Nov. 25, 1947. J. C. FERGUSON 2,431,471

MODULATING SYSTEM

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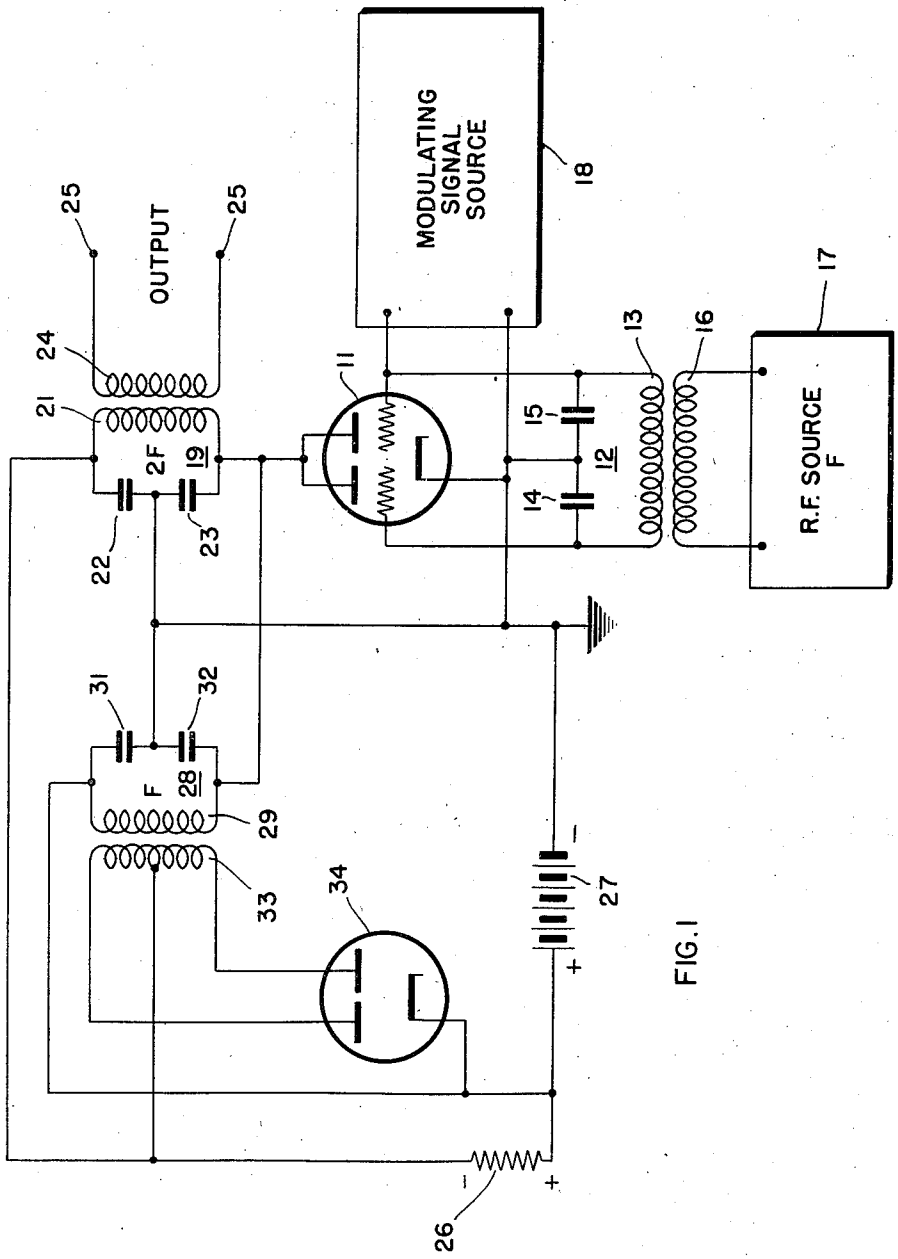


