Feb. 25, 1936. J. L. FINCH 2,031,639

METHOD OF AND MEANS FOR MODULATION

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Fig. 1

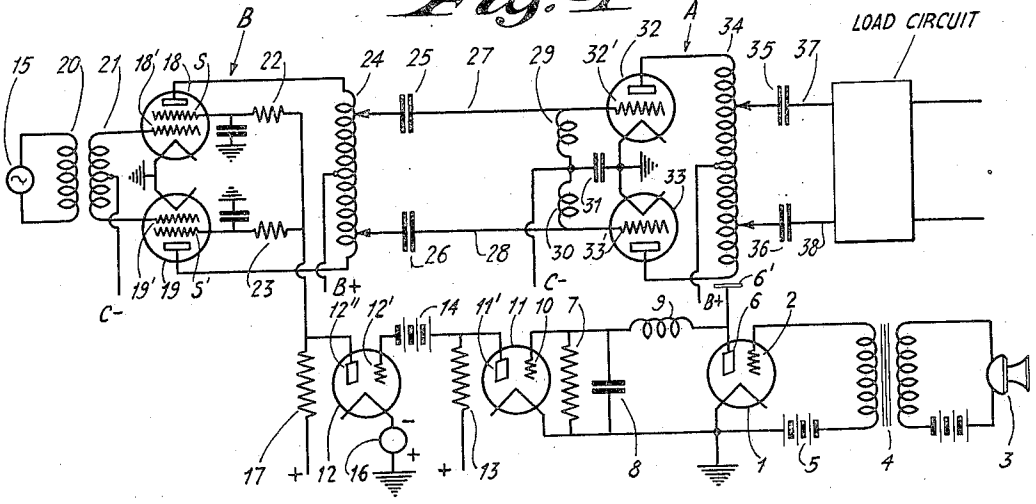
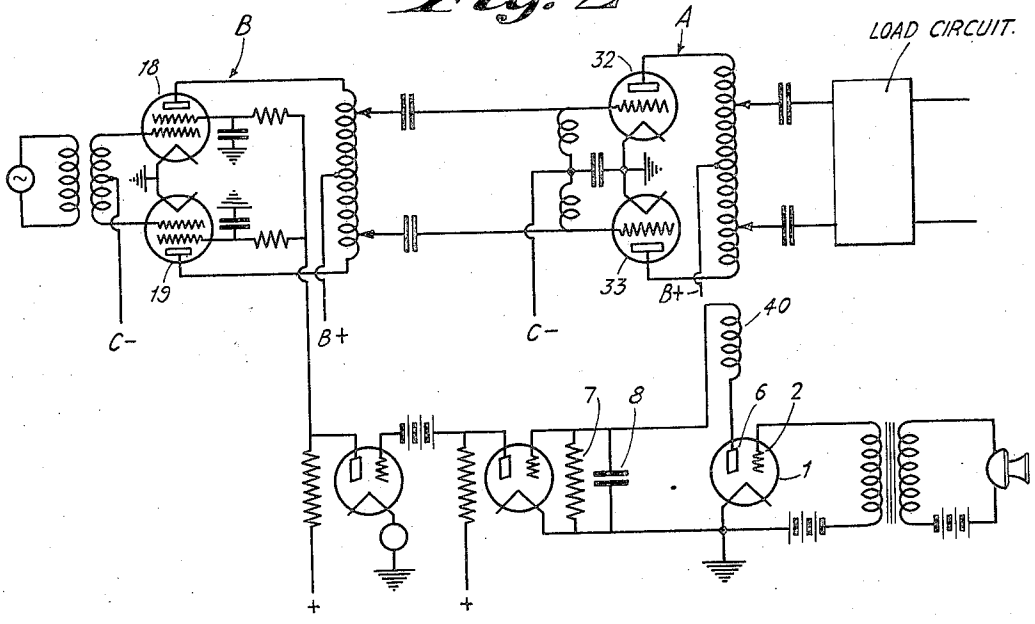


Fig. 2



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METHOD OF AND MEANS FOR MODULATION

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Fig. 3

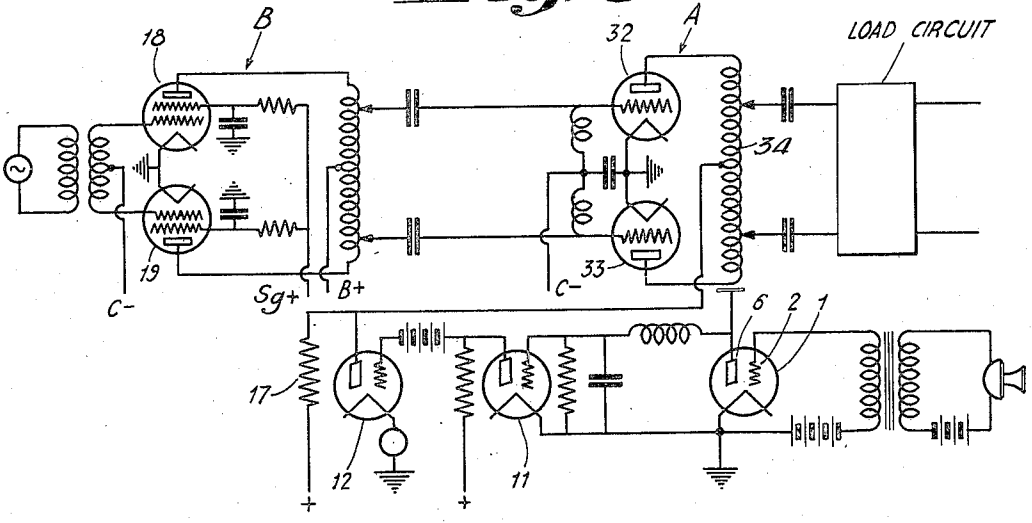
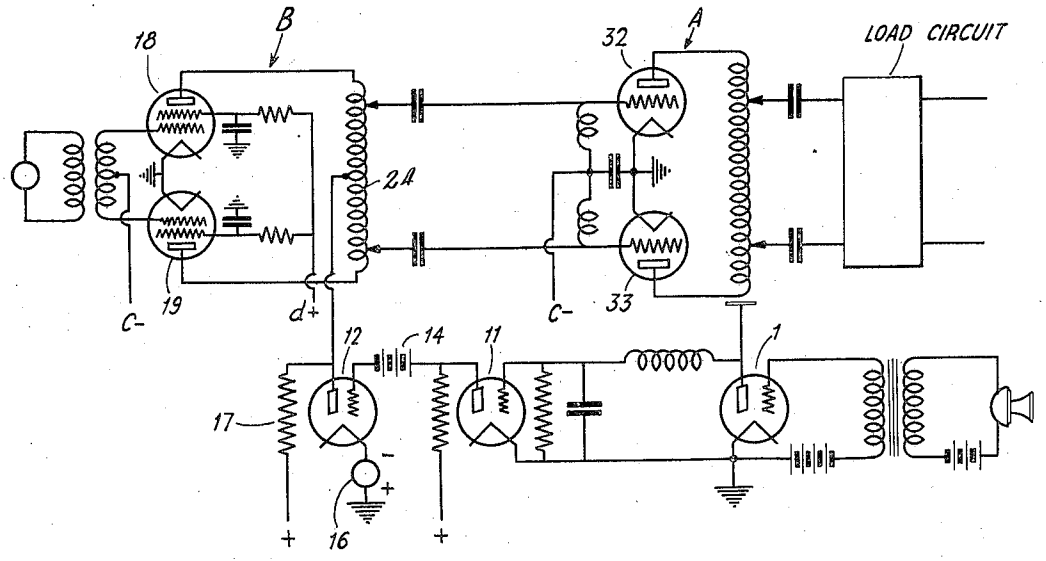


Fig. 4



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METHOD OF AND MEANS FOR MODULATION

