May 12, 1942. R. E. TAYLOR 2,282,347

MODULATION SYSTEM

Filed May 20, 1940 2 Sheets-Sheet 1

Fig. 1

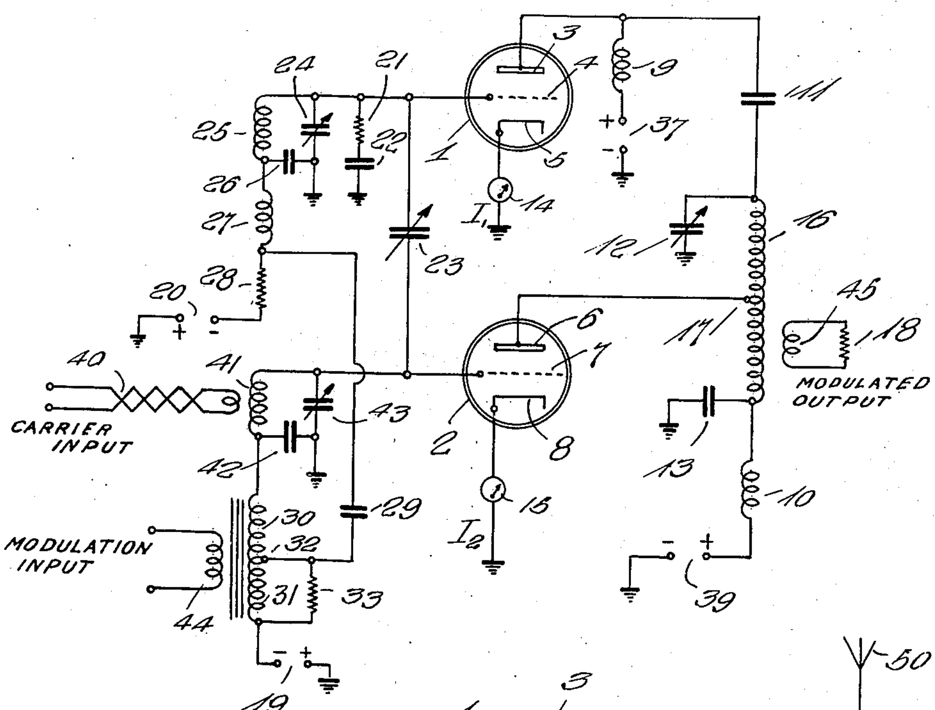

Fig. 2

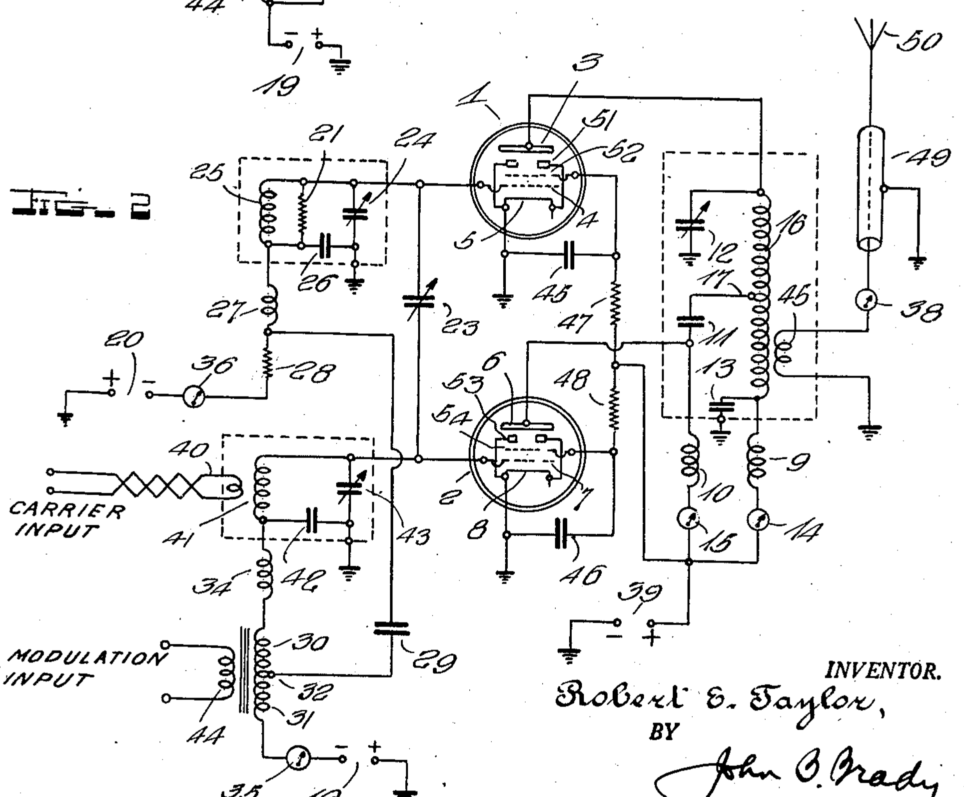

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FIG. 3

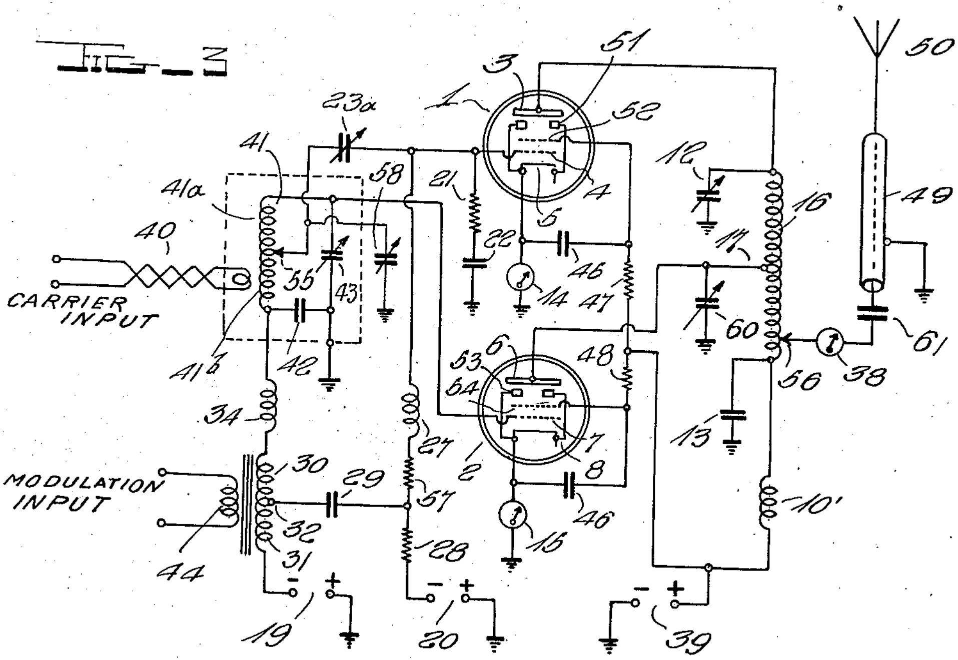
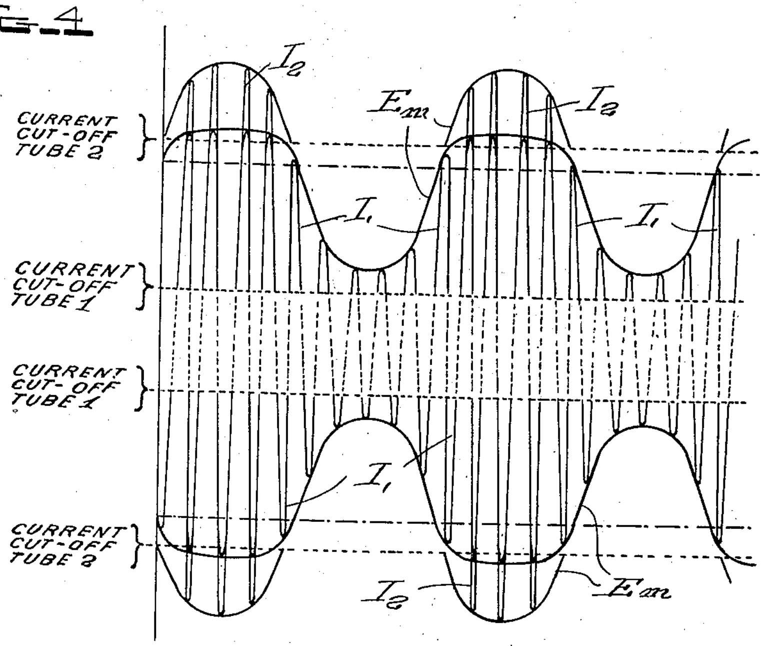


FIG. 4



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2,282,347

MODULATION SYSTEM

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Application May 20, 1940, Serial No. 336,256

14 Claims. (Cl. 179—171.5)

My invention relates broadly to modulation systems and more particularly to a system for simultaneous amplification and modulation at high efficiency.