FIG. 1

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FIG. 2

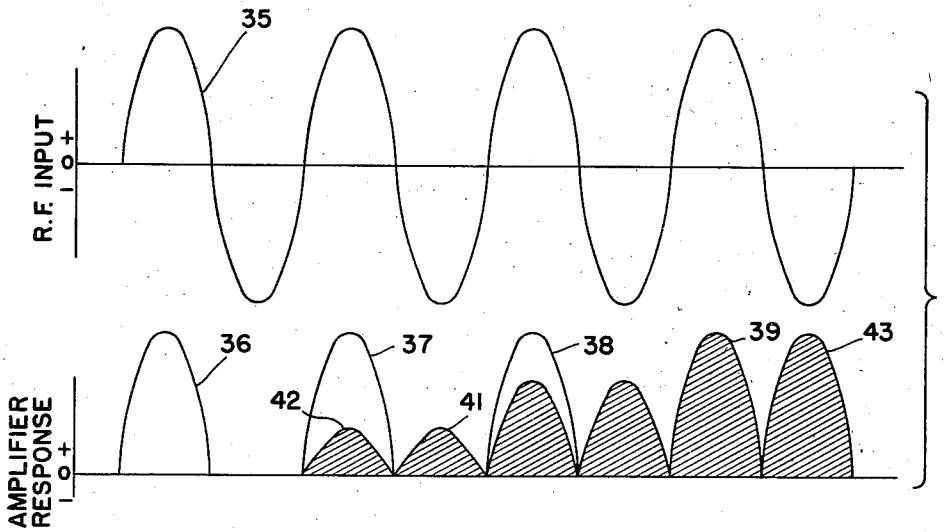
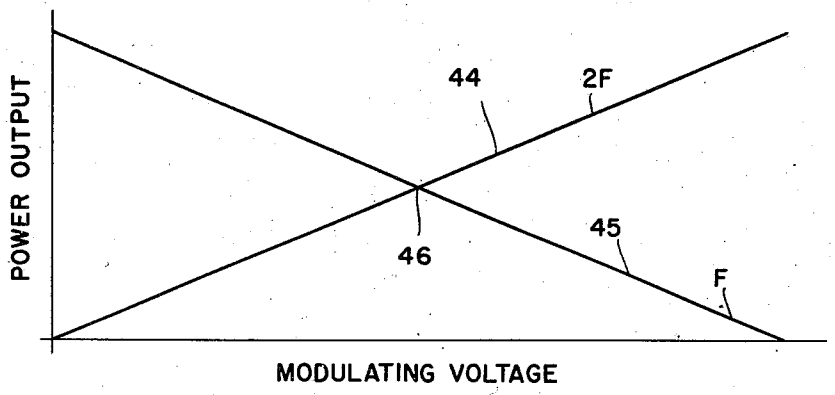


FIG. 3



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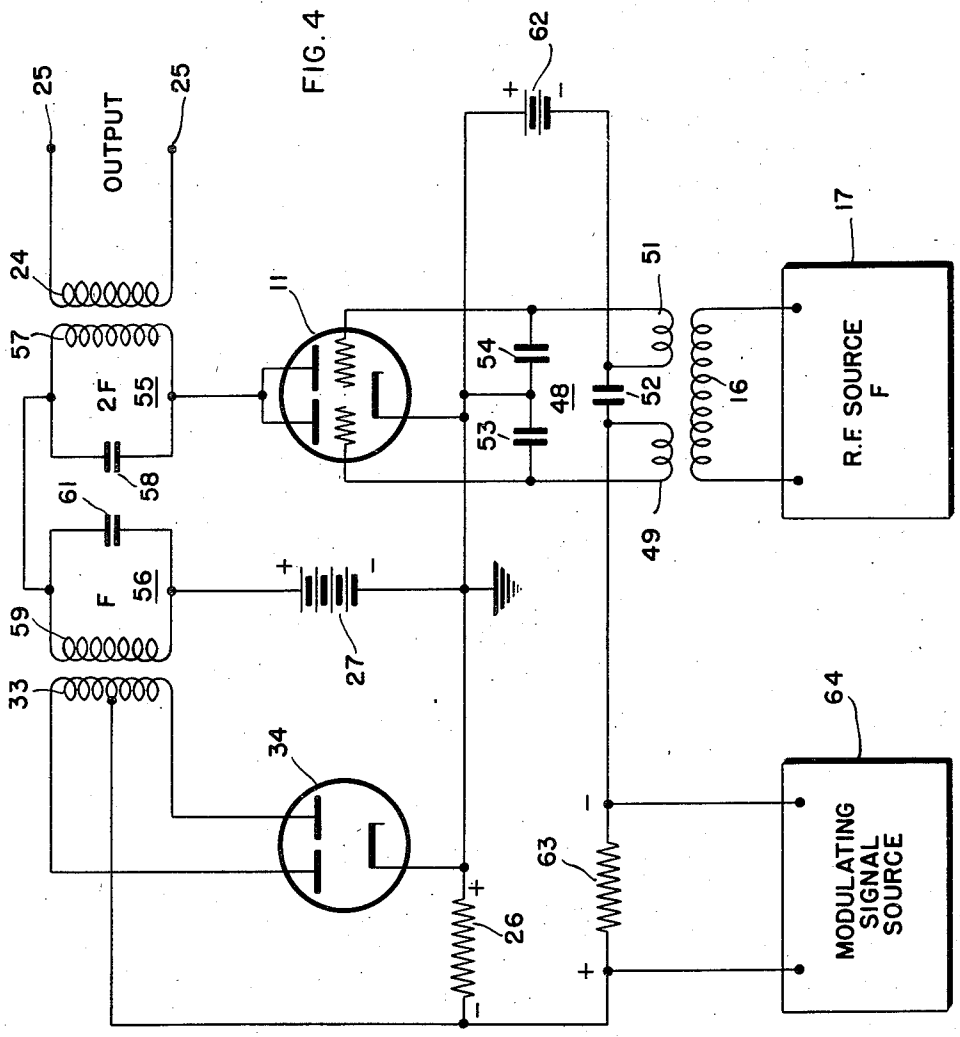
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MODULATING SYSTEM