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Fig. 5

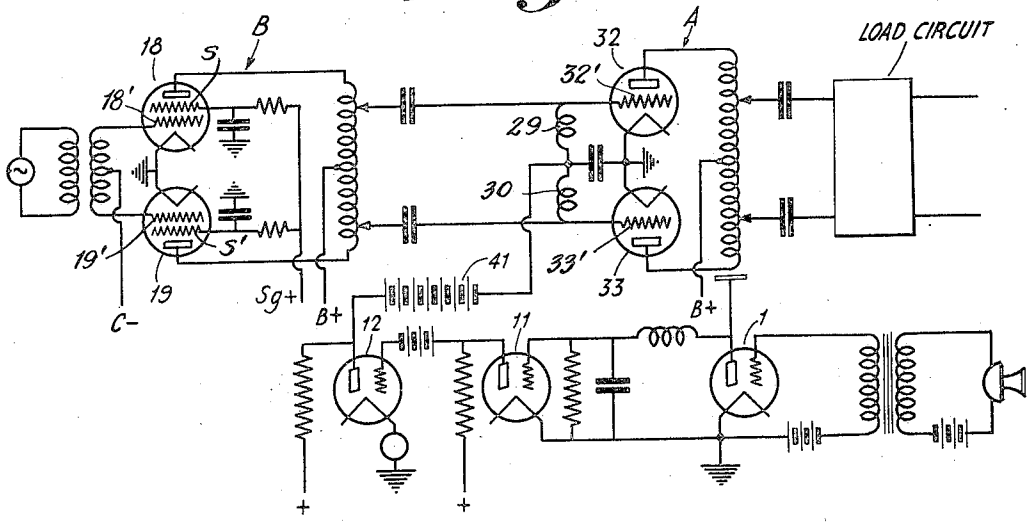
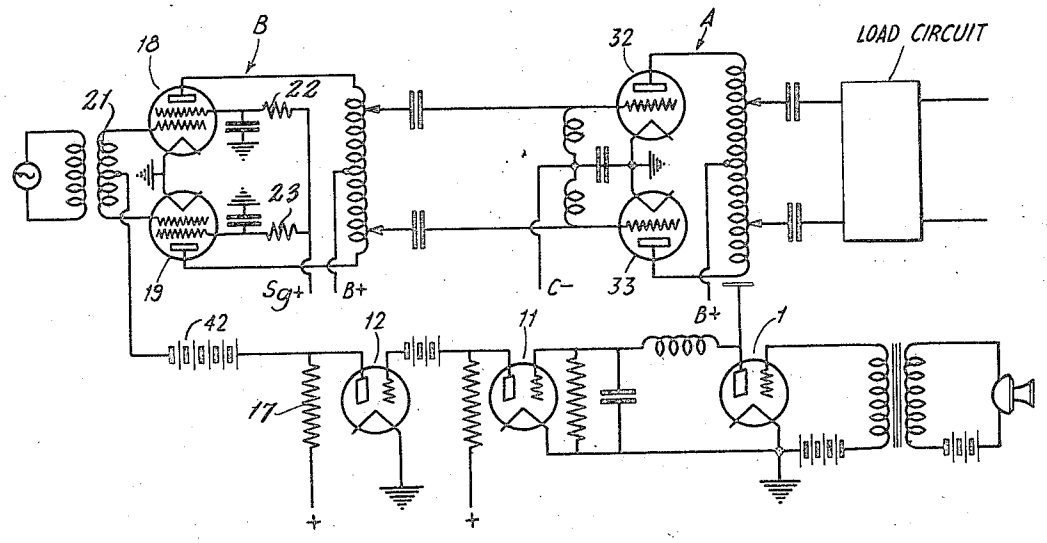


Fig. 6



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Fig. 7

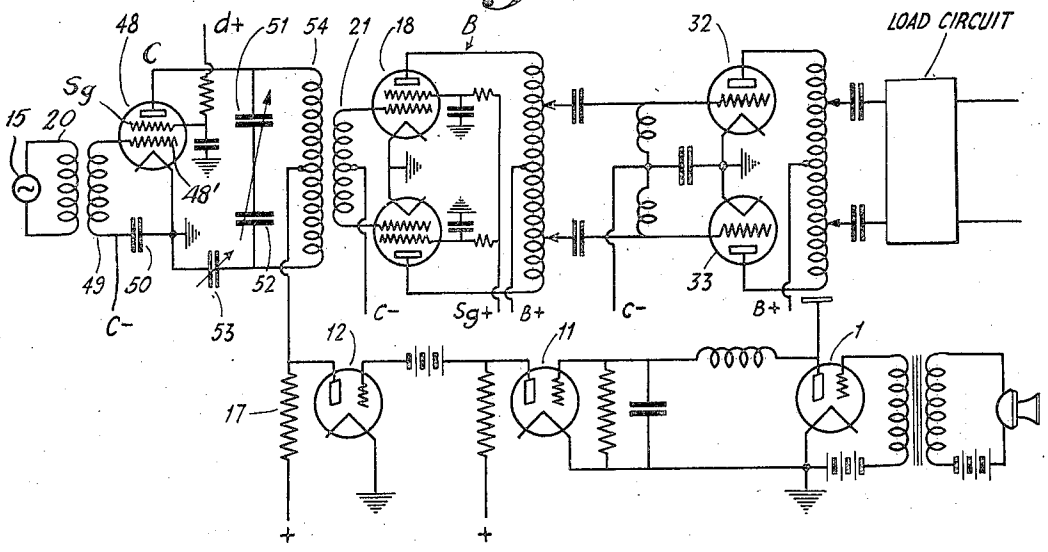
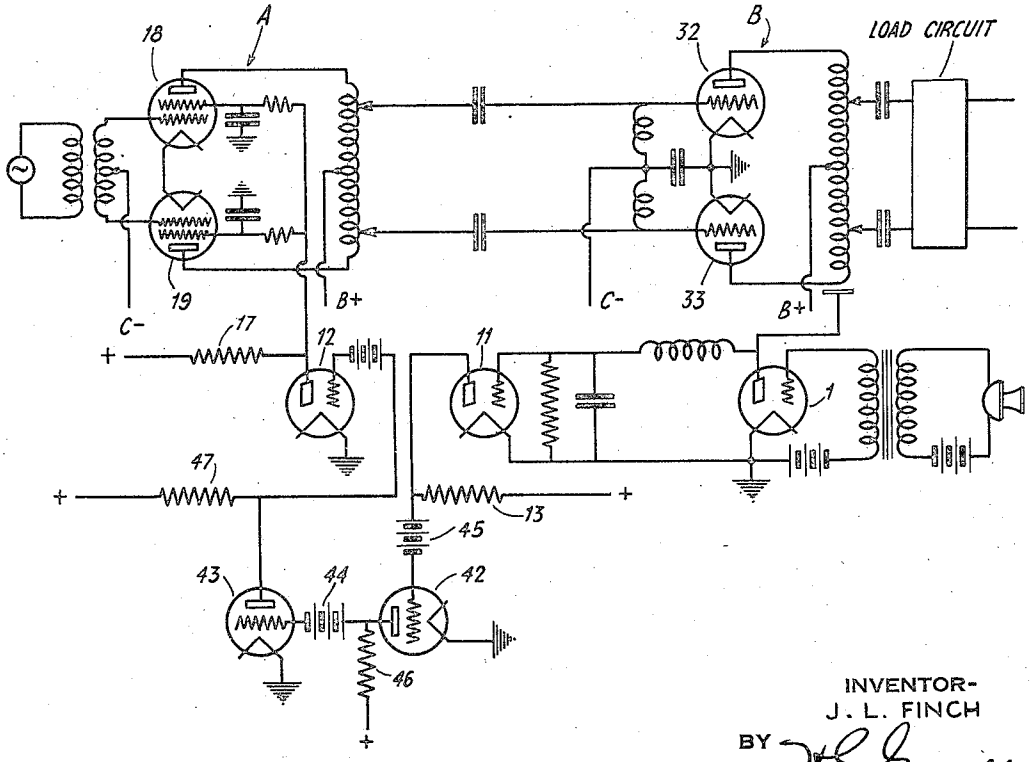


Fig. 8



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Fig. 9

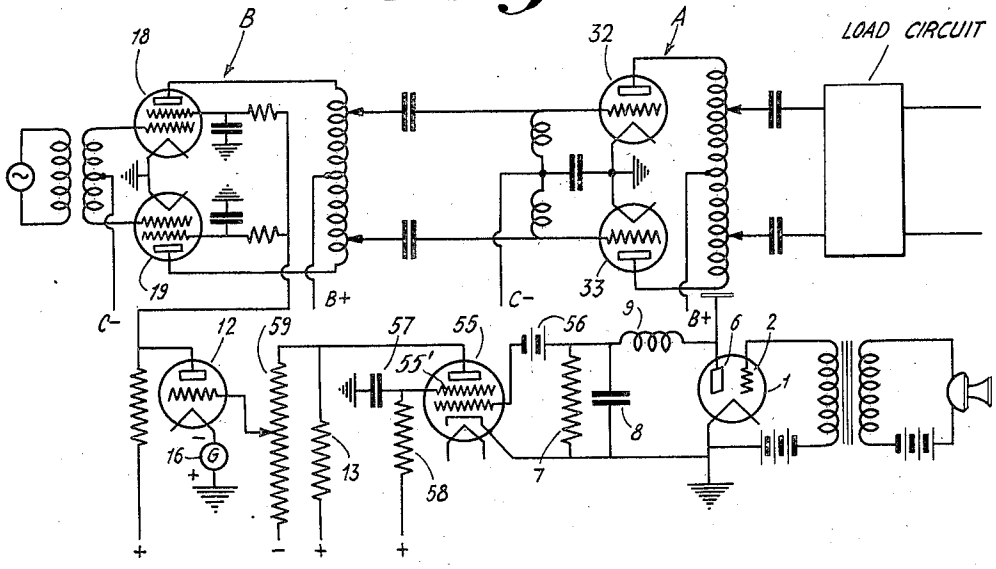
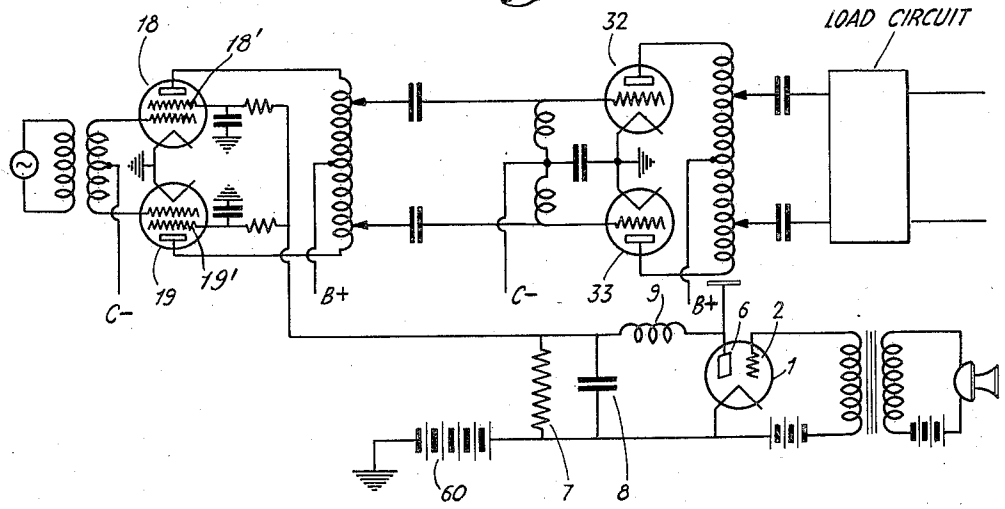


