

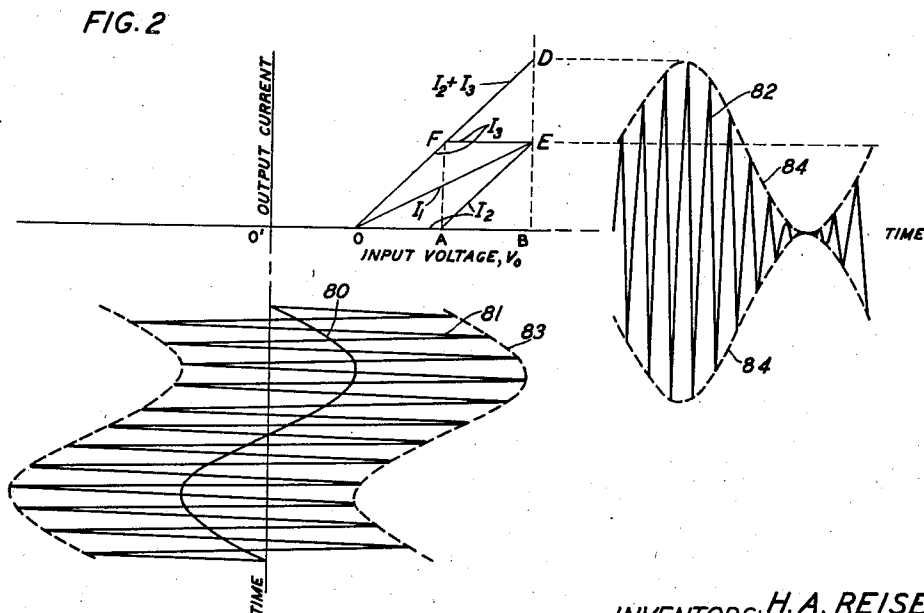
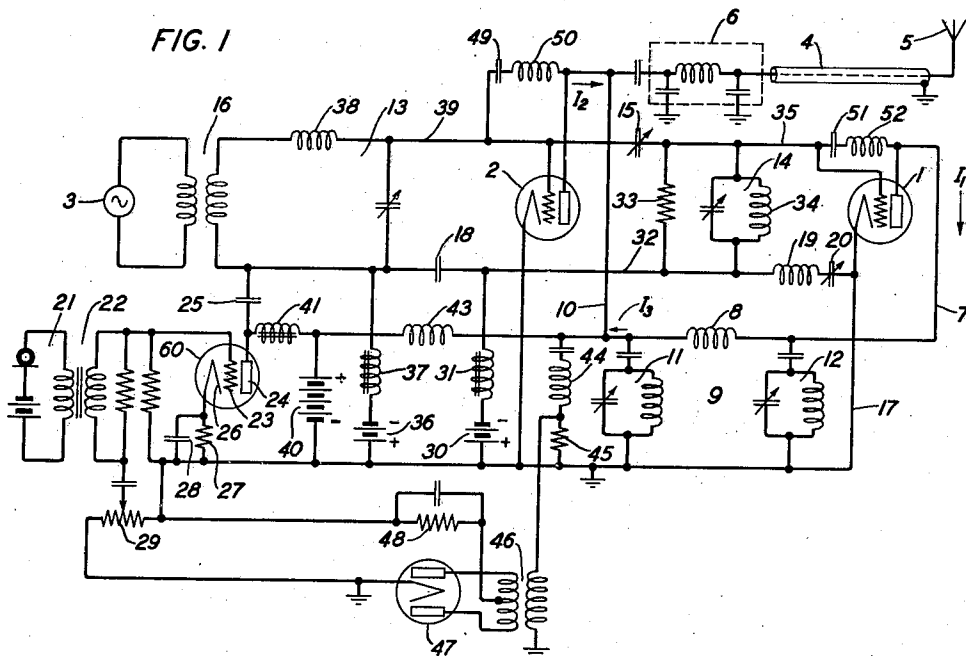
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GRID BIAS MODULATING SYSTEM

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GRID BIAS MODULATING SYSTEM

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This invention relates to modulating systems and more particularly to arrangements for effecting grid bias modulation in complex amplifier circuits.

