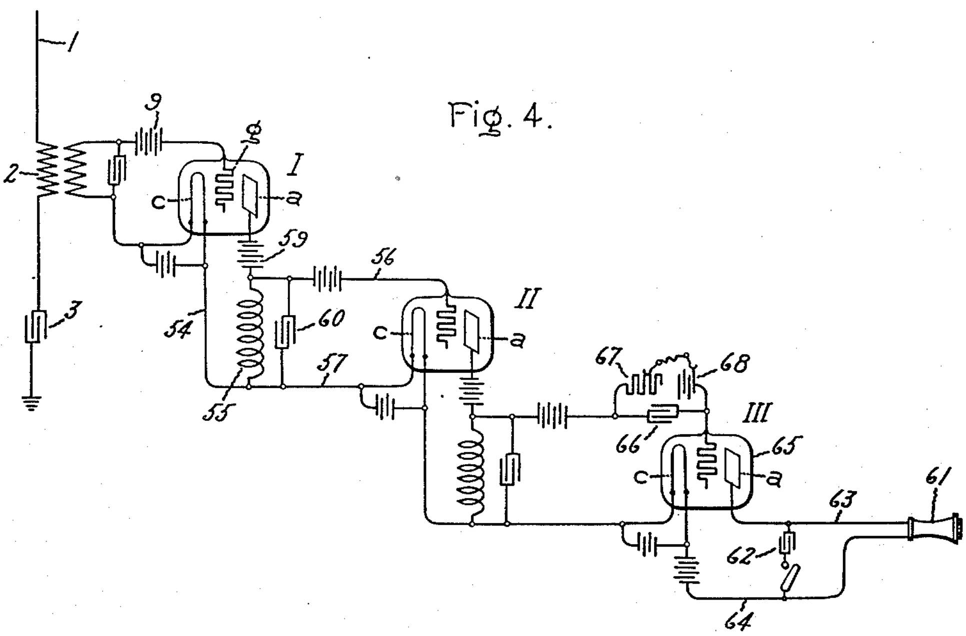
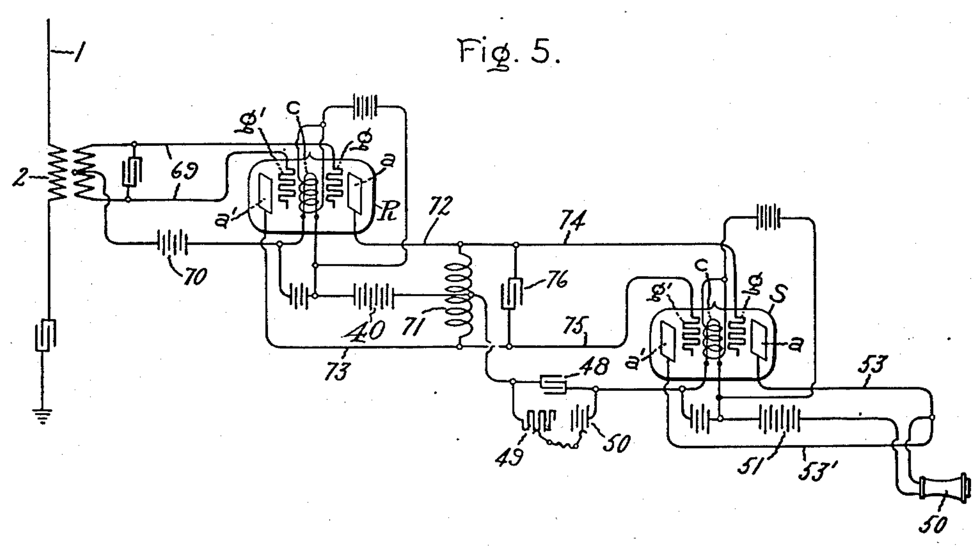


Fig. 5.



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UNITED STATES PATENT OFFICE.

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SELECTIVE TUNING SYSTEM.

1,173,079. Specification of Letters Patent. Patented Feb. 22, 1916.

Application filed October 29, 1913. Serial No. 797,998.