Fig. 10



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METHOD OF AND MEANS FOR MODULATION

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Fig. 11

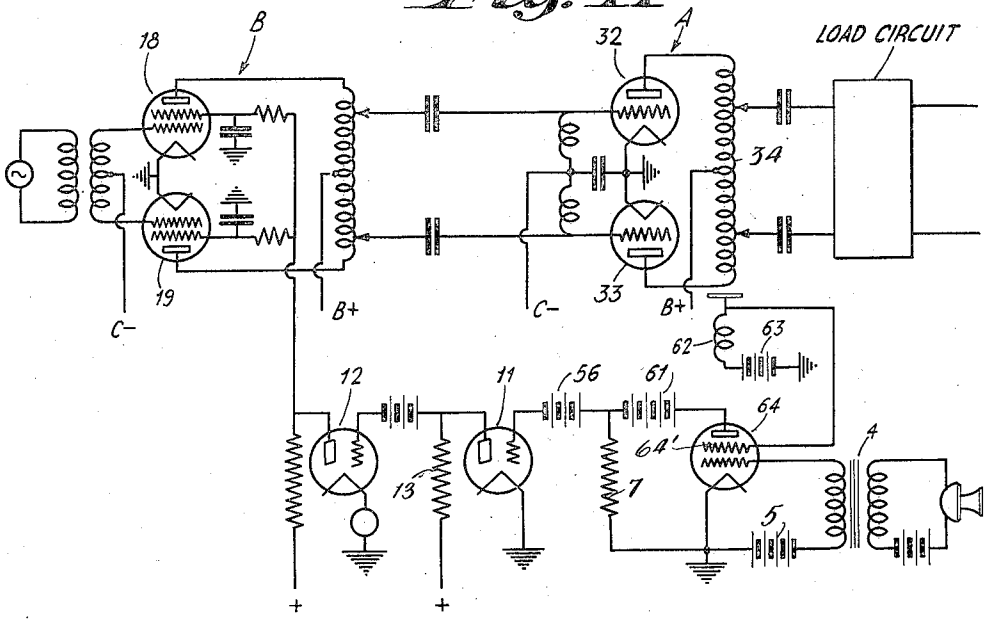
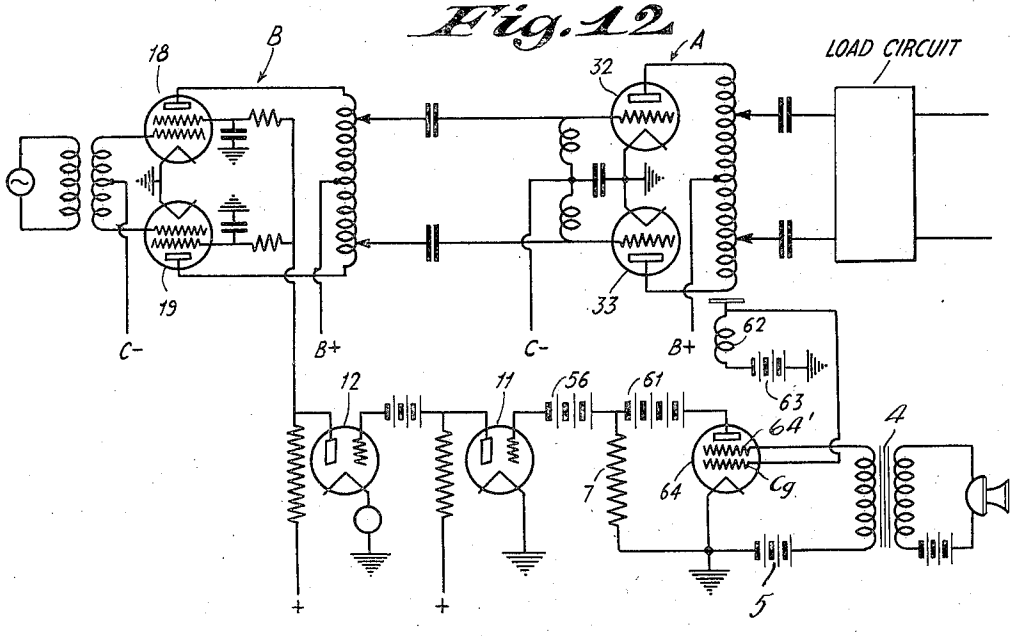


Fig. 12



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METHOD OF AND MEANS FOR MODULATION

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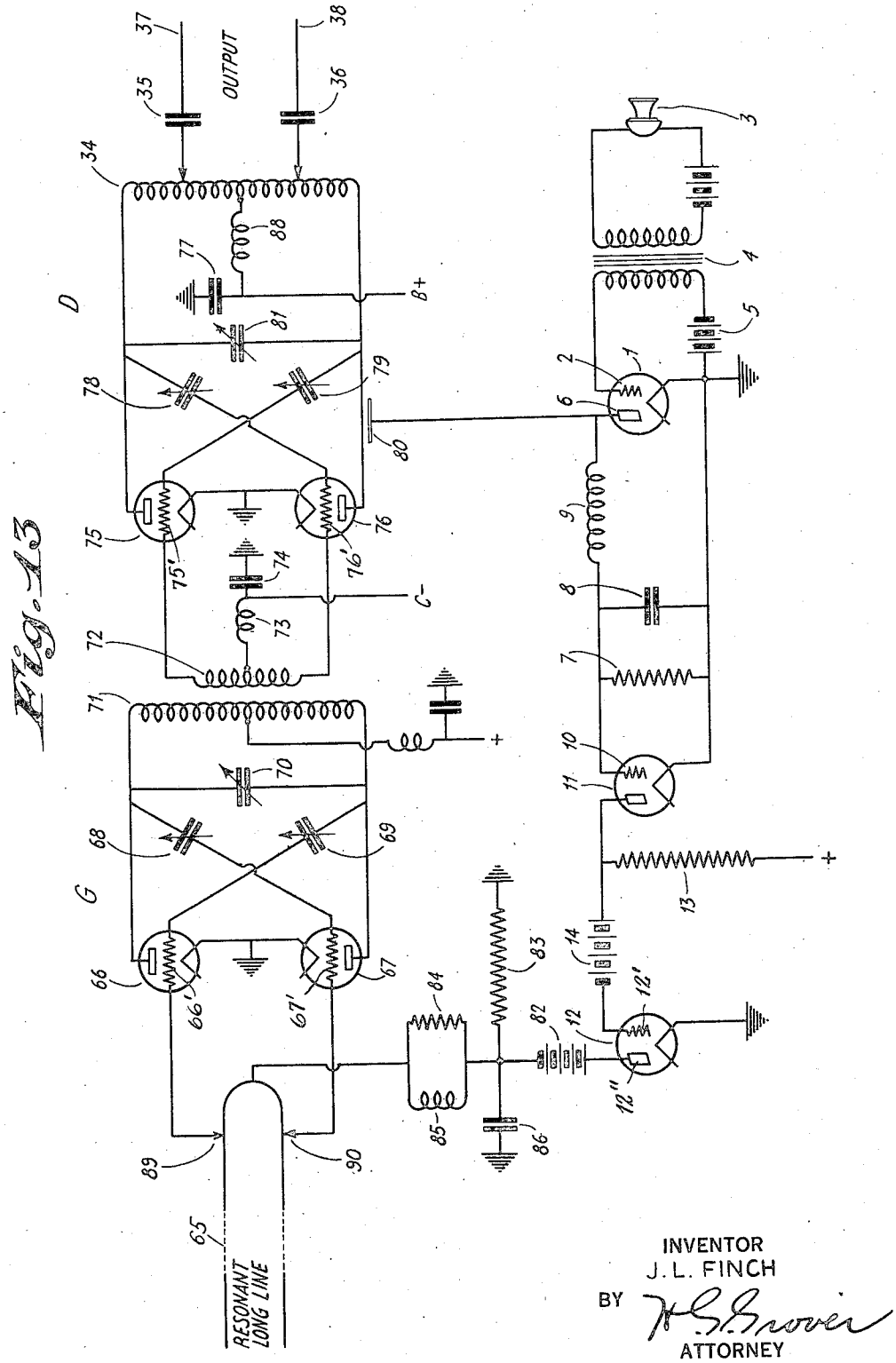


