My invention relates broadly to radio transmission systems and more particularly to a distortion reducing system for suppressed carrier transmission.

One of the objects of my invention is to provide a circuit arrangement for inverse or degenerative feedback in a suppressed carrier radio transmitter for reducing distortion arising in the transmitter.

Another object of my invention is to provide a modulation circuit for a suppressed carrier transmission system, including inverse or degenerative feedback means for reintroducing distortion components in the system for reducing the distortion arising therein.

A further object of my invention is to provide a push-pull audio frequency amplifier in the modulation input circuit of a suppressed carrier transmission system, with means for reintroducing distortion components derived from the suppressed carrier output of the system in unbalanced relation in the amplifier for reducing distortion arising in the system.

Still another object of my invention is to provide a push-pull amplifier in the modulation input circuit of a suppressed carrier transmission system, with means including a push-pull amplifier for reintroducing distortion components derived from the suppressed carrier output of the system in unbalanced relation, and with the separate phases of the audio waves in the output of the push-pull amplifier individually applied in the modulation circuit.

A still further object of my invention is to provide a push-pull amplifier in the modulation input circuit of a suppressed carrier transmission system and means including a push-pull amplifier in the modulation input circuit of the system for directly employing the rectified wave for the inverse or regenerative feedback of distortion components for the reduction of distortion arising in the system.

Still another object of my invention is to provide means for rectifying a portion of the output wave of a suppressed carrier radio transmission system and means including a push-pull amplifier in the modulation input circuit of the system for directly employing the rectified wave for the inverse or regenerative feedback of distortion components for the reduction of distortion arising in the system.

Other and further objects of my invention reside in the system and circuit arrangements hereinafter set forth more fully, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a preferred circuit arrangement embodying the principles of my invention; and Figs. 2, 3 and 4 are theoretical wave-form diagrams illustrating the voltage conditions in various portions of the circuit of Fig. 1, as will be defined.

Inverse or degenerative feedback is frequently used between the output and the input of an audio frequency amplifier for the purpose of reducing the amplitude (harmonic) distortion and other extraneous components, such as hum, which are present in the output of the amplifier but were not present in the input.

In the case of radio transmitters of the conventional type now employed in broadcasting, the output consists of a radio frequency carrier wave varying in amplitude in accordance with the variation of the audio frequency currents impressed on the input. In other words, a carrier wave is transmitted at all times and two side frequency waves are transmitted for each component present in the audio input, corresponding, respectively, to the sum and the difference of the carrier frequency and the audio frequency component. Inverse feedback may be used with this transmission system to reduce distortion generated in the transmitter which results in extraneous audio frequency components in the output of a linear detector or rectifier. Such feedback may be applied quite readily by rectifying a portion of the transmitter output to obtain audio currents which include the distortion products, and feeding said audio currents back to some part of the transmitter circuit in such a sense that the distortion components are partially nullified. An example of such an application of degenerative feedback to radio transmitters is described in copending application 26,830, for “Distortion reducing system”, filed by Walter H. Winkler, now Patent 2,133,410, granted October 18, 1938.

In the case of a radio transmitter in which the carrier frequency is suppressed and only the two side-frequency components transmitted, a linear rectifier applied to the output of the transmitter will not supply the proper audio components to be fed back to the transmitter circuit in the usual manner for the purpose of reducing distortion. In fact, such audio currents would include none of the original audio components supplied the transmitter but would comprise distortion components of a different kind from those required to nullify the distortion produced in the transmitter.

One possible means of securing the audio components required for feedback in a suppressed carrier system consists of a linear detector cir-
circuit supplied with a portion of the double-sidedband output of the transmitter together with some carrier frequency from the oscillator circuit of the transmitter. This carrier current reintroduced into the detector circuit must be carefully adjusted to have the same phase relation with respect to the two sideband components as the carrier wave would have had were it not suppressed in the transmitter circuits. Such an arrangement would be somewhat complicated and quite susceptible to misadjustment, particularly as concerns the phase of the reintroduced carrier.

My invention described herein relates to means for rectifying a portion of the double-sideband output of a suppressed carrier transmitter without reintroducing any carrier, and feeding the resulting audio frequency currents into the transmitter circuit in such a manner that partial nullification of the distortion results. It has been pointed out that such audio currents are not suitable for being fed back into the transmitter circuit by any method employed heretofore— as by injecting them in series with the audio circuit supplied with current from the microphone or other source of speech-frequency current, for example.