To all whom it may concern:

Be it known that I, Ernst F. W. Alexanderson, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Selective Tuning Systems, of which the following is a specification.

The present invention relates to the selection of oscillations of a given wave length from mixed oscillations, and comprises systems suitable for tuning out interferences in radio-telegraphy.

One of the chief problems encountered in radio-telegraphy is the suppression of waves of various wave lengths interfering with the waves constituting the signal to be received. The method now commonly employed for this purpose consists in using an electric circuit in which a train of waves of a given frequency acts cumulatively so that each successive impulse adds its energy to the previous impulse, while disturbing impulses of a different frequency have little effect. However, to screen out strong disturbing impulses effectively, when weak signals are to be received, requires an accuracy of adjustment which imposes a definite limit upon the possible selectivity of the system.

In accordance with the present invention, selective tuning is secured by the use of a plurality of resonant circuits arranged in cascade in such a manner that the selectivity of the system increases in geometric ratio with the number of circuits employed. The selective circuits are respectively interlinked by a relay controlling a separate source of energy to initiate oscillations corresponding to potential oscillations impressed upon the relay. As each tuned circuit is more or less opaque to disturbing oscillations differing in frequency from the oscillations to be selected, a certain percentage of the disturbances is eliminated in each circuit of the series, so that the purity of the incoming train of oscillations progressively increases as it is successively relayed. The relay preferably used for this purpose is an electron discharge tube having an incandescent cathode, an anode and a grid.

In the accompanying drawings, Figure 1 is a diagram illustrating a system in which three tuned circuits are employed, the last being provided with a telephone receiver; Fig. 2 illustrates a modification in the last circuit of the series to intensify the effect of the signals upon the telephone; Fig. 3 illustrates a system containing a modified relay responsive to both half waves of an alternating current, and Figs. 4 and 5 illustrate an arrangement in which transformers have been replaced by reactance coils affording direct metallic connection between successive circuits.

The electromagnetic waves received by a grounded antenna 1 are impressed upon a resonant circuit including the primary of a transformer 2 and a condenser 3. The secondary of the transformer is loosely coupled with the primary and is connected by means of conductors 5 and 6 with an electron discharge tube 1 such, for example, as described in co-pending applications, Serial Nos. 795,609 and 795,610, filed on October 16, 1913, by Irving Langmuir. This particular type of device operates with a substantially pure electron discharge, and comprises usually an incandescent cathode, and an unheated gas-free anode in a very highly evacuated space, the vacuum being so high that gas ionization by collision is substantially absent. However, my invention is not confined to a relay device operating with a pure electron discharge.

The conductor 5 is attached to a grid g and the conductor 6 to an electron-emitting cathode c consisting, for example, of a tungsten filament maintained at incandescence by the battery b. The anode a consists of a highly refractory metal, preferably tungsten, freed from gas by electron bombardment. The grid g preferably comprises a wire surrounding the cathode with closely adjacent turns.

Connected across conductors 5 and 6 in shunt with the transformer is a condenser 8 which with the electrostatic capacity of the grid g and the inductance of the loosely coupled transformer secondary determines the resonance of the circuit. If desired a separate inductance i may be used but is ordinarily not necessary. In the circuit conductor 5 is included a source of potential, for example, a battery 9. Connected to the cathode c and the anode a is a circuit 10 containing a local source of energy, such as a battery 11, and connected to the primary of a transformer 12. The anode a in the present case is plate-shaped and while it need not necessarily assume this particular form the circuit 10 between cathode and anode will herein be referred to as the "plate circuit".

The secondary of the transformer 12 is connected to a similar resonant circuit which in turn controls by means of a similar electron discharge tube II, a local source of energy, thus setting up another train of oscillations in circuit tuned to be resonant to oscillations of the same frequency to which the circuit 5—6 is resonant. The voltage oscillations in this circuit control another electron discharge tube III. Any number of circuits may thus be interlinked, in accordance with the closeness of tuning desired.

The various parts and connections of the apparatus will be more fully set forth and explained in connection with the description of its operation.