Fig. 13

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Fig. 14

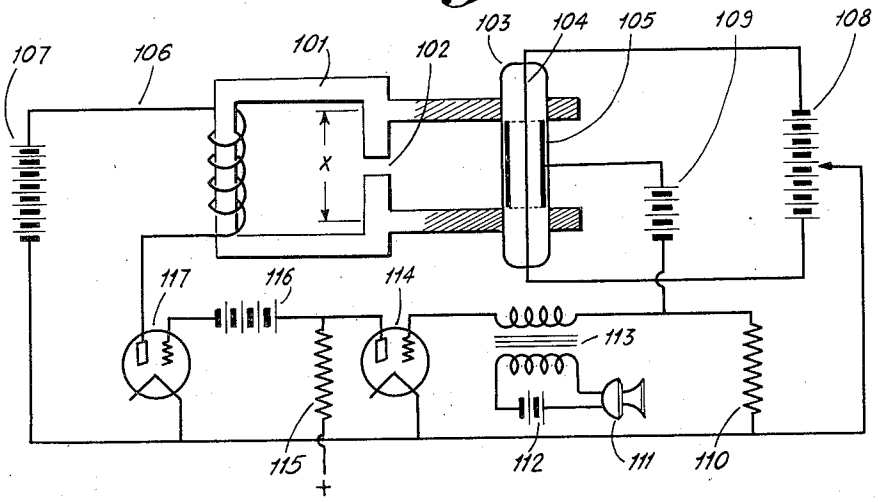
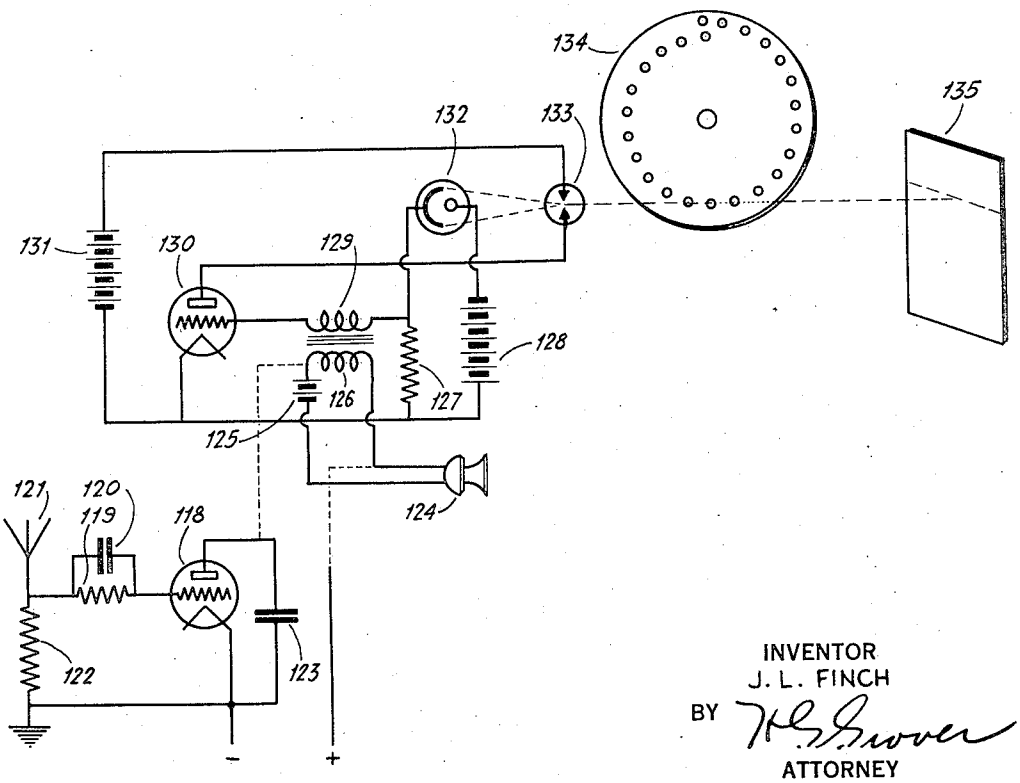


Fig. 15



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Patented Feb. 25, 1936 2,031,639

UNITED STATES PATENT OFFICE

2,031,639

METHOD OF AND MEANS FOR MODULATION

James Leslie Finch, Rocky Point, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application February 27, 1933, Serial No. 658,735

27 Claims. (Cl. 179—171)

This invention relates to a system of modulation and can be applied to a wide variety of uses, such as for the control of a system of power generation or transference in respect to its intensity, phase, frequency, or other properties. The invention is particularly applicable to modulation of high frequency oscillations in any of their characteristics at signal frequency. It can also be applied to the control of light or heat or fluid streams or of magnetic fields, or to the speed of moving elements or vehicles.

The principle upon which the present invention operates is that of providing a detecting device in the system after the point of change or modulation, which detecting device is responsive to the change or modulation desired. The detecting device is equipped with a control element and is so arranged that its output reacts back to a point earlier in the system so as to produce a degenerative effect. The control element in the detector permits the degenerative effect to go to a definite point which is determined by the control element, but no further than said point. The definite point is adjustable. Thus the system is changed or modulated in accordance with the control element in the detector.

In the prior art it has been the practice to produce modulation by means of some control element and to design the system to given linear response to this control element and to suppress any other factors which tend to produce extraneous modulation. Due to the difficulties encountered the resulting modulation is frequently distorted and different from that desired. My invention makes unnecessary these precautions, which are normally expensive and difficult to accomplish.

The novel features of my invention have been pointed out with particularity in the claims appended hereto. The nature of my invention and the operation thereof will be best understood from the detailed description thereof, which follows, and therefrom when read in connection with the attached drawings, in which:

Figure 1 shows a radio transmitter including my novel oscillation relaying device and my novel control means which determines the character of the oscillation as being relayed. In this arrangement energy is derived from the output of a high frequency amplifier connected to a modulator, impressed on a modulation frequency amplifier, and acts therein to control the character of the modulating potentials applied by way of coupling tubes from the modulation frequency amplifier to an electrode in the modulator stage to control the same.

Figures 2 to 13 inclusive show modifications of the arrangement of Figure 1; in Fig. 2, the energy derived from the output of the amplifier is impressed on an inductance connected to an electrode in the modulation frequency amplifier instead of on a capacity, as in Fig. 1; in Fig. 3, the controlled modulating potentials are applied to the output of the high frequency amplifier to accomplish control modulation in the same stage from which the controlling energy is derived; Fig. 4 is similar in many respects to Fig. 1. In Fig. 4, however, anode modulation is accomplished in the modulator stage rather than screen grid modulation, as in Fig. 1. In Fig. 5, which is similar in many respects to Fig. 3, the controlled modulating potentials are applied to the control electrodes of the amplifier stage to accomplish therein grid modulation. In Fig. 6, which is similar in many respects to Figs. 1 and 4, the controlled modulating potentials are applied by way of the coupling tubes to the control grid electrodes in the modulator stage. In Fig. 7, the controlled modulation circuits are similar in many respects to the corresponding circuits in Fig. 1, however, in Fig. 7, anode modulation is accomplished in a single stage which is coupled by way of a push-pull amplifier to the amplifier stage from which the controlling energy is derived. In Fig. 8, additional coupling tubes are interposed between the controlled modulation frequency amplifier and the modulator stage wherein screen grid modulation is accomplished. In the arrangement of Fig. 9, the first coupling tube between the controlled modulation frequency amplifier and the modulator stage is of the screen grid type. In the modification of Fig. 10, the output of the controlled modulation frequency amplifier is connected directly to the screen grid electrodes in the modulator stage to accomplish screen grid modulation therein. In the modifications of Figs. 11 and 12, the controlled modulation frequency amplifier is of the screen grid type and the screen grid and control grids are respectively capacitively and inductively coupled to the output of the amplifier stage. The remaining grid-like electrodes in each of the controlled modulation frequency amplifier tubes are connected to the source of modulated potentials. In Fig. 13, modulation is accomplished in an oscillator of the resonant long-line frequency controlled type. This circuit in other respects is somewhat similar to the circuit of Fig. 4; while,

Figures 14 and 15 show applications of the prin-

cipals of my invention to the control of a magnetic field or lines of flux and to the control of a light ray respectively.

I will describe specific embodiments of my invention as applied to the amplitude modulation of a radio transmitter, the modulation of a magnetic field, and the modulation of a beam of light. It will be understood, however, that the invention is readily applicable to other types of modulation.

Referring to Figure 1 of the drawings, A is the final stage of the transmitter. The final stage A is excited by stage B. The stage B comprises a pair of thermionic tubes 18 and 19 having the control grids 18' and 19' connected to the opposite terminals of a winding 21, the center point of which may be connected, as shown, to the pole of a biasing source, not shown, at —C. The inductance 21 may be coupled by way of circuit 20 to any source of high frequency oscillations 15. The oscillations impressed from 15 on 21 are repeated and amplified in the tubes 18 and 19 and appear in the inductance 24 connected between the anodes of tubes 18 and 19. The oscillations appearing in 24 are applied to the control grids 32' and 33' of tubes 32 and 33 by way of coupling and blocking condensers 25 and 26. Biasing potential for the grids 32' and 33' of tubes 32 and 33 is supplied from —C connected to a source, not shown, by way of choking coils 29 and 30 respectively. The high frequency oscillations impressed on the control grids of the power amplifier tubes in stage A are repeated and amplified in said tubes and appear in the inductance 34 connected between their anodes. The amplified oscillations may be supplied from the inductance 34 in any manner to a load circuit. For example, the energy may be fed to the load circuit through coupling condensers 35 and 36 in lines 37 and 38 tapped to inductance 34.

