Nov. 12, 1946. J. EVANS 2,411,130

PULSE SIGNALING SYSTEM

Filed Aug. 12, 1943 3 Sheets-Sheet 1

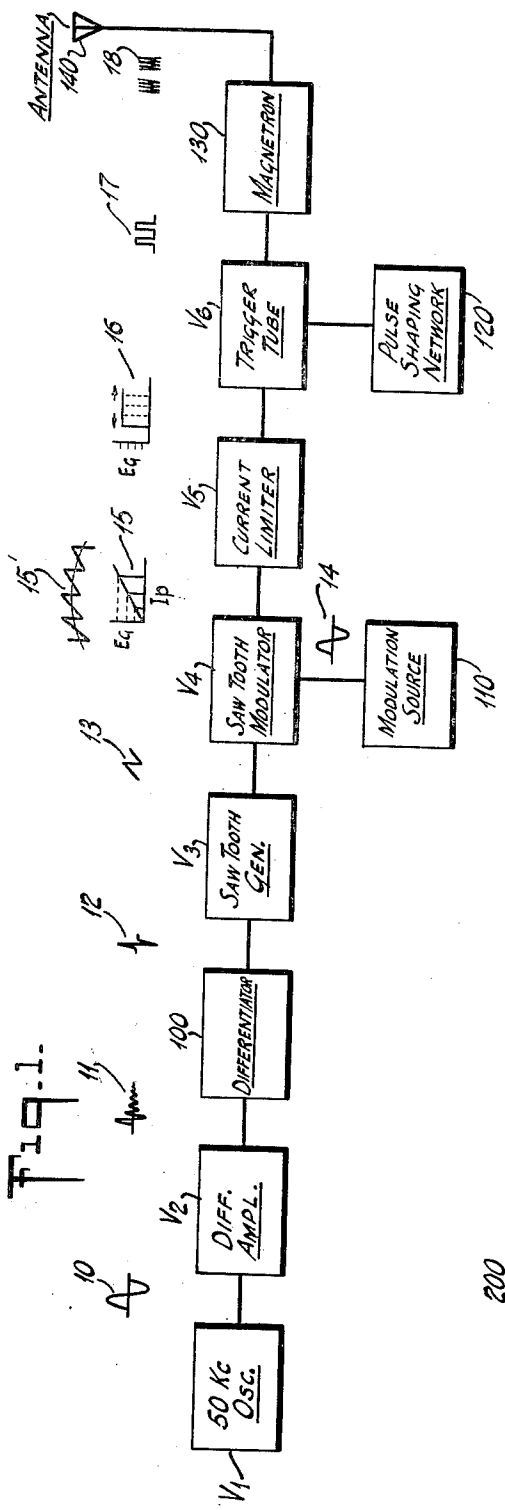


Fig. 1.

