March 17, 1936. E. F. CARTER 2,034,226

WAVE SIGNALING SYSTEM

Filed Sept. 11, 1930

Fig. 1,

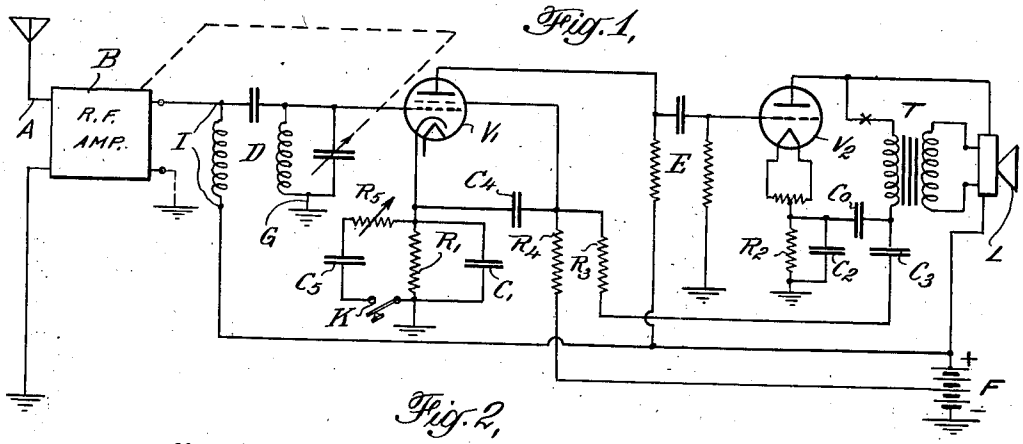


Fig. 2,

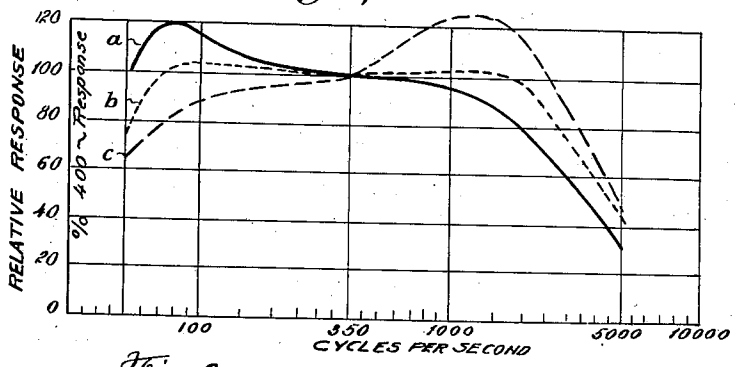


Fig. 3,

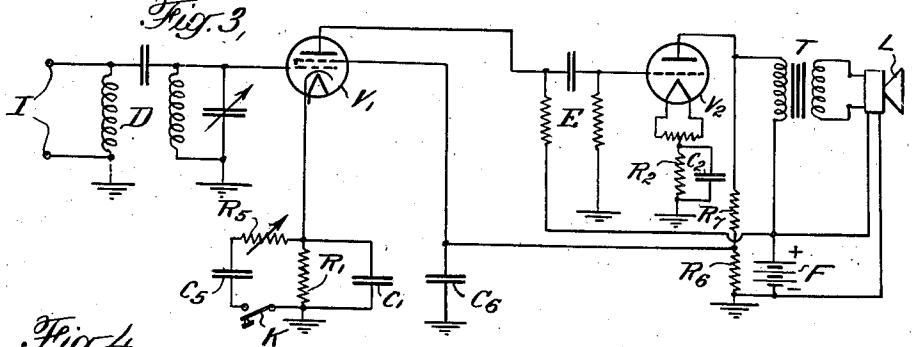
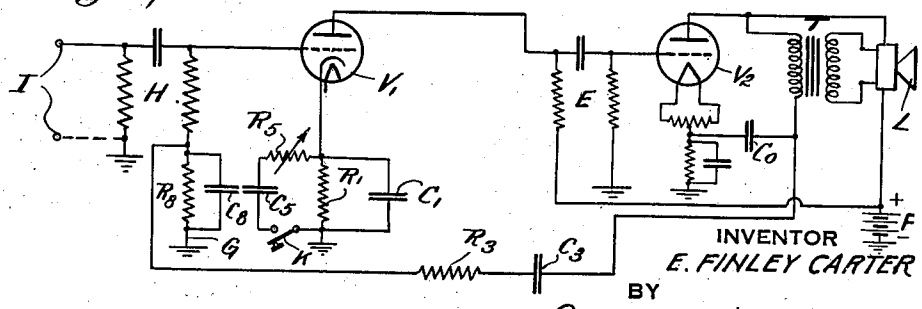