1 is a three element tube which serves as the detector variably coupled by way of its anode 6 and an element 6' to the final stage A and responsive to the amplitude of the output of said stage. The voltage on control grid 2 is made responsive to the voice currents in microphone 3 by means of transformer 4 and bias battery 5. When the voltage impressed on anode 6, due to the output of A, is high enough to overcome the effect of the blocking voltage on 2, anode current will flow in tube 1, the direct current component returning through resistor 7 and the alternating current component through smoothing capacitor 9. Reactor 9 is required to prevent the radio frequency anode potential, transferred to 6 from the final stage of A, from being short-circuited by 8. The control grid 10 of amplifier tube 11 has a potential impressed on it due to the resistance drop of the current flowing through 7. This amplifier tube 11 is resistance coupled to the control grid 12' of modulator tube 12 by means of resistor 13 and bias battery 14. The modulator tube 12 has its anode electrode 12'' connected to its cathode by way of resistance 17 and a source of direct current voltage not shown. The screen grid electrodes S and S' of tubes 18 and 19 are connected, as shown, to the resistance 17. A change of current intensity flowing in resistance 17 causes a change in the potential applied to the screen grids of tubes 18 and 19. As the current through 17 decreases the potential on the screen grid electrodes 18' and 19' increases and vice versa. In this manner the tube 12 modulates the screen grids of tubes 18 and 19 in the radio frequency amplifier stage B.

The proportions of these circuits are so chosen that when the peak radio frequency potential on 6 exceeds the cut-off voltage as determined by the voltage on 2 by an appreciable amount, the reaction back through the modulator tube 12 will reduce the amplitude of the oscillations supplied by stage B to stage A, and the power output of A until the peak radio frequency potential on 6 just barely exceeds the cut-off voltage. Thus, as the potential on grid 2 is varied in accordance with the voice, the cut-off voltage of 1 is varied in proportion and the peak radio frequency potential output is automatically adjusted to just exceed this voltage. Thus the output voltage is modulated truly in accordance with the modulating potentials.

Now, if some extraneous modulation is introduced, such as a power hum modulation on the output of radio frequency source 15, or if the gain of stage A or B is varied by reason of alternating current on the filaments, or due to inconstant plate or bias voltages, such modulation will be practically eliminated due to the degeneration introduced by the circuits of this invention. More specifically, such extraneous hum will cause an increase of the potential applied to 6. This increase in potential on 6 will act through amplifier 11 and modulator 12 to instantly reduce the potential on the screen grids S and S' of tubes 18 and 19 and reduce the amplitude of the oscillations supplied thereby to stage A.

It will be noted that the amplifier and modulator, tubes 11 and 12, employed in this invention need not have a linear characteristic since any distortion introduced from this cause is of a secondary order.

The filament of the modulator 12 is shown at a negative potential with reference to the filaments of the modulated stage B. This is necessary in order to fully modulate the stage B through the screen grids.

The operation of this invention as applied to a radio transmitter using voice control and amplitude modulation is as follows:

Starting with no modulation, grid 2 will assume a potential at the middle of its operating range. Assume also that momentarily tube 12 is blocked, thus allowing stage B to pass a maximum amount of power on to stage A. Stage A will in turn put out a maximum power and coincidently will induce a maximum radio frequency voltage on 6. This causes a direct current potential to be impressed on 7 of a value much in excess of that required when acting through amplifier 11 and modulator 12 to decrease the output of B to zero, but when this output has dropped to a value low enough for the voltage on the output of A to have dropped to half value, the voltage on 6 will have dropped to a value just sufficient for the peaks to exceed cut-off and thus a stable condition at this voltage is maintained. Now assume the voice causes 2 to drop to the most negative potential of its range. This will momentarily cut off tube 1, dropping the voltage on 7 to zero, which will in turn reduce the current in 17 and cause the screen grids of B to reach their maximum operating potential. This in turn will increase the gain of B and the output of A will rise to its maximum voltage value. The latter will be just sufficient to impress a high enough voltage on 6 to rectify a small amount of current and thus to maintain this value. Similarly, the output voltage will follow in inverse proportion any voltage impressed on 2 and thus will follow the voice currents.

It will be understood that the arrangement shown in Figure 1 may be modified in various manners without departing from the scope of the present invention. For example, the anode 6 of tube 1 may be variably inductively coupled by way of inductance 40 with the inductance 34 in the output circuit of the power stage A, as shown in Figure 2. When modified in this manner the choking inductance 9 of Figure 1 may be eliminated since the inductance 40 serves the dual purpose of preventing short circuit of the radio frequencies and for coupling the tube 1 to the power stage. The circuit in Figure 2 is, as shown, otherwise substantially the same as the circuit of Figure 1.

The modulation of the oscillations may be accomplished in the stage A and anode modulation may be used as shown in Figure 3. This is accomplished by connecting the anode of tube 12 to the lead supplying charging potentials to the anodes of the tubes 32 and 33 by way of the inductance 34. In this manner the modulating tube 12 and the amplifier tubes 32 and 33 both draw current through the resistance 17. The potential of the resistance 17 therefore determines the potential applied to the anodes of the tubes 32 and 33 and consequently determines the amplitude of the oscillations impressed from said anodes to the tank circuit including inductance 34. The circuit of Figure 3 may be the same in other respects as the circuits of Figures 1 and 2 and, as shown, is otherwise substantially the same as the circuit of Figure 1.

Instead of using screen grid modulation in the stage B, anode or plate modulation may be used as shown in Figure 4. When anode modulation is desired the anode electrodes of tubes 18 and 19 are charged by way of inductance 24 and resistance 17. Here tubes 18, 19 and 12 all draw their anode current through the same resistance 17. Consequently, when the tube 12 draws a heavy current, due to modulation potentials being applied, the potential at the terminal of 17 drops and consequently the potential applied to the anodes of tubes 18 and 19 falls, in this manner modulating the potentials applied to the anodes of said tubes. The circuit of Figure 4 may be otherwise the same as any of the prior circuits and is shown substantially the same as the circuit of Figure 1.

Where, for some reason, grid modulation in stage A is desired, the arrangement of Figure 5 may be used. In this arrangement, which may be otherwise the same as the prior arrangements and is shown similar to the circuit shown in Figure 1, the modulation potentials appearing on the anode of 12 are supplied by way of the battery 41 and the choking inductances 29 and 30 to the control grid electrodes 32′ and 33′ of tubes 32 and 33 respectively. The control grids 32′ and 33′ are normally maintained at a negative potential by the battery 41 connected as shown. This normal bias is altered in accordance with the potentials appearing across the resistance 17 and in this manner the bias applied to the control grid electrodes 32′ and 33′ respectively is altered at modulating frequency.

Grid modulation in the stage B, as shown in Figure 6, may be utilized when desired. In this arrangement the modulating potentials appearing at the terminal of the resistance 17 are impressed by way of battery 42 and inductance 21 to the control grid electrodes 18′ and 19′ of the tubes 18 and 19 respectively. When control grid modulation is utilized the screen grid electrodes S and S′ of tubes 18 and 19 may be maintained at the same constant direct current potential by the resistances 22 and 23 connected to the positive terminal of a direct current source not shown. This circuit may be similar to any of the prior circuits except in this respect.

Where more amplification is desired the amplifier stage B may be preceded by an additional amplifier stage C, as shown in Figure 7. Moreover, the oscillations provided from source 15 may be modulated in this additional stage. This stage may comprise an inductance 49 coupled to the inductance 20. Charging potential for the control grid 48′ of tube 48 can be supplied, from a source not shown. The high frequency current circuit between the grid 48′ and cathode of tube 48 is completed by way of a by-pass condenser 50. The high frequency oscillations repeated and amplified in tube 48 appear on the anode thereof and in the inductance 54. The inductance 54 is tapped, as shown, and one terminal thereof may be connected to the cathode by way of a balancing capacity 53. The anode circuit of the tube 48 may be tuned to the frequency of the source 15 by the series capacities 51 and 52. The tube 48 may be of any type and is shown as a screen grid tube. The screen grid electrode S_g is charged by way of a resistance R connected to the positive terminal $d+$ of a source of potential, not shown. This stage may be modulated in any manner. For example, anode modulation may be accomplished by connecting a point on the inductance 54 to a terminal of the resistance 17 so that the anode electrode of tube 48 draws its current through the resistance 17. Of course, if desired, screen grid modulation may be used. This is accomplished, as shown in Figure 1, by connecting the screen grid electrode of the tube 48 to the terminal of the resistance 17. When screen grid modulation is used the anode electrode of tube 48 may be charged from any direct current source by connecting a point on the winding 54 to said source. The circuit of Figure 7 as shown is otherwise similar to the circuit of Figure 1, but may be similar in other respects to any of the preceding circuits.

