

May 23, 1939.

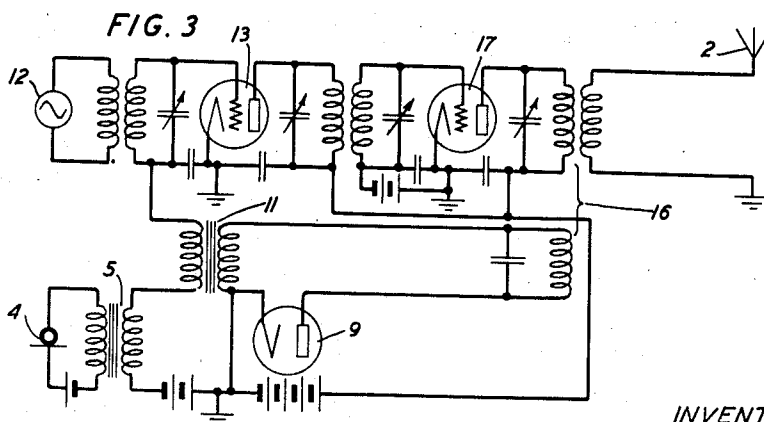
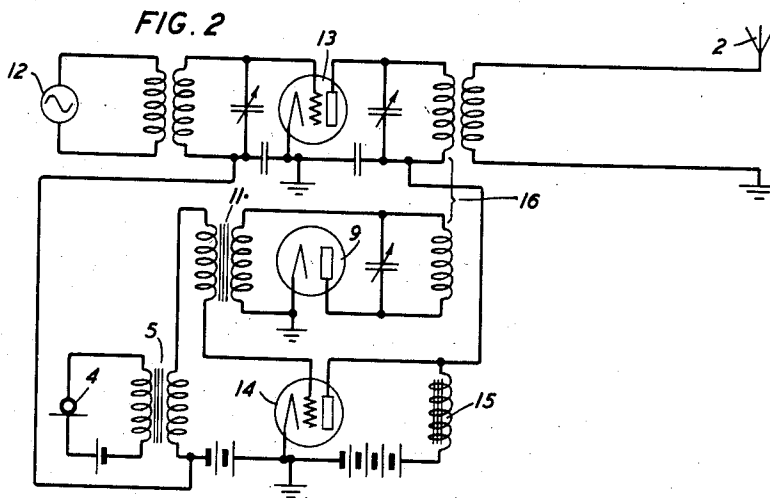
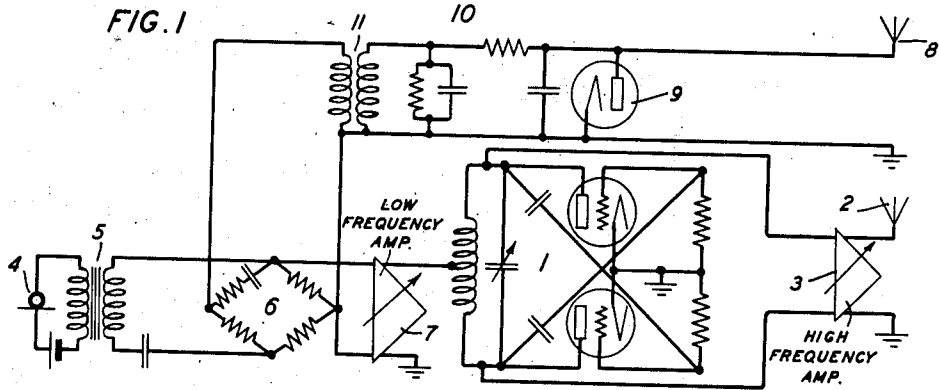
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2,159,020

