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MODULATION SYSTEM

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Fig. 1

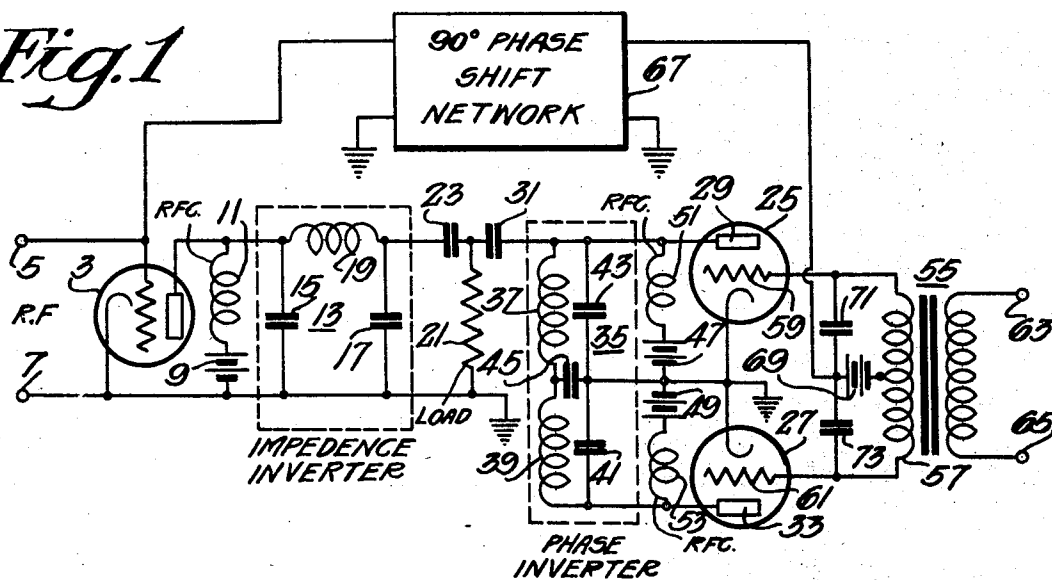
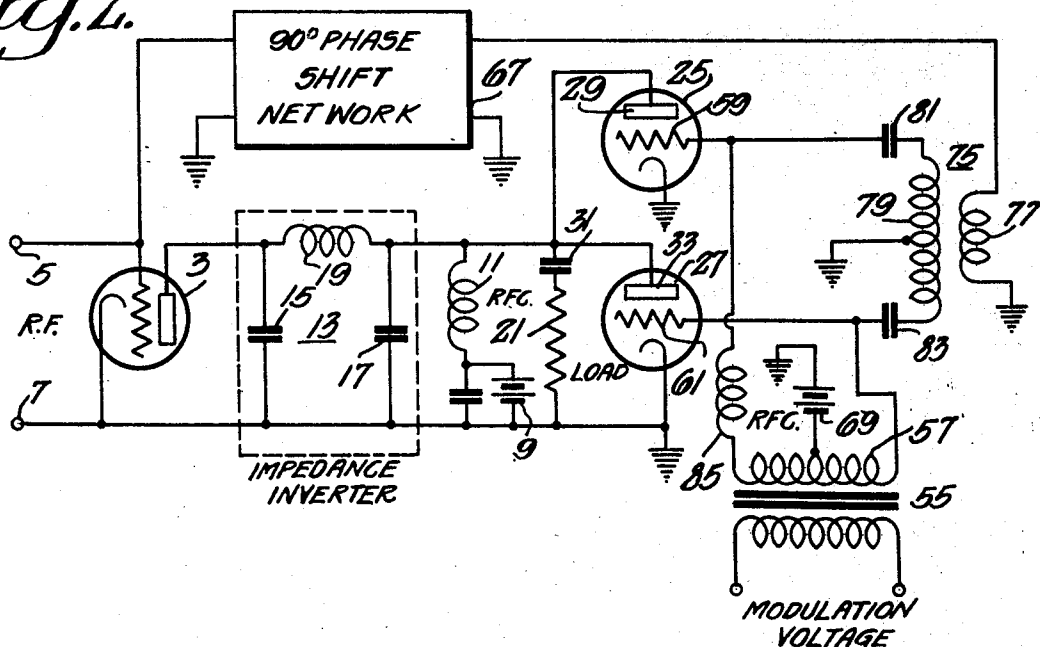


