July 20, 1948. J. C. FERGUSON 2,445,568

MODULATING SYSTEM

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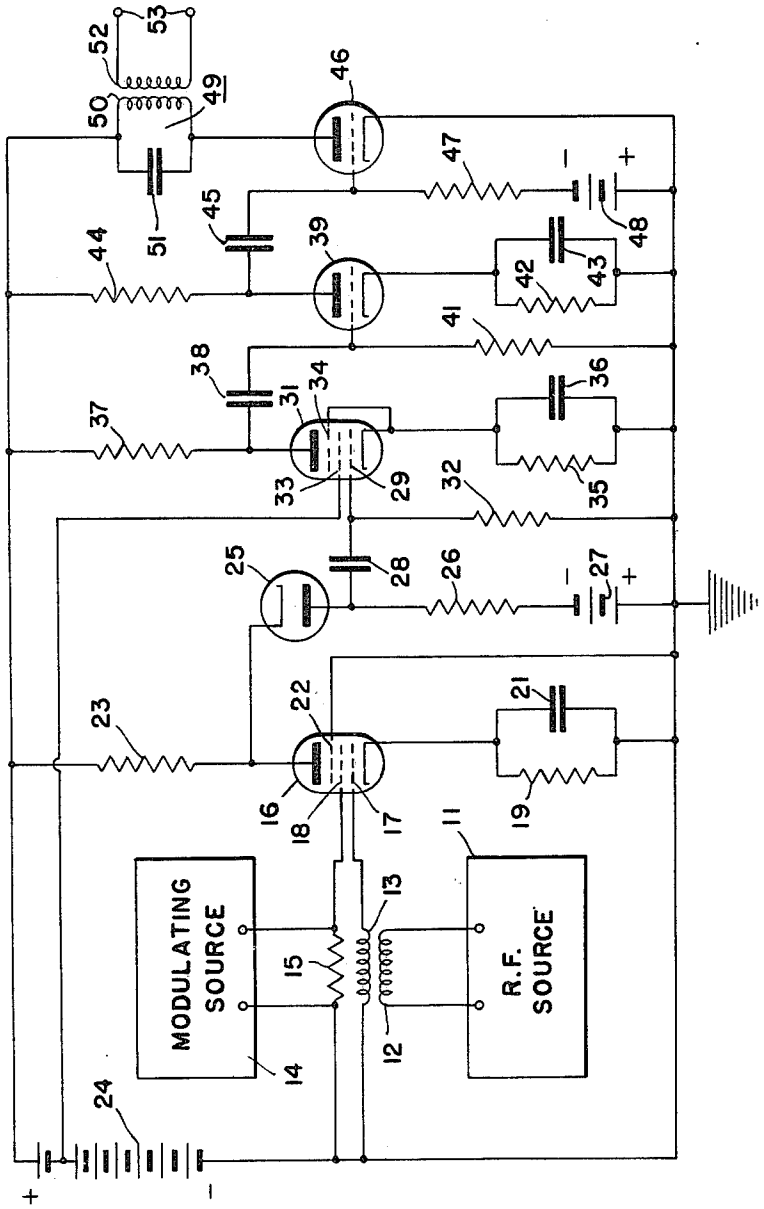