Fig. 4,



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WAVE SIGNALING SYSTEM

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16 Claims. (Cl. 179—171)

This invention relates to improvements in low-frequency thermionic amplifiers and more especially to such amplifiers as embodied in radio receivers intended for the reception of speech, music and similar sound effects.

A primary object of the invention is to provide a simple regenerative arrangement for controlling the signal response at the low-frequency end of the audio-frequency band in order for example, to improve the fidelity of sound reproduction.

A further object is to provide an arrangement for variably adjusting the degree of amplification with respect to frequency in order to "peak" the frequency-response curve at a desired point within the audio-frequency band with the view of adjustably controlling the region of tonal emphasis.

With respect to the first object mentioned, there exists in many types of low-frequency thermionic amplifiers, especially those embodied in modern radio broadcast receivers, several principal causes for a disproportionate reduction in amplification at the low audio-frequencies. One of these causes resides in the high impedance at such frequencies of the "blocking" or "coupling" condensers frequently associated with the output circuits of the low-frequency amplifier stages for separating the alternating and direct-current components. The coupling condenser although of capacity sufficiently large to introduce negligible loss throughout the major portion of the audible range, produces appreciable attenuation as the low-frequency limit is approached due to the marked increase in its impedance. Another principal cause for a disproportionate reduction of the lower audio frequencies is due to negative regeneration caused by insufficient by-passing of the low-frequency currents by the condenser in shunt to the grid biasing resistor usually interposed in the anode circuit of a thermionic element for applying a suitable negative biasing potential to the grid thereof. A third cause may result from insufficient inductance in one or more of the interstage audio-frequency transformers at the very low frequencies due to an economical design.

In accordance with this invention it is contemplated to compensate in greater or less degree as desired, for any or all of the above effects by introducing into the amplifier system, positive regeneration dependent upon the signal wave voltage which exists across a coupling condenser or other similarly operative capacitive impedance associated with the anode circuit of an amplifier stage. In this way a regenerative action is obtained which varies automatically with frequency in opposite fashion to that of the attenuation effects noted and thus is admirably adapted to compensate for such effects.

The principle of this invention is susceptible of embodiment in many specific forms several of which are included herein by way of illustration. In one embodiment the regenerative circuit is constituted by arranging a blocking condenser in the grounded cathode lead extending to the output circuit of an amplifier stage instead of in the anode lead, the latter being the usual connection. The regenerative circuit is then constituted by coupling the ungrounded terminal of the condenser to a control electrode of a preceding detector or audio-frequency amplifier stages which is so coupled to the tube containing the condenser as to accomplish a reversal in phase of the signal wave. As a consequence of this arrangement energy is fed back to the preceding tube in like phase relation with the incoming signal which tends to accentuate the lower audio-frequencies.

If desired the regeneration due to the blocking condenser or other mentioned capacitive impedance may be adjusted to normally increase the low-frequency response to a point where it exceeds that of the higher frequencies. The grid biasing impedance of the detector or an amplifier stage may then be rendered adjustable to vary the degree of low frequency negative regeneration thereby providing a means of varying the low-frequency response with respect to the higher frequencies. In this manner the "peak" of the frequency-response characteristic may be shifted throughout the frequency range for adjusting the region of tonal emphasis to a desired frequency without the necessity of reducing the available power output by consumption of power in the controlling element.

Referring now to the drawing:

Fig. 1 shows schematically a complete radio receiving system embodying one modification of the invention;

Fig. 2 depicts graphically the results of the frequency control adjustment; while

Figs. 3 and 4 are circuit diagrams showing modified forms of the invention.