Referring to the drawings in more detail, Fig. 1 is a portion of the circuit diagram of a suppressed carrier transmitter employing the feedback system of my invention. Reference characters 1 and 2 indicate audio frequency amplifying tubes, 3 and 4 the tubes of a balanced modulator, and 5 a conventional linear amplifier tube for amplifying the double-sideband output of tubes 3 and 4.

Audio frequency voltage is supplied to the primary of an input transformer 6 and thus impressed on the grids of tubes 1 and 2 in phase opposition, that is, in push-pull relation. Audio amplifiers 1 and 2 amplify the separate phases of the audio voltage independently and impress them, in push-pull, on the grids of the balanced modulator or tubes 3 and 4, through blocking condensers 11 and 12 and radio frequency choke coils 15 and 16.

Amplifiers 1 and 2 are supplied with plate voltage from battery 31 through audio frequency choke coils 9 and 10. Negative grid bias voltage is supplied to the grids of tubes 1 and 2 by battery 8 through a resistor 7 and the secondary winding of transformer 6. This bias voltage is such that tubes 1 and 2 act as conventional "class A" amplifiers; that is, plate current flows during all portions of the audio frequency cycle. The audio grid voltage supplied from transformer 6 is never so great as to make the grids of tubes 1 and 2 positive with respect to the cathode. Tubes 1, 2, 3, 4, and 5 have heater structures for the cathode electrodes shown, energized from battery or alternating current transformer circuits, which have been omitted from Fig. 1 in the interest of simplicity.

Tubes 3 and 4 of the balanced modulator circuit are supplied with radio frequency grid excitation voltage from a conventional oscillator circuit not shown, by means of the tuned circuit consisting of coil 17 and condenser 18, through blocking condensers 19 and 20. Grid bias voltage is supplied through blocking condenser 21 to the tuned circuit composed of condenser 22 and coil 23. Radio frequency voltage from circuit 22—23 passes through blocking condenser 25 to the grid of tube 5. Ballast resistor 24 acts as an energy absorbing means for providing the proper radio frequency load required by balanced modulator tubes 3 and 4.

Tube 5 is supplied plate voltage from generator 40 through radio frequency choke coil 29. Negative grid bias such as to make tube 5 act as a "class B" linear power amplifier is supplied by battery 41 through choke coil 28. Tuned circuit 30—31 receives the radio frequency output energy from the anode of tube 5 through blocking condenser 26 and induces current in antenna circuit 32. Condenser 36 is a neutralizing condenser operative to neutralize radio frequency feedback from the plate circuit to the grid circuit of tube 5.

It will be understood that the battery and generator sources of potential and power, as illustrated, are indicative only of the character of the energy supplied, and any suitable source or sources may be employed in lieu thereof.

The grid bias voltage from source 38 is such that, with plate voltage and radio frequency grid voltage applied to tubes 3 and 4 but with no audio frequency voltage supplied from tubes 1 and 2, no plate current flows in tubes 3 and 4. When this voltage is applied, however, one of the grids of tubes 3 and 4 is made less negative than its normal potential and the other more negative, depending on the instantaneous polarity of the audio voltage which is applied to the grids of tubes 3 and 4 in push-pull.

Assume that an audio frequency voltage varying sinusoidally with time is applied at transformer 6. Let $e_1$ represent the audio frequency component of grid voltage on tube 3, and $e_2$ that on tube 4. As represented in Fig. 2, then, $e_3$ and $e_4$ are sinusoidal voltages 180 electrical degrees out of phase because of the push-pull connection of the secondary of transformer 6. The radio frequency grid voltages applied to tubes 3 and 4 are also 180 electrical degrees out of phase because of the push-pull connection of tuned circuit 17—18.

The resultant modulated radio frequency current in tuned circuit 22—23 is then as shown in Fig. 3: that is a radio frequency wave varying so that the envelope of the peaks, representing the radio frequency variations in current, consists of successive halves of a sine wave. It will be noticed that during the first half of the audio frequency cycle while $e_1$ is positive, tube 3 is exciting current in tank circuit 22—23 and tube 4 is not conducting plate current. During the second half of the audio frequency cycle, $e_2$ is positive, tube 4 is exciting circuit 22—23 and tube 3 is non-conducting. Thus the radio frequency current in circuit 22—23 reverses phase at the end of the first half of the audio frequency cycle.