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FIG. 4



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UNITED STATES PATENT OFFICE

2,431,471

MODULATING SYSTEM

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15 Claims. (Cl. 179—171.5)

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This invention relates to modulating systems and particularly to systems of this character wherein a power amplifier is employed to modulate a carrier signal level in accordance with a modulating signal.

According to conventional practice, it is customary to control an electronic power amplifier by means of a relatively low power level modulating signal, whereby to vary the power output of the amplifier in accordance with the signal. The manner in which these systems function is such that maximum power is developed for transmission purposes to represent one limiting value of the modulating signal. Similarly, to represent a modulating signal of the other limiting value, minimum power is developed.

As is well understood in the art, however, when utilizing the minimum power output for transmission purposes, the utilizing power is but a relatively small proportion of the total power developed. The unutilized portion of the developed power constitutes a loss which reduces the efficiency of the system. The power losses vary during the operation of the system substantially in proportion to the percentage of signal modulation. In addition, it is necessary to dissipate the power losses in some manner. Generally, the dissipation occurs in the power amplifier tubes. The result of such a condition is a still further decrease in the overall efficiency of the system.

It is an object of the present invention, therefore, to provide a novel modulating system in which some of the energy which ordinarily would be lost is converted into a form suitable for use to supplement the modulating voltage.

Another object of the invention is to provide a method of signal-modulating the output of a power amplifier, whereby the energy losses will be minimized.

In accordance with the present invention, there is provided a power amplifier of a type capable of producing in its output circuit signal-modulated energy at two harmonically related radio frequencies, each of which bears a predetermined frequency relation to a radio frequency exciting source. The energy at one of the output circuit frequencies varies directly with the modulating signal and the energy of the other output circuit frequency varies inversely as the modulating signal. The signal-modulated energy at one of the output circuit frequencies is coupled into a utilization circuit. The signal-modulated energy at the other output circuit frequency is demodulated to develop a unidirectional voltage having an alternating current component corresponding to

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the modulating signal. The unidirectional voltage is applied to the power amplifier in a manner to produce additional modulation thereof.

More specifically, the invention is embodied in a modulator employing a pair of electronic devices arranged as a frequency doubling amplifier. The input circuits of the devices are connected in a push-pull arrangement to a radio frequency exciting source. One device is conditioned for a predetermined invariable conduction of space current during successive half cycles of one polarity of the exciting voltage. The other device is conditioned for a variable conduction of space current under the control of a modulating signal during successive half cycles of the opposite polarity of the exciting voltage. As a result of this arrangement there is developed energy, at the second harmonic of the driving radio frequency, which is modulated directly in proportion to the modulating signal. Also, there is developed energy at the fundamental radio frequency which is modulated in inverse proportion to the modulating signal. The signal-modulated energy at the second harmonic of the radio frequency is coupled to a utilization circuit. The signal-modulated energy at the fundamental exciting frequency is rectified to develop a unidirectional voltage varying in magnitude inversely as the modulating signal.

In one illustrative embodiment of the invention this unidirectional voltage is coupled back to the plate circuit of the power amplifier in a manner to effect plate modulation thereof of a character to supplement the primary signal modulation of the amplifier grid circuit. In the other illustrative embodiment of the invention the unidirectional voltage is coupled back to the grid circuit of the electronic device upon which is impressed the primary modulating signal. The manner in which the energy which is coupled back to the amplifier grid circuit is such that the primary amplifier modulation is supplemented by the rectified energy developed at the fundamental exciting frequency.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings:

Fig. 1 is a circuit diagram of a modulating system embodying the instant invention;

Fig. 2 is a group of curves illustrating the mode

of operation of apparatus embodying the invention;

Fig. 3 is a graph for use in connection with the explanation of the operation of apparatus; and

Fig. 4 is a circuit diagram of a further modification of the invention.