The invention is particularly applicable to high efficiency amplifiers of the type disclosed in an application of W. H. Doherty, Serial No. 72,147, filed April 1, 1936 and assigned to the assignee of the present application.

An object of the invention is to modulate the output of an amplifier by varying the grid bias under the control of an audio or other signal wave.

A particular object is to vary the respective grid biases of a pair of amplifier tubes which are excited in unlike carrier phases.

Another particular object is to vary the respective grid biases of a pair of cooperating amplifier tubes which have unequal initial grid potentials.

A feature of the invention is the application of grid bias modulation to a complex amplifier with a minimum alteration or disturbance of the grid biasing and carrier input networks.

The Doherty amplifier is essentially two separate amplifiers connected to a common load circuit, usually in parallel connection, but in series if desired. An impedance inverting network is inserted between the output terminals of one amplifier and the load in order to control in a particular way the impedance which each amplifier effectively places in parallel with the other amplifier. One amplifier, generally designated the No. 2 amplifier, is arranged to deliver substantially no power to the load until the excitation is increased to a predetermined amount sufficient to partially load the other, or No. 1, amplifier. It is usual to apply different initial grid biases to the two amplifiers to insure the taking up of the load first by the No. 1 amplifier alone, although suitable adjustments of the radio frequency grid circuits can be made to obtain the same results. In the usual case, as the excitation is applied and is gradually increased the No. 1 amplifier is finally loaded to a point where the plate voltage swing is a maximum consistent with high plate efficiency. The system is preferably designed so that upon further increase in excitation the No. 2 amplifier comes into play and begins to assume part of the load. As the No. 2 amplifier comes into action in parallel with the load it raises the effective terminating impedance of the network with a consequent lowering of the impedance presented to the No. 1 amplifier. The No. 1 amplifier is thereby enabled to

increase its power output gradually while working with a plate voltage swing that no longer increases. The No. 2 amplifier under the increasing excitation delivers an increasing amount of power to the load until its own condition of maximum plate efficiency is reached. At this point both amplifiers are fully loaded and are preferably dividing the load equally between them.

An impedance inverting network of the type usually employed is a quarter wave-length network composed of pure reactances. It has the property of causing a 90 degree phase shift at the operating frequency which is independent of the magnitude of the terminal load. In order that the two amplifiers may deliver their loads in the same phase to the output circuit, the input circuits are excited in phases which differ by 90 degrees. To accomplish the proper phasing of the input waves, it is customary to connect a phase-shifting network between the grid circuits of the respective amplifiers.

In accordance with the present invention certain modifications are made in the meshes of the grid phasing network and in the connections leading to the network whereby it is feasible to vary the grid biasing potentials of the respective amplifier tubes at an audio or signal frequency rate, utilizing portions of the network to impress the audio wave in the same phase upon the two grids as well as to impress the proper individual grid biases upon the tubes. In an illustrative case where the phase-shifting network comprises series and shunt elements, a series circuit resonant to the operating frequency or carrier wave is added, together with a blocking condenser, the individual biasing voltages and the audio input for modulating the amplifier being connected to the grids through the meshes of the phase shifting network.

The invention is described more in detail hereinafter with reference to the accompanying drawing in which:

Fig. 1 is a schematic representation of an embodiment of the invention; and

Fig. 2 is a diagram useful in explaining the operation of the circuit of Fig. 1.

Referring to Fig. 1, the conventional No. 1 and No. 2 amplifier tubes of a typical Doherty amplifier are shown respectively as tubes 1 and 2. The source of carrier waves required for exciting the amplifier is represented by a generator 3. The common load circuit for the amplifier tubes is shown as the concentric transmission line 4, the outer conductor of which is grounded and the inner conductor of which is connected to an an-

tenna 5 for the purpose of radiating modulated carrier waves. The plate of amplifier 2 is connected to the load circuit through an impedance matching network 6. The plate of amplifier 1 is connected to the load through conductor 7, series coil 8 of an impedance inverting network 9, conductor 10 and network 6. The impedance inverting network 9 has, in addition to the series element 8, a pair of adjustable shunt elements 11 and 12. The network 9 produces a phase retardation of 90 degrees at the carrier frequency.