A cascade connection of electron discharge devices, irrespective of tuning to secure selectivity, is described and claimed in a copending application, Serial No. 11,512, filed March 2, 1915, by Irving Langmuir.

As the incoming oscillations are received by a resonant circuit tuned to the particular frequency of the signals which are to be received, the effect of disturbing waves having a different frequency is suppressed to an extent dependent upon the tuning of the circuit. Because of its resistance and spacial distribution the antenna circuit cannot be closely tuned, so that the supression of interferences in this circuit may be disregarded in the present case. However, the waves of various frequencies picked up by the antenna are transferred by the transformer 2 to a resonant circuit 5, 6, the inductance and capacity of which may be closely adjusted so that the oscillations having the desired frequency have a maximum effect whereas the effect of wave impulses having a different frequency is suppressed to, say, for example, one-tenth their original value. The resulting voltage oscillations are superimposed upon the definite negative potential maintained upon the grid g of the electron discharge tube by the battery 9, and this varies the conductivity between the cathode c and the anode a in accordance with the variations of voltage. Preferably the negative terminal of the battery 9 is connected to the grid. The battery 11 sends through the plate circuit 10 a variable current, the oscillations of which are in step with the oscillations in the resonant circuit 5, 6. These oscillations are transferred by a transformer 12 to the resonant circuit 13, 14. The latter circuit containing condenser 15 is also tuned to give full effect to the oscillations of the desired frequency but to be largely opaque to oscillations different therefrom. Assuming that here also the disturbing oscillations are suppressed one-tenth their value it will be seen that they will have been reduced to one-hundredth of their original effect when received by the antenna circuit. The oscillations in the circuit 13, 14 are superimposed upon the grid potential maintained by the battery 16, also preferably negative with respect to the grid. The conductivity in the vacuous space between cathode and anode in the discharge tube II, is varied by the variations of grid charge, causing variable current to flow in the primary circuit of the transformer 18 from the battery 17.

In a third tuned circuit, containing a condenser 19, connected to the secondary of the transformer 18, the desired oscillations will again have substantially full effect while the disturbance will be once more reduced to one-tenth its value. The resulting oscillations in which disturbances have been reduced to one-thousandth their original value are superimposed in a similar manner upon the potential of the grid circuit, determined by a battery 20. The variation of grid potential will cause in the same manner, a variable current to be furnished by the battery 21 in a plate circuit 22. These oscillations will surge in and out of the condenser 23 which has an integrating effect so that a sound may be heard in the telephone receiver 24 for each train of oscillations.

If desired the size of the battery may be so arranged as to magnify the effect of the oscillations which are now practically free from disturbances and so may be readily distinguished by the telephone receiver. In the same manner other tuned circuits may be added and the disturbing impulses suppressed to a degree increasing in geometrical ratio with each tuned circuit added to the system.

It will be readily understood that instead of adjusting the grid potential of the relay devices, the potential of the battery in the plate circuit, and other variable features, to initiate oscillations in which the waves of the desired frequency are reproduced with undiminished intensity, the same relative result may be secured by magnifying the oscillations. While in this case the disturbing oscillations of undesired frequency are also magnified, selectivity will be secured because the waves of desired frequency will be more greatly magnified in geometric ratio with the number of systems employed. For example, when using three systems each with a tuning factor of 10 as above described, so arranged that the disturbances are transmitted without loss of intensity, then the oscillations to be selected will be magnified 1000 times.

The system shown in Fig. 2 is similar to that shown in Fig. 1, except as to the connections of a modified receiving apparatus shown in circuit 25, 26. The battery 20 of Fig. 1 has been replaced by a condenser 27, shunted by a variable high resistance 28 in series with a source of electromotive force as battery 29 which may also be varied.

