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GAIN CONTROL APPARATUS

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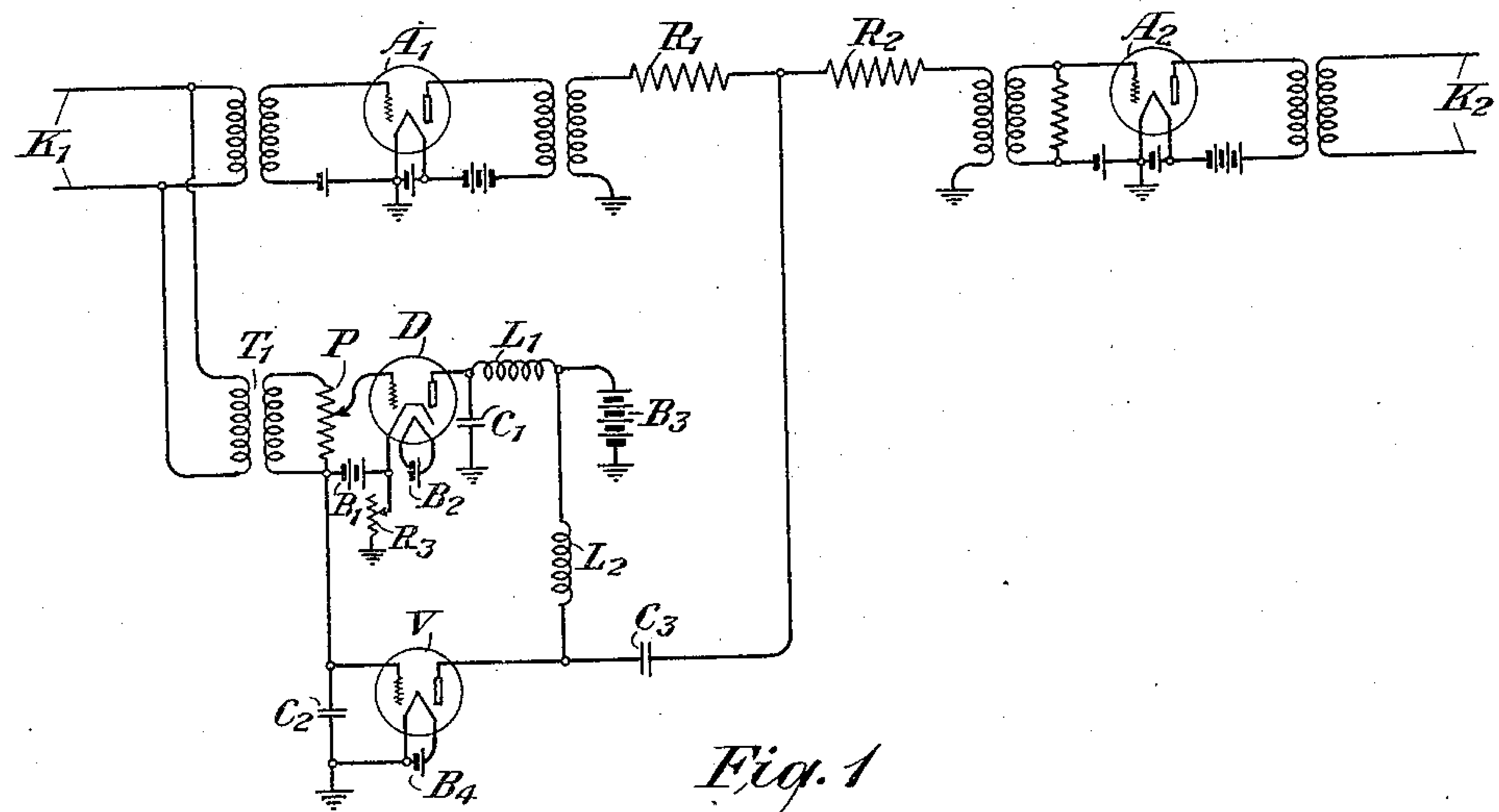

