July 28, 1953 C. A. E. BEURTHERET 2,647,173

MULTIPLE FEEDBACK SYSTEM

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Fig. 1.

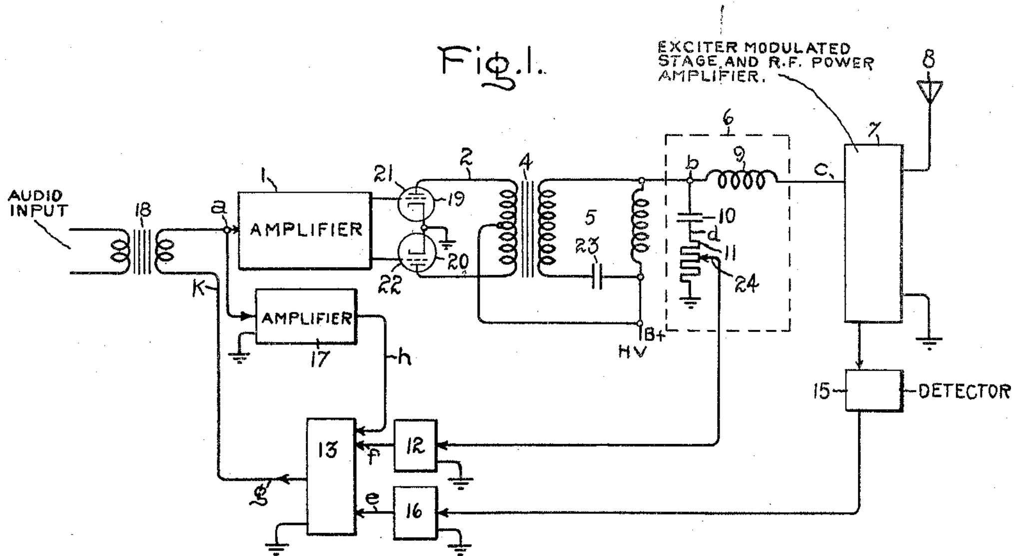

Fig. 2.

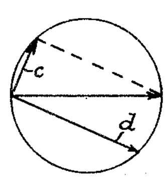

Fig. 3.

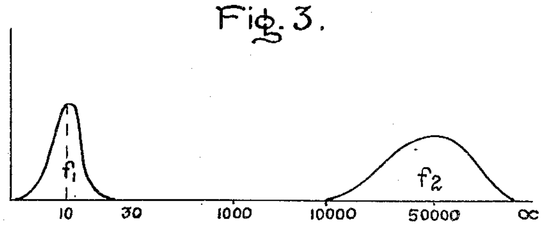

Fig. 4.

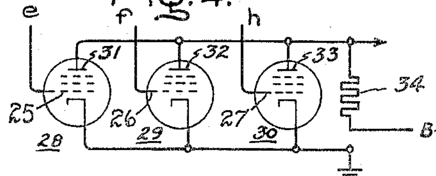

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Fig. 5.

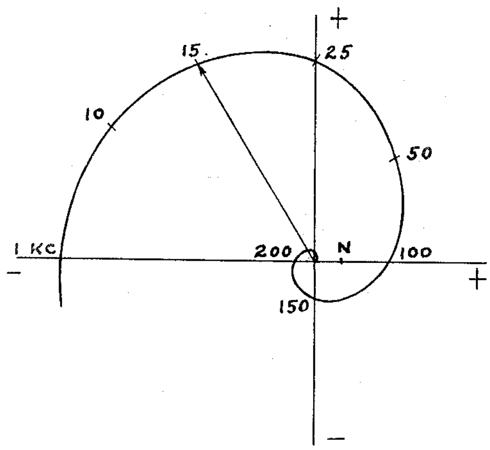


Fig. 6.