FIG. 1

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FIG. 2

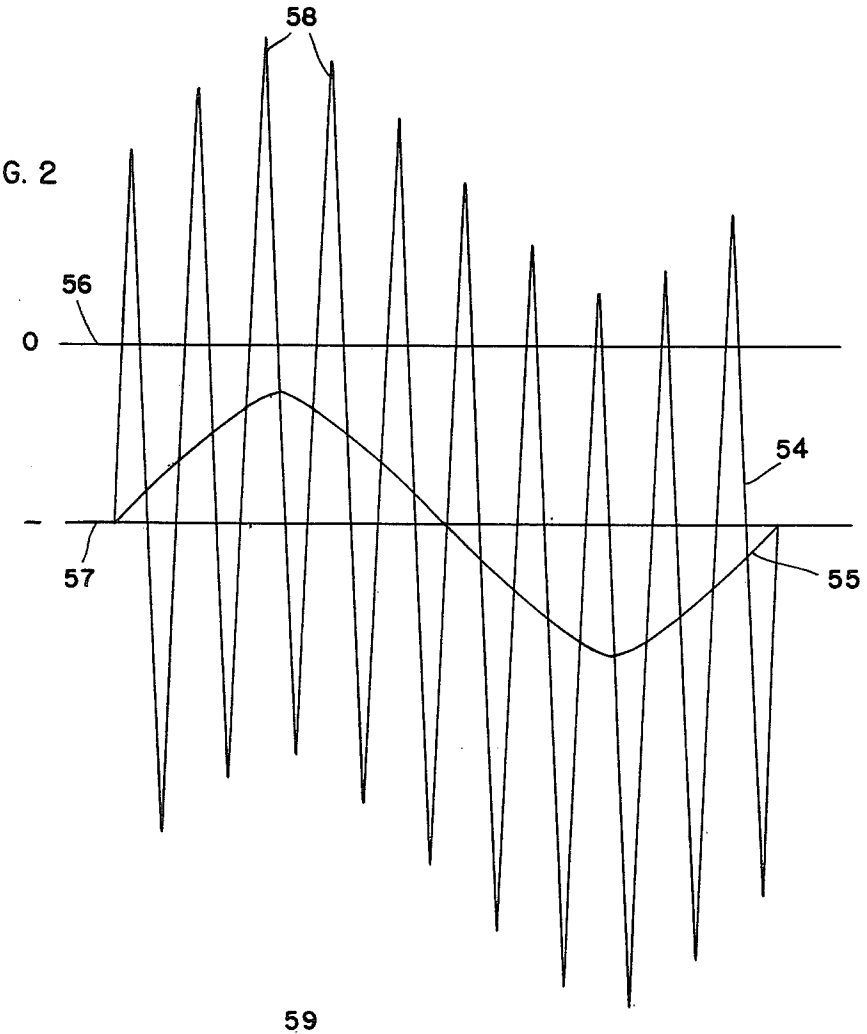

FIG. 3

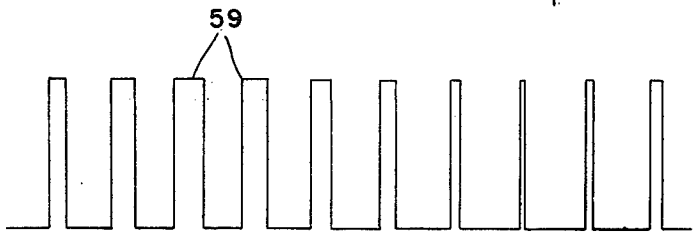

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FIG. 4

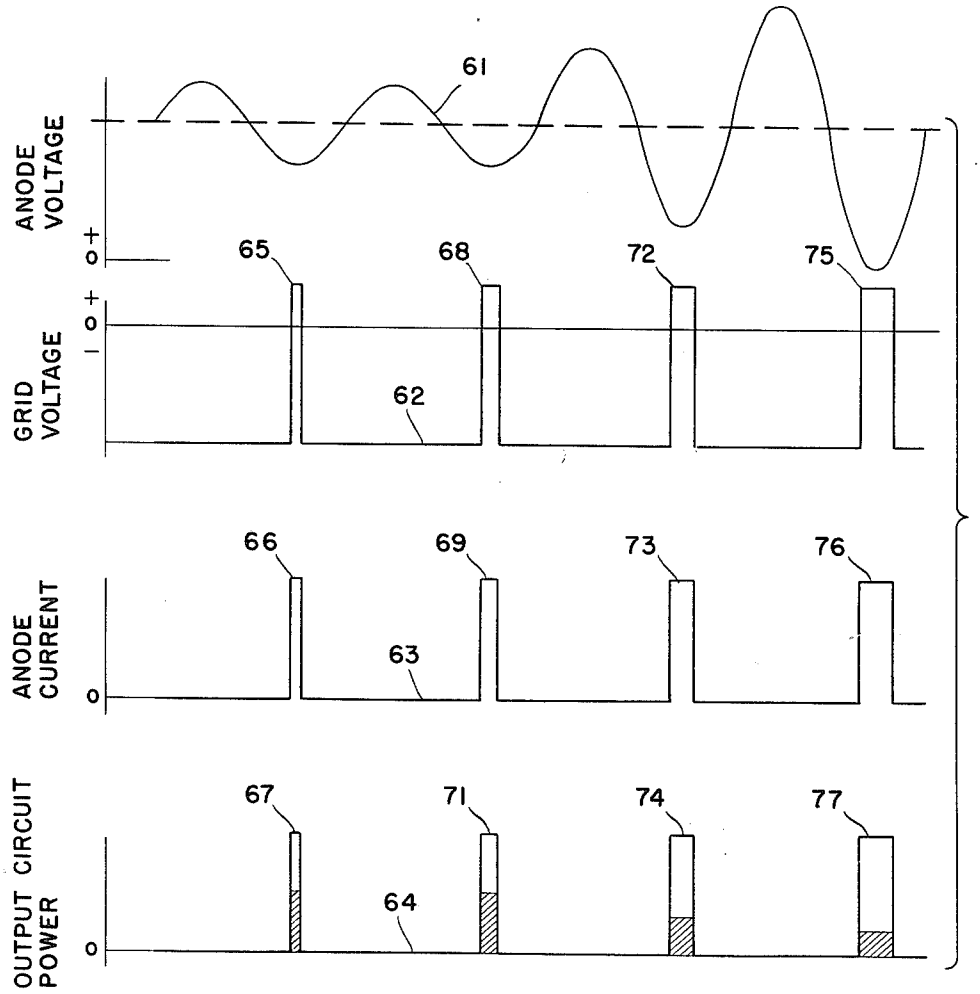

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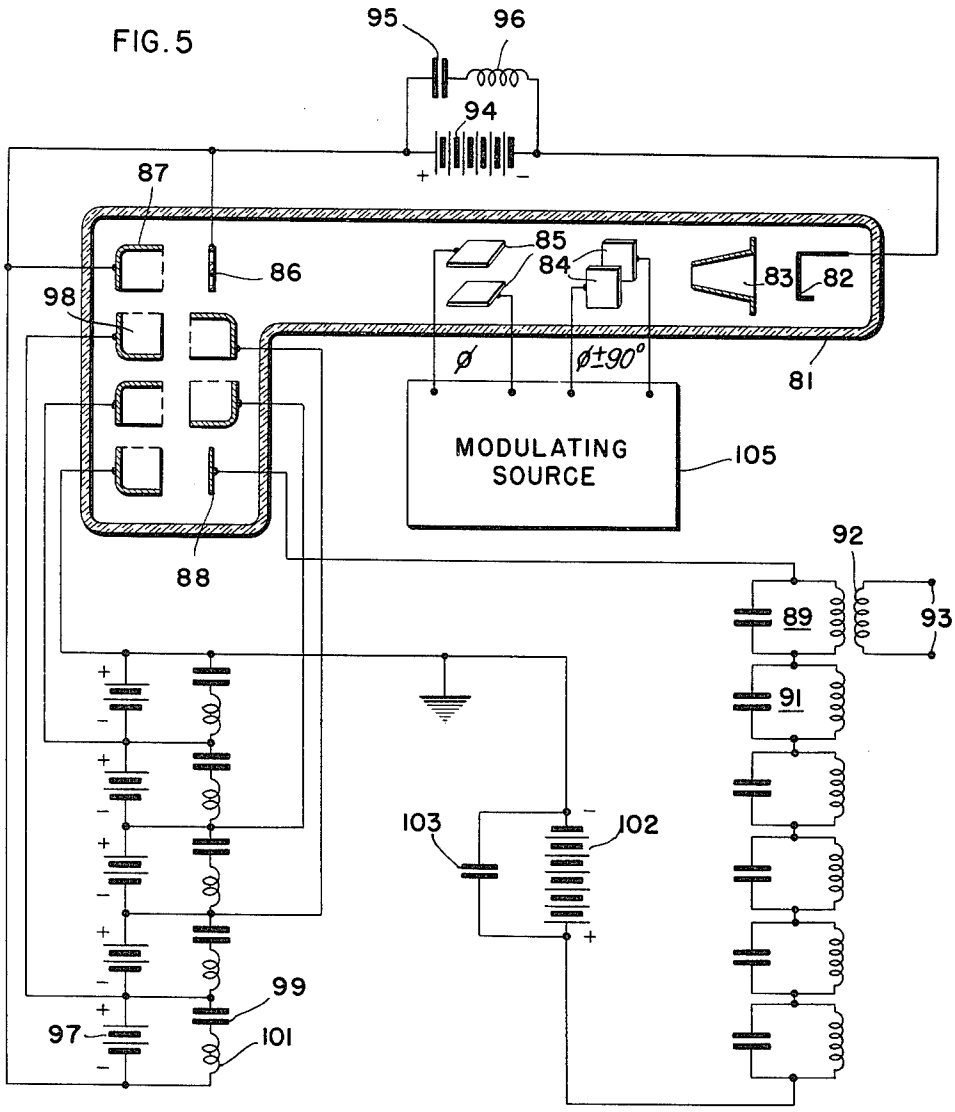
FIG. 5