Having reference now to Fig. 1 of the drawings, there is disclosed a modulating system in which there is provided a power amplifier including a vacuum tube 11. As illustrated, this tube comprises two independent space discharge paths within the same envelope. For the purpose of this description and the claims appended thereto, this device will be referred to as a pair of vacuum tubes, electronic devices, space discharge paths, etc. Obviously, the tube 11 may be replaced by a pair of similar vacuum tubes without departing from the invention. Also, the tube 11 is shown as a twin triode, but in accordance with practice well known in the art, such tubes require for satisfactory performance, some form of neutralization between the respective control grids and anodes thereof. Neutralization, if desired, may be effected in any conventional manner such as by suitably connecting condensers between the tube electrodes or by employing screen grid tubes. The control grids of the tube 11 are connected to a parallel resonant circuit 12 which comprises, in one branch thereof, an inductor 13 and, in the other branch, a series connection of two condensers 14 and 15. The cathode of the tube 11 is connected to the grounded junction point between the condensers 14 and 15. An inductor 16, coupled to the inductor 13, in turn, is connected to a source of radio frequency 17. The frequency of this source may be anything desired and is represented herein as a frequency F. These described connections to the control grids of the tube 11 are for the purpose of exciting the grids at the radio frequency F.

There is connected between the cathode and one of the grids of the amplifier tube 11, a source of a modulating signal 18. The circuit details of this source have not been shown for the reason that it may be any conventional type of signal source of which numerous examples are well known in the art.

The anodes of the tube 11 are connected together so that the device, with its associated circuits, constitutes a frequency doubler. The output circuit of the tube 11 is a parallel arrangement of two branch circuits. In one of these branch circuits there is connected a parallel resonant network 19 comprising an inductor 21 and, connected in multiple therewith, a series arrangement of two condensers 22 and 23. The junction point between the condensers is connected to ground. The network 19 is tuned to the second harmonic frequency of the radio frequency source 17 and is designated in the drawing by the legend 2F. An inductor 24 is coupled to the inductor 21 and its terminals are connected respectively to the output circuit terminals 25. The branch of the output circuit of the power amplifier including the network 19 also includes a resistor 26 and a source of space current for the power amplifier tubes such as a battery 27 of which the positive terminal is connected to the resistor 26 and the negative terminal is connected to ground.

The other branch of the output circuit of the power amplifier includes a parallel resonant network 28 comprising an inductor 29 and, in multiple therewith, the series connection of two condensers 31 and 32. The junction point between these condensers also is connected to ground. The network 28 is tuned to the fundamental frequency of the radio frequency source 17 as indicated by the legend F. This second branch of the parallel output circuit of the power amplifier is completed by a connection from the network 28 to the positive terminal of the battery 27.

A center-tapped inductor 33 is coupled to the inductor 29 and the terminals thereof are connected to the anodes of a twin diode rectifier 34. The center tap of the inductor 33 is connected to the junction point between the network 19 and the resistor 26. The cathode of the rectifier tube 34 is connected to the positive terminal of the battery 27.

Referring now to the operation of the embodiment of the invention shown in Fig. 1, additional reference will be made to the group of curves shown in Fig. 2. Assume that the signal-modulating voltage derived from the source 18 is at a minimum value corresponding to one limiting value of the modulating signal. Also, assume that under these conditions the grid circuit of the right hand portion of the amplifier tube 11 is provided with a sufficiently negative biasing voltage, which together with the signal-modulating voltage, prevents the conduction of space current in this portion of the tube. At the same time it is assumed that the grid circuit of the left hand portion of the amplifier tube is provided with a bias suitable to permit the conduction of the space current in this portion of the tube of a predetermined and invariable magnitude. As the two portions of the amplifier tube are alternately conditioned for the conduction of space current under the control of the radio frequency exciting voltage derived from the source 17, space current will flow periodically only in the left hand portion of the tube as a result of the described biasing of the tube grids. Consequently, only the left hand portion of the tube is effective to control the development of power in the amplifier output circuit, including the resonant networks 19 and 28.