The receiving system of Fig. 1 comprises an antenna circuit A connected through a radio-frequency amplifier B to a tunable coupling circuit D associated with the grid electrode of a thermionic tube V_1 of the screen-grid type ar-

ranged to operate as a detector. The detector output is resistance coupled by means of circuit E to the input circuit of a second thermionic tube V_2 operating as a stage of audio-frequency amplification. The output circuit of the tube V_2 contains a low frequency iron-core transformer T the secondary winding of which is connected to the actuating coil of a loud speaker L of the dynamic type.

A blocking condenser C_0 prevents the flow of direct current through the primary winding of transformer T, and accordingly the space current for tube V_2 supplied from battery F is returned through the field winding of the loud speaker unit. The blocking condenser C_0 would normally be included at X in the anode lead of the transformer primary winding, but in the present instance is included in the cathode lead thereof as shown in order to accomplish the ends of the present invention.

The filaments of tubes V_1 and V_2 may be heated in any suitable manner, (not shown) the cathodes in each instance being connected to ground through grid biasing resistors R_1 and R_2 shunted by the low-frequency by-passing condensers C_1 and C_2 respectively, for applying suitable negative biasing potentials to the respective grids in accordance with the space supply currents flowing through the resistor elements. This method of biasing the grids of the tubes while convenient and in many respects advantageous, is subject to the objection that it operates degeneratively upon the signaling current.

Thus referring more specifically to tube V_1, assume that at a given instant a signaling wave impressed upon the input thereto is such as to increase the negative potential of the grid electrode relative to the cathode. In accordance with the well-known operation of the tube, there will result a corresponding momentary decrease in the flow of space current which correspondingly reduces the potential drop across the resistor R_1 and thus in turn reduces the resultant negative potential applied to the grid of the tube, in this manner offsetting in some degree the effect of the applied signaling wave with consequent reduction in amplitude of the output current.

In order to minimize this effect the by-passing condenser C_1 is connected in shunt to the resistor element R_1, thereby affording a low impedance path around the resistor which reduces the above noted degenerative action to a negligible degree throughout the major portion of the audio-frequency band. At the lower audio-frequencies, however, the impedance of the by-passing condenser C_1 increases to such an extent as to introduce marked degenerative action with consequent reduction in amplification.

It will be observed that the attenuation due to the degenerative action of the grid biasing impedance R_1—C_1 produces the same kind of distorting effect upon the fidelity of signal reproduction as does the blocking condenser C_0. Hence the distortion due to either or both of these sources may be compensated by regeneratively applying a portion of the voltage drop due to the signal wave which exists across the condenser C_0 to a control electrode of tube V_1.

The regenerative coupling is in the present instance accomplished by connecting the ungrounded terminal of condenser C_0 through a second blocking condenser C_3 and a resistance R_3 to a control electrode, specifically the screen grid electrode of tube V_1. The screen grid of tube V_1 is in turn connected through a resistance R_4 to a point of suitable biasing potential on battery F; whereas a condenser C_4 adapted to by-pass the radio and higher audio frequencies, is connected from the screen grid electrode to the ungrounded terminal of the grid biasing resistor R_1.

The regenerative action with the coupling connection shown results from the reversal in phase accomplished between tubes V_1 and V_2 as a result of the well understood action of the resistance coupling circuit E. If a transformer were used in place of circuit E, the same result could be attained by properly poling the secondary relative to the primary winding.

The amount of feed-back may be controlled by the relative proportioning of resistances R_3 and R_4 thereby controlling the potential applied to the screen grid electrode. The upper frequency limit at which it is desired that the regenerative action become effective is controlled by properly proportioning the capacities C_0 and C_4; while the frequency below which it is desired that the regenerative action cease is determined by the magnitude of capacity C_3.

The regenerative action may, if desired, be adjusted to counterbalance exactly the decrease in amplification otherwise present at the lower frequencies, in which event the frequency-response characteristic of the amplifier will be substantially constant down to the low frequency cutoff point. On the other hand it is perfectly feasible with the arrangement described to either over emphasize or under emphasize the low frequencies throughout a desired portion of the audio frequency spectrum.

This suggests the possibility of variably controlling the frequency response characteristic in the manner described to "peak" the characteristic at any desired frequency thereby adjustably controlling the region of tonal emphasis, as is sometimes desired in radio reception for bringing out more distinctly the low, intermediate or high frequency notes as the case may be.