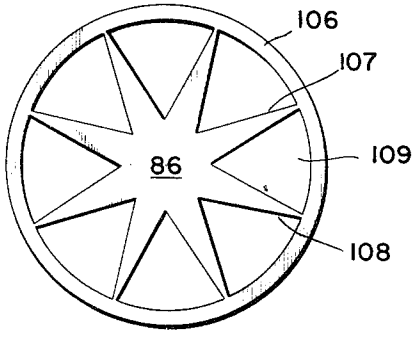


FIG. 6

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FIG. 7

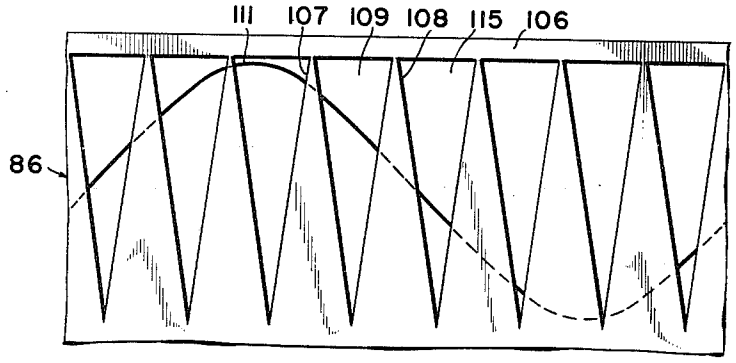


FIG. 8

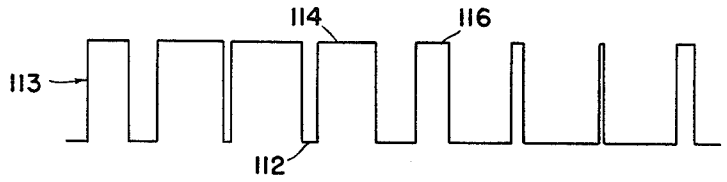
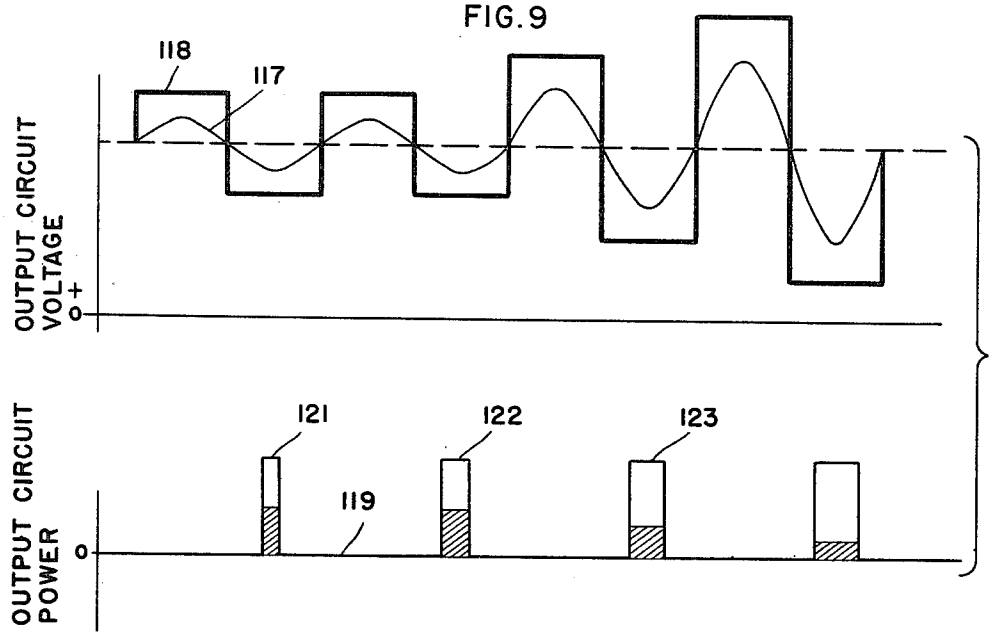


FIG. 9



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Patented July 20, 1948 2,445,568

UNITED STATES PATENT OFFICE

2,445,568

MODULATING SYSTEM

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Application October 7, 1943, Serial No. 505,291

3 Claims. (Cl. 179—171.5)

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This invention relates to modulating systems and particularly to a system of this character capable of being operated at a high efficiency which is substantially independent of the percentage of signal modulation.

According to conventional practice, a frequently employed means for modulating a carrier wave in amplitude in accordance with a modulating signal comprises an electronic device having included in the output circuit thereof a tuned network which is resonant at the frequency of the carrier wave. Energy varying in amplitude in accordance with the modulating signal is applied to the input circuit of the device periodically to control an electron flow in the device. In this manner pulsating energy, varying in magnitude in accordance with the modulating signal, is supplied to the tuned output circuit.

One such device of this character is a grid-modulated power amplifier arranged for so-called class C operation. The input circuit of the amplifier tube is coupled to a carrier wave generator for excitation thereby. The input circuit also is provided with a relatively large negative bias so that anode current flows only during predetermined portions of the alternating current cycles of the carrier wave. The time during which the anode current flows is controlled by the strength of the modulating signal. It is well known that the time during which plate current is allowed to flow corresponds to the time when the plate voltage is at a low positive value. At this time the voltage drop across the tube also is low so that the largest portion of the energy which is delivered to the amplifier will be absorbed by the tuned output circuit thereof. The remainder of the energy is dissipated at the anode of the tube. Consequently, such a device is capable of operation at a relatively high efficiency.