Fig. 1

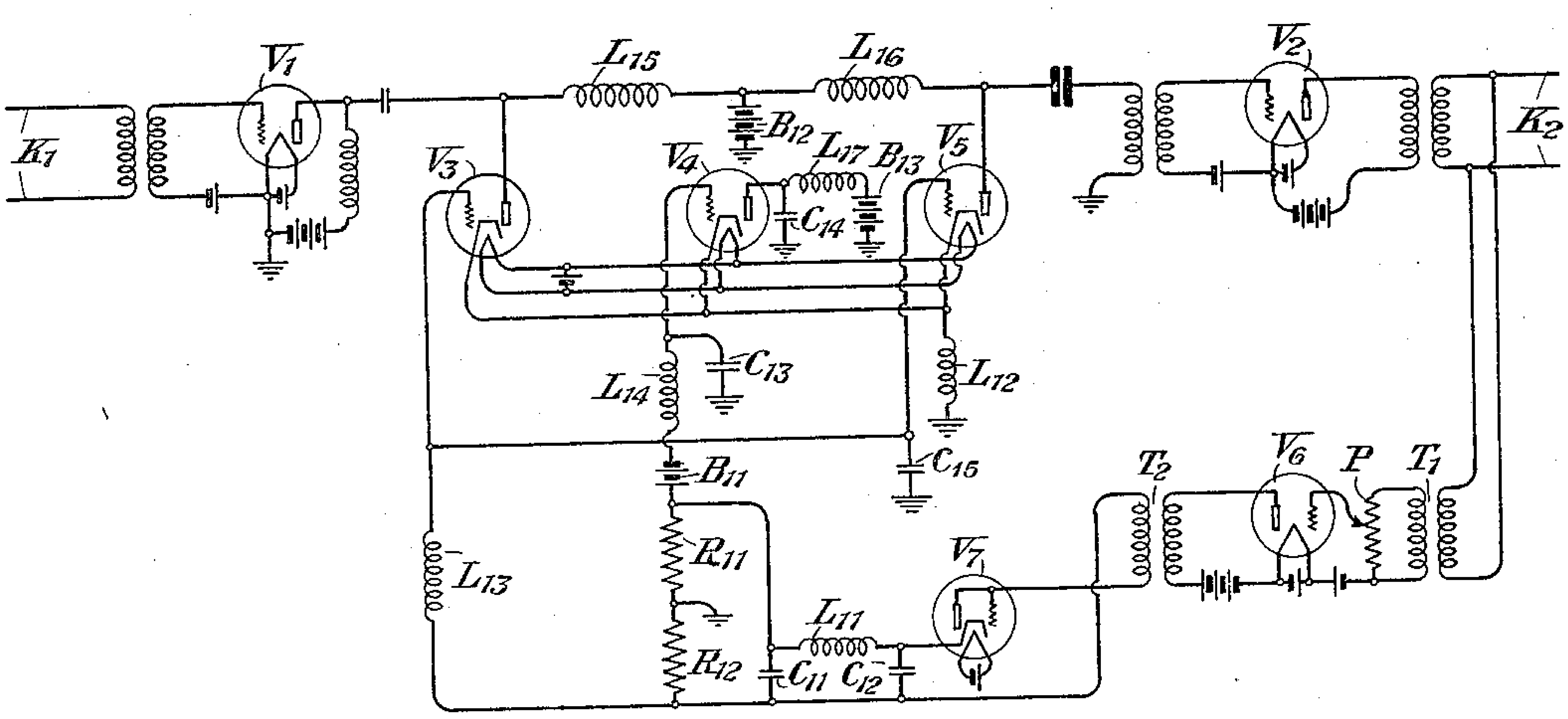

Fig. 2

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GAIN CONTROL APPARATUS

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This invention relates to signaling systems. More particularly, this invention relates to apparatus for the control of the level of signaling energy.

One of the objects of this invention is to automatically control the gain of a signal translating system. Another of the objects is to maintain the level of signaling energy constant in value, or variable within very narrow limits.

This application discloses novel arrangements for automatically controlling the gain of a signaling system embodying features which are believed to have many advantages over other prior arrangements for gain control. The arrangements of this invention require no ungrounded battery supplies other than dry cells for grid bias, and the elements are so set up as not to cause any modulation or distortion of the signals or currents, the gain of which the arrangements are intended to control. Consequently, this invention is adaptable to voice frequency circuits, or to multi-channel carrier amplifiers or other systems. No moving parts are required.

