Nov. 15, 1938. N. E. LINDENBLAD 2,136,448

RADIO FREQUENCY RELAY

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Fig. 1

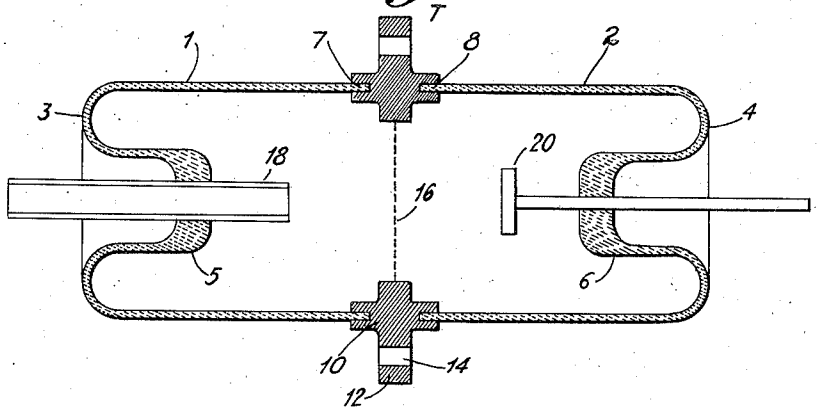
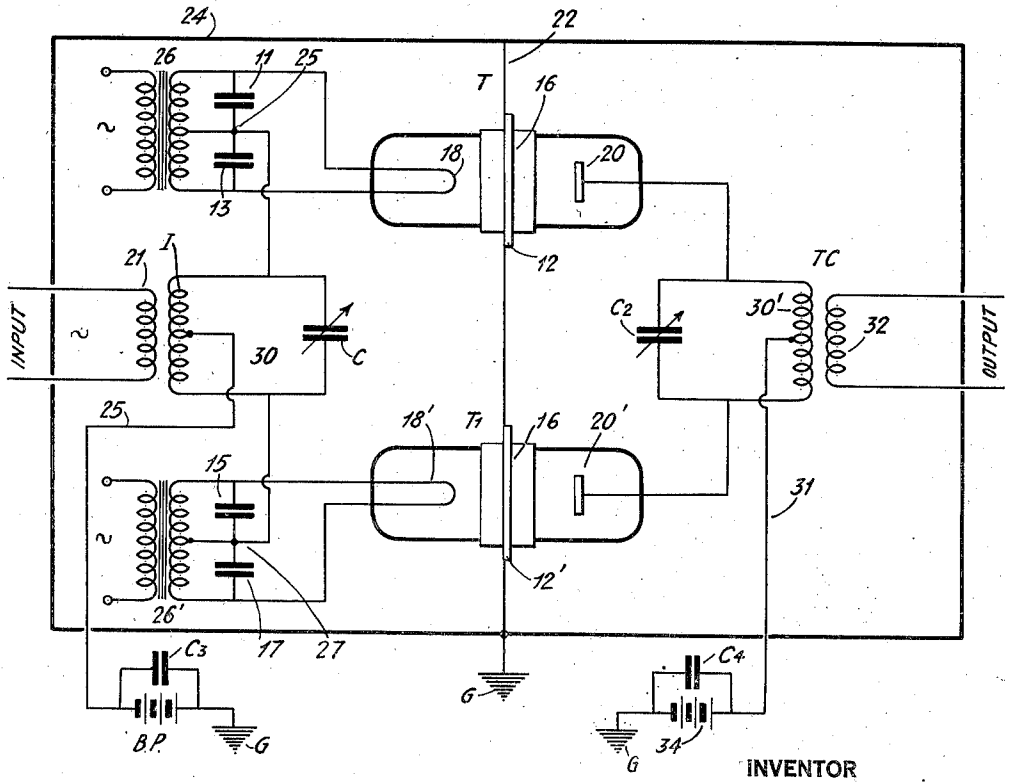