A circuit for accomplishing this end which operates very efficiently in conjunction with the regenerative circuit described comprises the variable resistance R_5 in series with a fixed capacity C_5 bridged across the resistor R_1 upon closure of switch K. The capacity C_5 is made sufficiently large that with resistance R_5 adjusted to zero it will in conjunction with capacity C_1 satisfactorily by-pass around resistor R_1 the entire range of audio-frequency currents. As resistance R_5 is increased in magnitude, however the degenerative action described above will be introduced, with ever increasing prominence and will extend over an increasing portion of the audio frequency band beginning with the low frequency end.

If now the regenerative circuit including condenser C_0 is so proportioned as to greatly over-emphasize or accentuate the lower frequencies with resistance R_5 at zero, it will be apparent that steadily increasing the magnitude of this resistance will cause the peak value of amplification to shift from the low frequency end of the audio-frequency band up to a higher frequency depending upon the value of C_1, so that the region of tonal emphasis may in this way be caused to occur at any desired frequency within the audible range. The capacity C_1 has a value which is determined by the point at which it is desired to start attenuating the lower frequencies as the resistance R_5 is increased from zero.

The curves of Fig. 2 show graphically the manner in which the fidelity of sound reproduction may be controlled with the circuit arrangement described. In the drawing curve *a* shows the frequency response characteristic obtained with the resistance R_5 set at zero, and with the regenerative circuit including condenser C_0 arranged to over emphasize the lower audio-frequencies. Curve *b* shows the result obtained with the resistance R_5 adjusted to such value as to obtain substantially uniform response over the essential range of audio frequencies; whereas curve *c* shows an adjustment of R_5 to a high resistance value such as to over emphasize the upper limit of the audio-frequency band.

The invention disclosed herein is susceptible of specific embodiment in a number of different ways. For example, in the circuit arrangement of Fig. 3 the regenerative action is obtained by connecting a pair of resistance elements R_6 and R_7 in series between the anode of tube V_2 and ground. A point between the resistance elements is connected directly to the screen grid of tube V_1 and also through a condenser C_6 to ground. The amplified signaling current flowing in the output circuit of tube V_2 impresses a potential drop across resistance elements R_6 and R_7 a portion of which is applied to the screen grid electrode of tube V_1 and thereby may be proportioned to accentuate the lower audio-frequencies to the extent desired.

The relative magnitude of resistances R_6 and R_7 are determined by the portion of the positive potential of battery F to be applied as a biasing potential to the screen-grid electrode of tubes V_1. The actual magnitude of elements R_6 and R_7 is determined on the basis of the signal current potential to be applied to the screen-grid of tube V_1 in order to accomplish the desired degree of regeneration. The point in the frequency scale at which the regenerative action commences as well as the rate of increase of the regenerative effect toward the low frequency limit is determined by the value of capacity C_6 with reference to that of resistance R_6.

It will be noted that the impedance C_6—R_6 while capacitively reactive and hence of increasing impedance to decreasing frequencies for accentuating the lower audio-frequencies, is nevertheless definitely limited in ultimate magnitude to that of resistance R_6. This definite limitation in maximum value of impedance C_6—R_6 prevents the regenerative effect from becoming excessive at the very low audio or sub-audio-frequencies to render the amplifier unstable by causing it to "flutter" or "motorboat" as the condition is termed. Inasmuch as elements R_6 and R_7 are bridged in series across the primary winding of transformer T the impedance of which decreases with frequencies, this factor also becomes effective to limit the regenerative action at the sub-audio-frequencies for preventing unstable operation of the circuit.

It is apparent of course that the capacitive impedance C_6—R_6 of Fig. 3, serves the same purpose insofar as the regenerative effect is concerned as the blocking condenser C_0 of Fig. 1 and is thus an alternative scheme for accomplishing the objects of the invention.

