June 30, 1942. E. B. FERRELL 2,288,275

MODULATING SYSTEM

Original Filed June 9, 1934 2 Sheets-Sheet 1

FIG. 1

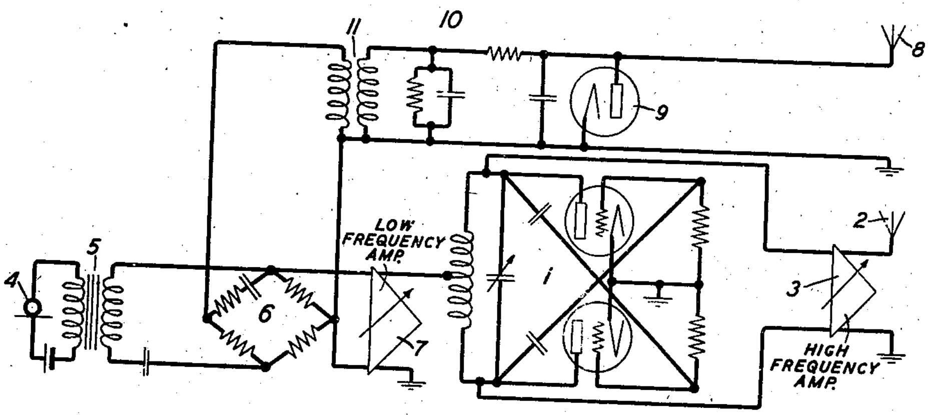

FIG. 2

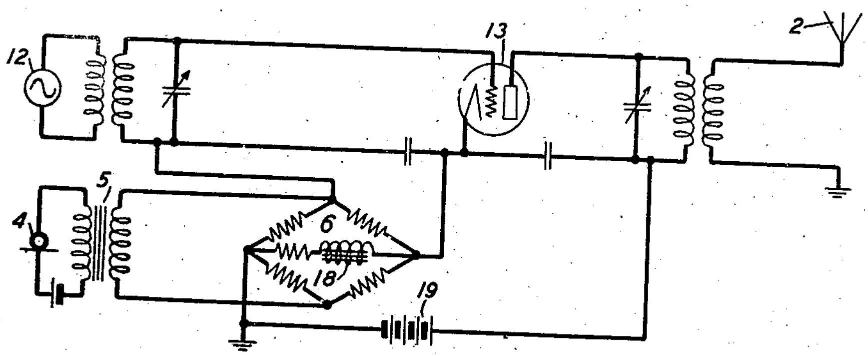

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FIG. 3

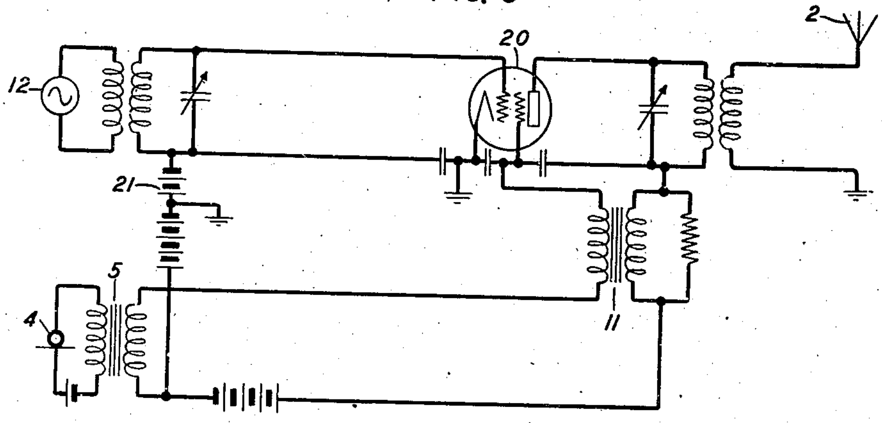
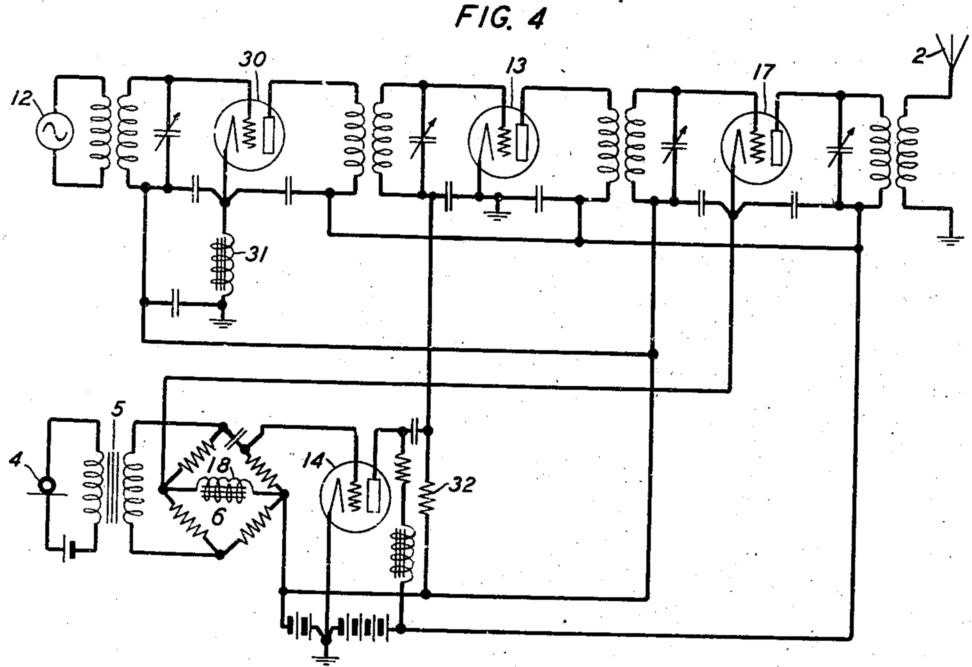


FIG. 4



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2,288,275

MODULATING SYSTEM

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Original application June 9, 1934, Serial No. 729,735, now Patent No. 2,159,020, dated May 23, 1939. Divided and this application June 3, 1938, Serial No. 211,548

19 Claims. (Cl. 179—171.5)

This invention relates to modulating systems and more particularly to means for regulating the transmission characteristics of such systems.

The invention has as its main object to reduce wave distortion in a modulator, particularly envelope distortion of a modulated wave.

Another object is to remove from an alternating current or carrier wave any undesired modulation such as noise effects and slow amplitude variations.

Noise and modulation effects have been successfully controlled in amplifiers by means of negative feedback or degeneration. The underlying principles involved in this method of control are disclosed by H. S. Black in an article entitled "Stabilized Feedback Amplifiers," published in the January 1934 issue of the Bell System Technical Journal, on pages 1–18 and in a copending application, Serial No. 606,871, filed April 22, 1932, Patent No. 2,102,671 December 21, 1937, and assigned to the same assignee as the present application. In a modulator, however, the problem of noise and distortion reduction is somewhat complicated by the necessary frequency changes which occur.

In accordance with the invention, detection is employed to derive a detected signal from a modulated carrier wave. In the absence of feedback in the system the detected signal varies somewhat from the original signal in its wave form according to the amount of noise and distortion introduced by the modulator. To reduce this distortion the detected signal is fed back degeneratively upon the signal input of the modulator. By making the fed-back component large compared with the original signal input and controlling its amplitude, the envelope distortion of the modulated wave may be reduced as much as may be desired.

Preferably a rectifier having a linear characteristic is used as the means for detecting the signal from the modulated wave since such a rectifier produces a faithful copy of the envelope of the modulated wave and introduces no additional signal distortion by itself.

In a modified form of the invention the principle of degenerative feedback is used to remove noise components and other undesired modulations from a carrier wave, thus providing a pure sinusoidal wave of constant amplitude which may be supplied to a modulating amplifier for signal modulation.