Fig. 2



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Fig. 3

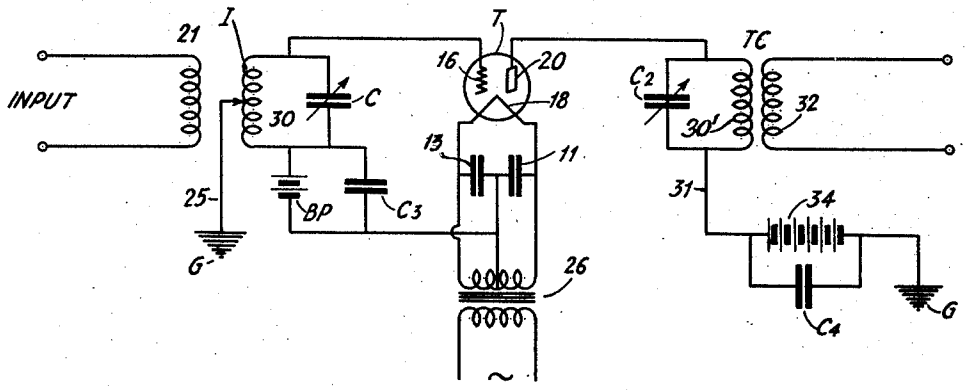
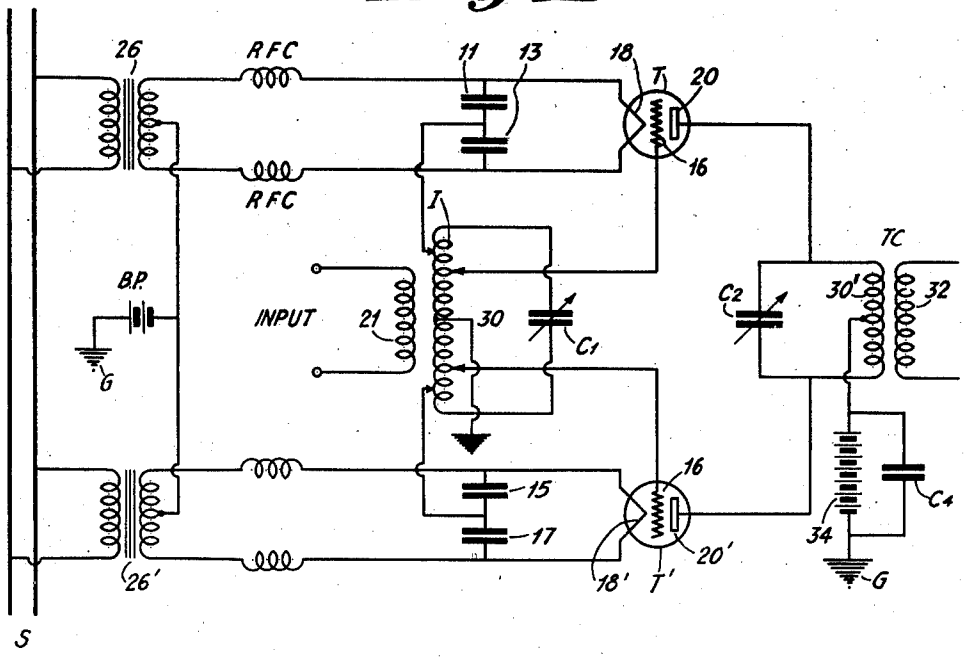


Fig. 4



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2,136,448

RADIO FREQUENCY RELAY

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Application April 14, 1932, Serial No. 605,274

16 Claims. (Cl. 179—171)

This invention relates to a novel method of amplifying ultra high frequency oscillations, to a thermionic tube for use in ultra high radio frequency signalling, and to a novel circuit for relaying electric energy at radio frequency in which the aforesaid novel tube is connected.

In tubes used hereinbefore to relay or amplify ultra high frequency oscillations, numerous difficulties have been encountered due to the internal capacity coupling between the several electrodes enclosed in the envelope of the tube, also due to the impossibility of providing low impedance leads from the tube elements in conventional tube design. This inter-electrode capacity is the cause of many undesirable effects. The use of a tube in which the inter-electrode capacity is present, even when compensated, is attendant with many serious disadvantages.