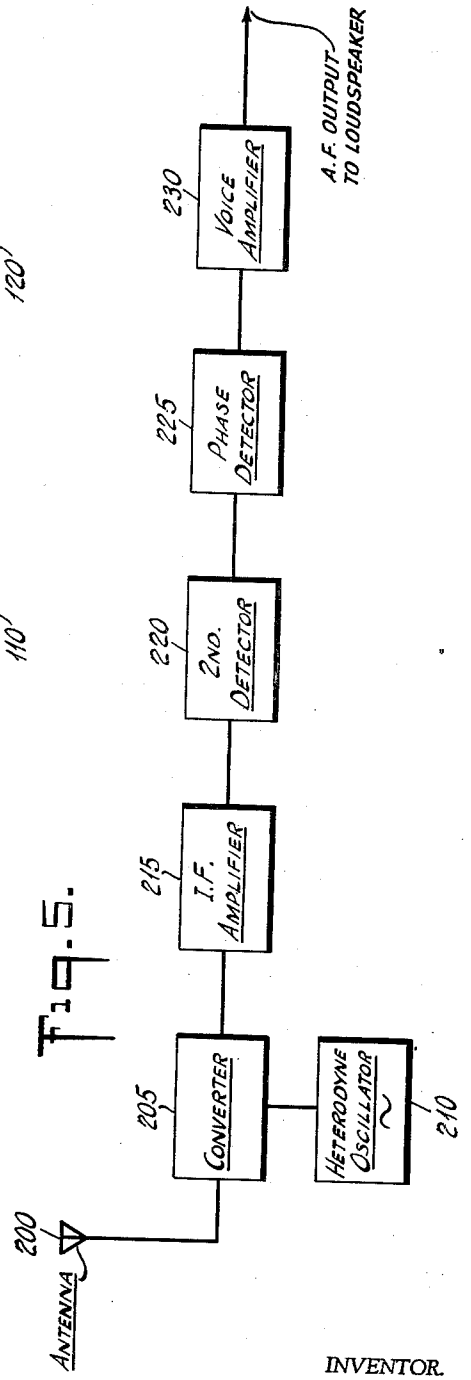


Fig. 5.

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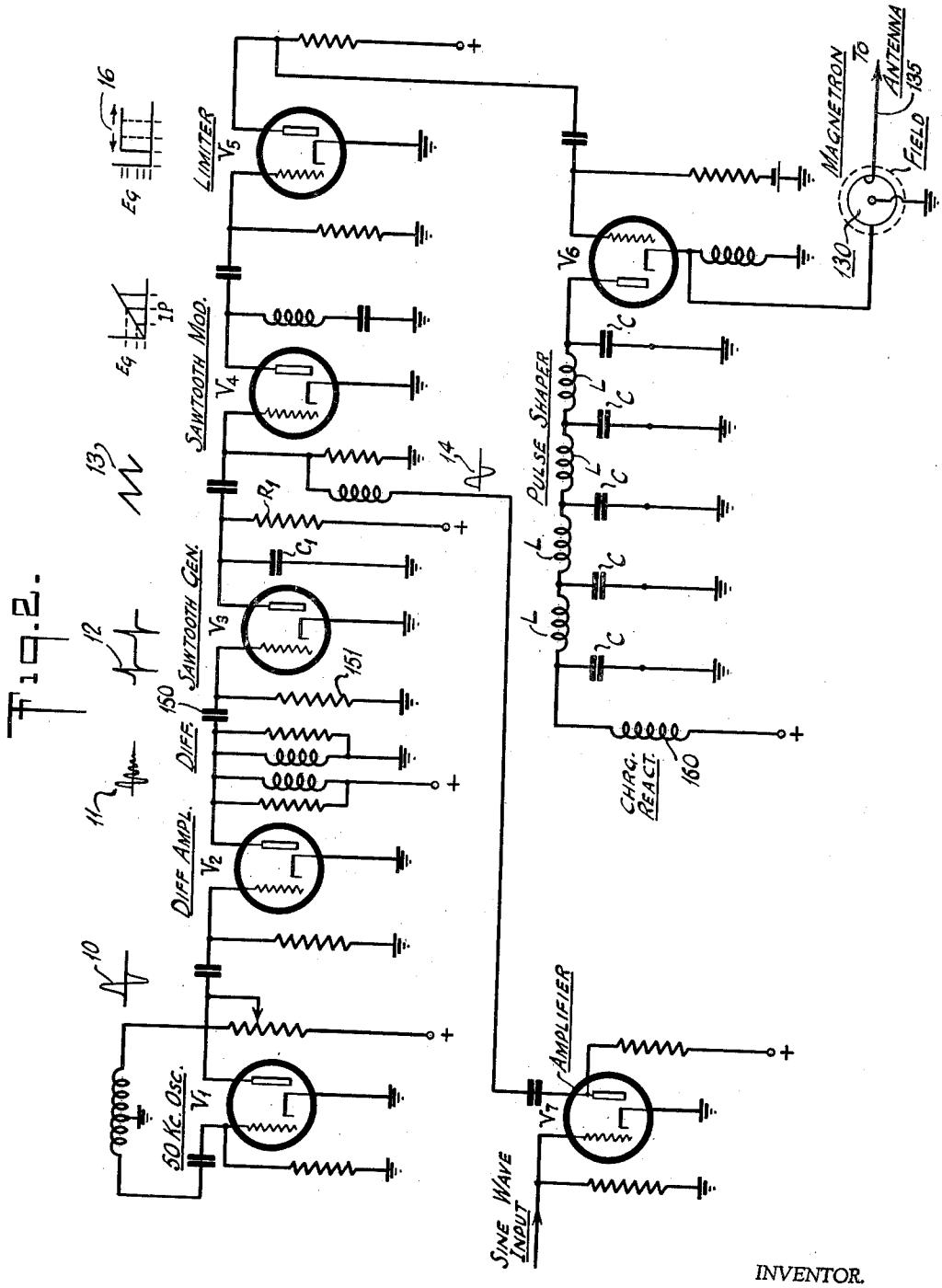


Fig. 2.