MODULATING SYSTEM

Filed June 9, 1934

3 Sheets-Sheet 1



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FIG. 4

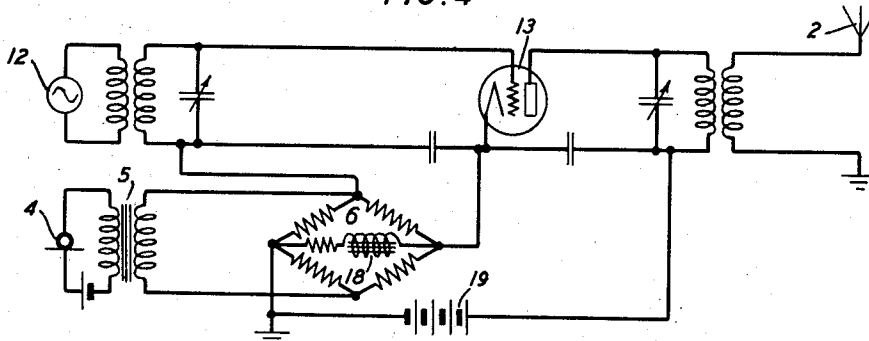


FIG. 5

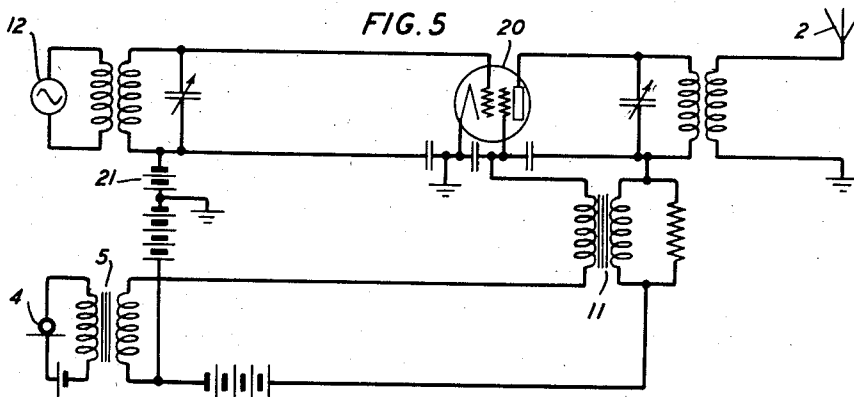
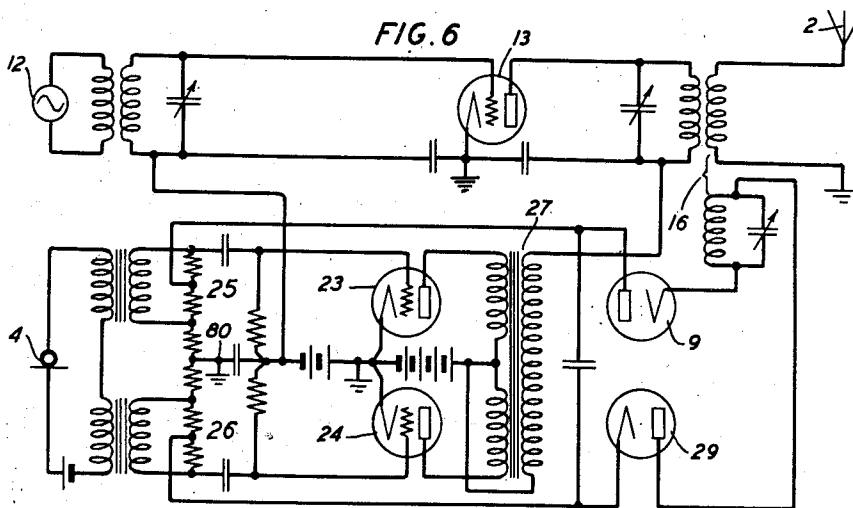


FIG. 6



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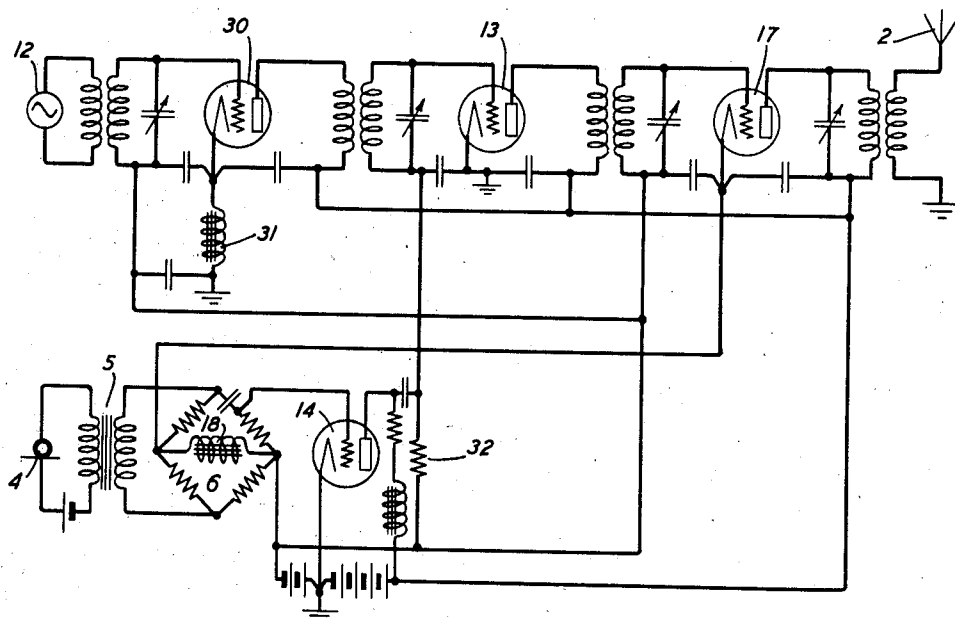
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FIG. 7



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2,159,020

MODULATING SYSTEM

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Application June 9, 1934, Serial No. 729,735

2 Claims. (Cl. 179—171)

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

5 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, 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, a detector 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.

40 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.