Where more amplification of the modulating signal is desired the circuit arrangement of Figure 8 may be used. In this circuit additional tubes 42 and 43 are connected between the amplifier 11 and the amplifier 12. Each of these tubes increases the amplitude of the modulating potentials. Modulating potentials of increased amplitude are applied, as in Figure 1, to the control grid electrode of tube 12 to determine the conductivity of said tube. The anode electrode of tube 12 is charged by way of a resistance 17 and the drop in potential across the resistance 17 may be used to modulate the high frequency oscillations in any manner. The circuit otherwise may be the same as any of the circuits in the preceding figures.

In some cases a different type of amplifier may be used between the tube 1 and the tube 12, as shown in Figure 9. For example a tube 55 of the indirectly heated cathode type may be utilized. Furthermore, this screen grid tube of the heater type may have its anode connected to the control grid tube of 12 by way of a potentiometer resistance 59 having one terminal connected to the anode of 55 and the other terminal connected to a negative source of potential. The control grid of 12 may be connected to the movable point on the potentiometer so that the control potential applied to the control grid 12 may be ad-

justed. The screen grid electrode 55' of the tube 55 may be charged with positive potential from a source not shown by way of a resistance 58. Radio frequency oscillations may be by-passed around said source by a by-pass condenser 57. This circuit may be otherwise substantially similar to the circuits shown in Figures 1 to 7 inclusive.

Where lower powers are used and the amplitude of the modulating potentials does not need to be so high, the circuit arrangement of Figure 10 may be used. In this circuit arrangement the modulating potentials appearing across the resistance 7 are applied directly to the screen grid electrodes 18' and 19' of tubes 18 and 19 respectively. These varying potentials vary the conductivity of the tubes 18 and 19 or alter the impedance of said tubes so that the potentials appearing on the anodes of tubes 18 and 19 are modulated at signal frequency.

The modulation frequency amplifier 1 may be a triode as shown in the preceding circuits, or may be of the screen grid type as shown in Figure 11. When a tube of the screen grid type, such as tube 64, is used the anode is connected by way of a charging source 61 to the terminal of the resistance 7. The resistance 7 is connected to the control grid 10 of amplifier 11 through a second source 56. The inductance 34 is capacitively coupled to the screen grid electrode 64' of tube 64. Charging potential for the screen grid electrode 64' of tube 64 is charged by way of a choke 62 and a source of potential 63, a terminal of which is grounded, as is the cathode of tube 64. When the radio frequency voltage induced on the screen grid 64' of 64 has attained the maximum positive value, it is assumed that the tube 64 will pass plate current then, and then only. This plate current reacts through the succeeding amplifiers 11, 12, etc., as explained before, to prevent the radio frequency voltage appearing in 34 from exceeding a critical value. This particular critical value changes with the control grid voltage on the control grid of tube 64. In this way modulation of the oscillations relayed in the stages A and B which is truly characteristic of the signal is accomplished. This tube 64 may be utilized to replace the tube 1 in any of the prior modifications.

In some cases it may be desirable to use a tube of the screen grid type as a control tube and apply the modulating potentials to the screen grid and the control potentials to the control grid. In this case a circuit as shown in Figure 12 may be used. Here, as in the prior case, the anode of the tube 64 is supplied with positive potential by a source 61 and the terminal of resistance 7 is connected to the control grid 10 of tube 11 through a second source 56. Here, however, the control potentials are applied on the control grid C_g of tube 64, which is maintained at a negative potential with respect to the cathode by a battery 63 connected to the choking inductance 62. It is noted that the battery here has its terminals reversed with respect to the battery 63 of Figure 11. The modulation potentials are applied to the screen grid electrode 64' from the secondary winding of transformer 4. It is noted here that the battery 5, connected with the secondary winding of transformer 4, has its potential reversed with respect to the battery 5 in the preceding figures. This is in order that a positive potential may be supplied to the screen grid to enhance the amplification characteristics of this tube.

This invention can be applied to any type of transmitter known in the prior art. For example, a transmitter comprising an oscillation generator stage G and a power amplifier stage D, as connected in Figure 13, may be utilized. The oscillation generator G may include a pair of thermionic tubes 66 and 67 having their control electrodes connected by way of movable taps 89 and 90 to a long line frequency control circuit 65 resonant to the frequency it is desired to produce. Such a long line frequency control generator has been illustrated in detail in United States application Serial No. 363,660, filed May 16, 1929, and a description thereof, except as given hereinafter, is thought unnecessary. Charging potential for the control grid electrodes 66' and 67' of tubes 66 and 67 respectively is suplied by connecting the electrical center of that portion of the frequency control circuit between the taps 89 and 90 to ground by way of inductance 85 and resistance 83. The inductance 85 acts as a stopper to the high frequency oscillations, while the resistance 83 is shunted by by-pass condenser 86 which forms a short circuit for any oscillations which get through the inductance 85. The inductance 85 may be shunted by a resistance 84, the purpose of which will be described later. The anode electrodes of tubes 66 and 67 are connected to a tank circuit including an inductance 71 and a tuning capacity 70. The desired feed-back necessary for oscillations in this circuit is attained by the use of two feed-back condensers 68 and 69 connected as shown. The oscillations developed in the tubes 66 and 67 may be supplied to the following balanced stage D by way of inductance 72 coupled to an inductance 71. The inductance 72 has its terminals connected to the control grids 75' and 76' of power amplifier tubes 75 and 76, as shown. The electrical center of the inductance 72 is connected by way of a choking inductance 73 to a source of negative potential not shown. The source of negative potential not shown is shunted by by-pass condenser 74. The anodes of tubes 75 and 76 are connected to a second tank circuit comprising a tuning capacity 81 and an inductance 34. Charging potential for the anodes of tubes 75 and 76 is supplied by way of a choking inductance 88 and any source of potential not shown. The source of positive potential not shown may be shunted by by-pass condenser 77 as shown. The circuit may be neutralized as shown by connecting the anode of tube 75 to the control grid electrode 76' of tube 76 by way of a neutralizing capacity 78, while the anode of tube 76 is connected to the control grid electrode 75' of tube 75 by way of a neutralizing capacity 79, thus preventing self-oscillations in this stage. The high frequency oscillations relayed and amplified in the tubes 75 and 76 appear in the tank circuit and may be supplied from the inductance 34 thereof to any utilization circuit by way of leads 36 and 37, as described more in detail hereinbefore.

The control circuit including the tubes 1, 11 and 12 is substantially similar to the equivalent elements shown in Figure 1. The anode 6 is coupled by a capacity 8 to the output circuit of tubes 75 and 76. Here, however, the anode 12'' of the tube 12 is connected to the positive terminal of a battery 82, the negative terminal of which is connected to the intersection between the resistance 84 and the resistance 83. In this manner variations in potential appearing on the anode 12'' of tube 12 are transmitted to the control grid electrodes 66' and 67' of tubes 66 and 67

respectively. As described hereinbefore, plate currents are set up in tube 1 and react in tubes 11 and 12 to control the output of the transmitter. In this case the tube 12 controls the bias on the master oscillator G of the transmitter when the radio frequency induced on plate 80 is sufficient to overcome the bias of tube 1 and cause current to flow. The flow of current through resistor 7 will produce a negative potential on the grid of tube 11, which in turn will produce a bias on the grid 12' of the tube 12 by virtue of the resistance and battery coupling 13 and 14 respectively. This decrease in bias on the control grid of tube 12 will allow more current to flow through the plate circuit of tube 12, through battery 82 and resistor 83. Change in flow through the resistor 83 produces changes in the potential dropped therein and consequently a change in the potential on the terminals thereof. This change in potential is impressed through resistor 84 and inductance 85 to the long line 65 and thence to the control grids 66' and 67' of the master oscillator tubes 66 and 67. This increase in bias voltage on the control grids of tubes 66 and 67 will decrease the output of the master oscillator, which in turn will decrease the output of the power amplifier. In this manner the output of the power amplifier will be maintained at a value just sufficient to cause current to flow in the plate circuit of tube 1, which in turn will be truly proportional to the voltage induced from the source 3 on the grid of tube 1.

While I have shown my control circuit as being especially applicable to radio frequency transmitters in connection with the modulation circuits therein, I do not wish to be limited to such circuits only since, obviously, this present invention has a wide application in the electrical and other arts. For example, the principles of my invention may be applied to the control of or the modulation of the intensity of a magnetic field, as illustrated in Figure 14.

Referring to Figure 14, 101 represents a core of magnetic material which has an air gap 102. A magnetic field is induced in this core by the passage of current through winding 106. I have assumed that we desire to modulate the intensity of the magnetic field across the portion marked X. Accordingly, I have shown two arms of magnetic material connected at this point, between which is placed magnetron 103. This magnetron has a filament 104 which is heated by a source of voltage 108. Surrounding this filament is a cylindrical plate 105. I make use of the well known property of the magnetron to present a variable plate to filament impedance in proportion to variations in the magnetic field in which it is placed. Battery 109 is used to force current through the plate filament circuit of the magnetron and through resistor 110. Thus the total voltage of 109 is divided between the plate filament circuit of 103 and resistor 110. It is assumed that the characteristics of 103 are such that the voltage across 110 will be caused to vary in proportion to the strength of the magnetic field through 103.