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Fig. 3.

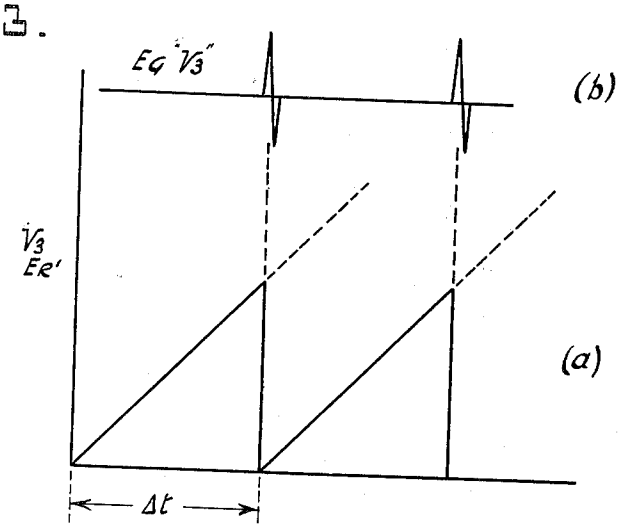
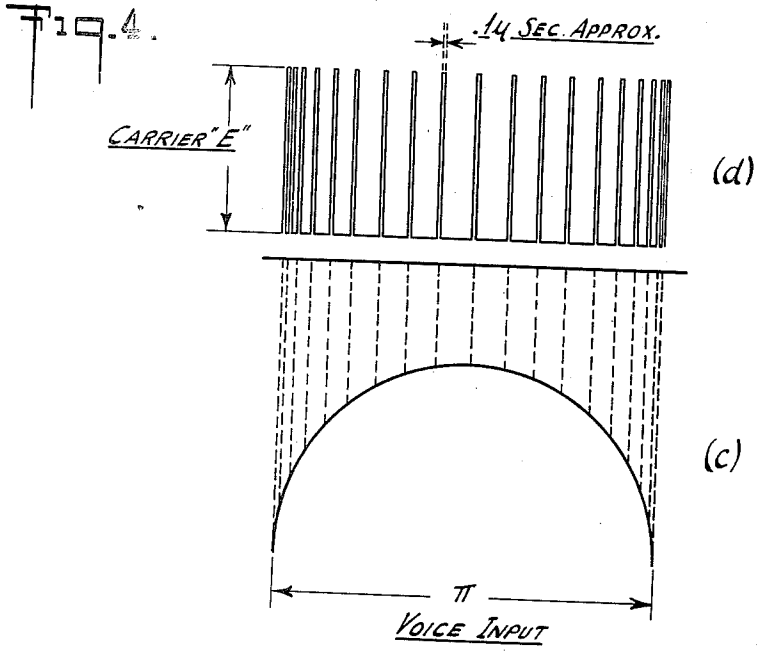


Fig. 4.



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UNITED STATES PATENT OFFICE

2,411,130

PULSE SIGNALING SYSTEM

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Application August 12, 1943, Serial No. 498,283

11 Claims. (Cl. 250—17)

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The present invention relates to a method of and apparatus for modulating a device inherently requiring a constant amplitude of voltage. In a more specific aspect, the invention relates to a pulse transmission system, and particularly to a method of and apparatus for generating pulses of ultra high frequency energy by means of a magnetron, and for varying the time of occurrence of these generated pulses in accordance with modulating potentials.

A requisite condition in employing a multiple resonant cavity type of magnetron to efficiently produce pulses of ultra high frequency energy is that the voltage to be applied momentarily to the magnetron for keying or firing the same should have a constant amplitude. This voltage should be in the form of a pulse of short duration having an extremely rapid rise and a top which is essentially flat. The pulse system of the present invention provides means for satisfying this condition and also means for varying the number of generated pulses of ultra high frequency per modulation cycle without changing the average pulse rate per second. Putting it in other words, the present invention describes a system for retaining the optimum shape of pulse to be supplied to the magnetron and for causing the pulse grouping to be a function of the instantaneous amplitude of the signalling component.