In Fig. 2 the sinusoidal curve 35 represents the periodic variation of the exciting voltage for the amplifier. If it is assumed that during the positive half cycles of the exciting voltage the left hand portion of the tube 11 is conditioned for the conduction of space current, the areas under the curves 36, 37, 38, and 39 represent the power delivered to the output circuit under the control of the left hand portion of the tube. It is seen that this power is of invariable magnitude and is delivered at the fundamental frequency of the exciting voltage.

Consequently, under the initial modulating condition assumed, all of the power delivered to the output circuit is absorbed by the resonant network 28. Accordingly, the voltage developed at the output terminals 25 is at a minimum value since no power at the second harmonic frequency is available for absorption by the network 19. Upon rectification by the diode 34 of the output circuit energy developed at the fundamental frequency, the unidirectional voltage corresponding thereto which is developed in the impedance 26 is at a maximum value. This voltage is in opposition to the voltage of the battery 27 so that the voltage impressed upon the network 19 is at its minimum value.

Assume now that, during the second illustrated cycle of the exciting voltage, the modulating signal voltage reduces the total negative grid bias of the right hand portion of the tube 11 sufficiently to permit the conduction therein of some

space current. As a result there is delivered to the output circuit of the amplifier during the second negative half cycle of the exciting voltage some power in addition to that furnished during the positive half cycles. This additional energy is represented in Fig. 2 by the shaded area under the curve 41. It is apparent that, under these conditions, a quantity of power is delivered to the output circuit of the amplifier at the second harmonic of the exciting voltage frequency. This second harmonic energy is absorbed by the resonant network 19. Obviously, one-half of the second harmonic energy must be obtained from the energy delivered to the output circuit under the control of the left hand portion of the tube 11. This portion of the second harmonic energy is illustrated by the shaded area under the curve 42 of Fig. 2. The portion of second harmonic energy which is derived from the total energy represented by the area under the curve 37 for absorption by the resonant network 19 results in a decrease in the energy available for absorption by the network 28.

Consequently, the unidirectional voltage developed in the resistor 26 is decreased correspondingly. This reduction in the magnitude of the voltage opposing the voltage of the battery 27 effects an increase in the voltage impressed upon the network 19. This increased voltage effects an additional plate modulation of the amplifier at the second harmonic frequency of a character to supplement the primary grid modulation thereof.

As the modulating signal voltage changes to increase further the magnitude of the space current conducted in the right hand portion of the tube 11, the energy delivered to the output circuit at the second harmonic frequency is increased correspondingly. At the same time the energy at the fundamental frequency available for absorption by the network 28 is decreased in like amount. Ultimately, when the modulating voltage reaches a value representing the other limiting value of the modulating signal, the right hand portion of the tube 11 is conditioned for the conduction of space currents of equal magnitudes to those conducted by the left hand portion of the tube. This condition is illustrated by the curves 39 and 43. The shaded area under the curve 39 represents the power delivered to the output circuit under the control of the left hand portion of the amplifier tube and the shaded area under the curve 43 represents the power delivered to this circuit under the control of the right hand portion of the tube. It is seen that the two are equal and since this power is delivered at the second harmonic frequency there is no energy available for absorption by the resonant network 28. In this case all of the output circuit power is absorbed by the resonant network 19. Consequently, there is no voltage developed in the resistor 26 for opposition to the voltage derived from the battery 27. As a result the voltage impressed upon the network 19 is at its maximum value, thereby effecting a maximum plate modulation of the amplifier corresponding to the maximum grid modulation thereof.

In Fig. 3 there is illustrated graphically the described variation in the output circuit power as the modulating voltage is varied. The curve 44 represents the increase in the power developed at the second harmonic frequency and the curve 45 illustrates the decrease in the power at the fundamental frequency as the modulating voltage is increased. It is seen that when one is a maximum the other is a minimum and that, at an intermediate point 46 corresponding approximately to 50% modulation, equal amounts of power are absorbed by the respective networks 19 and 28. The total power delivered to the amplifier output circuit is constant and its absorption shifts from one resonant network to the other with the modulating signal.

Referring now to the modification of the invention depicted in Fig. 4 of the drawings, there is shown an arrangement similar in some respects to the arrangement of the previously described embodiment. Elements of Fig. 4 which are similar to like elements shown in Fig. 1 are given identical characters of reference. In this instance, the exciting voltage is impressed upon the input circuits of the power amplifier tube 11 by a tuned circuit 48. This circuit comprises two parallel branches, in one of which there is arranged in series two inductors 49 and 51 and a condenser 52. The inductors are coupled inductively in the proper polarities to the output circuit inductor 16 of the radio frequency source 17. The other parallel branch of the network 48 comprises a series connection of two condensers 53 and 54, the junction point of which is connected to ground.