However, in the conventional arrangements of this type both the phase-opposed grid and plate voltages and, consequently, the in-phase grid and plate currents vary substantially sinusoidally. The result of such an arrangement is that, at the instant that the grid voltage is increased sufficiently to effect a flow of plate current, the plate voltage is considerably more positive than its minimum value which is reached later in the cycle. Consequently, the plate current which flows at this instant does so at a greater plate voltage than the plate current which flows later in the cycle at the time of minimum plate voltage. It is evident, therefore, that the ratio of the energy which must be dissipated at the plate

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of the tube with respect to the energy delivered to the output circuit varies in accordance with the time of its occurrence in the alternating current cycle and also varies in accordance with the amplitude of the modulating signal. In other words, there is inherent in such an arrangement a variation in efficiency of the device depending upon the percentage of carrier modulation.

It is well known in the art, however, that the maximum plate efficiency of a class C amplifier theoretically can be made to approach 100% if the time duration of the plate current flow is made exceedingly small so that it occurs only at the instant that the plate voltage is a minimum. In order to make the time interval during which plate current is allowed to flow exceedingly small, when sinusoidally varying grid voltages are employed, it is necessary to bias the input circuit of the tube sufficiently negative so that only the peaks of the grid voltage wave effect the flow of plate current in the tube. Obviously, such an arrangement decreases the input power to the tube with the consequent decrease in the output power. The result of such an arrangement is that, even though the device is capable of being operated at an extremely high efficiency, the power which it is possible to derive from the output circuit is so small that it has substantially no practical value. Therefore, it has been the practice heretofore to effect a compromise between high operating efficiency and high power output.

It is an object of the present invention, therefore, to provide a novel arrangement for modulating a power amplifier, whereby to effect a substantial increase in the operating efficiency thereof without sacrificing any of the output power.

It is another object of the invention to provide a modulating arrangement for a power amplifier, whereby the amplifier may be operated at a relatively high efficiency which is substantially independent of the percentage of modulation.

Still another object of the invention is to provide a modulating arrangement for a power amplifier in which the output energy thereof is varied only in accordance with the time duration of signal-modulated variable width impulses and, within limits, is independent of the amplitude of the impulses.

A further object of the invention is to provide a modulating system in which a novel excitation means is employed to produce output circuit cur-

rents of substantially constant values, irrespective of the percentage of signal modulation.

A still further object of the invention is to provide, in a modulating system, means for producing substantially constant peak values of both output circuit voltage and current, irrespective of the percentage of signal modulation.

Another object of the invention is to provide, in a modulating system, novel means for generating impulses having widths variable in accordance with a modulating signal.

Another object of the invention is to provide a novel method of signal-modulating a carrier wave by variable width impulses, whereby to obtain high power output at high operating efficiency.

In accordance with the present invention, there is provided an electronic device having an output electrode connected to a circuit which is tuned to the carrier frequency. Means are provided for exciting the device by impulses having variable time durations representative of the intelligence signals by which it is desired to modulate the carrier wave. Preferably, the exciting impulses are generated in a manner to impart thereto wave forms which are substantially rectangular. Such a system is susceptible of operation in a manner, whereby current flow in the electronic device occurs only when the voltage of the output electrode is at a minimum value.

In accordance with one of the illustrative embodiments of the invention, there is provided an electronic class C power amplifier, the anode of which is connected to an output circuit having a single resonant network tuned to the frequency of the carrier wave which it is desired to modulate. The variable width exciting impulses are generated at the carrier frequency, which in this embodiment is of relatively low frequency, that is, not exceeding two megacycles. The wave shape of the output circuit voltage in this case is substantially sinusoidal.

In accordance with the other illustrative embodiment of the invention, there is provided an electron multiplier as the signal-modulated power amplifier. The output electrode of the multiplier is connected in circuit with a plurality of resonant networks, one of which is tuned to the fundamental carrier wave frequency, and the others of which are tuned, respectively, to harmonics of the carrier wave frequency. The wave form of the output circuit voltage can be made to approximate a rectangular form by the employment of the harmonically tuned resonant output networks. The exciting rectangular wave form impulses are generated by the deflection of an electron beam over a multi-apertured electrode placed between the electron source and the initial stage of the electron multiplier. The apertures of the electrode are formed in such a manner that the electron beam is alternately intercepted and transmitted to the multiplier. Depending upon the amplitude of the beam deflection, the relative times of the beam interception and transmission are controlled to vary the time durations or the widths of the rectangularly shaped impulses generated thereby. The modulating signal is employed to control the amplitude of the electron beam deflection. In operation, the maximum frequency obtainable is limited only by the inherent limitations of the electron multiplier.

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 one embodiment of the invention capable of operation at relatively low frequencies;

Fig. 2 illustrates the modulation of the generated carrier frequency wave in accordance with a modulating signal, as produced by the apparatus of Fig. 1;

Fig. 3 shows typical amplifier exciting impulses generated by the apparatus of Fig. 1;

Fig. 4 is a group of curves illustrating the mode of operation of the apparatus of Fig. 1;

Fig. 5 illustrates an embodiment of the invention employing a novel impulse generating apparatus and capable of operation at relatively high frequencies;

Fig. 6 is a view, to an enlarged scale, of the electrode of Fig. 5 by means of which the variable width impulses are generated.

Fig. 7 is a developed view of the electrode of Fig. 6 showing the manner of electron beam deflection over the apertures thereof;

Fig. 8 illustrates the wave form of the electronic current generated by the apparatus of Fig. 5; and

Fig. 9 is a group of curves illustrating the mode of operation of the apparatus of Fig. 5.

Referring now more particularly to Fig. 1 of the drawings, a source of radio frequency waves 11 is connected to the primary winding 12 of a coupling transformer of which a winding 13 is the secondary. The radio frequency source may be conventional and develops an alternating current at the desired radio frequency having any predetermined wave form. As used in this embodiment of the invention a triangular wave form is preferred, although it will be obvious that the invention is not necessarily limited to such a wave form. There also is provided a source 14 of a modulating signal which likewise may be conventional. The modulating signal voltage is developed across a resistor 15.