In accordance with the embodiment of the present invention to be described herein, a sinusoid of voltage of varying frequency (as would be delivered for example by the output of a voice operated microphone or the voltage derived from a picture scanning system) is caused to modulate the output of a saw-tooth generator circuit, so that the starting time of the saw-tooth wave is variable. The output of the saw-tooth generator is delivered to a pulse shaping circuit whose purpose is to shape the pulses to a shape optimum for the operation of the magnetron. The variable time spaced pulses are caused to key a magnetron, as a result of which there are obtained pulses of radio frequency energy of constant amplitude and shape but which vary in time spacing. The pulses generated by the magnetron are transmitted over a suitable medium, such as by an antenna or wave guide, for example, and these transmitted pulses may be received on any suitable pulse receiving equipment such as one wherein the received pulses are caused to operate a phase sensitive circuit preceding the receiver low frequency amplifier.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

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Fig. 1 represents, in schematic outline, one embodiment of the invention applied to a transmission system;

Fig. 2 illustrates a circuit diagram following the outline of Fig. 1;

Fig. 3 graphically shows, by means of two curves *a* and *b*, the operation of the saw-tooth generator of Fig. 2;

Fig. 4 graphically illustrates, by means of two curves *c* and *d*, the output of the modulator of Fig. 2 and the final effect of the trigger tube and its associated circuits; and

Fig. 5 illustrates, by way of example, one form of receiving circuit for receiving the pulses transmitted by the system of Fig. 2.

Referring to Fig. 1 in more detail, there is shown a pulse transmission system in accordance with the invention which comprises a suitable oscillator V_1 supplying sine wave energy, of let us say 50 kilocycles, having a wave form **10** to a differentiating amplifier V_2. This differentiating amplifier is biased to cut-off in the absence of input signaling currents. The input signal of wave form **10** is of sufficient amplitude to operate amplifier V_2 at saturation. The output circuit of the differentiating amplifier is tuned with the stray capacity of the circuit elements and the interelectrode capacitance of the tube to a frequency of five megacycles. As a result of this, the positive peak of the input wave of form **10** triggers off the five megacycle resonant circuit in the output of the differentiating amplifier V_2 to produce a damped five megacycle train of wave form **11**. It should be noted that this wave form essentially comprises a substantially sinusoidal five megacycle wave of large amplitude followed by several smaller waves of diminishing amplitude. The wave form **11** is impressed upon the differentiator **100** comprising a suitable series capacitor-shunt resistor arrangement to produce a wave form **12** having a sharp positive peak followed by a sharp negative peak. Wave form **12** is impressed upon a saw-tooth generator V_3. This saw-tooth generator is so arranged that the positive peak of the differentiator pulse **12** causes the generator V_3 to discharge its condenser to produce a wave form such as **13**. Wave form **13** is impressed upon a saw-tooth modulator V_4 together with a sinusoid of wave form **14** from a suitable modulation source **110**. Modulation source **110** may be a voice operated microphone or a picture scanning system for supplying a sinusoid of voltage of varying frequency. The modulator V_4 is biased to cut-off for the maximum saw-tooth voltage from the generator V_3