Many schemes have been devised to counteract or compensate the effect of this internal capacity. In some arrangement, neutralizing capacities are placed at appropriate points external to the tube envelope and between the desired electrodes and/or throughout the interconnecting circuits to compensate or to counteract the effect of the inter-electrode capacity. While it is true that these neutralizing capacities were to some extent effective to counteract the internal capacity or to negative the effect of the internal capacity between electrodes and to decouple the input and output circuits, they are not entirely satisfactory at very high frequencies since the neutralizing capacities themselves, together with sufficient amounts of inductance, which is inherent and thus unavoidable, form new paths in which free oscillations can develop at some other, sometimes only slightly different, frequency. Thus, for very high frequencies, neutralizing, or rather balancing, can only be accomplished for one particular frequency at the time. As there is nothing to prevent the circuits from choosing these free oscillations, they provide a serious problem which offsets the advantages gained by the use of neutralizing capacities. Furthermore, these neutralizing capacities are usually added as directly as it is possible (outside the tube envelope) to the internal capacity between the electrodes in the tube and thereby contribute to a decrease in the maximum frequency, which can otherwise be relayed or amplified by the thermionic tube and its associated circuits. This decrease being due to increased total capacity with resulting lower capacitive reactance which holds down the voltage swing of the electrodes.

In other cases, tubes of the screen grid type were used. It was found that even these tubes and their associated circuits became very unstable in operation where ultra high frequencies were to be relayed or amplified, because of the difficulty of providing a low inductance, low capacity lead from the screen to ground.

All of the above disadvantages are obviated in accordance with the present invention by the use of a novel thermionic tube wherein the envelope comprises two vitreous portions separated by a metallic ring having an extending flange, the ring being connected with the grid electrode which is disposed somewhere near the median line of the ring and of the envelope. The anode electrode is disposed in one of the vitreous bulbs of the tube, and the heated cathode is disposed in the other vitreous bulb of the tube.

By the use of the novel tube, as described above, in a push-pull circuit in which the grid electrode is maintained at a constant potential and the cathode electrode is swung or oscillated at ultra high frequency with respect to the grid electrode, extremely stable and satisfactory operation may be obtained. Furthermore, the use of such arrangement permits higher frequencies to be relayed or amplified than has been heretofore possible.

Stable operation of thermionic relays and amplifiers, at frequencies where conventional neutralizing methods are successful, is also obtained in accordance with the present invention by the use of a tube of the type heretofore known in the art, or by the use of a tube constructed in accordance with the present invention in a new and improved circuit in which the elements of the circuit are so arranged that the circuits balance themselves without the use of neutralizing capacities or equivalent oscillation suppressing or preventing means. This is accomplished in accordance with the present invention by the use of a relay arrangement in which the high frequency energy to be relayed or amplified is fed into a circuit, a part of which is included in the ground to filament circuit of the tube, and a part of which is included in the ground to grid circuit of the tube. In other words, the circuit of the present modification is a sort of hybrid between a conventional circuit and the grounded grid circuit, and the grounded grid circuits referred to hereinbefore in which, as constructed in accordance with the present invention, degeneration is under control and stable operation is obtained without the use of neutralizing capacities.

In a modification the oscillations are fed into a circuit, a part of which is included in the filament to ground circuit, and another part of which is included in the grid to ground circuit of a pair of thermionic tubes symmetrically arranged. This last modification includes all of the advantages to be gained by the use of the prior modification and, in addition, the advantages attendant on the use of push-pull relays or amplifiers.

The novel features of the thermionic tube and

of the high frequency relay circuit have been pointed out with particularity in the claims appended hereto.