This application is a division of my copending application Serial No. 729,735, filed June 9, 1934, Patent 2,159,020, May 23, 1939, and is directed particularly to those embodiments of the invention that employ a self-detecting modulator or amplifier to effect the detection required for the reduction of distortion and noise, thereby eliminating a separate detector for that purpose.

The invention will be more fully understood from the following detailed description and from the accompanying drawings of which:

Fig. 1 shows a radio transmitting system referred to in explaining the invention;

Fig. 2 shows a radio transmitting system embodying the invention;

Fig. 3 shows an arrangement of the invention as adapted to a screen grid amplifier; and

Fig. 4 shows a transmitting system incorporating initial noise reduction in a carrier supply amplifier.

In order to facilitate understanding of the species of the invention claimed herein, there is first shown in Fig. 1, a system employing a separate detector for use in reducing distortion and noise in order to emphasize the role of the detecting function.

In Fig. 1, a balanced high frequency generating system 1 is shown connected to a transmitting antenna system 2 through a high frequency amplifier 3. A signal source 4 is associated with the output circuit of the generating system 1 by means of a transformer 5, a bridge network 6 and a low frequency amplifier 7. A receiving antenna 8 is provided with a rectifying detector 9, the output of the detector being connected through a filter 10 and transformer 11 to the bridge 6. Transformers 5 and 11 are placed in the opposite diagonals of the bridge, with the amplifier 7 across one of the ratio arms. Detector 9 may be a diode vacuum tube or a copper-oxide rectifier or other rectifying device exhibiting a linear relationship between its input voltage and output current.

In the operation of the system shown in Fig. 1, the high frequency output of the generator 1 is modulated by amplified signals from source 4 transmitted through the transformer 5, the bridge 6 and the amplifier 7. The modulated high frequency wave is amplified in the amplifier 3 and radiated from the antenna 2. The antenna 8 picks up energy from the radiated wave for detector 9, which feeds the detected wave back in reversed phase upon the input circuit of the low frequency amplifier 7. The feedback operates to diminish noise effects and distortion in the output wave from the system in accordance with the principles described in the hereinbefore mentioned paper by H. S. Black. The system diminishes noise and distortion originating in any portion of the loop comprising amplifier 7, generator 1, amplifier 3, detector 9, and their coupling arrangements. The greatest reduction of disturbing effects will occur when the feedback is as strong as possible and has a phase angle close to 180 degrees. Strong reversed feedback results, of course, in reduced output, but the modulation can be restored to its former strength by increasing the signal input. The phase requirement can generally be met by reversing one winding of the transformer 11, because with high grade amplifiers the phase shift in any stage will be either zero or 180 degrees. If the total phase shift around the loop is 180 degrees or an odd multiple thereof, the transformer may not be needed.

The general principles of reversed feedback operation are set forth in Black's article above cited. In the application of the principles to specific circuits it is well to note two definite limitations. One is that the system will not compensate for distortion which comes from interruption of the space current of a vacuum tube. Neither will it compensate for distortion due to exceeding the saturation voltage of a tube. The other limitation is imposed by the tendency to sing or set up self-sustaining oscillations. Nevertheless I have found by experiment that a substantial reduction of noise and distortion can be secured in radio transmitters by the use of my invention.

The bridge network 6 serves to isolate the feedback circuit from the signal supply circuit, making these circuits conjugate to each other and capable of independent adjustment. The filter 10 is employed to prevent high frequency feedback.

Fig. 2 shows the application of the invention to a modulating amplifier of class B or class C, that is, to an amplifier operated with sufficient negative grid bias to cut off or nearly cut off the plate current in the absence of impressed alternating current excitation. In the figure a carrier generator 12 is connected to the antenna 2 through a modulating amplifier 13. The signal source 4 is coupled to the input circuit of the amplifier 13 by means of the bridge 6 and the transformer 5. In the opposite bridge diagonal to the transformer 5 is inserted a low frequency coil 18 which is part of the plate circuit of the tube 13. The grid circuit of the tube 13 includes one of the ratio arms of the bridge. The plate supply battery is shown at 19.