in the absence of the impressed sinusoid of voltage 14. It will thus be seen that the modulator tube V_4 passes current substantially solely on the positive peaks of the sine wave 14, on which are superimposed the saw-tooth oscillations 13. This is shown graphically at 15 and 15'. The output of the saw-tooth modulator V_4, as graphically represented at 15, illustrates that with varying values of total grid voltage E_g (on the saw-tooth modulator) corresponding with varying amplitude of the sinusoid, there will be correspondingly differently positioned pulses of current I_p starting at different points of the E_g—I_p characteristic. Graph 15' illustrates the superposition of the saw-tooth oscillations upon the sinusoid. The sinusoid plus the saw-tooth components of graph 15' determine the peak instantaneous value of the grid voltage E_g. The output of saw-tooth modulator V_4, which is impressed on the current limiter V_5, comprises a series of pulses whose groupings are a function of the instantaneous amplitude of the sinusoidal voltage 14. The current limiter V_5 serves to remove small amplitude variations so as to provide pulses of uniform amplitude whose leading edges or time of occurrence, so to speak, are functions of the sine wave modulation amplitude. This is graphically represented at 16, wherein the vertical lines represent different positions which the pulses may take, depending upon the instantaneous amplitude of the sinusoidal voltage represented by the marks on the ordinate E_g. The output of the current limiter V_5 is impressed upon a trigger tube V_6 to which is connected a pulse shaping network 120. This network is preferably an artificial line comprising a plurality of sections of inductance and capacitance. The constants of the pulse shifting network 120 determine the shape of the output pulse of the trigger tube V_6. The trigger or discharge tube V_6 is caused to pass current by the application of the leading edge of the pulses applied to it from the output of the limiter, at which time the pulse shaping circuit will give up its energy at a finite rate to the magnetron 130. The voltage pulses applied to the magnetron 130 by the trigger tube are shaped to have a rapid rise, a flat top and a rapid decay, such as shown by the wave form 17. This voltage pulse 17, it will be seen, has extremely steep leading and trailing edges and serves to supply to the electrode of the magnetron 130 momentarily, for the duration of the pulse, a polarizing potential of constant amplitude which is sufficiently large to cause the magnetron to fire or oscillate for the duration of the pulse. The output of the magnetron 130 is in the form of a series of pulses 18 of radio frequency energy spaced in accordance with the spacings of the pulses 17. The output of the magnetron may be transmitted by a suitable line, such as a wave guide, to an antenna 140 for radiation to a suitable remotely located receiver.

Fig. 2 shows the circuit diagram for the system of Fig. 1. Vacuum tube V_1 with its associated circuits represents the 50 kilocycle oscillator. The sine wave output represented by 10 is taken from the anode of vacuum tube V_1 and supplied to the differentiating amplifier V_2, in whose output is a circuit tuned to five megacycles. Tube V_2 is biased to cut-off in the absence of an input wave from the oscillator V_1, and requires an input signal of sufficient amplitude to operate the tube V_2 at plate current saturation. The output of the differentiating amplifier V_2 is shown by wave form 11 which is applied to the differentiator comprising a condenser 150 and a resistor 151. This differentiator converts the first sine wave of large amplitude of wave form 11 to positive and negative peaks represented by wave form 12, the latter in turn being impressed upon the grid of tube V_3. Tube V_3 forms part of a saw-tooth generator having in circuit therewith an RC network composed of condenser C_1 and resistor R_1 whose time constant is approximately 2×10^{-5} second. The grid bias of tube V_3 is adjusted for class B operation. It will thus be seen that the condenser C_1 is charged through the resistor R_1 from the positive terminal of a source of anode polarizing potential, as shown, and that this charge on C_1 will remain thereon until the tube V_3 passes current, at which time the condenser C_1 will discharge through tube V_3. The positive peak of the pulse 12 applied to the grid of tube V_3 by the differentiator is of sufficient value to overcome the grid bias of the saw-tooth generator and to cause the condenser C_1 to discharge through the tube V_3 to produce a saw-tooth pulse 13, which is supplied to the grid of the modulator V_4. The saw-tooth generator thus produces saw-tooth waves at .2 microsecond intervals. The saw-tooth wave 13 represents a voltage wave produced across the resistor R_1. The positive differentiator pulse 12 is supplied to the grid of the saw-tooth generator to cause the discharge of the condenser C_1 at the completion of each charge cycle.

The operation of the saw-tooth generator may be best understood by reference to the graphs of Fig. 3, wherein curve *a* represents the saw-tooth wave form showing the linear rate of charge of the condenser C_1. The charge on condenser C_1 reaches its maximum value once for each charge cycle, at which time the positive impulse from the differentiator circuit represented by wave form *b* impressed on the grid of the tube V_3 causes the condenser to discharge. The graph *a* represents the voltage wave pulses across the resistor R_1.

The modulator V_4 is a tube operating in the class B condition. This modulator is biased to cut-off for the maximum saw-tooth voltage 13 and thus requires a positive voltage greater than a saw-tooth voltage to cause it to pass current. The modulator also has impressed on its grid a sinusoidal output represented by wave form 14 from a speech amplifier V_7. A suitable source of speech waves representing the output of a voice operated microphone or the voltage derived from a picture scanning system is impressed on the grid of the amplifier V_7. The modulator V_4 will pass current substantially only on the positive peaks of the sine wave 14, on which will be impressed the saw-tooth oscillations 13. Thus, it will be seen that each saw-tooth pulse from the generator V_3 produces a corresponding pulse in the output of the modulator V_4. Since the pulses of the saw-tooth wave form 13 are superimposed on the modulating sinusoidal wave 14, there will be a multiplicity of pulses in the output of the modulator V_4 for each positive half cycle of modulation from amplifier V_7.