The invention will be more fully understood from the following detailed description and from 55 the accompanying drawings of which:

Fig. 1 shows a radio transmitting system embodying this invention;

Fig. 2 shows an application to the Heising system of modulation;

Fig. 3 shows the application to a grid circuit modulator;

Fig. 4 shows the elimination of a separate detector at the transmitting station;

Fig. 5 shows a reversed feedback arrangement adapted to a screen grid amplifier;

Fig. 6 shows a modification of the system of Fig. 2 in order to utilize a signal input amplifier of the push-pull type; and

Fig. 7 shows a transmitting system incorporating initial noise reduction in a carrier supply amplifier.

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 hereinafore 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 a transmitter using the system for modulation disclosed in U. S. Patent 1,442,147 issued January 16, 1923 to R. A. Heising. A carrier generator 12 is coupled to the transmitting antenna 2 by means of an amplifier 13. A low frequency amplifier 14 has its plate circuit coupled to the plate circuit of the modulating amplifier 13 through a choke coil 15 as is conventional in the Heising system. The detector 9 is coupled to the output circuit of amplifier 13 by high frequency coupling 16 and to the input of amplifier 14 by the low frequency transformer 11. The signal source 4 is associated with the input of amplifier 14 by means of the transformer 5.

In the operation of the system of Fig. 2, the signal wave from the source 4 is amplified in the vacuum tube 14, the amplified wave being used to effect modulation in the tube 13. The modulated wave is impressed upon the antenna 2 and also through coupling 16 upon the detector 9. The detected wave is fed back upon tube 14 in reversed phase by means of the transformer 11. The feedback in this case operates to reduce noise and distortion originating in the audio system and in the plate circuit of tube 13.

Fig. 3 shows the application of the invention to a grid circuit modulator. The carrier generator 12 is connected to the antenna 2 through the modulating amplifier 13 and a power amplifier 17. The signal source 4 is connected into the grid circuit of amplifier 13 by means of the transformer 5. The detector 9 is coupled by high frequency coupling 16 to the output circuit of amplifier 17 and by low frequency transformer 11 to the input of amplifier 13.

In the operation of the system of Fig. 3, the signal wave is impressed upon the grid of tube 13 along with the carrier wave. The modulated output of tube 13 is amplified by tube 17 and then radiated by antenna 2. The detector 9 picks up energy from the output of amplifier 17 by means of the coupling 16. The detected wave is fed back upon the grid of tube 13 in reversed

phase relation to the signal wave by means of the transformer 11.

Fig. 4 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 the carrier generator 12 is connected to the antenna 2 through the modulating amplifier 13 as in Fig. 2. 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. 4, 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. 5 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. 5, 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. 6 shows the use of the invention in connection with a class B signal amplifier in a Heising

constant current modulating system. The carrier portion of the system is the same as shown in Fig. 2. The signal source 4 is connected through a pair of bridge networks 25 and 26 to push-pull connected tubes 23 and 24, the grids of which are normally biased to about the plate current cut-off point. The plate circuits of the tubes are coupled to the plate of tube 13 by means of a balanced transformer 27. Two detectors 9 and 29 are connected in series aiding relation to each other. The detectors are coupled to the antenna circuit by a high frequency coupling 16 and to the grids of the tubes 23 and 24 through the bridges 25 and 26, the latter having a common point at ground 80.

In the operation of the system of Fig. 6, the carrier is impressed upon the grid of the tube 13 and the signal upon the plate as is usual in the Heising system. The modulated wave is radiated by the antenna 2 and also a portion of its energy is transmitted to the detectors 9 and 29 by the coupling 16. The detected wave is fed back upon the grids of the tubes 23 and 24 through bridges 25 and 26 respectively, the detector circuit being balanced with respect to the ground 80 because of the symmetry of the feedback path. While the symmetry is promoted by the use of two detectors as shown, in some cases sufficient balance may be obtained if one detector is omitted.

In this arrangement, as in that of Fig. 2, the principal effect of the feedback is to remove the distortion and noise originating in the low frequency signal amplifier.

Fig. 7 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. 7, 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 modulator tube and an amplifier tube, grid and plate circuits for each of said tubes, a carrier source coupled to the grid circuit of the modulator, a signal source, means responsive to the difference between the instantaneous values of any two waves impressed thereon, said means being connected between said signal source and said amplifier tube, and said signal source being isolated from said modulating device except through said differentially responsive means, an impedance element common to the plate circuits of both tubes, and a detector associated by high frequency coupling with the modulator plate circuit and by low frequency coupling with said differentially responsive means.

2. A modulating system comprising a modulator tube and an amplifier tube, grid and plate circuits for each of said tubes, means for maintaining carrier waves in the plate circuit of the modulator tube, a signal source, means responsive to the difference between the instantaneous values of any two waves impressed thereon, said means being connected between said signal source and said amplifier tube, and said signal source being isolated from said modulating device except through said differentially responsive means, an impedance element common to the plate circuits of both tubes, and a detector associated by high frequency coupling with the modulator plate circuit and by low frequency coupling with said differentially responsive means.

ENOCH B. FERRELL.