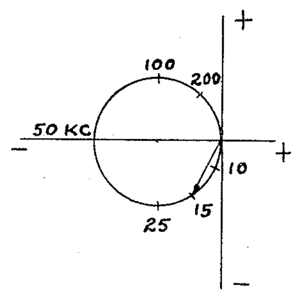
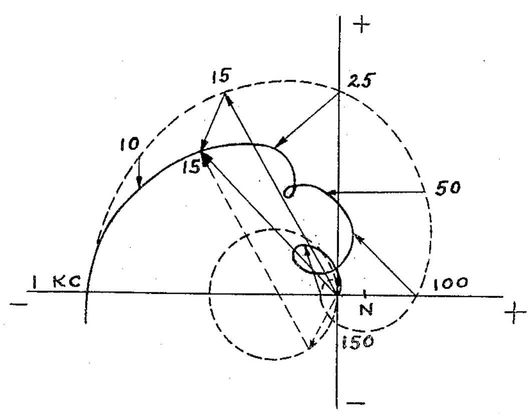


Fig. 7.



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MULTIPLE FEEDBACK SYSTEM

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4 Claims. (Cl. 179—171)

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My invention relates to amplifying systems and, more particularly, to systems using inverse voltage feedback.

Conventional broadcast transmitters usually use high level plate modulation in the final stage. Inverse voltage feedback may be used to obtain improved performance. However, in the past the amount of feedback voltage used has been limited due to the tendency of the amplifier to oscillate if the feedback voltage rises over a certain value.

It is an object of my invention to provide an improved amplifying system utilizing negative feedback, particularly useful in a transmitter.

A further object of my invention is to provide an improved multiple feedback system.

A further object of my invention is to provide means for substantially reducing signal distortion in an amplifier.

For additional objects and advantages, and for a better understanding of the invention, attention is now directed to the following description and accompanying drawings, and also to the appended claims in which the features of the invention believed to be novel are particularly pointed out.

Fig. 1 is a schematic diagram illustrating one embodiment of my invention;

Fig. 2 is a circle voltage diagram;

Fig. 3 is a curve showing the amplification characteristics of the auxiliary amplifier of Fig. 1;

Fig. 4 is a schematic diagram of the addition circuit of Fig. 1; and

Figs. 5, 6 and 7 are Nyquist diagrams to explain the operation of my invention.

In Fig. 1 I have illustrated, schematically, a transmitter comprising an amplifier stage 1, audio power amplifier stage 2, a modulation transformer 4, a modulation reactor 5, a coupling network 6, radio frequency stages 7 and an antenna 8. The radio frequency stage 7 may conventionally include an exciter, modulated stage and radio frequency power output stage.

A suitable source of high voltage supply is designated by the conventional symbol B+. The simplified blocks are for conventional elements and a detailed description will be omitted for simplicity. The coupling network 6 comprises inductance 9, capacitor 10 and resistance 11. A feedback voltage is obtained from the resistor 11 and is supplied through a phase-adjusting circuit 12 to an addition stage 13. Additional signal feedback is obtained from the output stage 7. The output signal is demodulated in detector 15

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and supplied to the stage 13 through a phase-adjusting circuit 16. An auxiliary amplifier 17 is connected, in parallel, with the amplifier 2. The output of the amplifier 17 is supplied to the stage 13. The output of 13 is returned as a feedback signal and combined with the incoming audio signal.

The amplifier 1 receives the incoming audio signal from a transformer 18. The output of the amplifier is connected to the grids 19 and 20 of the amplifier devices 21 and 22 which are connected in a conventional push-pull manner.

The transformer 4 transfers at high level the audio modulation to the final radio frequency stages 7 of the transmitter through a network consisting of the modulation transformer 4, a reactor 5 and a blocking condenser 23 by means of a coupling network 6 and thence to the antenna 8. The inductance 5 constitutes the modulator choke in the anode circuit of the modulator stage. The final stages 7 comprise the major portion of the load on the modulator stage. Ordinarily, the impedance presented by the final stage varies with frequency in such a manner that over the audio band it is primarily resistive.

The coupling circuit 6 possesses the general characteristics of a low pass filter and consists, essentially, of inductance 9 in series with the resistive load presented by the final stage 7 and a shunt circuit consisting of capacitor 10 and resistance 11 in series circuit relation. The circuit 6 is essentially of the type commonly known as a monocyclic network and presents a purely resistive impedance between point b and ground. This is accomplished by proportioning the network constants so that the resistance presented by the final stages 7 and the resistance 11 are equal and, in turn, are equal to the square root of L/C where L and C are the inductance and capacity of the elements 9 and 10. In order to limit the power dissipated in the resistor 11, the elements 9 and 10 are so chosen that their resonant frequency will lie well above the audio band. This circuit 6 thus possesses the fundamental characteristic that it presents a constant resistive load impedance to the modulator stage independent of frequency. In addition, the shunt arm comprising the capacitor 10 and resistor 11 forms a circuit in which high frequency distortion components are prevented from entering the final radio frequency stage as they form a low impedance path to ground.