The graph 15 shows the plate current I_p of the modulator V_4 as a function of the modulation voltage E_g on the grid of a modulator. The modulation voltages are represented by small horizontal marks on the ordinate E_g, while the plate currents are represented by the points of intersection of the vertical lines at the bases or apices of the graph. The resultant output of the tube V_4 with varying amplitude of the sinusoid

14 is essentially as shown in Fig. 4, graph *c*. An inspection of Fig. 4, graph *c*, will show that as the modulation voltage increases over the positive half of the modulation cycle of the sinuoid 14, the spacing between pulses in the output of the modulator increases. During the rising and falling period of this positive half cycle of operation, the pulses are grouped closer together than during the intermediate portion of the positive half cycle of oscillation, and the spacing between pulses varies as a sine function. These pulses are represented by the vertical dotted lines of graph *c*. It will be evident that the pulse grouping in the output of the modulator will therefore be a function of the instantaneous amplitude of the modulation signaling component from the speech amplifier V_7. The graphs of this Fig. 4 will be discussed later in this description.

The output of the modulator V_4 comprising the variably grouped pulses is impressed on the limiter V_5 which serves to remove small amplitude variations to provide, in its output, pulses of uniform amplitude whose leading edges or times of occurrence are functions of the sine wave modulation amplitude. The current limiter V_5 is so biased as to pass current at all times. The graph 16 represents by means of the vertical lines the different starting times of successive pulses impressed on its grid, depending upon the amplitude of the sine wave input represented by the grid voltage E_g.

The anode circuit of the limiter V_5, containing the uniform amplitude and variably grouped pulses, is connected to the grid of the trigger or discharge tube V_6. Trigger tube V_6 is normally biased to cut-off and has associated with its anode a pulse shaping circuit in the form of an artificial line composed of a series of sections of small value inductors L, L shunted by condensers C, C. The constants of the condensers and the inductors determine the shape of the output pulses from the trigger V_6. The artificial line is charged to a suitable value by a positive potential supplied to one end through a charge reactor 160. Although this charging reactor has been shown as a coil, it can be replaced by a resistor, although this is not preferred since a resistor would be inefficient on account of the losses produced thereby. The trigger or discharge tube V_6 is caused to pass current by the application of the leading edge of a pulse applied to its grid from the limiter V_5, at which time the artificial line pulse shaping circuit will give up its energy at a finite rate until the energy stored on condensers C, C in the different sections of the line is dissipated. The moment the trigger V_6 passes current, the artificial line applies a pulse of polarizing potential of steep rectangular wave form to the magnetron 130, thus causing the magnetron to pass current for the duration of the pulse applied thereto by the trigger.

The magnetron comprises a known type of ultra high frequency electron discharge device generator utilizing a resonant cavity in its anode. Such a magnetron may, for example, be of the type described in Hansell Patent 2,217,745, granted October 15, 1940. The magnetron is supplied with an electromagnetic field shown by the circular dotted line for supplying flux in a direction parallel to the cathode. The cathode is shown connected to ground while the anode is shown connected by means of a lead to the cathode of the trigger tube V_6. Output from the anode is supplied by means of a connection 135 connected at one end by means of a loop to the interior of the resonant cavity of the magnetron and connected at its other end to a suitable radiator such as a dipole antenna or an electromagnetic horn. Connection 135 may be a wave guide or a concentric transmission line. This type of magnetron requires a rectangular wave pulse of extremely steep slopes for optimum operation, and this wave form should have a finite operating voltage determined by the magnetic field of the magnetron. The trigger V_6 supplies the required finite voltage for operating the magnetron in pulses.