In the operation of the system of Fig. 2, the carrier wave is impressed upon the grid circuit of the tube 13 along with the signal wave from the bridge 6. The plate current from the battery 19 passes through the bridge 6 providing a strong negative grid bias for the tube, fixed by the potential drop in the ratio arm included in the grid circuit. Due to the strong bias the plate current flows in pulses when the carrier and signal waves are impressed. In the presence of the carrier without signals the pulses are uniform, but when the signals are applied the pulses vary in strength according to the signals. Consequently the plate current contains a component of low frequency, which is substantially a faithful copy of the envelope of the modulated wave in a properly adjusted modulator. The low frequency wave traverses coil 18, thus feeding back upon the grid of tube 13. This feedback is inherently a reversed one as it will be evident from the figure that an increase of plate current through coil 18 makes the grid more negative, while a decrease of plate current makes the grid less negative, these variations in the grid voltage being opposite in phase to the signal variations which cause the respective changes in plate current. This arrangement does not require a separate detector since the amplifier performs the detecting function. The system operates to diminish noise and distortion arising in the modulating amplifier or in the carrier generator.

Fig. 3 shows an arrangement where the reversed feedback is from the plate circuit to the screen circuit of a screen grid tube. The carrier source 12 is connected to the antenna 2 through a screen grid tube 20. The tube is provided with a large biasing battery 21 to effect class B or C operation. The signal source 4 is associated with the screen electrode of tube 20 by means of the transformer 5. Coupling between the plate and screen circuits at low frequencies is provided by the transformer 11.

In the operation of the system of Fig. 3, the carrier is impressed upon the grid and the signal upon the screen of the tube 20. The modulated wave generated in the plate circuit is radiated by the antenna 2. The low frequency component of the plate current generated by class B or C operation is fed back upon the screen by means of the transformer 11 which is so poled that an increase of plate current results in a decrease in the positive bias upon the screen and a decrease of plate current results in an increase of screen bias, which conditions evidently constitute reversed feedback.

Fig. 4 illustrates a reversed feedback system in which the wave fed back is a component of the plate current in a class B power amplifier. The carrier source 12 is connected to the antenna 2 through a carrier supply amplifier 30, modulating amplifier 13 and power amplifier 17. The carrier amplifier 30 is provided with a choke coil 31 which is common to the plate and grid circuits of the amplifier. The signal source 4 is coupled to the grid of the tube 14 through the transformer 5 and the bridge 6. The plate circuit of the tube 14 is coupled to the grid circuit of the tube 13 by means of a resistance 32. A choke coil 18 in the plate current return path of tube 17 is coupled to the grid of tube 14 through the bridge 6. All the amplifiers may be class B operated.

In the operation of the system of Fig. 4, the carrier input to the modulator is substantially freed from noise effects by negative feedback in the supply amplifier 30. The vacuum tube being operated as a class B amplifier, any variation in the carrier amplitude results in a fluctuation of the average plate current. The fluctuation is transmitted in reversed phase to the grid circuit by coil 31, producing a compensatory variation in the gain of the amplifier. That is, an increase of plate current causes the grid potential to become more negative, decreasing the gain, and a decrease of plate current makes the grid become less negative, increasing the gain. The controlled carrier wave is impressed upon the grid of tube 13 together with the signal wave from tube 14, the resulting modulated wave appearing in the plate circuit of tube 13. The modulated wave is amplified in tube 17, the amplified wave being radiated by the antenna 2. The low frequency component of the plate current of tube 17 is fed back upon the grid of tube 14 by means of choke coil 18. The system diminishes noise and distortion arising in amplifiers 13, 14 and 17 and also noise arising in generator 12 and tube 30.