To compensate for the phase retardation in the output network, a phase-shifting network is inserted between the grid circuits of the amplifiers 1 and 2. This network comprises essentially a pair of adjustable shunt elements 13 and 14 and a series condenser 15. The shunt element 13 comprises the parallel combination of a variable tuning condenser and an inductive branch consisting of a coil 38 and the secondary of a high frequency transformer 16. The network 13, 14, 15 introduces a phase advancement of 90 degrees at the carrier frequency. The carrier generator 3 is coupled to the shunt element 13 through the high frequency transformer 16. The shunt element 13 is directly connected to the grid of tube 2 and is connected by way of the condenser 15 to the grid of tube 1. The cathodes of tubes 1 and 2 are joined together by a conductor 17 which may be grounded. The high frequency connection from conductor 17 to the terminal of element 13 remote from the grids is made by means of a blocking condenser 18 and a series resonant circuit comprising a coil 19 and a condenser 20. The grid-cathode circuit of tube 2 is effectively connected to the input terminals of the network 13, 14, 15. The functions of the circuit elements 18, 19 and 20 with respect to audio frequencies and grid biasing voltages will be explained hereinafter.

A source of modulating potentials is shown as a microphone circuit 21 coupled through a transformer 22 to the grid 23 of an audio frequency amplifier tube 60. The plate 24 of this tube is connected through a blocking condenser 25 to that terminal of the secondary of transformer 16 which is remote from the grid of amplifier 2. The cathode 26 of the tube 60 is grounded through a parallel circuit comprising resistor 27 and a condenser 28, the grid 23 being connected through the secondary of the transformer 22 to the movable contactor of a potentiometer 29.

A source of grid biasing potential for amplifier 1 is represented by a battery 30, the positive terminal of which is grounded and the negative terminal connected to the grid of amplifier 1 through a choke coil 31, a conductor 32, the parallel combination of a resistor 33 and coil 34, and a conductor 35.

The source of grid biasing voltage for amplifier 2 is represented by a battery 36, usually of greater voltage than battery 30, connected to the grid of amplifier 2 through a choke coil 37, the secondary winding of transformer 16, the coil 38 of network 13, and conductor 39.

The source of anode potential for the system is represented by a battery 40 connected through a choke coil 41 to plate 24 and through a radio frequency choke coil 43 to the coil 8 and thence through conductor 7 to the plate of amplifier 1. Through conductor 10 the plate circuit for amplifier 2 is extended from the junction of choke 43 and coil 8 to the plate of amplifier 2.

Blocking condensers are inserted where needed as will be apparent to one skilled in the art.

A negative feedback has been provided of a type disclosed in an application of E. B. Ferrell, Serial No. 729,735, filed June 9, 1934, Patent No. 2,159,020, May 23, 1939, and assigned to the assignee of the present application. For this purpose a portion of the load is diverted through a coil 44 and a resistor 45. In parallel with the resistor 45 is connected a high frequency transformer 46 to the secondary of which is connected a full wave rectifier 47. In series with the rectifier 47 is a resistor 48 and the afore-mentioned potentiometer 29.

The amplifiers 1 and 2 are neutralized to prevent self-oscillations and other effects of grid to plate admittance by the respective series circuits 49, 50 and 51, 52 each of which tunes the respective grid-plate path to the carrier frequency in the manner described in Patent 1,325,879, issued December 23, 1919 to H. W. Nichols. Other methods of neutralizing will, however, operate equally well.

The operation of the system of Fig. 1, except for the modulating feature is similar to that of the systems disclosed in the Doherty application, particularly the one shown in Doherty's Fig. 10. Reference is made to the Doherty application for a detailed description of the operation of the system as an amplifier.