The intensity of the magnetic field in 101 is controlled by the amount of current flowing through winding 106. This current is induced by battery 107 and is controlled by vacuum 117. Vacuum tube 117 in turn is controlled by vacuum tube 114, which is coupled to it, for purposes of illustration, by means of the resistor 115 and bias battery 116. Vacuum tube 114 is in turn controlled through its grid by the voltage impressed across resistor 110 and by voltage induced in the secondary of transformer 113. The voltage induced in the secondary of 113 can be controlled as desired, as, for instance, by means of the voice operating through microphone 111 with battery 112 in the primary circuit of 113.

If we assume for the moment that no voltage is being induced in the secondary of 113 then a state of equilibrium will be found in which the magnetic field across X is of a particular value which can be adjusted to any desired value by adjusting the voltage of the various batteries. In case this field is temporarily in excess of this value then the impedance of magnetron 103 will be high. This will result in the voltage across 110 being low. This in turn will cause tube 114 to be more conducting, which will make the voltage on the grid of 117 more negative. This in turn will increase the impedance of 117 and will therefore restrict the current flowing through 106 and reduce the field at X to the value originally assumed. In case the field at X is lower than normal a similar chain of reasoning will show that it will rise to the normal value.

If we now assume that a voltage is induced in the secondary of 113 then a state of equilibrium will be attained at a different value of field at X. Following the same line of reasoning as above, it can be seen that the value of the field X will vary in proportion to the induced voltage in the secondary of 113, which is the condition which was originally desired. It will be noted that this will be the case in spite of any non-linearity which may exist between the field at X and the current in winding 106 within the limits of range of this apparatus.

The control system of the present invention can also be used to control or modulate the intensity of a source of light, as illustrated in Figure 15.

In Figure 15 I have shown my invention as applied to the modulation of a source of light as used in television. The source of light 133 is of the glow tube type such as is used in certain types of television apparatus. Its characteristic is such that an increase in current through it results in an increase in light emitted from it. This light casts a beam on screen 135 through holes in scanning disk 134 in the well known manner. In my invention I place a photoelectric cell 132 in such a position relative to 133 that the light it picks up is proportional to the light which is projected upon the screen 135. I have shown circuits by means of which the intensity of light is controlled by this photoelectric cell 132 to respond to the value required by some controlling element. In this particular illustration battery 128 forces a current through 132 and through resistor 127. The impedance to the passage of this current which 132 offers is assumed to be inversely proportional to the intensity of the light. Accordingly, voltage across resistor 127 will be proportional to the intensity of the light provided the relative values are properly chosen. In my illustration battery 131 forces current through lamp 133 and vacuum tube 130. This current will vary with the voltage which is impressed on the grid of 130. Accordingly, the light emitted by 133 can be controlled by the voltage on the grid of 130 although a proportional relationship will not necessarily exist.

The voltage on the grid of 130 is determined partly by the voltage across 127 and partly by the voltage induced in secondary winding 129 of a transformer with primary winding 126. If

for the moment we assume that no voltage is induced in 129 then a state of equilibrium will be obtained with a particular value of light as determined by the various constants of the circuit. Should this light be greater than this value the impedance of 132 will drop below normal and the voltage across 127 will become more negative than normal and this negative voltage is impressed on the grid of 130, and when the latter is more negative than normal the plate impedance of 130 will be higher than normal. This decreases the current which can flow through lamp 133 until the normal condition is attained.

If we now assume that currents are passed through primary winding 126 so as to induce voltages in secondary winding 129, it will be seen that new values of light will be emitted by lamp 133 in proportion to the voltages induced in 129. For purposes of illustration I have shown two methods of controlling the induced voltage in 129. In one case I have shown microphone 124 and battery 125 connected in series with 126. In this case the voice at the microphone would control the intensity of the light as projected on screen 135. In the other case it is assumed that 124 and 125 are disconnected and in its place is connected the radio receiving circuit numbered 118 to 123. In this case a signal is assumed to be impressed on antenna 121, causing a voltage to be set up across resistor 122. This is coupled to the grid of vacuum tube 118 through grid leak 119 and by-pass capacitor 120. Tube 118 acts as a detector being shunted by by-pass capacitor 123. Thus the currents passed through the primary of 126 and the plate circuits of 119 will be proportional to the envelope of the radio frequency signal which is impressed on 121. Thus, as explained above, the intensity of the light on screen 135 will vary in proportion to the envelope of the radio frequency signal impressed on 121.

While I have shown the present invention as being applied to the control of the amplitude of oscillations, the control of modulation of oscillations, the control of a magnetic circuit, and the control of the intensity of a beam of light, it will be understood that I do not intend to be limited by such showing since, obviously, the present invention is of much wider scope. For example, the method and means of the present invention may be utilized to control energy in practically any form. By energy I mean kinetic and potential energy, that is, energy in any form.

In the claims the words "level" or "value" of energy have been used to describe what may be controlled by my control method and means of the present invention. By level of energy I mean the maintenance in a predetermined state of energy of any type known, either potential energy or kinetic energy. Where the claims speak of controlling the value of energy they include the maintenance of kinetic or potential energy in any state, constant or otherwise, as long as it is a predetermined state.

The control method and means for carrying out the scheme of the present invention is applicable to practically all of the arts, electrical, mechanical and chemical. In particular, the method of and means for controlling values or levels of energies of the present invention is applicable to the elements enumerated below.

1. The level of fluid in a reservoir.
2. The velocity of a fluid stream.
3. The velocity of a moving object.
4. The voltage of an electrical power generator.
5. The intensity of a magnetic field.
6. The degree of heat in an oven.
7. The frequency of an electrical oscillation generator.
8. The deviation in phase of an electrical oscillation generator.
9. The current delivered by any part of a radio signalling system.

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

1. A signalling system comprising, a source of high frequency oscillations, a thermionic tube having its input electrodes connected to said source, a power amplifier having its input electrodes coupled to the output electrodes of said first named tube, a source of modulating potentials, an amplifier comprising a thermionic tube having its control grid electrode coupled to said source of modulating potentials and its output electrodes coupled to an electrode in said first named tube, a coupling between the output electrodes of said power amplifier and an electrode in said second named amplifier and means for biasing the control grid electrode of said second named amplifier tube to such a value that peaks only of the energy transferred by way of said last named coupling from the power amplifier to the electrode in the second named amplifier affect the operation thereof.

2. A signalling system comprising, a source of high frequency oscillations, a thermionic tube of the screen grid type having its input electrodes coupled to said source of high frequency oscillations, a first amplifier tube having its input electrodes coupled to the output electrodes of said screen grid tube, a source of modulating potentials, a second amplifier tube having its input electrodes coupled to said source of modulating potentials and its output electrodes coupled to the screen grid electrode in said first named tube, a coupling between the output electrodes of said first named amplifier and an electrode in said second named amplifier tube and means for biasing the control grid of said second named amplifier tube to such a value that peaks only of the energy transferred by way of said last named coupling from the first named amplifier to the electrode in the second named amplifier affect the operation thereof.

3. A signalling system comprising, a thermionic tube having its input electrodes coupled to a source of high frequency oscillations, a first amplifier having its input electrodes coupled to the output electrodes of said first named tube, a source of modulating potentials, a second amplifier comprising a thermionic tube having its input electrodes coupled to said source of modulating potentials and its output electrodes coupled to the output electrode in said first named tube, a coupling between the output electrodes in said first amplifier and an electrode in said second named amplifier tube and means for biasing the control grid of said second named amplifier tube to such a value that peaks only of the energy transferred by way of said last named coupling from the first named amplifier to the electrode in the second named amplifier affect the operation thereof.

4. A signalling system comprising, a thermionic tube having its input electrodes coupled to a source of high frequency oscillations, a first amplifier having its input electrodes coupled to the output electrodes of said first named tube,

a source of modulating potentials, a second amplifier comprising a thermionic tube having its input electrodes coupled to said source of modulating potentials and its output electrodes coupled to the input electrodes in said first named tube, a coupling between said first amplifier and an electrode in said second named amplifier tube, and means for biasing the control grid of said second named amplifier tube to such a value that peaks only of the energy transferred by way of said last named coupling from the first named amplifier to the electrode in the second named amplifier affect the operation thereof.

5. The combination of a high frequency oscillation repeater, of a source of modulating potentials, a transfer circuit including the impedance of a thermionic tube coupling said source of modulating potentials to said high frequency oscillation repeater to modulate the oscillations therein, said tube having a control electrode means for regulating the degree of modulation impressed by said source of modulating potentials on said high frequency oscillations, including a second circuit coupling said high frequency oscillation repeater to an electrode in said tube in said transfer circuit to impress peak radio frequency potentials on said electrode to determine the impedance of the latter in accordance with peak amplitude values of the oscillations in said high frequency source, and a source of direct current potential connected with the control electrode of said tube to bias the same to cut off at a point exceeded only by the peak radio frequency potentials impressed on said electrode.