One of the objects of my invention is to provide means for modulating a high frequency carrier wave at high efficiency while at the same time amplifying the carrier at high efficiency for delivering a signal wave of relatively high power for a given input with a minimum of equipment. The system, therefore, is adapted particularly for mobile transmitters, such as police, relay and aircraft, as well as for television transmission and commercial high power systems where great amplification and high efficiency are required.

Another object of my invention is to provide a system for amplification and modulation of a high frequency carrier wave at high efficiency by means of separate circuits biased to cut-off at different current levels, whereby positive modulation peaks are delivered from one circuit and negative modulation peaks from another circuit, both circuits operating at high efficiency.

A further object of my invention is to provide a modulation and amplification system including a separate circuit for delivering the positive modulation peaks, whereby the basic modulation circuit may be operated at high efficiency, and an output circuit for combining the basic modulated wave and the peaks in proper phase relation.

Still another object of my invention is to provide a simplified high efficiency amplification system for voltages of carrier frequencies wherein different portions of the wave are amplified in different circuits and combined in the output, the system being operative also for modulating the carrier wave.

A still further object of my invention is to provide a high frequency amplification system wherein different portions of the wave are amplified in different circuits for high efficiency and combined in the output, the amplification system being operated also to modulate the high frequency wave being amplified to provide low frequency components in the different circuits, whereby combination of the different portions of the high frequency wave may be effected in the output circuit in proper phase by adjustment with reference to the low frequency modulation in simplified manner.

The invention, therefore, should not be confused with customary high efficiency amplifiers, as for instance the Doherty Circuit, for amplification of modulated waves which are essentially of high frequency, and wherein high frequency phase relations must be accurately controlled if the peak portions are to synchronize with the base portions of the wave in the output. The input as well as the output branches of the Doherty system require unusual skill for their adjustment, besides requiring complicated networks, as is well known in the art.

In the system of my invention, both modulating voltages and carrier voltages are applied independently to appropriate simple input networks and the modulated and amplified components are superimposed in a simple straightforward output branch of the system. For this reason high frequency phase relations are not critical and the adjustment of the novel high efficiency system is simple.

The invention will be more clearly understood from the following description of practical embodiments of the invention made with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of the circuit arrangement of my invention showing the principal elements thereof in cooperative relation; Fig. 2 is a schematic diagram of a more complete arrangement employing basically the same elements shown in Fig. 1; Fig. 3 is a schematic diagram of a modified form of my invention; and Fig. 4 is a theoretical graphical representation of the modulated wave components as superimposed in the output circuit.

Referring to Fig. 1 which primarily illustrates the principles of my invention, electron tubes 1 and 2 are operative simultaneously as amplifiers and modulators, tube 1 being employed as a low level class C amplifier to deliver modulated high frequency current up to a predetermined maximum at high efficiency, while tube 2 is employed as a high level class C amplifier to deliver the peak portions of the modulated wave beyond the maximum set for tube 1 and to operate likewise at high efficiency. Referring to Fig. 4, the output current of tube 1 is shown at I_1 with a relatively flat characteristic at the predetermined maximum which is capped by the current I_2 from tube 2 in proper phase with respect both to the high frequency carrier and low frequency modulation factors. The relationship of the currents I_1 and I_2 is effected primarily by biasing control grid 4 of tube 1 at a negative potential about twice cut-off potential, and control grid 7 of tube 2 at a negative potential about six to eight times the cut-off potential, from sources connected at

20 and 19, respectively, as will be more fully described.