The operation of the system as a modulator is conveniently explained with reference to the diagram of Fig. 2. The upper left-hand portion of the diagram shows the relationship, somewhat idealized, between the input voltage of the system of Fig. 1 and the various radio frequency output currents I_1 , I_2 and I_3 , indicated by correspondingly labeled arrows on the diagram of Fig. 1. Curve 80 represents the audio input voltage as a function of the time. The curve 81 represents the superposition of the audio input wave and the carrier input wave. The curve 82 represents the combined output current ($I_2 + I_3$) of the two amplifiers in response to the input wave 81. The broken curve 83 is the locus of positive tips of the input wave 81. The broken curve 84 is the locus of the tips of the output wave 82.

The portion OABEDFO of the diagram corresponds generally to a similarly marked portion of Fig. 3 of the Doherty application.

The system is preferably so adjusted that in the absence of an audio wave and with the normal carrier wave impressed, the carrier input voltage amplitude is represented on Fig. 2 by O'A. The point O' is the origin of the input voltages in the diagram and is shown somewhat to the left of the point O, where it will be when somewhat greater initial biases are used than are suggested in the Doherty application. The output current with unmodulated carrier is indicated in amplitude by AF.

When an audio or modulating wave is impressed upon the system, the wave is superimposed upon the carrier wave and in effect the carrier wave is progressively shifted along the axis O'B. The adjustment is preferably such that when there is impressed an audio wave 80 of the maximum amplitude for which the system is designed to be accommodated, the positive tips of the superimposed wave 81 sweep back and forth between the limits of the voltage range OB. The corresponding output current is shown by the curve 82 which represents in effect a

completely modulated carrier wave as is well understood.

The audio wave is impressed upon the grids of amplifiers 1 and 2 in the same phase on each grid. The connection from the plate 24 of the audio amplifier 60 to the grid of amplifier 1 may be traced as follows at audio frequencies: from the plate 24 through blocking condensers 25 and 18, conductor 32, the parallel combination of resistor 33 and shunt element 14, and by way of conductor 35 to the grid. The condenser 18 acts as a low impedance for audio frequencies as well as for carrier frequencies. At the same time it serves as a blocking condenser to prevent the flow of direct current between batteries 30 and 36. The elements 19 and 20 are preferably adjusted to have a series resonance at the carrier frequency and they then act, at that frequency as the equivalent of a non-reactive, low resistance element or connector. The impedance for audio frequencies, however, is substantial enough to avoid shunting of audio frequency currents away from the grids of the amplifiers. The shunt element 14 of the network on the other hand, has a substantial impedance at carrier frequencies and a very small and substantially non-reactive impedance at audio frequencies. The branch 14 therefore serves both as a determinative element of the phase-shifting network and as a means for supplying audio frequencies to the grid of amplifier 1.

The audio frequency wave is transmitted to the grid of amplifier 2 by way of the condenser 25, the secondary winding of the transformer 16, the coil 38 and the conductor 39. Here again a portion of the phase-shifting network is employed for the additional purpose of supplying audio waves to the grid and the elements 19 and 20 prevent the shunting of the grid at audio frequencies.

The grid biasing voltage of amplifier 1 is supplied through the shunt element 14 of the phase shifting network, with condenser 20 serving as a blocking condenser. The grid biasing voltage for amplifier 2 is supplied through the secondary winding of transformer 16 and coil 38 with condensers 25 and 18 serving as blocking condensers.

It will be noted that the introduction of the audio and biasing voltages by way of the shunt elements of the phase-shifting network has not changed the essential nature of the network as far as operation at the carrier frequency is concerned. The added elements 18, 19 and 20 act simply as conductors at the carrier frequency. Condenser 15 in addition to serving as a series element of the network for phase-shifting purposes serves as a blocking condenser for direct current separation of the two grids.