6. The combination of a system responsive to high frequency oscillations, including an output circuit, of a source of modulating potentials, a relay circuit coupling said source of modulating potentials with said system responsive to high frequency oscillations for modulating any high frequency oscillations therein, a thermionic tube having an anode and cathode and control grid, a circuit connecting the anode to cathode impedance of said tube in shunt to said relay circuit, means for regulating the degree of modulation impressed by said modulating potential source by way of said relay circuit on the high frequency oscillation including a coupling between said output system of said circuit responsive to high frequency oscillations and an electrode in said tube in said relay circuit, and a source of direct current potential connected with the control electrode in said tube to bias the same to cut off at a point excited only by the peak radio frequency potentials impressed on said electrode.

7. In combination a source of high frequency oscillations, a source of modulating potentials, an amplifying device coupled to the output of said source of high frequency oscillations, a thermionic amplifier tube having input and output electrodes, an input circuit connected to said input electrodes, a circuit coupling said output electrodes to said amplifier device to modulate therein the oscillations from said source, a coupling between said amplifying device and an electrode in said amplifier tube to impress thereon peak radio frequency potentials from said amplifying device, and means in said amplifier tube input circuit to bias the input electrode of said tube to a value such that the cutoff point of said tube is slightly under the peak radio frequency potentials transferred to an electrode therein from said amplifying device, and means for varying said cutoff point at signal frequency, including a coupling between the input circuit of said amplifier tube and said source of modulating potentials.

8. A system for linearly modulating high frequency oscillations from a high frequency source in accordance with signals from a signal source comprising, a thermionic tube having input and output electrodes, means coupling the input electrodes of said tube to said source of high frequency oscillations, a power amplifier tube having its input electrodes coupled to the output electrodes of said tube, an additional thermionic amplifier tube having a control grid electrode connected in an input circuit and an anode connected in an output circuit, a source of potential connected between the control grid and cathode of said additional amplifier tube to bias the control grid of said additional amplifier tube negative with respect to the cathode of said additional amplifier tube, a coupling between the anode of said additional amplifier tube and the output electrodes of said power amplifier tube, a coupling tube connected with the output circuit of said additional amplifier tube, a circuit coupling the output of said coupling tube to an electrode in said first named thermionic tube, and a circuit coupling said source of modulating potentials to the input circuit of said additional amplifier tube.

9. In a system for linearly modulating high frequency oscillations in accordance with signal potentials, a thermionic modulator tube having input electrodes connected in an alternating current circuit which may be energized by said high frequency oscillations to be modulated, said tube also having output electrodes, a thermionic amplifier tube having input electrodes coupled to the output electrodes of said modulator tube, said amplifier tube also having output electrodes coupled to an alternating current circuit, a second thermionic amplifier tube having input and output electrodes, a circuit coupled between the input electrodes of said second named amplifier, said last named circuit being adapted to be energized by the signal potentials, a coupling between the anode electrode of said second named amplifier tube and the alternating current circuit coupled to the output electrodes of said first named amplifier tube, an impedance connected between the output electrodes of said second named amplifier, a plurality of thermionic coupling tubes connected in cascade, a circuit coupling the input electrodes of the first of said coupling tubes to said impedance, and a circuit coupling the output electrodes of the last of said coupling tubes to an electrode in said modulator tube.

10. A system as recited in claim 9 in which said modulator tube is of the screen grid type and in which the output electrodes of the last of said coupling tubes is coupled to the screen grid electrode in said modulator tube.

11. A system as recited in claim 9 in which the output electrodes of the last of said coupling tubes is coupled to the input electrodes in said modulator tube.

12. A system as recited in claim 9 in which the output electrodes of the last of said coupling tubes is coupled to the output electrodes in said modulator tube.

13. In a system for linearly modulating high frequency oscillations in accordance with signal potentials, a thermionic modulator tube having input electrodes connected in an alternating current circuit which may be energized by said high frequency oscillations to be modulated, said tube also having output electrodes, a thermionic amplifier tube having input electrodes coupled to

the output electrodes of said first named tube and output electrodes coupled to an alternating current circuit, a second thermionic amplifier tube having input and output electrodes, a circuit coupled between the input electrodes of said second named amplifier tube, said last named circuit being adapted to be energized by the signal potentials, a capacity coupling between the anode electrode of said second named amplifier tube and the alternating current circuit coupled to the output electrodes of said first named amplifier tube, a resistance and a capacity connected between the output electrodes of said second named amplifier, and a circuit coupling said resistance and capacity to an electrode in said modulator tube.

14. A system as recited in claim 13 in which said modulator tube is of the screen grid type and in which said last named electrode is the screen grid electrode in said modulator tube.

15. A system as recited in claim 13 in which said last named electrode is one of said input electrodes in said modulation tube.

16. A system as recited in claim 13 in which said last named electrode is one of the output electrodes in said modulator tube.

17. In a signaling system for linearly modulating high frequency modulations in accordance with signal potentials, a pair of thermionic modulator tubes each having a control electrode and an anode electrode, an alternating current circuit connected between said control electrodes, said circuit being adapted to be energized by high frequency oscillations to be modulated, a pair of thermionic amplifier tubes each having input and output electrodes, symmetrical circuits connecting the input electrodes of said second named pair of tubes to the anode electrodes of said first named pair of tubes, an alternating current circuit connected between the anode electrodes of said second named pair of tubes, a modulation frequency amplifier having an input circuit adapted to be energized by modulating frequency potentials, said modulation frequency amplifier having output electrodes connected in a circuit including resistance and capacity, a coupling between an electrode in said modulation frequency amplifier and the alternating current circuit connected between the anode electrodes of said second named pair of tubes, a thermionic coupling tube having its input electrodes coupled to said circuit including capacity and resistance, a second thermionic coupling tube having its input electrodes coupled to the output electrodes of said first named coupling tube, and a circuit coupling the output electrodes of said last named coupling tube to like electrodes in said first named pair of tubes.

18. A system as recited in claim 17 in which said modulator tubes are of the screen grid type and in which said last named like electrodes are the screen grid electrodes of the modulator tubes.

19. A system as recited in claim 17 in which said last named like electrodes are the anode electrodes of said modulator tubes.

20. A system as recited in claim 17 in which said last named like electrodes are the control electrodes of said modulator tubes.

21. In a signalling system, a carrier wave amplifier tube having a control grid, an anode, and a cathode, a circuit applying waves of carrier frequency to the control grid and cathode of said tube, an alternating current output circuit connected with the anode of said tube, means for controlling the gain of said tube when energy in said output circuit exceeds a predetermined peak value, and regulating means connected with said last named means for regulating at signal frequency the peak value at which said means becomes effective to control the gain of said tube.

22. In a signalling system, a carrier wave amplifier tube having a control grid, an anode, and a cathode, a circuit applying waves of carrier frequency to be amplified to the control grid and cathode of said tube, an alternating current circuit connected between the anode and cathode of said tube, means for lowering the gain of said tube when the energy in said alternating current circuit exceeds a predetermined peak value, and a signalling device connected with said means for controlling the peak value at which said means becomes effective to lower the gain of said tube.

23. In a signalling system, a carrier wave amplifying tube having a control grid, and anode, and a cathode, means for applying waves of carrier frequency to the control grid and cathode of said tube, an alternating current circuit connected with the anode and cathode of said tube, means coupled to said alternating current circuit and to an electrode in said tube for lowering the gain of said tube when said energy in said alternating current circuit exceeds predetermined peak values, means connected with said first named means for regulating the point at which said peak values become effective, and signalling means connected with said second named means for controlling said second named means at signal frequency.

24. In a signalling system, a carrier wave amplifier tube having a control grid, an anode, and a cathode, a circuit for applying waves of carrier frequency to said control grid and cathode, an alternating current circuit connected with the anode and cathode of said tube, means actuated by energy in said last circuit for lowering the gain of said tube when energy in said alternating current circuit exceeds predetermined peak values, and control means connected with said last named means and with a source of signal potential to be energized thereby for controlling the value at which said peak values become effective to lower the gain of said tube.

25. In a signalling system, a carrier wave amplifier tube having a control grid and a cathode energized by carrier wave oscillations, said tube having an anode connected in an alternating current output circuit, a discharge tube having an electrode connected with an electrode in said amplifier tube for lowering the gain of said amplifier tube when alternating current energy in said output circuit exceeds a predetermined peak value, a coupling between an electrode in said discharge tube and said alternating current output circuit for controlling the operation of said discharge tube by energy from said output circuit, and additional means for controlling the operation of said discharge tube at signal frequency.

26. In a signalling system, a carrier wave amplifier tube having a control grid and a cathode energized by carrier wave oscillations, said tube having an anode connected in an alternating current output circuit, a multi-electrode discharge tube having an electrode connected with an electrode in said first tube for lowering the gain thereof when alternating current energy in said output circuit exceeds a predetermined peak value, a coupling between an electrode in said discharge tube and said alternating current out-

put circuit for controlling the operation of said discharge tube by energy from said output circuit, a source of modulating potentials, and a circuit connecting said source of modulating potentials to an electrode in said discharge tube.

27. In a signalling system, a discharge tube having an anode, a control grid, and a cathode, alternating current circuits connected with said control grid and cathode and with said anode and cathode, a multi-electrode discharge device, a gain control circuit connecting an electrode in said device to an electrode in said tube for lowering the gain of said tube when energy in said circuits exceeds predetermined peak values, a coupling between an electrode of said device and an electrode in said tube for impressing energy peaks from the tube on the device, and a source of modulating potentials connected with an electrode in said device.

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