The output circuit of the amplifier tube 11 includes a series connection of networks 55 and 56 together with the battery 27. The network 55 is tuned to the second harmonic frequency of the source 17 and comprises a parallel connection of an inductor 57 and a condenser 58. The inductor 57 is coupled to the inductor 24. The network 56 is tuned to the fundamental frequency of the source 17 and comprises a parallel connection of an inductor 59 and a condenser 61. The inductor 59 is coupled to the inductor 33.

The right-hand portion of the amplifier tube 11 is provided with a fixed negative grid bias derived from a battery 62 which is connected between the cathode of the tube and one terminal of the inductor 51. The input circuit of the left-hand portion of the amplifier tube is connected through the inductor 49 to a resistor 63 across the terminals of which there is connected a source of modulating signal 64. This input circuit also includes the resistor 26 which is included in the output circuit of the rectifier tube 34.

Referring now to the operation of the modification of the invention shown in Fig. 4, assume that the maximum voltage is developed in resistor 63 to represent one limiting value of the modulating signal. The polarity of this voltage tends to prevent the conduction of space current in the left hand portion of the tube 11. The left hand amplifier grid is subjected to this voltage and also is subject to the voltage developed in the resistor 26. This latter voltage also is of a polarity tending to prevent the conduction of space current in this portion of the tube. Together the two voltages developed in resistors 26 and 32 are sufficient, under the assumed conditions, to bias the left hand portion of the tube 11 beyond cutoff so that there is developed in the output circuit of the tube no energy at the second harmonic frequency of the source 17.

The grid biasing of the right hand portion of the tube 11 by the battery 62 is suitable to effect the conduction of a predetermined space current in the right hand portion of this tube. As a consequence, a maximum of energy at the fundamental frequency is delivered to the amplifier output circuit. This energy is absorbed by the

network 56 and converted by the rectifier 34 into the unidirectional voltage developed in the resistor 26. Under the assumed limiting condition this voltage is a maximum.

As the modulating signal deviates from the assumed limiting value a corresponding decrease in the voltage developed in the resistor 63 is effected. Consequently, the conduction of space current in the left hand portion of the tube is initiated to deliver energy to the amplifier output circuit at the second harmonic frequency. As in the previously described modulation of the invention, this second harmonic energy is absorbed by the network 55 with the consequent reduction in the energy at the fundamental frequency available for absorption by the network 56. Hence, the unidirectional voltage developed in the resistor 26 is decreased correspondingly. The decrease of this voltage has the effect of producing additional grid modulation of the left hand portion of the amplifier tube 11 of a character to supplement the primary modulation effected directly by the modulating signal source 64.

When the voltage developed in the resistor 63 is at a minimum to represent the other limiting value of the modulating signal, substantially the entire output of the amplifier tube 11 is developed at the second harmonic frequency of the source 17. Therefore, the voltage developed in the resistor 26 which is representative of the energy available for absorption at the fundamental frequency in the amplifier output circuit also is at a minimum.

In view of the foregoing detailed description of these illustrative embodiments of the invention, it is evident that there is provided a novel means, whereby it is possible to secure additional advantages which are impossible of attainment in prior art systems. As a result, there is achieved a substantial increase in the operating efficiency of a signal-modulated power amplifier.

These advantageous results are produced by the disclosed forms of the invention wherein there is effected a recovery of energy which otherwise would constitute a loss. By recovering this energy, there is obviated the necessity of dissipating it in the amplifier. Hence, there is prevented a lowering of the amplifier efficiency which is an inevitable consequence of the dissipation of such energy by the amplifier tubes.

By reason of the described energy variations in the two output circuit resonant networks, there is produced an effective power shift between the networks in accordance with the modulating signal. The result is that the total power delivered by the amplifier tubes is substantially constant. Thus, the small energy dissipation required of the amplifier also is constant. Hence, the efficiency of the device does not vary substantially with the percentage of signal modulation.

Also, the incorporation by this system of means for converting the recovered energy into a form which may be utilized as an aid for accomplishing additional amplifier modulation obviates, or at least minimizes, the necessity of amplifying the modulating signal prior to the impression thereof upon the power amplifier. Such amplification is not always easy to accomplish. Hence, by means of the invention a more efficient use of the tube complement may be effected. These operational advantages considerably facilitate the attainment of modulation of a character suitable for television transmitters.