To promote linear operation of the system according to the teaching of the Ferrell application hereinbefore cited, a portion of the output wave is transmitted through the transformer 46 to the rectifier 47 in which an audio wave is recovered which represents the envelope of the modulated wave. The relatively large resistor 48, which may be provided with a high frequency by-pass condenser, is used to insure a linear action of the detector. The detected wave is impressed upon the grid 23 through the potentiometer 29 in substantial phase opposition to the audio wave which is impressed by the winding of transformer 22. By means of this negative feedback, the envelope of the modulated wave is controlled in such manner as to

follow very closely the form of the audio wave in transformer 22. For further description of this method of distortion correction, reference may be had to the Ferrell application. By virtue of the feedback the system is enabled to follow very closely the linear operating characteristics depicted in Fig. 2.

The grid 23 of the tube 60 is provided with a proper operating bias voltage which is produced by the plate current flowing through the resistor 27. The resistor is shunted by the condenser 28 for by-passing alternating currents, if desired.

It will be evident that the invention is not limited in its application to a specific amplifier nor to the Doherty amplifier. It can be applied to any system having a plurality of amplifier tubes and a phase-shifting network of some sort for the purpose of exciting the grids of two or more amplifiers in unlike phases at the carrier frequency. Moreover, the relative amplitudes of the carrier and audio waves and the amounts of grid bias indicated in the description of the preferred embodiment as shown in Fig. 2 can be varied over a considerable range while operating the system within the scope of the invention. Furthermore, the network joining the grids need not be a phase-shifting network but may be any complex input circuit for controlling the excitation of a plurality of amplifiers, nor need the audio and biasing sources be connected to the grids through shunt elements of the network, for in some cases it will be evident that series elements may be utilized for such connection.

What is claimed is:

1. In a modulating system, a pair of amplifier tubes each having a cathode, an anode and a grid, a carrier source, an audio source, a network effective for phase-shifting purposes at the carrier frequency, and a circuit branch having high impedance at audio frequencies and low impedance at carrier frequencies, said circuit branch being connected at one side to both of the cathodes and at the other side to each of the grids through paths of low and substantially non-reactive impedance at audio frequencies each of said paths including at least one element of said phase-shifting network, said audio source being connected effectively in parallel with said circuit branch of high audio and low carrier impedance, and said carrier source being coupled to the grid-cathode circuit of one of said tubes, whereby said grids are excited in substantial phase coincidence by said audio source and in unlike phases by said carrier source.

2. In an amplifying system, a pair of discharge tubes each having a cathode, an anode and a grid, a source of waves to be amplified, individual grid biasing means for said tubes, a network effective for phase-shifting purposes at the operating frequency of said source and interposed between the grid-cathode circuits of the respective tubes, and a circuit branch having high impedance to direct current and low impedance at the operating frequency, said circuit branch having one terminal connected directly to the cathode of one of said tubes and the other terminal having a conductive connection to the grid of the same tube through an element of the phase-shifting network, one of said grid biasing means being conductively connected in parallel with said circuit branch, and said wave source being coupled to the grid-cathode circuit of one of said tubes, whereby the grids are individually

biased and are excited in unlike phases at the operating frequency.

3. In an amplifying system, a pair of space discharge tubes each having a cathode, an anode and a grid, a source of waves to be amplified, individual grid biasing means for said tubes, and a network effective for phase-shifting purposes at the operating frequency, said network comprising shunt and series elements and being interposed between the grid-cathode circuits of the respective tubes, at least one of said series elements being blocked for direct current by means of a condenser, at least two of said shunt elements being conductive to direct current and each grid being conductively connected to one of said direct current conductive elements, a conductive connection between the cathodes, a conductive connection from the cathodes to each grid through one of the individual biasing means and one of the said direct current conductive elements of the network, and said source of waves being coupled to the grid-cathode circuit of one of said tubes, whereby the grids are individually biased and are excited in unlike phases at the operating frequency.