The nature of the tube and the circuit arrangement, and the operation of the latter, will be clear to the reader from the following detailed specification, and therefrom when read in connection with the attached drawings throughout which like reference characters indicate like parts, and in which:

Figure 1 shows a practical embodiment of my novel thermionic tube;

Figure 2 shows, for purposes of illustration, an ultra high frequency relay circuit in which a pair of tubes, as illustrated in Figure 1, are incorporated; while,

Figure 3 shows another method of an arrangement for preventing oscillations from taking place in a thermionic relay or amplifier; and,

Figure 4 shows a modification of the arrangement of Figure 3.

Referring to Figure 1, T indicates a thermionic tube having vitreous portions 1 and 2 which are closed at the ends 3 and 4 by re-entrant portions 5 and 6 respectively. The open ends 7 and 8 of the vitreous portions 1 and 2 are sealed by means of a metallic member 10 as indicated. Metallic member 10 has integral, or fastened thereto, an annular ring-shaped member 12 having bolt holes 14 therein or being threaded around its periphery. The ring-shaped member 12 permits mounting of the tube T. The grid electrode 16 of the thermionic tube T is suspended within the opening in the ring member 10. The specific nature of this grid forms no part of the present invention and need not be discussed in detail here. The grid, however, may be of any known shape or structure. The cathode or filament electrode 18 is supported in the re-entrant portion 5 of the bulb 1 while the anode electrode 20 is supported in the re-entrant portion 6 of the member 2. It will be obvious that if the ring 12 is mounted in an opening in a metallic sheet or support, the electrode 18 may be electrostatically isolated from the electrode 20 to a very high degree by means of the grid 16 and ring 12.

In Figure 2 is shown a symmetrical relay circuit which includes two thermionic tubes T and T', each constructed as illustrated in Figure 1. Each of these tubes is fixed by its ring 12 to a metal partition member 22 dividing the metal shielding closure member or box 24 into two separate portions. The cathode 18 of T and cathode 18' of T' are heated from any alternating current source through transformers 26 and 26', each having a symmetrical secondary winding, the outer terminals of which are connected to the cathodes 18 and 18' respectively, and the electrical midpoints 25 and 27 of which are connected to the terminals of an input circuit 30 comprising variable capacity C and inductance I. The input circuit 30 is tuned to the frequency of the incoming signal by means of the inductance I and the capacity C. The incoming signal, which may be derived from any source of ultra high frequency oscillations, is impressed on the inductance I by means of the inductance 21 coupled thereto. Biasing potential to maintain the cathodes 18 and 18' at the desired operating potential relative to grid electrodes 16 and 16' is provided by connecting the midpoint of inductance I through a lead 25 to a source of biasing potential BP having one terminal grounded as shown. The anodes 20 and 20' of the thermionic tubes T and T' are connected as shown in a tank circuit TC comprising a tuning capacity C_2 and inductance 30'. Oscillations appearing in the tank circuit TC are conveyed to any work circuit by means of an inductance 32 inductively coupled to inductance 30'. Charging potential for the anodes 20 and 20' is provided by a lead 31 connected on the one hand with the midpoint of the inductance 30' and on the other hand to the positive terminal of a source 34 having its negative terminal connected to ground. In order to prevent any radio frequencies appearing in the input circuit 30 from being introduced into the source of alternating current used to heat the cathodes 18 and 18', the leads 25 and 27 are connected at a point between pairs of radio frequency shunting condensers 11 and 13 and 15 and 17 respectively connected in parallel with the secondary winding of transformers 26 and 26'.

In operation, the high frequency oscillations are impressed from the source through winding 21 to the input circuit 30 of the thermionic tubes T, T'. The grids of these tubes are maintained at a constant potential lower than the potential of the cathodes. The grids may be at ground potential. The cathodes 18 and 18' of the tubes oscillate at the fundamental frequency of the ultra high frequencies to be relayed with respect to the grid electrodes. The oscillating potentials of the frequency to be relayed appearing on the anodes 20 and 20' are set up in the tank circuit TC from which they are led by means of inductance 32 to any work circuit.