This invention will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawings, in which Figure 1 represents one embodiment of this invention including a T-type network having equal series elements and a shunt element formed by the plate and filament electrodes of a vacuum tube, the impedance of which is varied by current derived from a rectifier, and Fig. 2 discloses a similar network embodying three vacuum tubes, two forming series elements and the third a shunt element, all automatically adjustable in impedance.

Referring to Fig. 1 of the drawings, the vacuum tubes A_1 and A_2 form two tubes of an amplifying system, the gain of which is to be automatically controlled. This amplifying system transmits signaling currents from an input circuit K_1 to an output circuit K_2. Vacuum tubes D and V are controlling devices which are interposed between the input circuit K_1 and the network coupling the amplifying tubes A_1 and A_2, as will be described in greater detail hereinafter. Resistances R_1 and R_2 and the plate impedance of the tube V, form the essential elements of a T network which is preferably one of a rather high impedance, for example, about 50,000 ohms, this being the effective impedance of the coupling arrangement when the tube V exhibits its maximum plate impedance.

The primary winding of the transformer T_1 is connected to the input circuit K_1. The secondary winding of this transformer is connected to the fixed terminals of a potentiometer P, the movable arm of which is connected to the grid electrode of the tube D which is one of the heater type and is employed to act as a rectifier. The lower terminal of the potentiometer P is connected to the heater of the tube D through a battery B_1. The filament of the tube D is heated by a battery B_2. The heater of the tube D is connected to ground through a variable resistance R_3. The plate electrode of the tube D is connected to ground through a battery B_3 and an inductance L_1. This electrode is also connected to ground through a condenser C_1.

The lower terminal of the potentiometer P is connected to grid electrode of the tube V, and a condenser C_2 is interposed between this electrode and the grounded filament of the tube V. The plate electrode of the tube V is connected to the positive terminal of the battery B_3 through an inductance L_2. The plate electrode of the tube V is also connected to the terminal common to resistances R_1 and R_2 through condenser C_3 which prevents the potential of the battery B_3 from reaching resistances R_1 and R_2 and the windings of the transformers connected thereto. The filament of the tube V is heated to incandescence by a battery B_4.

The potential of the grid electrode of the tube D is determined by the battery B_1 as well as by the voltage impressed by the input circuit K_1 through transformer T_1 and the potentiometer P. This potentiometer will determine the amplitude of the current rectified by the tube D, and it may be set so as to produce any fixed direct current for an input of any predetermined magnitude. The plate circuit of the tube D may be considered to include the battery B_3, inductance L_1, the plate electrode and the heater of tube D, the resistance R_3, and ground. The plate circuit of the tube V may be considered to include the battery B_3, inductance L_2, the plate and filament electrodes of the tube V, and ground. The plate and filament electrodes of the tube V are the essential elements forming the shunt impedance of the coupling T network of this invention, and it will be shown that this shunt impedance is variable in accordance with the level of signaling energy flowing in the circuit K_1.

The battery B_1 is of such a potential that it will render the grid electrode of the tube D sufficiently negative with respect to the heater that substantially no current will flow through the plate circuit of the tube D, especially if the input circuit K_1 impresses no voltage upon the tube D. Battery B_1 is, however, common to the grid electrode of the tube V, the circuit interconnecting the grid electrode of the tube V with its filament electrode including battery B_1, resistance R_3, and ground. For a fixed input to tube D, there will be a direct current of predetermined magnitude in the plate circuit of the tube D. Inductance L_1 and a condenser C_1 form a filter which acts to suppress any superimposed alternating current and, obviously, this filter may include further sections including series inductive elements and shunt capacitive elements.

As the input to tube D changes, the direct current flowing through the plate circuit of the tube D will correspondingly vary. This will similarly change the potential impressed across the terminals of the resistance R_3. As the current in the plate circuit of the tube D increases, the drop in potential across the resistance R_3 will increase, and since the potential impressed across the latter resistance acts in a direction opposite that of the battery B_1 so far as tube V is concerned, the impedance between the plate and filament electrodes of the tube V will be lowered. Consequently, the loss introduced by the T network between tubes A_1 and A_2 will be increased.