What is claimed is:

1. A modulating system comprising a vacuum tube having a cathode, a grid and a plate, a grid circuit and a plate circuit therefor, a carrier source coupled to the grid circuit, a bridge network, a signal source included in one diagonal of the bridge, and an impedance selective to low frequency included both in the other diagonal of the bridge and in the plate circuit of the tube, the grid circuit of the tube including a ratio arm of the bridge.

2. The method of correcting distortion normally produced in a modulation circuit comprising an electron discharge tube having input electrodes connected with a source of carrier waves and with a source of modulating potentials and having output electrodes connected through a modulation frequency impedor to produce in said impedor correcting potentials of modulation potential frequency which includes the steps of, impressing correcting potentials from said impedor on said input circuit in phase opposition with respect to the modulating potentials impressed thereon from said modulation potential source, and adjusting the amplitude of said correcting potentials to reduce distortion in said tube.

3. A modulating system with distortion correction, comprising a carrier wave source, a signal wave source, a self-detecting modulator of a type adapted to generate a pulsating output current analyzable into a modulated carrier wave component and a wave component simulating the signal wave with superposed distortion from the modulating process, said modulator comprising an electron discharge tube with a cathode, an anode and at least one grid electrode, an anode-cathode circuit and at least one grid-cathode circuit therefor, means for setting up carrier waves in the anode-cathode circuit of said modulator under the control of said carrier wave source, means for impressing waves from said signal wave source upon a grid-cathode circuit of said modulator to generate said pulsating output current in said tube, decoupling means between said signal wave source and said anode-cathode circuit, means connected to said modulator for selecting and utilizing said modulated carrier wave component of the output current, means for selecting the said simulated signal wave component of the output current and means for impressing a potential variation corresponding thereto upon the said grid-cathode circuit for distortion correction purposes.

4. A modulating system comprising a discharge tube having a cathode, an anode and a grid, an anode-cathode circuit and a grid-cathode circuit therefor, a carrier source, means to set up carrier waves in the anode-cathode circuit under the control of said carrier source, a source of modulating potentials coupled to the grid-cathode circuit, decoupling means between said source of modulating potentials and said anode-cathode circuit, an impedance device having one terminal connected to the cathode and the other terminal connected both to the grid and to the anode and means for producing in said impedance device correcting potentials of modulation potential frequency simulating the original modulating potentials and indicative of distortion normally produced in the modulating system.

5. A modulating system comprising a discharge tube having a cathode, an anode and a grid, an anode-cathode circuit and a grid-cathode circuit therefor, a carrier source, means to set up carrier waves in the anode-cathode circuit under the control of said carrier source, a source of modulating potentials coupled to the grid-cathode circuit, decoupling means between said source of modulating potentials and said anode-cathode circuit, a modulation frequency impeder having one terminal connected to the cathode and the other terminal connected both to the grid and to the anode, and means to substantially suppress the space current of the tube in the absence of impressed alternating current excitation, whereby there are produced in said modulation frequency impeder distortion correcting potentials of modulation potential frequency simulating the original modulating potentials with superposed distortion from the modulating process and whereby the said distortion correcting potentials are inherently in phase opposition with respect to the modulating potentials impressed upon the grid-cathode circuit from said modulating potential source.

6. A modulating system in accordance with claim 5 in which the modulation frequency impeder comprises an inductance.

7. A modulating system in accordance with claim 5 in which the modulation frequency impeder comprises a resistor shunted by a condenser.

8. A modulating system comprising a discharge tube having a cathode, an anode and a grid, anode-cathode and grid-cathode circuits therefor, a carrier source, means to set up carrier waves in the anode-cathode circuit under the control of said carrier source, a signal source coupled to the grid-cathode circuit and an inductance having substantial reactance in the frequency range comprising the waves from said signal source and having one terminal connected to the cathode and the other terminal connected to the grid and to the anode to selectively transfer between said anode-cathode and grid-cathode circuits, waves in the said frequency range.