A mixer tube 16, which preferably is a pentode is provided for combining the modulating signal with the radio frequency wave in a predetermined manner. For this purpose the secondary winding 13 is connected to the control grid 17 and the resistor 15 is connected to the screen grid 18 of the mixer tube. The cathode of the tube is connected to ground through a resistor 19 with which there is connected in parallel a by-pass condenser 21. The suppressor grid 22 of the mixer tube is connected directly to ground. The anode of this tube is connected through an output resistor 23 to the positive terminal of a battery 24 of which the negative terminal is connected to ground.

The output circuit of the mixer tube 16 is coupled to a diode 25 by means of a connection from the anode of the mixer tube to the cathode of the diode. The anode of the diode is connected to ground through a series arrangement of a resistor 26 and a negative biasing battery 27.

The output circuit from the anode of the diode 25 is coupled by means of a condenser 28 to the control grid 29 of an amplifier tube 31 which may be a pentode, as illustrated. The control grid of this tube also is connected through a grid leak resistor 32 to ground. The screen grid 33 of the amplifier tube is connected to an intermediate point on the battery 24. The suppressor grid 34 is connected to the cathode of the amplifier tube, which in turn is connected to ground through a

resistor 35 with which there is connected in parallel a by-pass condenser 36. The anode of the amplifier tube is connected through an output load resistor 37 to the positive terminal of the battery 24. The parameters of the amplifier tube circuits are adjusted so that the tube operates with a large amplification factor.

The output circuit of the amplifier tube 31 is coupled by means of a condenser 38 to the control grid of a clipper or limiter tube 39 which may be a triode, as illustrated. The control grid of the limiter tube also is connected to ground through a grid leak resistor 41. The cathode of the limiter tube is connected to ground through a resistor 42 with which there is connected in parallel a by-pass condenser 43. The anode of the limiter tube is connected through an output load resistor 44 to the positive terminal of the battery 24. The parameters of the circuits associated with this tube are adjusted so that the tube is operated, during substantially the entire time that space current is allowed to flow, in the saturation region.

The output circuit of the limiter tube 39 is coupled by means of a condenser 45 to the control grid of a power amplifier tube 46 which, as illustrated, may be a triode. The control grid of the power amplifier tube also is connected to ground through a series arrangement of a resistor 47 and a negative biasing battery 48. The anode of the power amplifier tube is connected through a parallel resonant circuit 49 comprising an inductor 50 and a condenser 51 to the positive terminal of the battery 24. A coil 52, inductively arranged with respect to the inductor 50, serves to couple the output circuit of the power amplifier tube to the output load circuit terminals 53. The voltage of the biasing battery 48 is selected for a value, whereby the power amplifier tube is arranged for so-called class C operation. The parallel resonant circuit 49 is tuned to the frequency of the radio frequency wave generated by the source 11.

In the following description of the operation of the embodiment of the invention shown in Fig. 1, reference to the curves of Figs. 2 and 3 will be made for explanatory purposes. Each half cycle of the alternating current wave generated by the source 11 and appearing in the secondary transformer winding 13 has a triangular form as illustrated by any of the half cycles of the curve 54 of Fig. 2. The generated wave is unmodulated so that the peak values of all half cycles of like polarity are equal. Also, the wave form of the voltage developed in resistor 15 of Fig. 1 may be as represented by the curve 55 of Fig. 2, it being assumed that a sinusoidal modulating signal is employed. By reason of the mixing of these two waves in the tube 16, the voltage developed in the output resistor 23 has the wave form and frequency of the generated radio frequency wave and is superimposed upon the modulating voltage wave 55 of Fig. 2 so that the output voltage envelope conforms to the wave shape of the modulated voltage. The envelope of the curve 55 of Fig. 2 illustrates this condition.

The mixed voltage wave is impressed upon the diode 25 which, because of the negative biasing by battery 27, is rendered conducting for only those half cycles of the signal-modulated alternating current wave which exceed a predetermined value. Thus, in Fig. 2 the diode is conducting for those half cycles of the alternating current wave which exceed in amplitude the voltage represented by the line 56. The line 57 represents the average value of the radio frequency wave which, as indicated, is considerably more negative than the threshold voltage of the diode represented by the line 56.

Consequently, only those portions of the positive half cycles of the alternating current wave 54 which are represented above the line 56 are utilized to develop voltages in the output circuit of the diode 25. It is readily apparent that the amplitudes of these voltages vary in accordance with the percentage of signal modulation. However, as will appear subsequently, the varying amplitude of the voltage impulses appearing in the output circuit of the diode is of no consequence in the operation of this system. Furthermore, it will be noted that the base portions of the impulses 58 vary in accordance with the percentage of signal modulation. Since the bases of these impulses are on the time axis of the curves, the widths of the bases are measures of different time durations which, as illustrated, vary in accordance with the modulating signal.

The triangular shaped impulses 58 are greatly amplified by the amplifier tube 31, whereby the relative steepness of the leading and trailing edges thereof is increased sufficiently so that these edges are substantially parallel to one another and perpendicular to the horizontal base line.

When these greatly amplified impulses of varying time durations are impressed upon the limiter tube 39, the space current in this tube is soon driven beyond the point of saturation. The result of this type of operation is that all of the impulses are limited to the same amplitude. Thus, in the output circuit of the limiter tube 39, there is produced a series of impulses having substantially rectangular wave forms as illustrated by the impulses 59 of Fig. 3. Although similar in wave form and in amplitude the impulses 59 differ from one another in their widths or time durations. It may be seen, by comparing the widths of the impulses of Fig. 3 with the base widths of the corresponding impulses 58 on the line 56 of Fig. 2, that they are identical. These base widths or time durations of the impulses 59 vary in accordance with the modulating signal and the impulses have a periodicity equal to that of the carrier wave from which they are derived.