When the grid is positively charged it will take up electrons at a rate varying with the degree of positive charge and when the grid is negatively charged the rate at which it absorbs electrons decreases with the degree of negative charge until an equilibrium is reached at which no more electrons are taken up. When oscillations are superimposed on the grid having a condenser in circuit a positive wave will cause it to take up more electrons which are not discharged during the succeeding negative wave. Each successive wave thus adds its increment to the negative charge which accumulates on the grid and the plate of the condenser connected to it, until the grid has received such a negative charge that it no longer takes up more electrons than it loses. When the wave train ceases this added negative charge leaks off. A variable current therefore tends to flow in the plate circuit 30, 31 of the tube III having a fundamental frequency equal to the group frequency which may be detected by telephone 33 and a high frequency component which is absorbed by the condenser 34. The proper adjustment of the grid potential to give the best results is obtained by varying the resistance and the battery potential in shunt with the condenser. This particular integrating feature is not part of my present invention but is described and claimed in a copending application Serial No. 797,985 filed October 29, 1913, by Irving Langmuir.

When the high resistance shunt 28 is closed around the condenser, the negative charge acquired by the condenser can leak off faster during the interval between wave trains. By including the battery 29 in circuit a definite positive potential may be impressed upon the grid *g* which enables better control to be obtained, especially with a fine grid, and also serves to neutralize the negative potential impressed upon the circuit by the battery 32. By varying the capacity of the condenser, the high resistance leak and the potential the best conditions may be secured.

In the system shown in Fig. 3, electron discharge relays having two grids and two anodes are employed so as to take advantage of both half waves of the oscillations. Conductors 35, 36 are connected respectively to grids *g* and *g'* located on opposite sides of the cathode *c*. The battery 37 included in the circuit 38, connected to the cathode *c* and to an intermediate point of the transformer secondary 39 serves to impress a negative potential on each grid. The battery 40 connected to an intermediate point on the primary of the transformer 41 and the cathode serves as a local energy supply. An additional grid 42 is used in this case connected to the positive terminal of a source of electromotive force, such as a battery 43, the negative terminal of which is connected to the cathode *c*. This additional grid prevents interfering reacting static effects between the respective grids. It constitutes with the filament a virtual source of electrons, as described and claimed in an application Serial No. 797,986 filed October 29, 1913, by Irving Langmuir.

The operation of the system shown in Fig. 3 is similar to that shown in Fig. 1, and, therefore, only two resonant circuits connected by a relay have been shown for the purpose of illustration, but it should be understood that any number of circuits may be used with the same advantage of suppressing disturbances in geometric ratio with the number of circuits used. The oscillations are received from the antenna 1 in a circuit resonant for the particular frequency which is to be detected. For this purpose the condenser 3 may be made adjustable. The voltage oscillations imposed alternately upon the negative potentials on the grids *g* and *g'* causes a variable electron current to flow from the cathode *c* alternately to anode *a* and *a'* thereby producing variable currents in the primary of the transformer 41. The oscillations are impressed upon the tuned circuit 45, 46, connected to the secondary of the transformer 41, and the disturbances are suppressed in accordance with the tuning factor of the circuit as already explained. The signals are detected in a receiving system similar to that described in connection with Fig. 2 and containing an electron discharge tube 47, having an incandescent cathode *c*, grids *g* and *g'* and anodes *a* and *a'*. The condenser 48, shunted by means of the variable resistance 49 and a variable battery 50, is connected to an intermediate point of the secondary of transformer 41, and in that manner to each of the grid circuits 45, 46. This condenser integrates the high frequency oscillations similarly to the condenser connected to the grid circuit in Fig. 2. The battery 51 sends variable current alternately to anodes *a* and *a'* in accordance with the voltage fluctuation of the grids *g* and *g'*, thereby producing audible signals in the telephone receiver 52 which is connected to the battery 51 and to the anode conductors 53, 53′.

In the system illustrated by Fig. 4 a direct metallic connection is used between the respective resonant circuits instead of a transformer connection. The plate circuit 54 of the relay tube I is connected to the terminals of the inductance 55 which is also attached to the grid circuits 56 and 57 of the second relay II. Current impulses are transmitted through this inductance coil by battery 59 in step with the voltage fluctuation of the grid *g* in the same manner as already described. The inductance of the coil 55 and the capacity of the condenser 60 are adjusted to make the grid circuit of the relay II resonant to the same frequency as the grid circuit of the relay I. In this manner the disturbances are progressively suppressed as the oscillations are transferred from circuit to circuit as already described. The signal may be finally detected by a suitable receiving instrument, such as the telephone receiver 61, connected in shunt with a condenser 62 to the plate circuit 63, 64, of an electron discharge tube 65. In a grid circuit of this discharge tube there is a condenser 66 shunted by means of an adjustable resistance 67 to an adjustable source of potential, such as battery 68, which operates to integrate the high frequency oscillations as already described in connection with Fig. 2.