While there has been described what, at present, is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it, therefore, is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a modulating system, a power amplifier having an input and an output circuit and adapted to develop in said output circuit signal-modulated energy at a fundamental radio frequency and signal-modulated energy at a harmonic of said radio frequency, a source of a radio frequency wave, means for exciting said amplifier at a radio frequency derived from said source, a source of modulating signal coupled to the input circuit of said amplifier to effect signal modulation, means in the output circuit of said amplifier for developing said signal-modulated energy at said fundamental radio frequency, additional means connected in the output circuit of said amplifier for developing said signal-modulated energy at said harmonic of the radio frequency, means for developing from said fundamental signal-modulated radio frequency energy a unidirectional voltage varying in accordance with said modulating signal, and means for applying said unidirectional voltage to said amplifier in a manner to effect additional signal modulation.

2. In a modulating system, a frequency doubler having an input and an output circuit, a source of a radio frequency wave, means for exciting said frequency doubler at a radio frequency derived from said source, a source of modulating signal coupled to said input circuit to effect signal modulation, means connected in said output circuit for developing signal-modulated energy at double said radio frequency, additional means connected in said output circuit for developing signal-modulated energy at said radio frequency, means for developing from said signal-modulated radio frequency energy a unidirectional voltage varying in accordance with said modulating signal, and means for applying said unidirectional voltage to said frequency doubler in a manner to effect additional signal modulation.

3. In a modulating system, a frequency doubler comprising, a pair of space discharge paths each having an input and an output circuit and arranged in a push-push connection, a source of a radio frequency wave, means for exciting said space discharge paths at a radio frequency derived from said source, a source of modulating signal coupled to the input circuit of one of said space discharge paths to effect signal modulation, means connected in the output circuits of said space discharge paths for developing signal-modulated energy at double said radio frequency, additional means connected in the output circuit of said space discharge paths for developing signal-modulated energy at said radio frequency, means including a rectifier for developing from said signal-modulated radio frequency energy a unidirectional voltage varying in accordance with said modulating signal, and means for applying said unidirectional voltage to one of said space discharge paths in a manner to effect additional signal modulation.

4. In a modulating system, an amplifier having an input and an output circuit and adapted to develop in said output circuit signal-modulated energy at two harmonically related radio frequen-

cies, means for exciting said amplifier at a frequency having a predetermined relation to said harmonically related frequencies, a plurality of networks connected to the output circuit of said amplifier, one of said networks being adapted to develop energy at a first one of said harmonically related frequencies and the other of said networks being adapted to develop energy at a second one of said harmonically related frequencies, a utilization circuit coupled to said first harmonically related frequency network, means coupled to said second harmonically related frequency network for demodulating the energy developed therein, a source of modulating signal, means for coupling said modulating signal source to the input circuit of said amplifier, and means for impressing said demodulated energy upon the input circuit of said amplifier in a manner to supplement said modulating signal.

5. In a modulating system, a power amplifier having an input circuit and an output circuit and adapted to develop in said output circuit signal-modulated energy at a fundamental radio frequency and at a harmonic of said radio frequency, means for exciting said amplifier at said radio frequency, a plurality of resonant networks connected to the output circuit of said amplifier, one of said networks being tuned to said fundamental radio frequency and the other of said networks being tuned to said harmonic of the radio frequency, a utilization circuit coupled to said harmonic frequency network, a rectifier coupled to said fundamental frequency network, a source of modulating signal, means for coupling said modulating signal source to the input circuit of said amplifier, and means for coupling the output circuit of said rectifier to the input circuit of said amplifier in a polarity to supplement said modulating signal.

6. In a modulating system, a power amplifier having an input circuit and an output circuit and adapted to develop in said output circuit signal-modulated energy at a fundamental radio frequency and at the second harmonic of said radio frequency, a source of a radio frequency wave, means for exciting said amplifier from said source, a plurality of resonant networks connected to the output circuit of said amplifier, one of said networks being tuned to the fundamental frequency of said source and the other of said networks being tuned to the second harmonic frequency of said source, a utilization circuit coupled to said second harmonic frequency network, a full wave rectifier coupled to said fundamental frequency network, a source of modulating signal, means for coupling said modulating signal source to the input circuit of said amplifier, and means for coupling the output circuit of said rectifier to the input circuit of said amplifier in a polarity to supplement said modulating signal.