The radio frequency output current plotted in Fig. 3 is of the form

$$I = A \sin(\omega t)$$

where $A$ is the maximum value of the current,

$$\rho = 2\pi$$

the audio frequency in cycles per second,

$$\omega = 2\pi$$

the carrier frequency in cycles per second, and

$\tau$ = the time in seconds.

This expression is that of two sideband frequen-
cles only, with the carrier frequency suppressed, as shown by the trigonometric identity

\[ a(\sin \omega t)(\sin \omega t) = \frac{a}{2}(\cos \omega t - \cos (\omega t + \delta)) \]

Fig. 3 shows the envelope of the radio frequency current curve of the same shape as the curves representing \( e_1 \) and \( e_2 \). Because of non-linear relations in the balanced modulator tubes 3 and 4, this is not exactly the case and there results a portion of the distortion which is the purpose of this invention to avoid. During the first half of the audio frequency cycle when tube 3 is conducting, tube 4 is inoperative, and could be removed from the circuit and replaced by condensers equivalent to its interelectrode capacitance without affecting the momentary operation of the circuit. If a voltage proportional to the distortion components in the envelope of the radio frequency output wave is now fed back to the grid of tube 3 in such sense as to oppose the flow of current in tube 3, such an arrangement will constitute inverse feedback for distortion and result in closer agreement in wave shape between the envelope of the radio frequency input wave and the audio frequency grid voltage wave impressed on tube 3.

In the form of this invention disclosed in Fig. 1, a portion of the radio frequency output of linear amplifier tube 5 is induced in coil 33 by inductive coupling with coil 31, and rectified by rectifier element 34. After the remaining radio frequency components in the output of rectifier 34 are removed by filter 35, the wave form of the rectifier output voltage will be as shown in Fig. 4 with such distortion components as may have arisen in the system. This voltage is then applied across resistor 7 in series with the center tap connection of transformer 6; that is, as a pulsating direct current. In the same polarity with respect to the grid of tube 1 as to the grid of tube 2, in contrast to the original audio frequency input voltage which is applied in push-pull to the grids of tubes 1 and 2. Such rectified voltage tends to make the grid of tube 1 more positive and thus, by virtue of the phase reversing properties of tube 1, to make the grid of tube 3 more negative, opposing the flow of current in tube 3 and constituting inverse feedback.

For one half-cycle, the voltage across resistor 7 is opposite in polarity to the audio frequency input across the portion of the secondary of transformer 6 connected with tube 1, as shown by polarity markings on Fig. 1, so that the modulation component in the voltage across resistor 7 is cancelled by a portion of the audio frequency input voltage from transformer 6, leaving the distortion components alone effective for inverse feedback operation in tube 3. The remaining major portion of the audio frequency input voltage modulates the transmitter through tube 3, as hereinbefore described. During the same half-cycle, the voltage across resistor 7 is of the same polarity as the audio frequency input across the portion of the secondary of transformer 6 connected with tube 2, as shown by polarity markings on Fig. 1, so that all components of the rectified voltage tend further to maintain tube 4 inoperative and have no inverse effect with respect thereto. It will be remembered that the polarity of the modulating voltage on resistor 7 will remain the same while the polarity of the voltage across the secondary of transformer 6 reverses with respect to tubes 1 and 2 at each half-cycle. Thus, during the second half of the audio frequency cycle, when tube 4 is operative by virtue of a negative potential on the grid of tube 2, and tube 3 is inoperative, the voltage across resistor 7 is opposite in polarity to the voltage across the portion of the secondary of transformer 6 connected with tube 2 and the modulation component of the rectified voltage is cancelled, leaving the distortion components in inverse sign for distortion reducing effects in tube 4. Simultaneously, the voltage across resistor 7 aids the positive potential on the grid of tube 1 in maintaining tube 3 inoperative. Distortion compensation by inverse feedback is thus effected throughout the full audio frequency cycle of the current supplied to transformer 6, successive direct current pulses of a period equal to that of each half cycle of the audio frequency wave being employed for inverse feedback in the manner set forth.