9. A modulating system comprising a discharge tube having a cathode, an anode and a grid, anode-cathode and grid-cathode circuits therefor, a carrier source, means to set up carrier waves in the anode-cathode circuit under the control of said carrier source, a source of modulating potentials coupled to the grid-cathode circuit, decoupling means between said source of modulating potentials and said anode-cathode circuit, an impedance device having one terminal connected to the cathode and the other terminal connected both to the grid and to the anode, and means to substantially suppress the space current of the tube in the absence of impressed alternating current excitation, whereby there are produced in said impedance device distortion correcting potentials of modulation potential frequency simulating the original modulating potentials with superposed distortion, and whereby said distortion correcting potentials are inherently in phase opposition with respect to the modulating potentials impressed upon the grid-cathode circuit from said modulating potential source.

10. A modulating system with distortion correction, comprising a discharge tube having a cathode, an anode and a grid, anode-cathode and grid-cathode circuits therefor, a carrier source, means to set up carrier waves in the anode-cath-

ode circuit of said tube under the control of said carrier source, a source of modulating potentials coupled with the grid-cathode circuit, decoupling means between said source of modulating potentials and said anode-cathode circuit, a modulation frequency impeder having one terminal connected to the cathode and the other terminal connected both to the grid and to the anode and means to substantially suppress the space current of the tube in the absence of impressed alternating current excitations, whereby there are developed in the anode-cathode circuit including said modulation frequency impeder distortion corrective currents of modulating potential frequency.

11. A modulating system comprising at least one high frequency amplifier-detector tube, grid and plate circuits therefor, a carrier source, a utilization circuit for waves of carrier frequency in the plate circuit of said tube, a signal source, means to combine carrier waves and signal waves from said respective sources to produce a modulated carrier wave in the plate circuit of said amplifying tube, means to impress upon a grid of said amplifying tube sufficient negative biasing potential to substantially cut off the space current of the tube in the absence of impressed alternating current excitation, whereby signal waves cause self-detected signal frequency variations in the space current of said amplifying tube and means to feed said signal frequency space current variations into a grid circuit of the system previously traversed by signal waves and in such phase as to effect substantial phase opposition between said signal waves and said signal frequency space current variations in said grid circuit.

12. A modulating system comprising a self-detecting amplifying tube, grid and plate circuits therefor, a carrier source, a utilization circuit for waves of carrier frequency in the plate circuit of said tube, a signal source, means to combine carrier waves and signal waves from said respective sources to produce a modulated carrier wave in the plate circuit of said amplifying tube together with self-detected signal frequency variations in the space current of said tube, and means to feed said signal frequency space current variations into a grid circuit of the system previously traversed by signal waves and in such phase as to effect substantial phase opposition between said signal waves and said signal frequency space current variations in said grid circuit.

13. A high frequency amplifying system comprising a plurality of space discharge tubes connected in cascade, grid and plate circuits for said tubes, a utilization circuit for waves of carrier frequency in the plate circuit of one of said tubes, a carrier source, a signal source, means to modulate carrier waves and signal waves from said respective sources and thereby to produce a modulated carrier wave in the aforesaid plate circuit, means including a self-detecting amplifying tube whereby the application of signal waves to said system produces signal frequency variations in the space current associated with the aforesaid plate circuit and means to feed said signal frequency space current variations through a portion of the circuit of a preceding tube including a point traversed by signal waves in substantial phase opposition to the said signal waves.

14. The method of correcting distortion normally produced in a modulation circuit comprising an electron discharge tube having an input circuit, including input electrodes, said electrodes being connected with a source of carrier waves and with a source of modulating potentials and having output electrodes connected through a modulation frequency impeder to produce in said impeder correcting potentials of modulating potential frequency, which includes the steps of impressing modulating potentials upon said input circuit from said modulation potential source and impressing correcting potentials from said impeder on said input circuit in phase opposition with respect to the modulating potentials impressed thereon from said modulation potential source.