When the input to tube D is very small, there will be substantially no current in the plate circuit of the tube D and the potential impressed across the resistance R_3 will be very small. Therefore, the impedance between the plate and filament electrodes of the tube V will be very high, and the loss introduced by the T network coupling tubes A_1 and A_2 will also be very low.

Thus, it will be seen that the coupling network of this invention varies the loss introduced between a pair of amplifying tubes as the shunt impedance of the tube V is varied. The surge impedance of this network will vary, but inasmuch as this is arranged in the inter-stage circuit between the two amplifying tubes, it will not introduce any reflection troubles or distortion, especially if suitably designed transformers are employed.

The following table gives the performance of a T network of the type employed in this invention, for various values of the shunt resistance. The series resistances R_1 and R_2 are assumed to be 50,000 ohms each, and the transformer ratios are such that the network appears to be terminated in 50,000 ohms at each end. The values given below represent the losses for the overall circuit and have been determined after proper consideration of variations due to changes in the impedance of the network.

Shunt resistance	Total loss in decibels
1,000	40.0
3,000	32.0
5,000	26.0
8,000	23.2
10,000	21.6
15,000	18.8
20,000	16.9
35,000	13.8
50,000	12.0
80,000	10.3
100,000	9.6
∞	6.0
0	∞

It will be seen that the variations in the plate resistance of the tube V causing a change from 3,000 to 35,000 ohms, will vary the gain of the amplifier by about 14.8 decibels.

It is to be noted that the plate impedance of the tube V is varied by changing the direct current bias of its grid electrode. This is accomplished by the novel employment of the equi-potential tube D acting as a rectifier. The plate current of this rectifying tube rises as the input thereto increases, and correspondingly changes the potential impressed across the resistance R_3.

Obviously, the effectiveness of the gain control arrangement of Fig. 1 can be varied by changing the input to the rectifier D by means of the potentiometer P or changing the resistance R_3. The rapidity with which this arrangement will readjust gain is determined by the cutoff frequency of the filter L_1—C_1 or by the time constant of the circuit R_3—C_2, whichever is the lower.

In carrier frequency systems where the input to the rectifier D is a pilot current, in which case the transformer T_1 would be tuned as, for example, by placing a variable condenser in series with its primary winding and/or a variable condenser in shunt with its secondary winding, the arrangement shown can be allowed to operate quite rapidly, as it would be impracticable to attempt to slow down the action of the device so as to disregard ordinary line swings. For voice frequency circuits, the condenser C_2 would be about one microfarad, especially since the resistance R_3 should not be more than about 10,000 ohms, a value which is determined by the normal electrical leakage from the cathode to the heater of the rectifying tube D.

Fig. 2 shows another arrangement for coupling a pair of vacuum tubes acting as amplifiers, the coupling arrangement forming a T network including two series space discharge paths and one shunt space discharge path. The reference characters V_1 and V_2 represent the amplifying tubes and these are interposed between the input circuit K_1 and the output circuit K_2 in order to amplify the transmitted signals. Tubes V_3, V_4 and V_5 represent three tubes, all of the heater type, forming the essential elements of the T network, tubes V_3 and V_5 forming the series elements and tube V_4 the shunt element. It will be shown that these tubes provide impedances which simultaneously vary, the impedances of the tubes V_3 and V_5 varying by equal amounts in the same direction.

Part of the energy in the output circuit K_2 is transmitted to an amplifier V_6 through transformer T_1 and potentiometer P. The amplified energy is then transmitted through transformer T_2 to a rectifying tube V_7 which is also of the heater type. The rectifying circuit includes the secondary winding of the transformer T_2, the plate electrode and the heater of the tube V_7, a winding L_{11} and resistances R_{11} and R_{12}. Winding L_{11} and condensers C_{11} and C_{12} form a section of a wave filter which is intended to suppress low frequency alternating currents.