Fig. 2



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2,224,314

MODULATION SYSTEM

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5 Claims. (Cl. 179—171.5)

My invention relates to modulation systems and more particularly to a device for modulating radio frequency currents in which a pair of radio frequency amplifiers are connected in parallel across an antenna, and in which the phase of one of the radio frequency amplifiers is controlled by a modulating voltage. The current in the antenna of such a transmitter is varied by the modulating voltage so that the resultant antenna current is the sum of two radio frequency currents during positive peaks of modulation, and is equal to the difference of the two radio frequency currents during negative peaks of the modulating voltage.

The present practice with respect to transmitter design is to provide a radio frequency power output stage having sufficient capacity to handle the power which is developed at 100% modulation upwards. The average operating output is far below the peak value. Consequently, the tube operating conditions cannot be adjusted to give maximum efficiency during intervals which correspond to the average output. The tubes, as well as the associated equipment, must be designed to handle a peak load which is utilized only a small fraction of the time. This further increases the unit cost of the transmitter.

In a copending application, Serial No. 210,304, filed May 27, 1938, Patent No. 2,184,571, December 26, 1939, and entitled "Modulation system," A. W. Vance describes a modulation system which provides a new approach to the problem of obtaining efficient amplitude modulation. The present invention is an improvement of the system therein described. The general system which is employed in the Vance application and in the present application, requires the use of a radio frequency power output tube which is designed to supply but one-half the maximum load. An auxiliary tube is called into play to supply an in-phase current which increases the effective power output during upward peaks of modulation. Downward modulation is accomplished by reversing the phase of the radio frequency current supplied by the auxiliary tube. The auxiliary out of phase current cancels some, or all of the output from the first output tube and thereby reduces the net power which is supplied to the antenna.

The present invention is an improvement over the method described by Vance, in that a simplified system of providing the out of phase radio frequency current is shown herein. Instead of utilizing a balanced modulator and an additional power amplifier to provide the in and out of

phase auxiliary currents, a pair of auxiliary power tubes are directly coupled to the antenna, and means are provided for reversing the phase of the radio frequency output of one of the auxiliary tubes. The auxiliary tubes are driven by the modulating voltage in such a manner that one tube responds to positive peaks of modulating voltage while the other tube responds only to negative peaks of the modulating voltage.

It is an object of this invention to provide an improved modulation system.

It is a further object of this invention to provide a simplified method of adding in phase and out of phase radio frequency currents in accordance with a modulating signal.

It is a further object of this invention to provide a more economical system of modulating a radio frequency carrier.

It is a still further object of this invention to provide an improved system of modulating a radio frequency carrier by means of parallel-connected output tube supplying in phase and out of phase radio frequency currents.

It is a further object of this invention to provide a system for separately generating carrier and side band energy, and subsequently combining them to produce an amplitude modulated wave.

This invention will be better understood when considered in connection with the accompanying drawing. Its scope is indicated by the appended claims. Similar reference numerals are used to indicate similar parts throughout the drawing.

Figure 1 is a schematic drawing of one embodiment of my invention.

Figure 2 is a schematic drawing of an alternative embodiment of my invention.

Referring to Fig. 1, unmodulated radio frequency energy is supplied to a power output amplifier 3 from a source which is not shown by means of connections to a pair of input terminals 5 and 7. The amplifier 3 is a power triode amplifier designed in the usual manner but rated at a maximum power output equal substantially to one-half the desired transmitter output. Anode potential is supplied by a battery 9 which is connected to the anode of amplifier 3 through a radio frequency choke 11. The output of this amplifier 3 is connected to the input of an impedance inverter 13. The impedance inverter comprises a pair of capacitors 15 and 17 and an inductor 19 which are connected to form a quarter-wave resonant circuit. The load circuit, which may be an antenna, or the like, is represented by a resistor 21, one side of which is grounded. The

output of the impedance inverter is connected to the load resistor through a coupling capacitor 23. As is well known, if a low impedance is connected across the output of an impedance inverter, a high impedance effectively appears across the input. The function of this inversion will be explained subsequently.