15. A modulation system comprising a source of carrier waves, a source of modulating potentials, a modulation frequency impeder, an electron discharge tube having input electrodes connected with said source of carrier waves and with said source of modulating potentials, and having output electrodes connected through said modulation frequency impeder, means to substantially suppress the space current of said tube in the absence of impressed alternating current excitations, whereby there are produced in said modulation frequency impeder correcting potentials of modulation potential frequency, and means for impressing correcting potentials from said impeder on said input electrodes in phase opposition with respect to the modulating potentials impressed thereon from said modulating potential source.

16. In a modulation system, a source of carrier wave oscillations, a source of modulating potentials, an electron discharge tube having a control grid, a cathode and an anode, a circuit coupling said source of carrier wave oscillations to said cathode and control grid, a circuit coupling said source of modulating potentials to the control grid and cathode of said tube to impress modulating potentials on said control grid and cathode to modulate in said tube said oscillations substantially in accordance with said modulation potentials, said last circuit including an impedance and means to impress upon said control grid sufficient negative biasing potential to substantially cut off the space current of the tube in the absence of impressed alternating current excitation and means for correcting distortion inherently accomplished during modulation of said carrier wave oscillations by said modulating potentials including a source of direct current potential and said impedance connected between the anode and cathode of said tube, and means for setting up in said impedance potentials characteristic of the modulation frequency flowing in said last-mentioned circuit which oppose said modulating potentials.

17. In a modulating system, a source of oscillations of carrier wave frequency, a source of modulating potentials, an electron discharge device having a control grid, a cathode and an anode, a circuit coupling the control grid and cathode of said device to said source of oscillations, a transformer having its primary winding coupled to said source of modulating potentials, said transformer having a secondary winding in which said modulating potentials are induced, a series circuit between the control grid and cathode, said series circuit including said secondary winding and a resistance and means to impress upon said control grid sufficient negative biasing potential to substantially cut off the space current of the tube in the absence of impressed al-

ternating current excitation, said last circuit being for applying said modulating potentials to said control grid and cathode to modulate the said oscillations substantially in accordance with said modulating potentials, an alternating current circuit connected with the anode and cathode of said device and means for compensating for distortion inherently accomplished during said modulation including a circuit including a source of direct current potential connecting the anode to the cathode of said device, and means in said last-named circuit for producing potentials in said resistance of a value characteristic of the currents in said circuit which oppose said modulating potentials induced in said secondary winding.

18. A modulating system with distortion correction, comprising a carrier wave source, a signal wave source, a self-detecting modulator of a type adapted to generate a pulsating output current analyzable into a modulated carrier wave component and a wave component simulating the signal wave with superposed distortion from the modulating process, said modulator comprising an electron discharge tube with a cathode, an anode, a control grid and a screen grid, an anode-cathode circuit and a screen grid-cathode circuit therefor, means for setting up carrier waves in the anode-cathode circuit of said modulator under the control of said carrier wave source, means for impressing waves from said signal wave source upon said screen grid-cathode circuit to generate said pulsating output current in said tube, decoupling means between said signal wave source and said anode-cathode circuit, means connected to said modulator for selecting and utilizing said modulated carrier wave component of the output current, means for selecting the said simulated signal wave components of the output current and means for impressing a potential variation corresponding thereto upon the said screen grid-cathode circuit for distortion correcting purposes.

19. A modulating system comprising a modulating amplifier tube, a combined power amplifier and detector tube, a low frequency amplifier tube, grid and plate circuits for each of said tubes, means for setting up carrier waves in the plate circuit of said modulating amplifier tube, a bridge network including an arm coupled to the grid circuit of said low frequency amplifier tube, a signal source included in one diagonal of said bridge network, an impedance element included both in the plate circuit of said power amplifier and detector tube and in the other diagonal of said bridge network and a second impedance element coupling the grid circuit of said modulating amplifier tube and the plate circuit of said low frequency amplifier tube.

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