Tube 1 includes anode 3, control grid 4 and cathode 5, while tube 2 includes anode 6, control grid 7 and cathode 8. Anode 3 obtains operating potential from a source at 37 through choke 9, while the modulated output current I_1 passes blocking condenser 11 and through inductance 16 and by-pass condenser 13 to ground; cathode 5 is grounded through meter 14 which measures the output current I_1. Anode 6 connects with inductance 16 at tap 17, which is substantially central of the inductance, and delivers the output current therethrough to ground by way of condenser 13 while operating potential is supplied to anode 6 from a source at 39 through choke 10. Cathode 8 of tube 2 is connected to ground through meter 15 which indicates the output current I_2. In the lower portion of inductance 16, below tap 17, the currents I_1 and I_2 are combined substantially as represented in Fig. 4. The modulated output is applied to a load represented by resistance 18 through inductance 45 coupled with inductance 16. Tuning condenser 12 is provided substantially in shunt with inductance 16 for tuning the output circuit to resonance at the common high frequency of the carrier components delivered from tubes 1 and 2.

Carrier energy is supplied to the system through a coupling link 40 from any suitable source, not shown. A tuned circuit including inductance 41 and condenser 43, and blocking condenser 42, is coupled with the link 40 and has a connection directly to control grid 7 of tube 2 and a branch connection through coupling condenser 23 with the control grid 4 of tube 1, whereby carrier energy is supplied to tubes 2 and 1 for amplification. A tuned circuit including inductance 25 and condenser 24, and blocking condenser 26, is connected between grid 4 and cathode 5 of tube 1, in resonance with the carrier energy for stabilizing the operation. Coupling condenser 23 may be variable, as shown, for adjusting the carrier drive in the respective grid branches of tubes 1 and 2 for maximum over-all efficiency. The tubes 1 and 2 individually operate as class C amplifiers at high efficiency by virtue of the high negative grid biases from sources 20 and 19, respectively.

Low frequency modulation energy is supplied to the system from inductance 44 coupled with secondary inductances 30 and 31 which are connected together at 32. Low frequency energy is applied from inductance 31 through blocking condenser 29, high frequency choke 27 and inductance 25 to grid 4 of tube 1; and similarly, low frequency energy from both inductances 30 and 31 is applied through high frequency tuned inductance 41 to grid 7 of tube 2. Bias source 20 connects from ground through resistance 28, choke 27 and inductance 25 to grid 4, while bias source 19 connects from ground through resistance 33, which shunts inductance 31, and through inductances 30 and 41 to grid 7. Resistance 28 is in circuit with secondary inductance 31 and a portion of the bias on grid 4 is due to the voltage drop across resistance 28 due to the low frequency current and the rectified high frequency current. Similarly, low frequency current in resistance 33 from secondary inductance 31 produces a voltage drop effective for the bias on grid 7. At the same time, resistance 33 and condenser 29 are so constituted as to proportion the amount of low frequency modulation energy supplied to tubes 1 and 2; tube 1 has impressed thereon a low frequency voltage the positive excursions of which are limited, while tube 2 receives the positive peaks of the low frequency voltage which require the greater proportion of the low frequency power for effective operation. The relative power outputs of the two tubes, however, are dependent upon other factors as well as the proportion of low frequency input, and are adjusted for maximum over-all efficiency in the system.

The grid voltage in tube 1 is limited by the action of resistance 21 and condenser 22, series connected in shunt between grid 4 and cathode 5. Resistance 21 limits the carrier frequency voltage and regulates the low frequency peaks, while 22 acts as a blocking condenser to maintain the bias potential of grid 4.

Many experiments show that the system of my invention is admirably applicable to short wave systems, and that there is no difficulty at all in adjusting the circuits to operate at high efficiency and with good fidelity even at 30 megacycles and higher. This order of magnitude of frequency is given only as an illustration however, and not as a limit as regards the carrier frequency. The condenser 23 does not have to be variable, although by means of a suitable variation the magnitude of the energy impressed on tube 1 can be established at the best value. This variation is by no means critical and after having found the appropriate setting, a fixed condenser can be used. It is to be understood that in my system condenser 23 is not used for producing a ninety degree phase shift since I do not use impedance inverters in my system, as is, for instance, the case in the Doherty system. The carrier frequency reactance of condenser 23 is not required to have a certain impedance relation to resistance 21, since in my system this resistance merely relieves grid 4 of excessive control voltage at times when the applied voltage lies within the most positive cap portion of the low frequency wave.

It can therefore be seen, so far as the input elements of my system are concerned, that there can be no great difficulty in the adjustment of the elements. From the simplicity of the dynamic plate branches it is also seen that only tuning by means of condenser 12 is necessary. The simplicity of the system of my invention may perhaps be best appreciated by describing how the circuits are adjusted.