In the system shown in Fig. 5, discharge tubes having two grids and two anodes are shown used in a system having inductance coils instead of transformers connecting the resonant circuits. In general the connections are analogous to those already described in connection with the other systems.

The oscillations produced in the circuit 69 tuned to the particular frequency which is to be selected, impresses voltage fluctuations upon the grids *g* and *g′* which are maintained at a given negative potential by the battery 70 and thus causing a variable current to flow from the cathode *c* to the anodes *a* and *a′* in an electron tube R, such as already described above, in connection with Fig. 3. The resulting variable current which is in step with the oscillation in the resonant circuit 69 pulsates in the inductance coil 71. The terminals of the coil 71 are connected to the anode circuits 72, 73, and through a battery 40 to the cathode as indicated. This inductance also forms part of the circuit 74, 75 containing a condenser 76 which is adjusted to make the circuit resonant with respect to the frequency to be selected. The disturbances are again suppressed in this circuit, as in circuit 69. In this manner any number of circuits may be arranged to still further suppress disturbing oscillations. It is believed that it will be clear in view of Fig. 4, how these connections may be made and, therefore, the circuit 74, 75 has been shown connected directly to a receiving circuit by means of a relay S. The connections of the telephone receiver 50 and the condenser 48 to the relay S are the same as described in connection with Fig. 3, and for that reason the description will not be repeated at this point. In fact any other suitable receiving instrument may be used in place of the telephone receiver and a battery may be used in place of the condenser 48 similar to the battery 20 in Fig. 1.

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

1. The method of selecting sustained oscillations of a given frequency from disturbing oscillations differing therefrom in frequency which consists in impressing all the oscillations upon a circuit, resonant to the frequency of the oscillations to be selected, thereby reducing the effect of disturbing oscillations in accordance with the degree of tuning of the resonant circuit, and controlling by means of the oscillations in said circuit an independent source of energy to initiate oscillations in step therewith and impressing the second set of oscillations upon a second circuit, resonant to the frequency of the oscillations to be selected.

2. A receiving apparatus for electromagnetic waves comprising a plurality of tuned circuits largely opaque to oscillations of other than a given frequency, means linking adjoining circuits, said means comprising a source of energy and an energy transmitting apparatus varying in conductivity with impressed oscillations for initiating oscillations in step with received oscillations and means associated with the last circuit of the series for detecting the oscillations.

3. A tuned receiving system for detecting sustained oscillations of a given frequency comprising a plurality of circuits resonant to the frequency of the oscillations to be detected and arranged in cascade, relay devices joining each of said circuits to another comprising an evacuated envelop, an electron-emitting cathode, a coöperating anode, and a grid, said device being connected to one of said circuits at the cathode and grid and to another circuit at the cathode and anode and a local source of energy in the second circuit.

4. The combination of an energy controlling device comprising an evacuated envelop, an incandescent cathode, an anode, and a grid for statically controlling the transfer of energy between said electrodes, a resonant circuit connected to the cathode and grid of said device, a second circuit resonant to the same frequency as the first circuit connected to the cathode and anode of said device and a local source of energy in the latter circuit.

5. The combination of an electron discharge device comprising a highly evacuated

envelop, an incandescent cathode, an anode, means for statically controlling the energy transfer between cathode and anode, a resonant circuit connected to the cathode and said static controlling means, a source of potential in said circuit, a second circuit, resonant with respect to the same frequency as the first circuit, connected to the cathode and anode of said device and a local source of energy in said circuit.