It has been found that by maintaining the grids at an alternating current potential lower than the potential of the cathode, or by grounding the grid electrode as to alternating current potentials, extremely stable operation is obtained. It has further been found that by mounting the tubes, as shown in Figure 2, not only are the anodes and cathodes of the tubes shielded from each other to a high degree, but the output and input circuits of the relay system are electrically separated.

In practice I have found that oscillations at undesired frequencies, taking place in thermionic relays or amplifiers known heretofore, may be prevented and a high degree of amplification obtained by the use of a relay arrangement in which the oscillations to be relayed are impressed in part on the cathode to ground circuit and in part on the grid to ground circuit of the tube. Here, the grid is not maintained directly at ground alternating current potential as in the modifications hereinbefore described.

The method of operation of a circuit of this type will now be described. The general arrangement of such a circuit will be understood by reference to Figure 3.

Referring to Figure 3, T indicates a thermionic tube having a grid electrode 16 connected to an input tank circuit 30 comprising a tuning capacity C and an inductance I. Tube T also includes a cathode 18 adapted to be energized from any alternating current source through a transformer 26. The electrical midpoint of the cathode 18 is connected to one terminal of the input tank circuit 30. A path for the radio frequency oscillations between the tank circuit 30 and cathode 18 is provided by series capacities 11 and 13 connected, as indicated, across the terminals of cathode 18. In order to control the effect from the reaction from taking place between the electrodes in tube T, and to insure stable operation, the inductance I is connected

to ground G by a lead 25 connected to a tap on the inductance I. Oscillations to be relayed or amplified are impressed on the inductance 21 inductively coupled to the inductance I in the grid cathode tank circuit. Biasing potential for the control electrode 16 may be obtained from a source BP connected, as indicated, between the tank circuit 30 and the cathode 18. Radio frequency oscillations are shunted around the impedance of the source BP by means of a capacity C_3. A utilization circuit or tank circuit TC is connected between the anode 20 and ground through a source 34, as indicated. Source 34 is shunted by a radio frequency by-pass condenser C_4, as shown.

In operation the oscillations impressed on the input inductance 21 are transferred to the inductance I and from the inductance I are impressed on the cathode 18 and control electrode 16 of the tube T. The oscillations, after being relayed in T, appear on the anode 20 and on the output circuit TC, from which they may be transferred to any utilization circuit by way of inductance 32. In this modification, since there is less of the excitation circuit included in the plate cathode circuit, the degeneration effect of the plate current flowing in the excitation circuit is decreased. Therefore, stable operation is performed without materially decreasing the amplification characteristics of the thermionic tube T. The arrangement is such, however, as to insure the elimination of oscillations in the amplifier. This is accomplished without the use of neutralizing capacities or equivalent means.

In Figure 4 is shown an arrangement somewhat similar to the arrangement of Figure 3. In the arrangement of Figure 4, however, a pair of thermionic tubes T and T' are connected in push-pull relation. In this modification, as in the modification of Figure 3, the input oscillations are impressed on a grid tank circuit 30, a portion of which is included in the filament to ground circuit of each tube, and a portion of which is included in the control electrode to ground circuit of each tube. In this modification, as in the prior modification a small portion only of the excitation circuit is in the plate cathode circuit. therefore, the degeneration effect of the plate current in said circuit is small.

In any case, in this modification, as in the prior modification, the degenerating effect resulting from grounded or partly grounded grids becomes less objectionable at higher frequencies as the overall efficiency of this and conventional methods becomes approximately the same. Since some of the features of the present invention are especially applicable to ultra high frequencies, the degeneration effect due to the plate return current flowing through a reactive branch to the filament, which also includes the excitation circuit, is negligible compared with other losses at these very high frequencies. In the case of partly grounded grids, however, this method remains efficient also for lower frequencies.