As the output of amplifier tube 5 is rectified and fed back to the input of tubes 3 and 4, it is seen that the circuit of my invention partially nullifies not only the distortion generated in the modulator circuit 3-4 but that generated in power amplifier 5 as well. No substitution for the suppressed carrier in the output wave is made before rectification so that no question of synchronization of high frequency waves is involved in the system of my invention.

An important feature of this invention is that tube 1 is coupled to tube 3 independently of the coupling between tubes 2 and 4, so that tubes 1 and 2 pass on to the grids of tubes 3 and 4 not only the original audio frequency components which are in push-pull, but also the feedback components which are effectively in parallel with respect to the grids of tubes 1 and 2.

Another feature of this invention is that the coupling means employed between tubes 1 and 3, for example, is simply a blocking condenser 11 of large capacitance, with low frequency choke 40 coils 9 and 13 inserted in the leads supplying the direct current potentials required in plate and grid circuits, respectively. Such a coupling arrangement is much more desirable than a transformer, for example, because the condenser has negligible impedance to the audio frequencies and harmonics of audio frequencies which are to be transmitted to the grids of tubes 3 and 4. When it is considered that a wave of the form shown in Fig. 4 consists of many high order harmonics of the original audio frequency wave, it is seen that a coupling transformer could not transmit this wave without wave form distortion resulting from the leakance reactance of the transformer winding, which would have a different effect on the high order harmonics, the low order harmonics and the fundamental wave, such as \( e_0 \), which are to be transmitted.

The system of my invention has proven efficient and highly effective in operation in the form I have disclosed as a preferred embodiment thereof, but I desire it understood that modifications may be made in the circuits and arrangements illustrated and that no limitations upon my invention are imposed by the scope of the appended claims.

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

1. In combination with a balanced suppressed carrier modulation system, a push-pull audio frequency amplifier in the modulation input of said system, means for rectifying a portion of the modulated output of said system, and means for applying the rectified wave in like polarity in both
branches of the input of said push-pull amplifier, said rectified wave being effective in inverse relation for reducing distortion in said modulation system.

2. In combination with a balanced suppressed carrier modulation system, a push-pull audio frequency amplifier in the modulation input of said system, and means for reducing distortion in said system by degenerative feedback of distortion components in the modulated output of said system, means for applying a resistor connected in neutral relation in the input of said push-pull amplifier.

3. In combination, a suppressed carrier modulation system including a balanced modulator circuit, and distortion reducing means including means for rectifying a portion of the modulated output of said modulation system, and means for reintroducing the rectified wave for operation in inverse relation in said modulator circuit for countering distortion arising therein.

4. In combination, a suppressed carrier modulation system including alternately operated electron tube devices for producing a double sideband output wave, means for rectifying a portion of said double sideband wave, and means for reintroducing distortion components in the rectified wave in coordination with the alternate operation of electron tube devices in inverse relation in the operative one of said devices for countering distortion arising in said modulation system.

5. In combination, a pair of electron tube devices, means for supplying high frequency carrier current to said devices in push-pull relation, means for applying low frequency modulating voltage to said devices in push-pull relation, said devices being alternately operative with reversal in phase of said modulating voltage for producing a double sideband suppressed carrier output wave, means for rectifying a portion of said output wave for producing successive half-cycle modulating voltage components of like phase, said rectified wave including distortion components, and means for applying said rectified wave in the same relation with respect to said electron tube devices in phase opposition to the modulating voltage on the operative one of said electron tube devices and in phase synchronism with the modulating voltage on the inoperative one of said devices, the said distortion components being effective in inverse degenerative relation in the operative one of said devices for reducing the distortion arising therein.

6. In combination, a suppressed carrier modulation system including alternately operative electron tube devices for producing a double sideband output wave, means for rectifying a portion of said output wave for producing successive half-cycle modulating voltage components of like phase, said rectified wave including distortion components, and means for reintroducing said distortion components in coordination with the alternate operation of said electron tube devices in inverse relation in the operative one of said devices for countering distortion arising in said modulation system.