The manner in which these impulses are employed to control the power amplifier including the tube 46 will be described in connection with Fig. 4 of the drawings. As in any class C power amplifier, the conduction of space current in the tube is arranged to coincide with the time during which the anode potential is in its least positive region. The current conduction in the tube is in the form of a series of impulses having time durations of less than 180° of an alternating current cycle of amplifier operation. The magnitude of the space current in the tube 46 at any instant is determined by the combined anode and grid potentials at that instant. The anode potential of the tube varies sinusoidally and its amplitude corresponds to the amplitude of the modulating signal as will be demonstrated presently. In distinction to conventional class C amplifiers where the periodic grid potentials to effect conduction in the tube also vary in accordance with the modulating signal, the corresponding grid potentials in a device according to the present invention are maintained substantially constant, as indicated by the uniform amplitude of the rectangular impulses of the curve 62 of Fig. 4. These impulses may be generated in the manner described and are the equivalents of the impulses 59 of Fig. 3. The

amplitude is sufficient to produce saturated space current in the tube for all values of the anode potential. Consequently, the space current in the tube 46 does not vary in its instantaneous magnitude in accordance with variations of the anode potential during the period when the tube is permitted to conduct. The space current impulses in the tube are indicated by the curve 63 of Fig. 4.

In the transformation of direct current power derived from the battery 24 into alternating current power varying in magnitude in accordance with the modulated signal, there is delivered to the amplifier at any instant power or energy derived from the battery which is the product of the instantaneous space current in the tube 46 and the voltage of the battery 24. Since the battery voltage and the space current amplitude are constant, the power delivered to the amplifier varies in correspondence with variations of the time duration of the space current flow in the amplifier tube. The curve 64 of Fig. 4 represents variations in the energy delivered to the amplifier as the amplitude of the modulating signal changes.

The energy delivered to the amplifier is divided between the resonant circuit 49 and the tube 46. The portion which is delivered to the tube at any instant is equal to the product of the instantaneous space current in the tube and the instantaneous anode voltage. This portion of the energy is dissipated in the form of heat at the anode of the tube and represents a loss. The portion of the energy delivered to the amplifier which is absorbed by the resonant circuit 49 serves to sustain sinusoidal oscillations in this circuit. Since this circuit is tuned to the particular radio frequency at which the device is required to operate the circuit acts as a resistance at this frequency. Consequently, any variation in the power delivered to the resonant circuit 49 effects a corresponding variation in the voltage drop across the circuit and in the current circulating therein. These voltage and current variations are transferred to the output circuit terminals 53 by means of the inductive coupling between the inductors 50 and 52.

For a more detailed description of the operation of this embodiment of the invention, assume that in Fig. 4 during the first illustrated cycle of the anode potential voltage curve 61, a voltage impulse 65 of minimum width or time duration is applied to the grid of the tube 46. It is assumed that such an impulse corresponds to a modulating signal voltage of minimum amplitude. During the time that the tube 46 is conditioned for conduction under the control of the impulse 65, the space current flowing therein is represented by the rectangular impulse 66 of curve 63. The power which is delivered to the amplifier during the relatively short conduction period of the tube 46 is represented by the rectangular impulse 67 of the curve 64. The shaded portion of the impulse 67 represents the energy lost by dissipation at the anode of the amplifier tube and the unshaded portion represents the useful power absorbed by the resonant circuit 49. If it be assumed that the magnitude of the useful power is just sufficient to maintain the voltage and current amplitudes in this circuit at the same level as in the alternating current cycle under discussion, then these voltage and current amplitudes during the succeeding alternating current cycle will be of equal magnitude. This is illustrated by the curve 61 wherein the first two alternating current cycles are of equal amplitude.

Assume that during the second alternating current cycle an impulsive voltage represented by the rectangular voltage impulse 68 of curve 62 is impressed upon the grid of the tube 46. The amplitude of this impulse is the same as that of the impulse 65 but the width or time duration thereof is greater. Consequently, the tube is permitted to conduct space current for a longer time than during the preceding alternating current cycle. However, since the tube is operated in the anode current saturation region, the anode current represented by the rectangular impulse 69 of the curve 63 is of substantially the same amplitude as the rectangular impulse 66 but is of longer duration by the difference in time durations of the grid voltage impulses 65 and 68. Similarly, the energy impulse 71 of curve 64 is of the same amplitude but is of greater width than the preceding energy impulse 67. It is clear that, in the second case, there is a greater amount of energy delivered to the amplifier than in the case of the preceding cycle. Inasmuch as the space current in the tube is permitted to flow while the anode potential is slightly greater at the beginning and end of the conducting period than during the preceding cycle, the energy dissipated at the anode of the tube may be slightly greater than in the first case as shown by the shaded portion of the impulse 71. However, the useful energy available for absorption by the resonant circuit 49 also is greater as represented by the unshaded portion of the impulse 71. Since the impedance of the resonant circuit is unchanged, the delivery of additional energy to this circuit effects a corresponding increase in the amplitude of the voltage and current thereof.

Consequently, during the third alternating current cycle, the amplitude of the anode voltage of the tube 46 is greater than in the two preceding cycles. This condition is represented by the third cycle of curve 61 of Fig. 4. If, during the third cycle, a voltage represented by the impulse 72 of even greater width is impressed upon the grid of the tube 46, a space current represented by the impulse 73 is permitted to flow in the tube. It is noted that the width or time duration of this space current impulse is greater than either of the impulses 66 or 69. The power developed is represented by the impulse 74, in which the proportion of the total lost by dissipation at the tube anode and represented by the shaded portion of the impulse 74 is less than in the preceding cycle since the anode current conduction is effected at a lower anode voltage. Hence, an increased proportional amount of energy is available for absorption by the resonant circuit 49 as indicated by the unshaded portion of the impulse 74. A still further increase in the amplitude of the voltage and current in the resonant circuit 49 thereby is effected.