The cathodes 18 and 18' are energized from transformers 26, 26' through radio frequency chokes RFC, which prevent high frequencies relayed in the tubes T, T' from reaching the low potential source connected with the cathodes 18, 18'. The grid electrodes 16, 16' are connected to movable points on the inductance I, while the points between the capacities 11 and 13 and 15 and 17 are connected to points on the inductance I. In this manner the amount of inductance included in the cathode to ground circuits and the amount of inductance included in the control electrode to ground circuits can be adjusted. Biasing potential may be supplied to the control electrodes from a battery BP inserted in the connection between the electrical centers of the secondary windings of transformers 26 and 26' and ground, as shown. Input oscillations are impressed on the inductance I from a source, not shown, connected with inductance 21 inductively coupled to I. The impressed oscillations are repeated in the tubes T, T', amplified therein, and transferred therefrom to the tank circuit TC connected between the anodes of the tubes. The anode charging potential source 34 in this modification, as in the prior modifications, is shunted by radio frequency by-pass condensers C_4.

In operation the oscillations to be relayed or amplified are impressed on the inductance 21 and from there to the tuned tank circuit 30 and to the cathodes and control electrodes of the tubes T, T'. The oscillations, after being repeated in the tubes T, T' appear in the tank circuit TC, from which they may be transferred to any utilization circuit by way of inductance 32.

The tapped connections between the cathodes and the inductance I and the control electrodes and the inductance I permit the desirable amount of said inductance to be included in the cathode to ground and control electrode to ground circuits. In this manner the amount of excitation circuit included in the anode to cathode circuit may be altered and the amount of degeneration effect resulting from anode current flowing in the excitation circuit may be altered. These tapped connections between the cathodes and control electrodes and the inductance I likewise permit an electrical balance of the circuit with respect to ground and with respect to the excitation source to be maintained, thereby further enhancing the balance effect of the amplifier and reducing any tendency of said amplifier and the circuits therein to oscillate due to dissymmetry of said circuits with respect to ground and with respect to each other, and to the radio frequency energizing source not shown.

The arrangement of Figure 2 may be used as a frequency multiplier. If the arrangement of Figure 2 is used as frequency multipliers the anodes of the tubes may be connected in parallel or push-push relation. The arrangement for frequency multiplication in other respects may be as shown in the drawings.

Having thus described my invention and the operation thereof, what I claim is:

1. The method of translating signal oscillations by means of a thermionic tube having a cathode heating circuit and a control electrode cathode circuit which includes the step of applying the signal oscillations to the electrical center of said cathode heating circuit, and maintaining the control electrode at substantially ground alternating current potential.

2. The method of translating ultra high frequency oscillations by means of a pair of thermionic tubes, each having a control electrode and a symmetrically tapped cathode heating circuit which includes the steps of setting up oscillations at ultra high freuqency between the electrical centers of said cathode heating circuits, and maintaining said control electrode at substantially ground alternating current potential.

3. The method of relaying electric oscillations by means of a pair of thermionic tubes connected in symmetrical circuits and each having cathodes

and cathode heating circuits, and control electrodes, which includes the steps of applying the oscillations in part to the electrical centers of said cathodes, and in part to the control electrodes.

4. The method of relaying electrical oscillations by means of a pair of thermionic tubes each having a cathode and control electrode, said electrodes being connected in symmetrical circuits which includes the steps of, applying the oscillations between the electrical centers of said cathodes, and maintaining said control electrodes at substantially ground alternating current potential.

5. A relay comprising a thermionic tube having an envelope, a pair of vitreous portions each closed at one end, a metallic ring member having one end sealed to the open end of one of said portions and the other end sealed to the open end of the other of said portions, an output electrode sealed in one of said end portions, a cathode sealed in the other end portion, a cathode heating circuit therefor, an auxiliary electrode sealed in said metal ring portion, means for applying energy to be relayed to said cathode heating circuit, and means for maintaining said auxiliary electrode at substantially ground potential.