In the operation of the system of the invention, it will be seen that the number of pulses applied to the trigger tube V_6 per cycle of operation varies in accordance with the ratio of modulation frequency to the oscillator frequency of V_1. Thus, if the oscillator frequency from V_1 is 50 kilocycles and the modulation frequency from tube V_7 is 1000 cycles per second, then the trigger tube will supply to the magnetron 50 pulses per cycle of modulation, whereas if the modulation frequency is 100 cycles per second, then the number of pulses supplied by the trigger tube to the magnetron would be 500 pulses per cycle of modulation. It will thus be evident that although the number of pulses per cycle of modulation is varied, there will be a constant number of pulses applied to the magnetron per second, and that this constant number is equal to the frequency of the originating oscillator, namely 50 kilocycles.

The output pulses from the magnetron are of ultra high frequency and may have a duration of less than .2 microsecond pulse assumed above applied to the grid of the trigger V_6. The power output from the magnetron is essentially constant. As mentioned above, the leading edge of the impulses applied to the grid of tube V_6 by the output of the limiter serves to trigger off the energy in the pulse shaping circuit and this energy is in turn applied to the magnetron load. The energy in the pulse shaping circuit may be discharged or dissipated in a shorter time than the time interval of the impulse applied to the grid of tube V_6. The magnetron will cease generating oscillations immediately upon the complete discharge of the artificial line. As an example, if the impulses applied to the trigger V_6 are each .2 microsecond, the line may be so designed that it will discharge in about .1 microsecond, as a result of which the magnetron will fire or produce oscillations for only .1 microsecond. It is essential, however, that the impulse applied to the grid of trigger V_6 have a time duration sufficiently long to permit the energy in the line pulse shaping circuit to discharge completely, but sufficiently narrow not to prevent the line pulse shaping circuit from starting to recharge. The artificial line must be able to recharge at a time commensurate with the highest modulation frequency involved.

Fig. 4 graphically illustrates, by graphs *c* and *d*, the operation of the trigger tube V_6 and its associated circuits. Each pulse (graph *d*) of approximately .1 microsecond duration represents the envelope shape for the high frequency carrier in the output of the magnetron. The positions of these pulses with respect to the positive half of the modulation cycle, are shown in graph *c*.

The receiver for use with the pulse transmission 2 of Figs. 1 and 2 may, if desired, take the form of Fig. 5. This receiver comprises a suitable antenna pick-up 200 which is connected to a fre-

quency converter 205. The received energy in the converter 205 beats with the oscillations from a heterodyne oscillator 210 to provide in the output of the converter tube pulses at the rate of 50 kilocycles per second of a 20 megacycle carrier. These pulses are amplified in intermediate frequency amplifier 215 and detected in a 50 kilocycle detector 220 which supplies unidirectional pulses at the 50 kilocycle rate to a phase detector 225. This phase detector may, if desired, be a modified type of discriminator circuit for detecting phase changes in pulses. The output of the phase detector is supplied to the voice frequency amplifier 230.

Although I have described a pulsing system wherein pulses are transmitted during only the positive halves of the modulation cycle, it should be understood that the principles of the invention are not limited to such an arrangement because the same principles are applicable to a system wherein symmetrical modulation may be attained by duplication (that is, a composite system) producing pulses during both the positive and negative halves of the modulation cycle.

What is claimed is:

1. In a pulse transmission system, a magnetron, and means for supplying said magnetron with pulses of voltage of constant amplitude, said means including an electron discharge device having a cathode, a grid and an anode, a circuit for biasing said grid negative relative to said cathode to thereby prevent the flow of current through said device, a pulse shaping circuit in the form of a plurality of artificial line sections connected between said anode and a source of unidirectional voltage for charging said line sections, a connection from said cathode to said magnetron, and means for supplying to said grid variably spaced relatively positive voltage pulses of a magnitude sufficient for triggering said electron discharge device to pass current at the occurrence of each of said variably spaced positive pulses, said magnetron generating oscillations solely during the time intervals of the pulses of voltage supplied thereto by said device.

2. A pulse transmission system in accordance with claim 1, characterized in this that each of said variably spaced voltage pulses applied to said grid has a time duration sufficiently long to permit the energy stored in said pulse shaping circuit to discharge substantially completely through said device, but sufficiently short not to prevent said pulse shaping circuit from recharging between said pulses.