4. In an amplifying system, a pair of discharge tubes each having a cathode, an anode and a grid, a source of waves to be amplified, individual grid biasing means for said tubes, and a network operative at the frequency of the waves to be amplified, and designed to differentiate the wave impressed upon one of said tubes by said wave source from the wave impressed by said source upon the other tube, said network comprising a plurality of elements and being interposed between the grid-cathode circuits of the respective tubes, and a coupling branch having high impedance to direct current and low impedance at the operating frequency, one terminal of said coupling branch being directly connected to the cathode of one of said tubes and the other terminal having a conductive connection to the grid of the same tube through an element of said wave differentiating network, one of said biasing means being conductively connected in parallel with said coupling branch, and said wave source being coupled to the grid-cathode circuit of one of said tubes, whereby the grids are individually biased and are excited in unlike manner at the operating frequency.

5. In an amplifying system, a pair of amplifier tubes, each having a cathode, an anode and a grid, a source of waves to be amplified, individual grid biasing means for said tubes, and a network operative at the frequency of the waves to be amplified and designed to differentiate the wave impressed upon one of said tubes by said wave source from the wave impressed by said source upon the other tube, said network comprising a plurality of elements and being interposed between the grid-cathode circuits of the respective tubes, certain of said network elements being blocked for direct current by means of condensers, two others of said elements being conductive to direct current and respectively connected by conductive connections to the grids of the amplifier tubes, a conductive connection between the cathodes, a conductive connection from the cathodes to each grid through one of the individual biasing means and one of the said direct current conductive elements of the network, and said wave source being coupled to the grid-cathode circuit of one of said tubes, whereby the grids are individually biased and are excited in non-identical manner at the operating frequency.

6. In a modulating system, a pair of amplifier tubes each having a cathode, an anode and a grid, a carrier source, an audio source, a network operative at carrier frequency and designed to differentiate the wave in its output circuit from the wave in its input circuit, said network comprising a plurality of elements interposed between the grid-cathode circuits of the respective tubes, and a coupling branch having high impedance at audio frequencies and low impedance at carrier frequency, one terminal of said coupling branch being directly connected to both cathodes and the other terminal having a connection to each of said grids of low and substantially non-reactive impedance at audio frequencies by way of an element of said wave differentiating network, said audio source being connected effectively in parallel with said coupling branch at audio frequencies and said carrier source being coupled to the grid-cathode circuit of one of said tubes, whereby said grids are excited in substantial phase coincidence by said audio source and the grids are excited at carrier frequency by the network input and output waves respectively.

7. A modulating system comprising a carrier source, a continuously operative amplifier, a load, a quarter wave network coupling the amplifier to the load, an intermittently operative amplifier directly connected to the load, circuits coupling said carrier source to the amplifier inputs, said circuits including phase-shifting means for exciting the amplifiers in quadrature, said amplifiers being biased beyond their respective cut-offs and said intermittently operative amplifier being biased relatively more negatively than said continuously operative amplifier, a signal source and circuits for impressing signal voltages from said signal source upon the amplifier inputs in like phase.

8. A modulating system comprising a carrier source, an amplifier biased beyond cut-off, a load, a quarter wave network coupling the amplifier to the load, a second amplifier more negatively biased than said first amplifier and connected directly to the load, a circuit coupling said carrier source to the amplifier input circuits, said circuit including phase-shifting means for exciting the amplifiers in quadrature, a source of signalling voltages and circuits for impressing signals upon the amplifier input circuits in like phase.

9. A modulating system comprising a carrier source, a continuously operative amplifier, a load, a quarter wave network coupling the amplifier to the load, an intermittently operative amplifier directly connected to the load, circuits coupling said carrier source to the amplifier inputs, said circuits including phase-shifting means for exciting the amplifiers in quadrature, means for biasing the amplifiers beyond their respective cut-offs, and means for impressing signals upon the amplifier inputs in like phase.