With tube 2 removed, the negative grid bias 20 of tube 1 is set at about twice the cut-off voltage for an appropriate steady plate potential applied to anode 3 through high frequency choke 9. The tuning condensers 24 and 12 in the input and output branches of tube 1 are varied until maximum power is noted in the load branch 45, that is, until maximum current from tube 1 flows over the proper resistance 18. The current measured by meter 14 was, in one experiment, 75 milliampers. Tube 2 is then inserted and the negative grid bias 19 is set at about eight times the cut-off voltage of tube 2 when operating at rated steady supply voltage on anode 6 applied through high frequency choke 10 and tap 17 on coil 16. The input branch of tube 2 is then tuned by means of condenser 43 and condensers 24 and 12 are slightly retuned until absolute resonance in the input and output is established. Under these conditions, there is essentially the same power transfer to the load branch 45 since for such a high negative bias 19 on grid 7, tube 2 is blocked, that is, no current flows through meter 15 and therefore no power is delivered from the anode circuit of tube 2. The negative grid bias 19 is now decreased until a small plate current begins to flow in tube 2. In the same experiment meter 15 registered 10 milliampers. With same carrier power excitation acting on coil 41 and no modulation power applied through coil 44, the settings of condensers 24 and 43 are adjusted until maximum response is secured in tube 2; this condition is reached when the meter 15 indicates a maximum current. This adjustment does not put the circuits off resonance as condensers 24 and 43 are dynamically in multiple; the adjustment gives, however, a change in the L/C ratio without a change of the CL product. In the experiment here described, the current maximum on meter 15 was 20 milliamperes. The negative bias 19 is then again increased until cut-off occurs, that is, until the meter 15 again indicates zero current. In addition, the modulation voltage is now applied by means of excitation in output coil 44 and increased until maximum power is obtained in the load branch 45, that is, until maximum current flows in resistance 18; this maximum will be about twice that obtained from tube 1 alone. For 100% modulation the reading of meter 15 increased to about 60 milliamperes and the reading in meter 14 decreased to about 30 milliamperes.

It is to be understood that internal modulation can be accomplished also by cathode modulation, and in screen grid tubes by applying the modulation energy to the screen. I have found, also that the "beam" tubes are especially suitable. Neutralization is avoided by using the screen grids of such tubes for preventing objectionable feedback from anode to control grid.

Fig. 2 schematically shows the use of "beam" tubes in the positions of tubes 1 and 2 of Fig. 1, with the major portion of the circuit of Fig. 2 the same as in Fig. 1; like reference characters indicate like elements in Fig. 2 so that it will be necessary only to describe the modifications introduced in Fig. 2. Elements 51 in tube 1 and 53 in tube 2 represent the beam forming electrodes connected with the respective cathodes 5 and 8. Screen grids are shown at 52 in tube 1 and at 54 in tube 2, and are energized through series resistors 47 and 48, respectively from the source of anode potential 39. Conventional by-pass condensers are provided at 45 and 46. Meter 35 in the negative bias circuit for grid 7 of tube 2, meter 36 in the negative bias circuit for grid 4 of tube 1, plate current meter 15 of tube 2, plate current meter 14 of tube 1, and meter 38 of the load branch are used for adjusting to optimum output power. The adjustment is carried on as described above in connection with Fig. 1. The pick-up coil 45 in the load branch connects to ground and over a high frequency ammeter 38 and through a concentric line 49 to aerial 50. A single source of anode potential is provided at 39 to supply the anode power to both tubes 1 and 2 instead of the separate sources of Fig. 1. Choke coils 9 and 10 and blocking condenser 11 are effective as in Fig. 1, however, for isolating the separate anode potentials while by-pass condenser 13 provides a path for the high frequency currents to ground, as in Fig. 1. Various other arrangements may be employed for applying the proper anode potentials, from one or separate sources, to the anodes 3 and 6. Resistance 33 is omitted and choke 34 is added in the low frequency supply circuit to tube 2 as a further variation from the circuit of Fig. 1. Also, resistance 21 is connected from the grid to a point above blocking condenser 26, thus permitting elemination of blocking condenser 22 in Fig. 2.