Power is also supplied to the load 21 by a pair of auxiliary triodes 25 and 27 which are connected in parallel in the manner which will now be described. The anode 29 of the first auxiliary triode 25 is connected by means of a coupling capacitor 31 to the load resistor 21. The anode 33 of the second auxiliary triode 27 is connected to the anode 29 through a phase inverter circuit 35. The phase inverter circuit consists of a pair of inductors 37 and 39 and three capacitors 41, 43 and 45. One terminal of each inductor is connected to one terminal of capacitor 45. The remaining terminals of the two inductors are respectively connected to a terminal of the input and output capacitors 41 and 43, respectively. The remaining terminals of the three capacitors are grounded. The junction of inductor 39 and the input capacitor 41 is connected to the anode 33. The junction of the inductor 37 and the output capacitor 43 is connected to the anode 29.

The inductors and capacitors which constitute the phase inverter 35 are so chosen that at the frequency of operation the phase of a voltage which is applied across the terminals of capacitor 41 will be opposite to the phase of the voltage which will be induced across the terminals of capacitor 43. This condition is obtained when the circuit constants are chosen so that a half wave resonant filter is obtained, that is the capacitive reactance of the input and output capacitors is equal to the inductive reactance of the two inductors, and the capacitive reactance of the middle capacitor 45 is equal to one half of this value.

Anode potential is supplied by a pair of batteries 47 and 49, or the like, which are respectively connected to the anodes 29 and 33 through radio frequency chokes 51 and 53.

A push pull audio frequency transformer 55 has its secondary 57 connected between the grids 59 and 61 of the auxiliary triodes. Modulating voltage, from a source which is not shown, is connected to the input terminals 63 and 65 which are connected to the transformer primary.

Radio frequency energy is also supplied to the two auxiliary triodes. In order to compensate for the 90 degree phase shift which takes place in the impedance inverter 13, it is necessary to provide a similar shift in the phase of the radio frequency current which is applied to the auxiliary triodes. This is accomplished by inserting a phase shifting network 67 in series with a lead which connects the radio frequency input terminal 5 to the center tap of the secondary winding 57. A grid biasing battery 69 is included in series with this lead. The two halves of the secondary winding 57 are bypassed, for radio frequency, by a pair of condensers 71 and 73.

The grid biasing voltage which is applied to the grids of the auxiliary triodes is adjusted to such a value that, in the absence of modulation, substantially no power is delivered to the load by either of the auxiliary triodes. When a modulating voltage is impressed across the terminals of the transformer 55 the voltage is impressed on the grid of each auxiliary triode. Due to the push pull connection, however, when the voltage at any instant on the grid 59 of the first auxiliary triode is positive, that on

the grid 61 of the second auxiliary triode is negative. A positive modulating impulse, therefore, impresses a positive potential on the grid of the first auxiliary triode, permitting it to draw plate current, and to impress a voltage across the load resistor 21 which is in phase with the voltage impressed across the load by the radio frequency amplifier 3. A negative modulating impulse, however, causes the second auxiliary triode 27 to draw plate current and the amplified output voltage which is impressed across the load resistor 21 is in the opposite phase due to the action of the phase inverter 35. The result is that there is an increase in the antenna current when the modulating pulse is positive, and a decrease in the antenna current when the modulating pulse is negative. Amplitude modulation of the radio frequency carrier is therefore effected in accordance with the modulating voltage.

The impedance inverter 13, which is connected between the output tube 3 and the load, reflects in opposite sense the change in load impedance which is caused by the action of auxiliary triodes. As a result, when the power output is doubled by the in-phase current from the first auxiliary triode, the load impedance which is presented to the output triode 3 changes in such a direction that its output is also effectively doubled. Thus, the condition that the peak output at maximum modulation be four times the average value is met.

The embodiment of my invention which is illustrated in Figure 2 differs from that just described in that the radio frequency voltage is applied out of phase to the two auxiliary triodes 25 and 27. This makes it unnecessary to invert the phase of the output of the second auxiliary amplifier 27. The phase inverter 35 is no longer necessary. The anodes 29 and 33 of the two auxiliary triodes are therefore connected directly together and coupled to the load resistor 21 by a capacitor 31, as before. The anodes 29 and 33 are also connected directly to the output of the impedance inverter 13. This provides a direct connection, for direct current, from the anodes of all the tubes to the radio frequency choke 11, which now supplies anode current for all the amplifiers.