10. A modulating system comprising a carrier source, a biased amplifier, a load, a quarter wave network coupling the amplifier to the load, a second amplifier more negatively biased than said first amplifier and connected directly to the load, circuits coupling said carrier source to the amplifier input circuits, said circuits including phase-shifting means for exciting the amplifiers in quadrature, a signal source, and means for impressing voltages from said signal source upon the amplifier input circuits in like phase.

11. A modulating system comprising a carrier source, a continuously operative amplifier, a load,

a quarter wave network coupling the amplifier to the load, an intermittently operative amplifier directly connected to the load, circuits coupling said carrier source to the amplifier input circuits, said coupling circuits including phase-shifting means for exciting the amplifiers in quadrature, a signal source, and means for impressing voltages from said signal source upon the amplifier input circuits in like phase.

12. A modulating system comprising a carrier source, an amplifier, a source of biasing voltage for said amplifier, the voltage being at least sufficiently great to bias the amplifier to cut-off, a load, a quarter wave network coupling the amplifier to the load, a second amplifier more negatively biased than said first amplifier and connected directly to the load, circuits coupling said carrier source to the amplifier input circuits, said circuits including phase-shifting means for exciting the amplifiers in quadrature, a signal source, and means for impressing voltages from said signal source upon the amplifier input circuits in like phase.

13. A modulating system comprising a carrier source, an amplifier, means for biasing said amplifier at least to cut-off, a quarter wave network coupling the amplifier to the load, a second amplifier connected directly to the load, means for biasing said second amplifier at least to cut-off, circuits coupling said carrier source to the amplifier input circuits, said circuits including phase-shifting means for exciting the amplifiers in quadrature, a signal source, and means for impressing voltages from said signal source upon the amplifier input circuits in like phase.

14. A modulating system comprising a carrier source, an amplifier biased beyond cut-off, a load, a quarter wave network coupling the amplifier to the load, a second amplifier more negatively biased than said first amplifier and connected directly to the load, a circuit coupling said carrier source to the amplifier input circuits, said circuit including phase-shifting means for exciting the amplifiers in quadrature, a source of signalling voltages and circuits for impressing signals upon the amplifier input circuits in like phase and substantially equal amplitude.

15. A modulating system comprising two amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, a common load circuit fed by said tubes, means for impressing independent biasing potentials upon said tubes, a source of modulating potentials, and means for superposing said modulating potentials upon said respective biasing potentials in substantial phase coincidence in the two tubes.

16. A modulating system comprising two amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, a common load circuit fed by said tubes, means for impressing independent biasing poten-

tials upon said tubes, a source of modulating potentials, and means for superimposing said modulating potentials upon said respective biasing potentials in substantially equal amplitude and coincident phase in the two tubes.

17. A modulating system comprising two amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, a common load circuit fed by said tubes, means for impressing unequal biasing potentials upon said tubes, a source of modulating potentials, and means for superposing said modulating potentials upon said respective biasing potentials in substantial phase coincidence in the two tubes.

18. A modulating system comprising two amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, a common load circuit fed by said tubes, means for impressing unequal biasing potentials upon said tubes, a source of modulating potentials, and means for superimposing said modulating potentials upon said respective biasing potentials in substantially equal amplitude and coincident phase in the two tubes.

19. A modulating system comprising a pair of grid bias modulated amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, and a common load circuit fed by said tubes, said tubes having independent initial grid bias potentials and being supplied with modulating potentials in like phase.

20. A modulating system comprising a pair of grid bias modulated amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, and a common load circuit fed by said tubes, said tubes having independent initial grid bias potentials and being supplied with modulating potentials in like phase, and substantially equal amplitude.

21. A modulating system comprising a pair of grid bias modulated amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, and a common load circuit fed by said tubes, said tubes having unequal initial grid bias potentials and being supplied with modulating potentials in like phase.

22. A modulating system comprising a pair of grid bias modulated amplifier tubes, a common source of carrier waves arranged to excite said tubes, impedance inverting means coupling the output circuits of said tubes, and a common load circuit fed by said tubes, said tubes having unequal initial grid bias potentials and being supplied with modulating potentials in like phase, and substantially equal amplitude.

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