6. The combination of a resonant circuit, means for impressing mixed oscillations on said circuit, and an electron discharge relay having a discharge-controlling grid, said relay being connected to said resonant circuit at its cathode and grid, a source of negative potential connected to said grid, a second circuit resonant with respect to the same frequency as the first connected to the electrode circuit of said relay, a source of energy in the electrode circuit of the second relay, delivering to the second resonant circuit oscillations in step with the oscillations in the first resonant circuit and means for detecting the oscillations in the second resonant circuit.

7. The combination of a resonant circuit containing an inductance and a condenser, an incandescent cathode relay having its grid circuit connected to the terminals of said condenser, a source of energy connected to the electrode circuit of said relay, and a second circuit resonant to the same frequency as the first resonant circuit connected to be supplied with current from the relay electrode circuit.

8. A selective receiving system for receiving oscillations of radiant energy comprising an antenna, a circuit operatively related thereto resonant to the frequency of the oscillations to be detected, a relay device sensitive to potential oscillations impressed thereon, a second circuit resonant to the same frequency as the first connected to the cathode and an anode of said relay, a source of energy in said second circuit controlled by said relay, and means for detecting oscillations in said circuit.

9. The combination of an electrical discharge device comprising an envelop, a cathode adapted to emit negative charges, an anode and means for controlling a discharge between said electrodes, a circuit electrically resonant to variable current of a given frequency, electrical connections between said circuit and the discharge controlling means of said device, a second circuit resonant to variable current of the same frequency, a source of electrical energy in circuit with the electrodes of said device, and means for impressing a variable current initiated by said source of energy upon the second resonant circuit.

10. The combination of an electrical discharge device comprising an evacuated envelop, a cathode operable at incandescence, a coöperating anode and a discharge-controlling grid, a circuit electrically resonant to electrical oscillations of a given frequency and substantially opaque to oscillations of a different frequency, connections between said circuit and the cathode and grid of said discharge device, a second circuit resonant to oscillations of substantially the same frequency as said first circuit, a source of energy in the electrode circuit of the discharge device, connections for delivering current from said source to said second circuit, and means for detecting oscillations in said second circuit.

11. A system for selecting electrical oscillations of a given frequency from oscillations differing therefrom in frequency comprising a series of resonant circuits substantially opaque to oscillations of other than the given frequency, a relay device between two successive circuits, said device comprising an evacuated vessel, an electron-emitting cathode, an anode and a grid, connections between one of said circuits and the cathode and grid and connections between a second circuit and the cathode and anode.

12. A system for selecting electrical oscillations of a given frequency from oscillations differing therefrom in frequency comprising a series of resonant circuits largely opaque to oscillations of other than the given frequency, and means linking adjoining circuits, said means comprising a source of electric energy and an energy-transmitting apparatus varying in conductivity in accordance with oscillations impressed thereon from one circuit whereby oscillations are set up by said source of energy in another linked resonant circuit of said series having the same frequency as the impressed oscillations.

13. The combination of an electrical discharge device comprising an electron-emitting cathode, an anode, means for varying the conductivity between said electrodes and an inclosing envelop so highly evacuated that current is passed between said electrodes substantially independent of positive ionization, a resonant circuit substantially opaque to oscillations other than a given frequency connected to the discharge-varying means of said discharge device, a source of electrical energy in the electrode circuit of said device, and a second circuit resonant to oscillations of substantially the same frequency of the first circuit connected to receive current from said source.

14. The combination of a circuit containing an inductance and capacity arranged to be resonant to electrical variations of a given frequency, an incandescent cathode relay having a grid for controlling the transmission of current between the cathode and the anode, a battery connected to said grid, a

source of energy connected to the cathode and anode of said relay, connections for impressing oscillations in said resonant circuit upon said battery, a second circuit containing inductance and capacity arranged to be resonant to the same frequency as the first circuit, and means for transferring current from the relay electrode circuit to the second resonant circuit while maintaining the frequency substantially unchanged.

In witness whereof, I have hereunto set my hand this 28th day of October, 1913.

ERNST F. W. ALEXANDERSON.

Witnesses:

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MARGARET E. WOOLLEY.