7. In combination, a suppressed carrier modulation system operative to produce a double sideband output wave, means for rectifying a portion of said output wave for producing successive half-cycle modulating voltage components of like phase, said rectified wave including distortion components, means for directly countering said half-cycle modulating voltage components of like phase by half-cycle components of opposite phase in separate modulating voltage waves of opposite phase, and means for reintroducing said distortion components for operation in inverse relation in said modulation system for reducing distortion arising therein.

8. In a suppressed carrier modulation system, a balanced modulator circuit comprising a pair of electron tube devices having a push-pull connected input circuit, means for supplying high frequency carrier energy to said input circuit, means for applying low frequency modulating voltage to said input circuit comprising a push-pull audio frequency amplifier having an input circuit connected in balanced relation to a source of modulating voltage and dual output circuits separately connected with said electron tube devices, said devices being alternately operative in accordance with the phase of the modulating voltage whereby a double sideband output wave emanates from said modulator circuit, means for rectifying a portion of said output wave for producing successive half-cycle modulating voltage components of like phase, said rectified wave including distortion components, and means for reintroducing said distortion components in coordination with the alternate operation of said electron tube devices in inverse relation in the operative one of said devices for countering distortion arising in said modulation system.

9. In a suppressed carrier modulation system, a balanced modulator circuit comprising a pair of electron tube devices having a push-pull connected input circuit, means for supplying high frequency carrier energy to said input circuit, means for applying low frequency modulating voltage to said input circuit comprising a push-pull audio frequency amplifier having a push-pull audio frequency amplifier having an input circuit connected in balanced relation to a source of modulating voltage and dual output circuits separately connected with said electron tube devices, said devices being alternately operative in accordance with the phase of the modulating voltage whereby a double sideband output wave emanates from said modulator circuit.

10. In a suppressed carrier modulation system, a balanced modulator circuit comprising a pair of electron tube devices having a push-pull connected input circuit, means for supplying high frequency carrier energy to said input circuit, means for applying low frequency modulating voltage to said input circuit comprising a push-pull audio frequency amplifier having an input circuit connected in balanced relation to a source of modulating voltage and dual output circuits separately connected with said electron tube devices, said devices being alternately operative in accordance with the phase of the modulating voltage whereby a double sideband output wave emanates from said modulator circuit.
Ondary winding connected at opposite terminals with said grid electrodes, a connection from said cathode electrodes to the middle of said secondary winding including a source of bias potential for said grid electrodes and a resistor, means for applying an alternating voltage to said grid electrodes through said transformer, and means for applying successive half-cycle alternating voltage components of like phase across said resistor.

13. In combination with a balanced suppressed carrier modulation system, a push-pull amplifier comprising a pair of electron tubes having control grid, anode and cathode electrodes, means for applying the modulating voltage in opposite sign to the grid electrodes for push-pull operation of said amplifier, said cathode electrodes being connected at ground potential, means for connecting said anode electrodes with the modulation input of said suppressed carrier modulation system, means for rectifying a portion of the output wave of said system for producing successive half-cycle distorted modulating voltage components of like phase, and means for applying said voltage components across said resistor, the potential on one of said grids due to said components being effective in inverse relation to the potential due to said modulating voltage.

14. In combination with a balanced suppressed carrier modulation system, a push-pull amplifier comprising a pair of electron tubes having control grid, anode and cathode electrodes, an input transformer having a middle-tapped secondary winding connected at opposite terminals with said grid electrodes, a connection from said cathode electrodes to the middle of said secondary winding including a source of bias potential and resistor, means for applying modulating voltage to said grid electrodes through said transformer, means for connecting said anode electrodes with the modulation input of said suppressed carrier modulation system, means for rectifying a portion of the output wave of said system for producing successive half-cycle distorted modulating voltage components of like phase, and means for applying said voltage components across said resistor, the potential on one of said grids due to said components being effective in inverse relation to the potential due to said modulating voltage.

15. In combination, a suppressed carrier modulation system including a balanced modulator circuit for producing a double sideband output wave; and distortion reducing means including means for rectifying a portion of said output wave for producing successive half-cycle modulating voltage components of like phase, and means for applying said half-cycle components in inverse relation respectively to phases of the modulating voltage causing said double sideband output wave in said balanced modulator circuit, distortion components in said rectified wave being effective in degeneration of distortion arising in said modulation system.

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