7. In a modulating system, a frequency doubler including a pair of space discharge paths, an output circuit for said frequency doubler comprising a pair of resonant networks, one of said networks being tuned to a fundamental radio frequency and the other of said networks being tuned to the second harmonic of said fundamental frequency, a utilization circuit coupled to the network tuned to said second harmonic frequency, a rectifier coupled to the network tuned to said fundamental frequency, an output circuit for said rectifier comprising an impedance, a source of a carrier wave having a radio frequency equal to said fundamental frequency, means for coupling said source to the input circuit of said frequency doubler for the excitation thereof, a source of a modulating signal, means for coupling said signal source to the input circuit of one of said space discharge paths, and means for coupling said impedance to the input circuit of said one space discharge path in a polarity to supplement said modulating signal.

8. In a modulating system, a frequency doubler comprising first and second space discharge paths, each having input and output circuits, means for exciting the input circuits of said space discharge paths at a fundamental radio frequency, a source of modulating signal coupled to the input circuit of one of said space discharge paths to effect an input circuit modulation of said frequency doubler, means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at the second harmonic frequency of said radio frequency, additional means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at said radio frequency, means for rectifying said signal-modulated radio frequency energy, and means utilizing said rectified energy for plate modulating said frequency doubler in a manner to supplement the input circuit modulation thereof.

9. In a modulating system, a frequency doubler including first and second space discharge paths, each having input and output circuits, means for exciting the input circuits of said space discharge paths at a fundamental radio frequency, a fixed biasing voltage for said first space discharge path to effect an invariable conduction of space current therein, means including a source of modulating signal for varying the biasing voltage of said second space discharge path in accordance with a modulating signal, means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at the second harmonic frequency of said radio frequency, additional means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at said radio frequency, means for rectifying said signal-modulated radio frequency energy, and means utilizing said rectified energy for additionally varying the biasing voltage of second space discharge path.

10. In a modulating system, a frequency doubler comprising first and second space discharge paths each having input and output circuits, means for exciting the input circuits of said space discharge paths at a fundamental radio frequency, a source of modulating signal coupled to the input circuit of one of said space discharge paths for grid-modulating said frequency doubler, means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at the second harmonic frequency of said radio frequency, additional means coupled to the output circuits of said space discharge paths for developing signal-modulated energy at said fundamental radio frequency, means for rectifying said signal-modulated fundamental radio frequency energy, and means utilizing said rectified energy for effecting additional grid modulation of said frequency doubler.

11. In a modulating system, a power amplifier having input and output circuits and adapted to develop in said output circuit signal-modulated energy at two harmonically related radio frequencies, each bearing a predetermined frequency relation to a fundamental radio frequency, means

for exciting said amplifier at said fundamental radio frequency, a source of modulating signal coupled to the input circuit of said amplifier to effect signal modulation, respective means connected in said output circuit for developing signal-modulated energy at said two harmonically related radio frequencies, means for deriving from one of said energy developing means a unidirectional voltage varying in accordance with said modulating signal, and means for applying said unidirectional voltage to said amplifier in a manner to effect additional signal modulation.

12. In a modulating system, a power amplifier having an input and an output circuit and adapted to develop in said output circuit signal-modulated energy at a fundamental radio frequency and additional signal-modulated energy at a harmonic of said radio frequency, a source of a radio frequency wave, means for exciting said amplifier at a radio frequency derived from said source, a source of modulating signal coupled to the input circuit of said amplifier to effect signal modulation, means in the output circuit of said amplifier for developing said signal-modulated energy at said fundamental radio frequency, additional means connected in the output circuit of said amplifier for developing said signal-modulated energy at said harmonic of the radio frequency, means for deriving from one of said energy developing means a unidirectional voltage varying in accordance with said modulating signal, and means for applying said unidirectional voltage to said amplifier in a manner to effect additional signal modulation.

13. In a modulating system, means including a signal-controlled power amplifier for developing

signal-modulated energy at a plurality of harmonically related frequencies, means including a space discharge rectifier tube for demodulating the energy developed at one of said harmonically related frequencies, and means for impressing said demodulated energy upon said power amplifier for the development of additional signal-modulated energy at said harmonically related frequencies.

14. In a modulating system, means including an electronic device for developing signal-modulated energy at a plurality of different frequencies, means for rectifying the energy developed at all but one of said frequencies, and means for impressing said rectified energy upon said electronic device for the development of additional signal-modulated energy at said one frequency.

15. In a modulating system, means for developing signal-modulated energy at a plurality of different frequencies, means for rectifying the energy developed at one of said frequencies, and means for impressing said rectified energy upon said energy developing means to effect the development of additional signal-modulated energy at one of said frequencies.

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