It is not necessary that the regenerative potential be applied to the screen-grid electrode of tube V_1 as is shown in the modification of Figs. 1 and 3, the action being equally well obtained by coupling the regenerating voltage drop across the capacitive impedance element back to the grid circuit of the preceding tube V_1 as is shown, for example, in Fig. 4. In Fig. 4 the ungrounded terminal of the blocking condenser C_0 of Fig. 1 is connected through capacity C_3 and resistance R_3 to the ungrounded terminal of a resistance R_8 shunted by a capacity C_8 interposed in the ground lead extending from the grid electrode of tube V_1. The energy fed back from capacity C_0 flows through resistor R_8 in additive phase relation to the incoming signal impressed upon terminals I, and thus serves to offset the degenerative action caused by the flow of current in the grid biasing impedance R_1—C_1 connected to the cathode of tube V_1.

It will be observed that the arrangement of Fig. 4 is well adapted for use in conjunction with triode tubes. It will be observed further with specific reference to Fig. 4 that the tube V_1 need not necessarily be a detector tube having a tunable input circuit associated therewith, but may with equal facility comprise a stage of audio-frequency amplification connected to input terminals I through a suitable resistance coupling circuit H or other untuned low frequency network.

The regenerative circuit of Fig. 3 may of course by obvious changes extend to the grid circuit of tube V_1, after the fashion shown in Fig. 4.

What is claimed is:

1. In a wave signaling system, a plurality of space discharge elements coupled in tandem, one of said elements having a control electrode, and a succeeding element having an anode and a cathode, the anode-cathode circuit of said succeeding element including a blocking condenser connected between the cathode and the output circuit thereof, and a lead containing a condenser connected between the terminal of said blocking condenser remote from said cathode to said control electrode.

2. In a wave signaling system, in combination, a first thermionic space discharge element coupled in tandem to a second space discharge element, each said element having anode, cathode and control electrodes, a source of anode potential for said elements, an output coupling means for said second element, a blocking condenser in series with said output coupling means for preventing the passage of direct current through said output coupling means, and a regenerative path from said blocking condenser to a control electrode of said first element for compensating low frequency discrimination of said blocking condenser.

3. A combination according to claim 2 in which said regenerative path comprises a condenser and a resistance in series.

4. In a wave signaling system, in combination a first thermionic space discharge element coupled in tandem to a second space discharge element, said elements having anode, cathode and control electrodes, a source of anode potential for said elements, an output coupling means for said second element, a blocking condenser in series with said output coupling means for preventing the passage of direct current through said output coupling means, a regenerating path from said blocking condenser to a control electrode of said first element, a resistance in said regenerating path and a resistance in said control circuit, the values of which resistances control the degree of regeneration.

5. In combination, a thermionic detector having an anode, a cathode, a screen-grid for screening the detector anode and an input grid, a ther-

mionic amplifier having an anode, cathode and grid, a source of anode potential for said amplifier and detector, the anode circuit of said detector being coupled to the grid circuit of said amplifier through signal wave phase reversing means, an output circuit for said amplifier, comprising an output transformer and a blocking condenser in series, the first terminal of said condenser being connected to said amplifier cathode, and a regenerative feed-back connection from the second terminal of said condenser to the screen-grid of said detector, whereby tonal distortion occasioned by said blocking condenser is compensated.

6. In a low frequency electric wave signaling system, a pair of space discharge devices having cathode, anode and control electrodes, means for supplying anode potential to said anodes, a resistor in the anode circuit of the first of said devices for furnishing negative biasing potential to the grid thereof, a low frequency by-passing condenser shunted across said grid biasing resistor, a capacitive impedance in the anode circuit of the second of said space discharge devices, and a regenerative wave path leading from said capacitive impedance to a control electrode of said first device whereby tone distortion due to said capacitive impedance and resistor circuit may be compensated.

7. In a low frequency electric wave signaling and sound reproducing system, a pair of thermionic space discharge devices arranged in cascade connection, each device having anode, cathode, and control electrodes, a capacitive impedance associated with the output circuit of the second of said devices having one terminal connected to the cathode thereof, a regenerative path extending from the other terminal thereof to a control electrode of the first of said tubes proportioned to accentuate the lower audio-frequencies, and a mesh in the anode circuit of said first device, said mesh comprising a grid-biasing resistance, capacity and variable resistance for adjusting the tonal emphasis of reproduced sound.