It is to be understood that the modulation power can also be supplied by means of a choke and condenser coupling arrangement from the modulation input or by using a peaking coil in series with a suitable resistor in the modulation input and transferring the power either directly or over a condenser or other suitable coupling to the separate tubes 1 and 2. Parallel peaking circuits can also be used. These various arrangements are applicable especially where the system of my invention is used in connection with television transmission. It is to be further understood that ordinary screen grid tubes can be used although beam tubes, as indicated in Figs. 2 and 3, are especially effective in the upper megacycle range.

Fig. 3 shows another modification of the novel system of my invention. Tubes 1 and 2 are of the type shown in Fig. 2, with anode potentials supplied from the source 39 through choke 10' and load inductance 16 to both anodes 3 and 6, anode 6 being connected at tap 17 as in Fig. 1 and blocking condenser 11 being eliminated. The output is supplied to antenna 50 from a tap connection 56 on load inductance 16 in lieu of pick-up coil 45. The particular feature of Fig. 3 resides in the provision of only one tuning condenser 43 in the carrier input circuit while there are two tuning condensers 12 and 60 provided in the respective anode circuits of tubes 1 and 2. Tap 55 on input coil 41 and condenser 23 are used for adjusting the carrier input to tubes 1 and 2; tube 1 receives carrier energy through coupling condenser 23*a*, tap 55 and the portion 41*b* of coil 41, while tube 2 receives carrier energy direct from coil 41 by connection to the upper portion 41*a*. Limiting resistor 21 and blocking condenser 22 are provided for tube 1 as in Fig. 1. The low frequency modulation input is substantially the same as in Fig. 2, the grid 7 of tube 2 being energized through choke 34 and coil 41. Grid 4 of tube 1, however, receives modulation energy directly in Fig. 3 by connection through high frequency choke 27, resistor 57, which balances the impedance of the circuit, and coupling condenser 29 to tap 32. A tuning condenser is shown at 58. The adjustments in Fig. 3 are similar to those above prescribed in reference to Fig. 1; condensers 12 and 60 which are dynamically in multiple in the output circuit are manipulated like condensers 24 and 43 in Fig. 1, while the respective tuning condensers 43 and 58 in the input are adjusted like condenser 12 in Fig. 1. Reference character 61 denotes a blocking condenser to isolate the potential of the D. C. source from the antenna circuit.

Though not shown here, the system of my invention may also be embodied in a push pull arrangement. Inasmuch as the circuits illustrated in Figs. 1, 2 and 3 indicate that the two tubes 1 and 2 are dynamically in multiple, even though different voltages may be effective therein, the push pull arrangement would require four tubes or the equivalent in electrodes. If two small tubes are used in push pull to furnish the base portion of the wave, one large tube can be inductively or directly coupled to my system to supply the cap portions. In my experiments I have also found that with certain degrees of input excitations I can produce output currents where the two side bands are very pronounced while the carrier is almost suppressed. I have also experimented with excitations where one side band was emphasized by means of suitable adjustment of condenser 60 of Fig. 3. Condenser 60 can be omitted if double side band transmission is used.

The high efficiency of the system of my invention is evident from the following experimental data. The anode potential measured at tube 1 was 800 volts, and the corresponding anode current at meter 14 was 75 milliamperes; the negative grid bias was −110 volts and the corresponding grid current flow at meter 36 was 100 microamperes. For tube 2, the anode potential measured 800 volts, the anode current was 10 milliamperes, and the negative grid bias measured 260 volts, which effectively blocked grid current. Carrier frequency power of 12 watts was applied to the system by means of the link circuit 40, and no modulation energy was employed at this time. The carrier frequency was about 33 megacycles/sec. The total plate input for both tubes was, therefore, $800\times85\times10^{-3}=68$ watts. The effective output resistance was 73 ohms and the effective load current 0.82 ampere at meter 38, giving an unmodulated carrier power output of $73\times0.82^2=49$ watts. This yields an efficiency of 4900/68=72%. Thereafter, modulation energy was applied for internal modulation as has been described hereinbefore, the voltages on the respective anodes and grids being the same as for the unmodulated condition. For 100% modulation as verified by a cathode oscillograph, the andoe current I_1 as measured with a direct current meter in the anode circuit of tube 1 dropped to only 15 milliamperes while the anode current of tube 2 rose to 100 milliamperes; the grid currents were 700 microamperes in tube 1 and 3.5 milliamperes in tube 2. The link circuit 40 supplied 12 watts unmodulated carrier power at 640 volts effective, while modulation energy at 300 volts was effective for internal total modulation. The same load resistance of 73 ohms produced for an increased modulated output current of 1.05 amperes, or an output power of 80.3 watts which, compared with the total anode input power of 93 watts, gives anode efficiency as high as 87%. It is to be noted that I can completely modulate 50 watts unmodulated carrier with only about 1 watt of modulation power input, as compared with the usual requirement of 50 watts modulation energy for completely modulating 50 watts carrier energy in a high level class C amplifier.