The heaters of the tubes V_3, V_4 and V_5 are grounded in common through a winding L_{12}. The grid electrodes of the tubes V_3 and V_5 are connected to the lower terminal of the resistance R_{12} through a winding L_{13}. These electrodes are both grounded through a condenser C^{15}. The upper terminal of the resistance R_{11} is connected to the grid electrode of the tube V_4 through a winding L_{14} and a grid biasing battery B_{11}. The terminal common to the resistances R_{11} and R_{12} is grounded and the upper terminal of the winding L_{14} is grounded through a condenser C_{13}. The plate electrodes of the tubes V_3 and V_5 are tied together through windings L_{15} and L_{16} and the terminal common to these windings is grounded through a plate battery B_{12}. The plate electrode of the tube V_4 is connected to ground through a winding L_{17} and a battery B_{13}. The plate electrode of tube V_4 is also connected to ground through a condenser C_{14}.

The rectified current transmitted through tube V_7 flows through resistances R_{11} and R_{12} and causes voltages to be impressed across the terminals of these resistances. If these resistance are of equal magnitude, as they may be considered for this illustration, the voltages impressed across the terminals of these resistances will be equal. However, if the resistances are of unequal magnitudes, the voltages impressed thereacross will differ by a corresponding amount. The voltage produced by resistance R_{11} will be impressed on the grid electrode of tube V_4 through battery B_{11} and winding L_{14}, the voltage of battery B_{11} opposing that produced by the resistance R_{11}. The voltage produced by the resistance R_{12} will be equally impressed on the grid electrodes of the tubes V_3 and V_5 through the winding L_{13}.

As the current rectified by tube V_7 increases above a predetermined value by virtue of an increase in the energy in the circuit K_2 and impressed upon the amplifier V_6, the voltages across the resistances R_{11} and R_{12} will increase above certain normal values. Then, there will be a reduction in the bias on the grid electrode of the tube V_4 and, moreover, an increase in the bias on the grid electrode tubes V_3 and V_5. Hence, the loss introduced by the T network will, accordingly, be increased. As the rectified current flowing through tube V_7 is reduced below its normal, predetermined value, the voltages produced by resistances R_{11} and R_{12} will also be reduced below their normal values. Hence, there will be an increase in the bias of the grid electrode of the tube V_4 and decreases in the bias of the grid electrodes of the tubes V_3 and V_4. Accordingly, the loss introduced by the T network will be reduced.

Thus, it will be seen that the coupling apparatus shown in Fig. 2 will maintain the output at the circuit K_2 constant or variable within very narrow limits. The tubes V_3 and V_5 provide impedances which are the series elements of the coupling arrangement and the tube V_4 provides the impedance forming the shunt element of the arrangement. All of these impedances are simultaneously variable and, moreover, the terminating impedances of the network are maintained highly constant under all conditions. Consequently, the effectiveness of the control arrangement is vastly improved.

While this invention has been shown and described in certain particular arrangments merely for the purpose of illustration, it will be understood that this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a gain control system for a pair of amplifiers, the combination of a circuit interconnecting said amplifiers, a pair of equal resistances connected in series in said circuit, a tube having electrodes forming a space discharge path and a control electrode, said electrodes forming the space discharge path of said tube being connected in shunt across said circuit from the point common to said resistances, and means to adjust the potential impressed upon the control electrode of

said tube in accordance with the energy transmitted through said amplifiers.

2. In a gain control system, the combination of a transmission circuit, three tubes each having two electrodes forming a space discharge path and a control electrode, the electrodes forming the space discharge paths of two of said tubes being connected in series with said transmission circuit, the electrodes forming the space discharge path of the third tube being connected in shunt with said transmission circuit from the point common to the space discharge paths of the first two tubes, and means to simultaneously vary the potentials of the control electrodes of all of said tubes.

3. In a gain control system, a coupling network comprising three tubes each having two electrodes forming a space discharge path and a control electrode, the electrodes forming the space discharge paths of two of said tubes being connected in series relationship in said network, the electrodes forming the space discharge path of the third tube being connected in shunt in said network from the point common to said space discharge paths of the first two tubes, and means to simultaneously vary the potentials of the control electrodes of the first two tubes and the potential of the control electrode of the third tube in mutually opposite directions.

In testimony whereof, I have signed my name to this specification this 15th day of December, 1930.

WILLIAM H. T. HOLDEN.