This further increase in the amplitude of the voltage and current in the resonant circuit is illustrated in the fourth alternating current cycle of the curve 61. If, now, during the least positive half cycle of this portion of the anode voltage a further increase in the magnitude of the modulating signal is effected, the representative grid voltage is illustrated by the rectangular impulse 75 of the curve 62. The increased width of the grid current impulsive voltage produces an anode current of corresponding width or time duration as represented by the rectangular impulse 76 of the curve 63. The rectangular impulse 77 of curve 64 represents the additional power or energy delivered to the amplifier. It will be noted that the energy for absorption by the resonant circuit

49 represented by the unshaded portion of the impulse 77 is greater in magnitude than the unshaded portion of the rectangular impulse 74. Consequently, the amplitude of the voltage and current in the resonant circuit during the following or fifth alternating current cycle (not shown) will be greater than in any of the other preceding cycles. The energy which is dissipated at the anode of the tube 46 is represented by the shaded portion of the impulse 77. Again, it is noted that the ratio of the useful energy to the total energy delivered to the amplifier is greater than in the instance of the preceding alternating current cycle. In other words, the efficiency of the device is still further increased.

In the operation of a device of the character described the optimum angle of operation (pulse width in degrees of one alternating current cycle) for the grid to produce maximum efficiency is established initially. Then by decreasing this angle of operation in accordance with a modulating signal there is effected a corresponding decrease in the power available for absorption by the resonant output circuit of the amplifier. This variation of the power output of the amplifier effects an amplitude modulation of a carrier wave substantially as outlined in the foregoing description.

An embodiment of the invention capable of operating at relatively high frequencies in excess of two megacycles is illustrated diagrammatically in Fig. 5, to which reference now will be made. The impulse generation and modulation, together with the amplification thereof may be accomplished in a single electronic device of novel construction. Such a device is enclosed within an evacuated envelope 81. In one end of the envelope there is provided an electron emitting cathode 82 and a conical or otherwise suitably shaped beam-forming electrode 83. The beam so formed is directed between a pair of horizontal deflecting plates 84 and also a pair of vertical deflection plates 85.

The deflected electron beam is directed then to a specially apertured impulse-generating electrode 86, an illustrative form of which will be described presently. Those portions of the electron beam which pass the electrode 86 impinge upon the first secondary emissive electrode 87 of a multi-stage electron multiplier. The multiplier may include any desired number of such electrodes, depending upon the degree of amplification desired. The amplified electron beam is collected from the last stage of the multiplier by an electrode 88 which is connected to an output circuit.

The output circuit includes a plurality of parallel resonant networks of which the network 89 is tuned to the fundamental radio frequency. The other networks, such as 91 etc., are tuned to different harmonics of the fundamental radio frequency. An inductor 92 is coupled to the resonant network 89 and is connected to output load terminals 93 at which there is developed the modulated radio frequency wave in a manner which will be described subsequently.

The impulse-forming electrode 86 is maintained at a positive potential with respect to the cathode 82 by a source of direct current such as a battery 94. This battery may be shunted by a series tuned circuit, including a condenser 95 and an inductor 96 for the purpose of by-passing the radio frequency components and for providing selectivity in the operation of the device in cases where it is to be used in radio frequency or

intermediate frequency amplifier circuits. Each succeeding electrode of the electron multiplier is maintained at an increasingly higher positive potential by means of suitable sources of direct current, such as a battery 97, connected between the first and second multiplier electrodes 87 and 88, respectively. These sources of direct current also may be provided with radio frequency by-pass circuits, such as the tuned circuit, including a condenser 99 and an inductor 101, connected in shunt with the battery 97.

The electrode potentials for the multiplier are shown as separate direct current sources, which is a preferred arrangement in cases where the device is to be operated in a manner necessitating high current densities in the multiplier portion thereof. In this manner the device is not subject to poor voltage regulation. However, it is contemplated that the multiplier electrode potentials may be supplied in any other conventional manner such as from a voltage divider connected to a single source of direct current. The potential for the output circuit of the device is provided by a source of direct current such as a battery 102 which also may be shunted by a condenser 103 for the purpose of by-passing the radio frequency component.

The deflection of the electron beam is accomplished by supplying the deflection voltages to the plates 84 and 85 from a source of modulating signal 105. Such an arrangement may be effected in any conventional manner, whereby a circular deflection or rotation of the electron beam is produced. The radius of the circular path traversed by the beam is determined by the strength of the modulating signal.

In Fig. 6 there is shown, to an enlarged scale, one of several different forms of the impulse-forming electrode 86. In the illustrative form of this electrode there is provided an outer supporting ring 106. Extending radially from the center of the electrode to the ring 106 are a number of triangular shaped web members such as 107 and 108. These members are formed to define a plurality of sector-like apertures such as 109. These apertures are not true sectors of a circle since the straight sides thereof do not radiate from the center of the curved side thereof. Consequently, the angular distance between the straight sides of the apertures 109 varies in accordance with the radial distance from the center of the electrode at which the angular distance is measured.

Referring now to the operation of the modification of the invention disclosed in Fig. 5, additional reference will be made to Figs. 7, 8, and 9. Assume that a sinusoidal modulating signal is employed to control the deflection of the electron beam over the apertured electrode 86. In Fig. 7 there is shown a developed view of the electrode 86 and the manner in which the electron beam is alternately intercepted and transmitted by the electrode. For the purpose of illustrating the operation of the device, assume that, in one rotation of the beam, a complete alternating current cycle of the modulating signal occurs. Actually, of course, the beam will make a large number of traversals at a constant angular rate over the electrode during one cycle of the modulating signal. The electron beam is represented in this figure by the sine wave curve 111. The solid lines indicate those portions of the beam transmitted through the electrode apertures. The broken lines indicate the beam portions intercepted by the web members of the electrode.

While the beam is traversing that portion of its path which causes its impingement upon the radial web member 107, it is intercepted and prevented from reaching the first stage multiplier electrode 87. In Fig. 8 this condition is represented by the portion 112 of a curve 113. Subsequently, when the electron beam is being deflected between radial web members 107 and 108 it passes through the aperture 109 to impact the multiplier electrode 87, whereby to produce an electron current in the multiplier which is represented by the portion 114 of the curve 113. It is readily apparent that the passage of the electron beam through the following aperture 115 produces an electron current in the multiplier which is represented by the portion 116 of curve 113. Thus, it is seen that a series of substantially rectangular electron current impulses, such as 114 and 116, are generated. Also, depending upon the amplitude of beam deflection, the time durations or widths of the generated impulses vary accordingly. Also, it is evident that these impulses are generated at a fundamental frequency which is a function of the number of apertures provided in the electrode 86 and the rate of rotation of the beam.