Feedback voltage is also derived directly from the final output power amplifier by means of detector 15. The voltage produced is proportional in magnitude and phase to the voltage present at the point *c*. An additional feedback voltage is taken from a point 24 on the resistor 11 and fed to the addition stage 13 through a phase adjusting circuit 12. A theoretical study of the circuit comprising the elements 9, 10, 11 and 7 will show that the vector sum of the voltages present at *c* and *d* with respect to ground will be constant and independent of frequency, as illustrated by the vector diagram in Fig. 2. The stage 13 adds vectorially the voltages *e* and *f* over the feedback frequency spectrum. In the region of the audio band, the vector sum *g* is supplied almost exclusively by the feedback from the final stage there being a slight phase correction in the phase-adjusting circuit 16.

At the high frequencies above the audio band, *g* is composed substantially of the frequency components derived from the resistance 11 as the voltage across 11 increases with frequency. A proper voltage level is maintained by tapping the resistance 11 at a suitable point 24 so that the circle diagram of Fig. 2 is obtained.

Stray capacities between the point *c* and ground have very little effect upon the system and do not materially affect the principle of operation. Usually, the phase adjusting circuits 12 and 16 allow sufficient compensation for this stray capacity.

The feedback frequency spectrum contains frequencies that are both above and below the audio band. The problem of stability is concerned mainly with those frequencies which lie outside of the audio band. By the proper control of those frequencies outside of the band, the amplifier will be stable when feedback is applied. If the feedback were taken from the point *c* and applied directly to the point *k*, the amplifier would probably oscillate as is illustrated in the Nyquist diagram of Fig. 5. It can be seen that the Nyquist point $1+jO$ is included within the diagram, thus satisfying the condition for oscillation.

The circuit 13 adds vectorially the voltages *e* and *f* derived from the output circuit to a third voltage *h* from an auxiliary amplifier 17. The input of this auxiliary amplifier is connected to the same point as that of the amplifier 1. The amplifier 17 possesses a transmission characteristic as illustrated in Figs. 6 and 3. This characteristic is so chosen that the vectorial addition of Figs. 5 and 6 will result in a Nyquist diagram as illustrated by Fig. 7. The Figs. 5, 6 and 7 are drawn to cover the part of the frequency spectrum above the audio band. Similar figures in the appropriate quadrants may be obtained by similar methods for the frequency region lying below the audio band. In the audio band the amplifier 17 has substantially zero amplification but possesses substantial amplification at high and low frequencies, as illustrated by the curve of Fig. 3, so that the vector addition of the voltages *h*, *f* and *e* will result in a Nyquist diagram in which the point $1+jO$ is always outside of the diagram. Thus, it can be seen that it is possible to increase the amount of inverse feedback in the audio band by a substantial amount and thereby improve the characteristics of the amplifier.

It is not necessary that the frequencies f_1 and f_2, as shown in Fig. 3, correspond exactly to the frequencies at which the amplifier would oscillate were the amplifier 17 and the feedback circuits not present. For practical operations these frequencies need be only approximate.

In Fig. 4, I have shown a schematic diagram of

the addition circuit 13 which comprises three pentode discharge devices in which the voltages *e*, *f* and *h* are impressed on the grids 25, 26 and 27 of three respective devices 28, 29 and 30 whose anodes 31, 32 and 33 are connected to a common anode resistance 34. It can be seen that with this arrangement the voltage appearing across the resistor 34 will be the vector sum of *e*, *f* and *h*.

The application of this system permits a substantial increase in the inverse voltage feedback making possible substantial economies in manufacturing in that the filtering of the high voltage supply may be reduced and also it permits a large amount of filament hum in the radio frequency amplifier devices.

Modulation transformers and reactors in which distortion, due to poor magnetic material, would be excessive when used with conventional amplifier systems, can be used with my system without reduction in performance.