8. In an audio-frequency wave signaling and sound reproducing system, a plurality of thermionic tubes in cascade connection, each tube having anode, cathode and control electrodes, a capacitive impedance included in the anode circuit of one said tube, and a grid biasing impedance including resistance shunted by capacity arranged in the anode circuit of a preceding tube, means for regeneratively applying upon a control electrode of said preceding tube a potential dependent upon the signal wave voltage which exists across said capacitive impedance and proportioned to increasingly accentuate the frequencies toward the low frequency end of audible frequency range, and means comprising a fixed capacity in series with variable resistance shunting said grid biasing impedance for adjustably controlling the degree of said regeneration at the lower frequencies whereby the tonal emphasis may be controlled.

9. In a wave signaling system comprising a plurality of thermionic tubes in cascade connection, each tube having anode, cathode and control electrodes, resistance in shunt to the anode circuit of one said tube, a regenerative connection from said resistance to a control electrode of one said tube, and a condenser connected from said control electrode to a point of different signal current potential on said resistance.

10. In a low frequency wave signaling system comprising a plurality of thermionic tubes in cascade connection, each tube having anode, cathode and control electrodes, resistance connected from the anode of one said tube to a point of ground potential, a regenerative connection from an intermediate tap of said resistance to a control electrode of one said tube, and a condenser connected from said control electrode to ground, the degree of said regeneration being dependent upon the relative magnitude of the tapped resistance portions, said capacity increasingly controlling said regeneration toward the lower audio-frequencies.

11. In a low frequency wave signaling system including a pair of thermionic tubes in cascade connection, each tube having anode, cathode and control electrodes, resistance connecting the anode of the second said tube to a point of ground potential, a regenerative connection from an intermediate tap of said resistance to a control electrode of the first said tube, and a condenser connecting said control electrode to ground, the tapping point on said resistance and the magnitude of said capacity being selected to increasingly accentuate the lower audio-frequencies and means for adjustably controlling the region of tonal emphasis of said system comprising a grid biasing resistor shunted by capacity included in the anode circuit of said first tube, and capacity and variable resistance in series shunting said resistor.

12. A signaling system comprising a plurality of vacuum tubes in cascade connection, each tube having anode, cathode and grid electrodes, a coupling condenser in circuit between said tubes, and an audio frequency selective circuit from the output circuit of a succeeding tube to the input circuit of a preceding tube of said cascade, a condenser in the output circuit of said succeeding tube and a direct lead from said condenser to a grid of a preceding tube.

13. The combination of a line adapted to transmit a band of audio frequency currents, a vacuum tube amplifier therefor, and means comprising an adjustable device in circuit with said amplifier whereby said adjustable device in successive positions of its adjustment is adapted respectively to (*a*) peak the frequency response of said band of currents as frequencies less than 350 cycles per second, (*b*) uniformly transmit said band of currents over a wide range of frequencies and (*c*) peak the frequency response of said band of currents in the high frequency portion of said band above 350 cycles per second.

14. Arrangement for transmitting a band of audio frequency currents in modified wave form comprising the combination of a line adapted to transmit a band of audio frequency currents, a vacuum tube amplifier therefor, and adjustable means in circuit with said amplifier adapted to (*a*) peak the frequency response of said band of currents in the low frequency portion of said band, (*b*) uniformly transmit said band of currents over a wide range of frequencies, and (*c*) peak the frequency response of said band of currents in the high frequency portion of said band.

15. Arrangement for transmitting a band of audio frequency currents in modified wave form comprising the combination of a line adapted to transmit a band of audio frequency currents, a vacuum tube amplifier therefor, adjustable means in circuit with said amplifier adapted to (*a*) peak the frequency response of said band of currents in the low frequency portion of said band, (*b*) uniformly transmit said band of currents

over a wide range of frequencies and (c) peak the frequency response of said band of currents in the high frequency portion of said band, and means for limiting the frequency range within which said adjustable means is effective.

16. Arrangement for transmitting a band of audio frequency currents in modified wave form comprising the combination of a source of a band of audio frequency currents, a vacuum tube amplifier therefor, and adjustable means in circuit with said amplifier adapted to peak the frequency response of said band of currents at selected portions of said band from the low frequency portion of said band to the high frequency portion thereof, and to gradually shift the peak over a wide range of frequencies, and at another point of adjustment to uniformly transmit said band of currents over a wide range of frequencies.

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