The simplified control arrangement for adjusting the circuits for maximum efficiency is attributable to the dependence of current flow in tube 2 upon the modulating voltage. Synchronism of the currents from tubes 1 and 2 in the output is dependent, therefore, primarily on phase relations in reference to the low frequency modulation and not the high frequency carrier, and may accordingly be controlled with greater ease and stability. Phase relations at carrier frequency are of secondary concern, and inasmuch as purposeful phase displacement is avoided the maintenance of satisfactory phase relations in this respect is facilitated.

While I have disclosed my invention in certain known embodiments thereof, I desire it understood that further modifications may be made therein, and that no limitations upon my invention are intended except as may be 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, a continuously operable low level class C electron tube amplifier, an intermittently operable high level class C electron tube amplifier, means for supplying carrier energy to said amplifiers in substantially parallel paths, means for supplying modulation energy to said amplifiers for modulating said carrier energy in both said amplifiers, means for selectively regulating the carrier and modulation energy applied to said low level amplifier for delivering carrier energy therefrom at maximum efficiency substantially at the level of unmodulated carrier energy and for limiting the modulation therein substantially to the negative peaks of the modulation energy below the said level of unmodulated carrier energy while the modulation in said high level amplifier is effected substantially under the positive peaks of the modulation energy above the said level of unmodulated carrier energy intermittently as such positive peaks occur, and an output circuit for combining the modulated carrier energy from both said amplifiers.

2. In combination, a low level class C electron tube amplifier, a high level class C electron tube amplifier, separate circuits for supplying carrier energy to said amplifiers in substantially parallel relation, a modulation energy input circuit including parallel paths for supplying modulation energy to each of said amplifiers for modulating said carrier energy in both said amplifiers, means connected with said low level amplifier for regulating the carrier and modulation energy applied thereto for delivering carrier energy therefrom at maximum efficiency substantially at the level of unmodulated carrier energy and for limiting the modulation therein substantially to the negative peaks of the modulation energy below the said level of unmodulated carrier energy while the modulation in said high level amplifier is effected substantially under the positive peaks of the modulation energy above the said level of unmodulated carrier energy intermittently as such positive peaks occur, and an output circuit for combining the modulated carrier energy from both said amplifiers.

3. In combination, a low level class C electron tube amplifier, a high level class C electron tube amplifier, a carrier energy input circuit including parallel paths for supplying carrier energy to each of said amplifiers, a modulation energy input circuit including parallel paths for supplying modulation energy to each of said amplifiers for modulating said carrier energy in both said amplifiers, means for selectively regulating the carrier and modulation energy applied to said low level amplifier for delivering carrier energy therefrom at maximum efficiency substantially at the level of unmodulated carrier energy and for limiting the modulation therein substantially to the negative peaks of the modulation energy below the said level of unmodulated carrier energy while the modulation in said high level amplifier is effected substantially under the positive peaks of the modulation energy above the said level of unmodulated carrier energy intermittently as such positive peaks occur, and an output circuit for combining the modulated carrier energy from both said amplifiers.

4. The combination set forth in claim 2 including tuning means in each of said separate circuits for supplying carrier energy to said amplifiers and in said output circuit for adjusting the combination for operation at maximum efficiency.

5. The combination set forth in claim 3 wherein said amplifiers are connected with parallel portions of said output circuit, and including tuning means in said carrier energy input circuit and in each portion of said output circuit for adjusting the combination for operation at maximum efficiency.

6. In combination, a pair of non-linear electron tube amplifiers, means for supplying carrier energy to said amplifiers in substantially parallel paths, means for supplying modulation energy to said amplifiers for modulating said carrier energy in both said amplifiers, an output circuit for combining the modulated carrier energy from both said amplifiers, and means for selectively regulating the operation of each of said amplifiers for limiting the modualtion in one of said amplifiers below the level of unmodulated carrier energy therein substantially to the negative peaks of the modulation energy and the modulation in the other of said amplifiers substantially to the positive peaks of the modulation energy intermittently as they occur.