Since the electron current impulses generated in the manner described are substantially rectangular in wave form there is developed at the output electrode or anode 88 energy at the fundamental frequency of the impulses and at substantially all harmonics thereof. Energy at the fundamental impulse frequency is to be utilized in the output circuit connected to the terminals 93. Consequently, the resonant network 89 is tuned to the fundamental frequency for absorption of the generated energy at this frequency. By also including in the output circuit of the device a suitable number of networks such as 91, each tuned to a different harmonic of the fundamental frequency, the energy which is developed at the anode 88 at the harmonic frequency will be absorbed by the respective harmonically tuned networks. In this manner the wave shape of the anode voltage variations may be made substantially rectangular.

Referring to Fig. 9, the sinusoidal curve 117 represents the variation in the voltage drop across the resonant network 89. The rectangular wave form curve 118 represents the voltage variation at the anode 88 of the electronic impulse generating device. It is assumed that the deflection of the electron beam over the apertured electrode 86 is appropriate to generate a series of electron current impulses similar to the impulses 114 and 116 of Fig. 8 but successively increasing in width or time duration. Similarly to the correspondence between output circuit current and power in the embodiment of the invention illustrated in Fig. 1, the wave shape of the power delivered to the output circuit of Fig. 5 is rectangular, corresponding to the current impulses. Some of these rectangular power impulses are illustrated by the curve 119 of Fig. 9. The increased widths of successive ones of these impulses represent corresponding variations in the magnitude of the modulating signal. If it is assumed that the energy represented by the unshaded portion of the impulse 121 is just sufficient to maintain the amplitude of the curves 117 and 118 as represented by the first cycle of these curves, then the second illustrated cycle will be of equal amplitude as illustrated. The impulse 122 is generated during this second cycle and is of greater width or time duration than the impulse 121. Consequently, the energy available for absorption by the resonant circuit 89, as represented by the unshaded portion of the impulse, is greater than in the previous instance. The result is an increase in the amplitude of the voltage and current of the resonant circuit during the succeeding cycle. Likewise, if the third generated impulse 123 is of still greater width, a further increase in the voltage and current of the circuit 89 will be produced during the fourth alternating current cycle, as illustrated.

It is noted that during the entire time that the electron current is permitted to flow, the voltage of the anode 88 is at a constant minimum value during any particular alternating current cycle. Therefore, it is possible to adjust the various circuit parameters in such a manner that the energy which must be dissipated at the anode is maintained at a substantially constant value, irrespective of the percentage of signal modulation. Obviously, a system of this character is capable of operation at an efficiency which is substantially independent of the percentage of signal modulation.

Improved operation of a signal-modulated power amplifier in accordance with the instant invention is achieved by obviating the need for a negative grid bias considerably greater than that required to effect the cutoff of anode current. In conventional class C power amplifiers this greater grid bias is required because of the manner in which the tube is periodically conditioned for operation under the control of the modulating signal and the alternating exciting voltage. The varying amplitude of the modulating signal has the effect of correspondingly altering the effective grid bias of the amplifier tube so that successive positive half cycles of the exciting voltage can produce corresponding variations in the operating grid angle. It is seen that, by using substantially rectangular grid voltage impulses varying in width in accordance with the modulating signal as the means for controlling the power amplifier, it is only necessary to bias the amplifier tube sufficiently negative to effect cutoff of anode current when the grid control voltage is at its minimum value.

It is contemplated that the various novel features disclosed in the two illustrative embodiments of the invention may be combined in a single system in numerous ways, all of which are deemed to be within the skill of those versed in the art and within the scope of this invention. For example, the output circuit of the amplifier tube 46 of Fig. 1 may include addition parallel resonant networks in the manner disclosed in the embodiment of Fig. 4.

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 therefore, it 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. A device for generating a series of impulses having variable time durations comprising, means for producing a beam of electrons, means for effecting a variable amplitude deflection of said beam, an electrode disposed in the path of said electron beam and having an aperture for effecting periodic passages of said beam therethrough, said aperture being triangularly shaped

to effect a variation in the time durations of said beam passages in accordance with the amplitude of said electron beam deflection and being defined by web members having their inner ends joined together at the center of said electrode and their outer ends joined together at the periphery of said electrode, and means including an electron multiplier disposed in a manner to intercept and amplify the portions of said electron beam passing through said apertured electrode for developing corresponding voltage impulses of substantially constant amplitude and having time durations varying in accordance with said modulating signal.

2. A device for generating a series of impulses having time durations varying in accordance with a modulating signal comprising, means for producing a beam of electrons, means for effecting a deflection of said beam proportional in amplitude to the modulating signal, an apertured electrode disposed in the path of said electron beam, said electrode having a plurality of apertures for effecting periodic passages of said beam therethrough, said apertures being triangularly shaped to effect a variation in the time durations of said beam passages in accordance with the amplitude of said electron beam deflection and being defined by triangular web members having their bases and apexes respectively joined together and supported respectively at the center and periphery of said electrode, and means including an electron multiplier disposed in a manner to intercept and amplify the portions of said electron beam passing through said apertured electrode for developing corresponding voltage impulses of substantially constant amplitude and having time durations varying in accordance with said modulating signal.

3. A device for generating a series of substantially rectangular voltage impulses of uniform amplitude having time durations varying in accordance with a modulating signal comprising, means including an electron emitting cathode and a focusing anode for producing a beam of electrons, means including a plurality of deflecting elements for effecting a rotational deflection of said beam under the control of said modulating signal, the radius of said rotational deflection being proportional to the modulating signal, an apertured electrode disposed in the path of said

electron beam, said electrode having a plurality of radially extending triangular-shaped apertures for effecting periodic passages of said beam therethrough, said apertures being defined by triangular web members having their bases joined together at the center of said electrode and their apexes supported by an outer ring, the time durations of said beam passages varying in accordance with the radius of rotation of said electron beam, an electron multiplier having a plurality of secondary emissive electrodes disposed in a manner to effect the impingement of the portions of said electron beam passing through said apertured electrode upon one of said multiplier electrodes, an electrode in said multiplier for the collection of said multiplied electron beam portions, and means including an output circuit impedance device coupled to said electron collecting electrode for the development of said voltage impulses.

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