6. An ultra high frequency relay comprising a pair of thermionic tubes, each having an anode and a cathode separated therefrom by a grid electrode, mounting means for each of said tubes comprising a metallic sheet integral with the grid electrode, said metallic sheet being a continuation of the grid electrodes interposed between said anodes and said cathodes, a symmetrical heating circuit for each of said cathodes, means for impressing high frequency oscillations symmetrically on said heating circuits, and a tank circuit connected between the anodes of said tubes.

7. The method of relaying electrical oscillations by means of a pair of thermionic tubes, each having a cathode and control grid electrode, which includes the steps of, applying said oscillations in phase opposition to the electrical centers of the cathodes of said tubes, and maintaining the control grids of said tubes at substantially ground alternating current potential.

8. The method of relaying electrical oscillations by means of a pair of thermionic tubes, each having a cathode and control grid electrode, which includes the steps of, applying said oscillations in phase opposition to the cathodes of said tubes, and simultaneously applying said oscillations in phase opposition to the control grids of said tubes.

9. A device for relaying and amplifying electrical oscillations of ultra high frequency comprising, a pair of thermionic tubes, each having anode, cathode and control electrodes, a repeater circuit connecting the anodes of said circuit in parallel, a source of oscillations to be relayed, an inductance coupled thereto, a circuit connecting spaced points on said inductance to the cathodes of each of said tubes, a circuit connecting spaced points on said inductance to the control electrodes of each of said tubes, and a connection between said inductance and ground.

10. The method of relaying ultra high frequency oscillations, without altering the wave form of said oscillations by said relaying, by means of a thermionic tube having a control grid electrode and an emission element with a heating circuit therefor connected to ground by a high frequency reactance and a high frequency circuit connecting said control grid to ground which includes the steps of, impressing the oscillations to be relayed on a point of said heating circuit which is symmetrical with respect to said circuit and said emission element and to a point on said control grid to ground circuit, the oscillations impressed on said last point being displaced in phase relative to the oscillations impressed on said first named point.

11. The method of relaying ultra high frequency oscillations, without altering the wave form of said oscillations by said relaying, by means of a thermionic tube having a control grid electrode and a filamentary cathode element and a high frequency circuit between said cathode element and ground and between said grid electrode and ground, which includes the steps of, impressing said oscillations in phase and in like amplitude to the terminals of said filamentary cathode, and simultaneously on the grid electrode to ground circuit, the phase of said oscillations impressed on the last named circuit being displaced relative to the phase of the oscillations impressed on the terminals of said filamentary cathode.

12. In combination with an electrostatic shield for separating a pair of tuned circuits, a thermionic tube comprising an envelope containing an anode, a cathode, and a control electrode positioned between said anode and cathode, said control electrode forming a continuing portion of said shield, one of said tuned circuits being connected to said anode and the other to said cathode.

13. In combination with an electrostatic shield for separating a pair of tuned circuits, a thermionic tube comprising an envelope containing an anode, a cathode, and a control electrode positioned between said anode and cathode, said control electrode passing through the wall of said envelope to form a continuing portion of said shield, one of said tuned circuits being connected to said anode and the other to said cathode.

14. In combination with an electrostatic shield for separating a pair of tuned circuits, a thermionic tube comprising an envelope containing an anode, a cathode, and a control electrode positioned between said anode and cathode, said control electrode having a central perforate portion and a peripheral imperforate portion, said imperforate portion being extended through the walls of said envelope to form a continuation of said shield, one of said tuned circuits being connected to said anode and the other to said cathode.

15. In combination with a grounded electrostatic shield for separating a pair of tuned circuits, a thermionic tube comprising an envelope containing an anode, a cathode, and a control electrode positioned between said anode and cathode, said control electrode forming a continuing portion of said shield, one of said tuned circuits being connected to said anode and the other to said cathode.

16. In combination, a pair of tuned circuits, an electrostatic shield positioned to prevent coupling between said circuits, said shield having an aperture therein, and a thermionic tube having an envelope containing an anode, a cathode and a grid therebetween, said grid being peripherally extended through said envelope to close said aperture, one of said circuits being connected to said anode, the other to said cathode.

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