7. In combination, a pair of non-linear electron tube amplifiers each including an anode, a cathode and a grid electrode, means for energizing said electrodes including a source of grid bias potential individual to each of said amplifiers, means for applying voltages of carrier frequency in like phase to both said grid electrodes, means for applying voltages of modulation frequency to said grid electrodes for modulating the carrier energy in both said amplifiers, an output circuit for combining the modulated carrier energy from both said amplifiers, and means including said individual sources of grid bias potential for selectively regulating the operation of each of said amplifiers for limiting the modulation in one of said amplifiers below the level of unmodulated carrier energy therein substantially to the negative peaks of the modulation energy and the modulation in the other of said amplifiers substantially to the positive peaks of the modulation energy intermittently as they occur.

8. The combination set forth in claim 7 wherein said sources of grid bias potential are adjusted for class C operation of said amplifiers, one at high level for positive peak modulation and the other at low level, and including means connected with the amplifier operative at low level, class C, for relieving the grid electrode therein of excessive voltage at times when the applied voltage includes the positive peaks of the modulation energy.

9. In combination, an electron tube including cathode, grid and anode electrodes, a tuned circuit connected between said cathode and grid electrodes, and means for biasing said grid electrode substantially beyond cut-off potential; a second electron tube including cathode, grid and anode electrodes, a second tuned circuit connected between the last mentioned cathode and grid electrodes, and means for biasing the last said grid electrode substantially beyond cut-off potential at a level relatively higher than that of the bias potential on the first said grid electrode; means for supplying energy of carrier frequency to both said tuned circuits, and means for applying modulation energy simultaneously to both said grid electrodes for modulating said energy of carrier frequency in both said electron tubes, modulation in the first said electron tube being effected substantially under the negative peaks of said modulation energy below the level of unmodulated carrier energy and that in the said second electron tube substantially under the positive peaks of said modulation energy above the level of unmodulated carrier energy, by virtue of the different grid bias potentials;, and an output circuit for combining the modulated carrier energy delivered from both said electron tubes.

10. The combination set forth in claim 12 including tuning means in said output circuit, the aforesaid tuned circuits being individually adjusted for maximum efficiency of operation in said electron tubes and said output circuit being tuned by said tuning means for resonance with both said tuned circuits.

11. The combination set forth in claim 9 including a resistance and a blocking condenser connected in series between the cathode and grid electrodes in the first said electron tube; said resistor having a potential drop thereacross, resulting from carrier and modulation energy therein, effective to suppress modulation in the first said electron tube substantially under the positive peaks of said modulation energy.

12. In combination, an electron tube including cathode, grid and anode electrodes, means for biasing said grid electrode substantially beyond cut-off potential, and a tuned output circuit connected between said cathode and anode electrodes; a second electron tube including cathode, grid and anode electrodes, means for biasing the last said grid electrode substantially beyond cut-off potential at a level relatively higher than that of the bias potential on the first said grid electrode, and a tuned output circuit connected between the cathode and anode electrodes in the said second electron tube; an input circuit for applying energy of carrier frequency to both said grid electrodes, and means for applying modulation energy simultaneously to both said grid electrodes for modulating said energy of carrier frequency in both said electron tubes, modulation in the first said electron tube being effected substantially under the negative peaks of said modulation energy below the level of unmodulated carrier energy and that in the said second electron tube substantially under the positive peaks of said modulation energy above the level of unmodulated carrier energy, by virtue of the different grid bias potentials; said tuned output circuits having portions in common for combining the modulated carrier energy delivered from both said electron tubes.

13. The combination set forth in claim 12 including tuning means in said input circuit; the said tuned output circuits being individually adjusted for maximum efficiency of operation in said electron tubes and said input circuit being tuned by said tuning means for resonance with both said tuned output circuits.

14. The combination set forth in claim 12 including a resistance and a blocking condenser connected in series between the cathode and grid electrodes in the first said electron tube; said resistor having a potential drop thereacross, resulting from carrier and modulation energy therein, effective to suppress modulation in the first said electron tube substantially under the positive peaks of said modulation energy.

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