While certain specific embodiments have been shown and described, it will, of course, be understood that various modifications may be made without departing from the invention. The appended claims are, therefore, intended to cover any such modifications within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an amplifier system, a source of signal voltages, a first amplifier, a second amplifier, means for impressing said signal voltages across the input of said amplifiers, a radio frequency stage, a constant impedance coupling circuit connecting the output of said first amplifier to said radio frequency stage, said coupling circuit comprising an inductance in series with said output and a capacitance and resistance forming a shunt branch, means for deriving a feedback voltage from said shunt branch, means for deriving a second feedback voltage from said radio frequency stage, means for combining said feedback voltages with the output voltage of said second amplifier, means for impressing the resultant voltage upon the input of said amplifiers to provide substantial feedback voltage thereby to improve the stability of said amplifier.

2. An amplifier system for amplifying voltages extending over a band of frequencies, a main amplifier having an input and an output circuit, a load circuit, a coupling network connecting said output circuit to said load circuit, means for deriving from said load circuit a voltage decreasing with increase in frequency beyond said band, means for deriving from said coupling network a second voltage increasing with increase in frequency beyond said band, means for adding said voltages whereby the phase of the resultant voltage does not vary appreciably over a range of frequencies beyond said band, an auxiliary amplifier having an input circuit connected in shunt with the input circuit of said main amplifier and an output circuit, means for combining said resultant voltage and the output from the output circuit of said auxiliary amplifier and applying said combined voltage to the input circuits of said amplifiers, said auxiliary amplifier having a substantially zero gain at the frequencies of said signal voltages and gain and phase shift characteristics outside of said band which alter the magnitude and phase of feedback applied from the output of said main amplifier to the input thereof, whereby the output of said main amplifier is applied to the input thereof in inverse phase relationship over said band of frequencies

to improve the operation of said system for said band of frequencies and the feedback from the output to input of said main amplifier beyond said band is rendered insufficient to cause self-oscillation of said main amplifier.

3. An amplifier system for amplifying voltages extending over a band of audio frequencies, a main amplifier having an input and an output circuit, a load circuit, a coupling network connecting said output circuit to said load circuit, said coupling network comprising a constant impedance coupling circuit for signal frequencies contained within said band and having an impedance which increases with increase in frequency outside of said band, means for deriving a voltage decreasing with increase in frequency beyond said band from said load circuit, means for deriving a second voltage increasing with increase in frequency beyond said band from said coupling network, means for adding said voltages whereby the phase of said resultant voltage remains substantially constant over a range of frequencies beyond said band, an auxiliary amplifier having an input circuit connected in shunt with the input circuit of said main amplifier and an output circuit, means for combining said resultant voltage and the output from the output circuit of said auxiliary amplifier and applying said combined voltage to the input circuit of said amplifiers, said auxiliary amplifier having a substantially zero gain at the frequencies of said signal voltages and having gain and phase characteristics outside of said band which alter the magnitude and phase of the feedback applied from the output of said main amplifier to the input thereof, whereby the output of said main amplifier is applied to the input thereof in inverse phase relationship over said band of frequencies to improve the stability of said main amplifier over a range substantially greater than that of said given frequency band.

4. An amplifier system for amplifying voltages extending over a band of frequencies, a main amplifier having an input and an output circuit, a load circuit, a coupling network connecting said output circuit to said load circuit, said coupling network being so proportioned to provide a constant resistive load substantially independent of frequency for signal frequencies contained within said band and an impedance varying with frequency outside of said band, means for deriving a voltage decreasing with increase in frequency beyond said band from said load circuit, means for deriving a second voltage increasing with increase in frequency beyond said band from said coupling network, means for adding said voltages whereby the phase of said resultant voltage remains substantially constant over a range of frequencies beyond said band, an auxiliary amplifier having an input circuit connected in shunt with the input circuit of said main amplifier and an output circuit, means for combining said resultant voltage and the output from the output circuit of said auxiliary amplifier and applying said combined voltage to the input circuits of said amplifiers, said auxiliary amplifier having a substantially zero gain at the frequencies of said signal voltages and gain and phase shift characteristics outside of said band which alter the magnitude and phase of feedback applied from the output of said main amplifier to the input thereof, whereby the output of said main amplifier is applied to the input thereof in inverse phase relationship over said band of frequencies to improve the operation of said system for said band of frequencies and the feedback from the output to input of said main amplifier beyond said band is rendered insufficient to cause self oscillation of said main amplifier.

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