The modulating voltage is applied out of phase to the two grids 59 and 61 by means of a push-pull transformer 55, as before. The radio frequency input to the auxiliary triodes, however, is impressed on the grids out of phase by means of a push-pull radio frequency transformer 75. The primary 77 of this transformer is connected between the output of the phase shift network 67 and ground. The secondary 79 of the radio frequency transformer 75 is connected between the grids of the auxiliary triodes through a pair of coupling capacitors 81 and 83. The purpose of these capacitors is to prevent the secondary of the radio frequency transformer from short-circuiting the secondary of the audio frequency transformer 55 which is connected across it. Likewise, to prevent the audio frequency transformer from short-circuiting the radio frequency transformer, a radio frequency choke coil 85 has been connected in series with one side of the secondary winding 57.

As before, the auxiliary triodes are biased by a battery 69 so that in the absence of modulation, substantially no current is drawn by either tube. The auxiliary triodes are alternately made to impress a radio frequency voltage on the load re-

sistor in accordance with the modulating voltage. Since the radio frequency current applied to the two grids is out of phase, it is seen that modulating potentials of one polarity cause an in-phase radio frequency voltage to be impressed across the load, while modulating potentials of the other polarity cause out of phase potentials to be impressed across the load.

It was pointed out in the Vance application, above identified, that the plate voltage of the auxiliary tube is varied by the radio frequency voltage which is impressed across the load by the unmodulated amplifier. Thus the condition under which in-phase current must be delivered to the antenna is different from the condition under which out of phase current must be delivered, for the in-phase current must start to flow when the effective plate voltage is at a minimum and the out of phase current starts when the effective plate voltage is at a maximum. In the present system in which two auxiliary tubes are directly coupled to the load, a similar condition exists.

A solution is found, as in the Vance application, by applying unequal bias to the two auxiliary tubes, or by supplying a "radio frequency bias." Either of these methods are applicable to my invention, and in addition, I propose another system. By suitably selecting the reactors and capacitors which constitute the phase reversing network a voltage ratio between input and output may be obtained which is greater or less than unity, as desired. An unbalanced condition is therefore provided which compensates for the difference in plate voltage which appears upon the plates of the tubes.

I claim:

1. In a device of the character described, a utilization device, a source of unmodulated carrier frequency currents, means for impressing said currents on said utilization device, a source of modulating voltage, a pair of thermionic amplifier tubes having input and output electrodes, means for applying said modulating voltage to said input electrodes in phase opposition, means for applying said unmodulated carrier frequency in phase to said input electrodes, means coupling the output electrode of one of said amplifier tubes to said utilization device, a phase inverter coupling the output of the other of said amplifier tubes to said utilization device, whereby modulating

voltages of one polarity increase the effective current in said utilization device and of the opposite polarity decrease the effective current in said utilization device.

2. In a device of the character described, a utilization device, a source of unmodulated carrier frequency currents, means for impressing said currents on said utilization device, a source of modulating voltage, a pair of thermionic amplifier tubes having input and output electrodes, means for applying said modulating voltage to said input electrodes in phase opposition, means for applying said unmodulated carrier frequency currents in phase to said input electrodes, means for directly coupling the output electrode of one of said amplifier tubes to said utilization device, means for coupling the output of the other of said amplifier tubes to said utilization device, said last named means comprising a 180° phase inverting network, whereby modulating voltages of one polarity increase the effective current in said utilization device and of the opposite polarity decrease the effective current in said utilization device.

3. A device of the character described in claim 2 in which said 180° phase inverting network has a voltage input to voltage output ratio other than unity.

4. A device of the character described in claim 2 which is further characterized in that said 180° phase shifting network comprises a pair of inductors connected in series between said output electrode and said utilization device having capacitors effectively connected, respectively, between said output electrode and ground, said utilization device and ground, and the junction of said inductors and ground.

5. A device of the character described in claim 2 which is further characterized in that said 180° phase shifting network comprises a pair of similar inductors connected in series between said output electrodes and said utilization device having a capacitor whose capacitive reactance is equal to the inductive reactance of said inductors connected from opposite terminals of said inductors to ground, and a capacitor whose capacitive reactance is equal to one half the inductive reactance of said inductors connected from the junction of said inductors to ground.

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50