3. In a pulse transmission system, a magnetron, and means for supplying said magnetron with pulses of voltage of constant amplitude, said means including an electron discharge device having a cathode, a grid and an anode, a circuit for biasing said device to cut-off, a pulse shaping circuit in the form of a plurality of artificial line sections connected between said anode and a source of unidirectional voltage for charging said line sections, a connection from said cathode to said magnetron, and means for supplying to said grid voltage pulses of constant amplitude which are variably spaced in accordance with the intelligence to be transmitted and of sufficient magnitude and polarity to trigger said electron discharge device to pass current, said pulses having a time duration which is small compared to the interval between them but sufficiently long to permit the energy stored in said pulse shaping circuit to discharge substantially completely through said electron discharge device, the duration of said pulses being sufficiently short, however, not to prevent said pulse shaping circuit from recharging to a desired value in the interval between pulses, said magnetron generating oscillations solely during the time intervals of the pulses supplied thereto.

4. In a pulse transmission system, a source of sine waves of superaudible frequency, a differentiating amplifier coupled to said source for providing damped pulses of steep wave front, said amplifier having a resonant output circuit tuned to a radio frequency, a differentiator coupled to the output circuit of said amplifier, a saw-tooth generator having a control electrode coupled to said differentiator, said generator producing saw-tooth waves under control of the positive peaks of voltage supplied by said differentiator, a modulator coupled to the output of said saw-tooth generator, said modulator being biased to cut-off for the maximum saw-tooth voltage, and a source of sinusoidal voltage waves also coupled to said modulator for enabling said modulator to pass current during the positive portions of said sinusoidal voltage waves, an ultra high frequency oscillator, and means under control of said modulator for keying said oscillator to produce pulses of ultra high frequency energy.

5. In a pulse transmission system, a source of sine waves of superaudible frequency, a differentiating amplifier coupled to said source for providing damped pulses of steep wave front, said amplifier having a resonant output circuit tuned to a radio frequency, a differentiator coupled to the output of said amplifier, a saw-tooth generator having a control electrode coupled to said differentiator, said generator producing saw-tooth waves of a duration less than one microsecond under control of the positive peaks of voltage supplied by said differentiator, a modulator coupled to the output of said saw-tooth generator, said modulator being biased to cut-off for the maximum saw-tooth voltage, and a source of sinusoidal voltage waves also coupled to said modulator for enabling said modulator to pass current during the positive portions of said sinusoidal voltage waves, said current being modulated by said saw-tooth waves, means in the output of said modulator for converting the modulations therein to unidirectional pulses of substantially constant amplitude and whose groupings are a function of the instantaneous amplitude of the sinusoidal voltage waves, a keyer connected to the said means and under control thereof, an energy storage circuit connected to said keyer, said energy storage circuit being so constructed and arranged as to produce a pulse of rectangular wave form with steep slopes when it discharges, a magnetron, and a connection from an electrode of said magnetron to said keyer, whereby the operation of said keyer causes said storage circuit to discharge through said magnetron at the frequency of said unidirectional pulses, said magnetron generating oscillations solely during the time intervals in which said storage circuit discharges therethrough.

6. The method of operating a pulsing system which comprises producing equally spaced pulses of radio frequency energy recurring at a superaudible rate, converting said pulses to unidirectional pulses and producing from said unidirectional pulses other pulses of equal duration which are grouped as a function of the instantaneous amplitude of a sinusoidal voltage wave.

7. The method of operating a pulsing system which comprises producing equally spaced pulses

of radio frequency energy recurring at a superaudible rate, converting said pulses to unidirectional pulses each having a duration short compared to the time intervals between them, utilizing said unidirectional pulses to produce other pulses which are of equal duration but whose spacing is modulated as a function of the instantaneous amplitude of a signal wave, and radiating equal duration pulses of ultra short wave energy of constant power in accordance with the variable spacing between said modulated pulses.

8. The method of operating a pulsing system which comprises producing equally spaced pulses of radio frequency energy recurring at a superaudible rate, converting said pulses to unidirectional pulses each having a duration short compared to the time intervals between them, utilizing said unidirectional pulses to produce other pulses which are of equal duration but whose spacing is modulated as a function of the instantaneous amplitude of a signal wave, removing amplitude variations from said space modulated pulses, and producing from said modulated pulses correspondingly positioned pulses of ultra short wave energy of constant power and equal duration.

9. The method of operating a pulsing system which comprises producing equally spaced pulses of radio frequency energy recurring at an appreciably lower rate, converting said pulses to unidirectional pulses each having a duration short compared to the time intervals between them, utilizing said unidirectional pulses to produce other pulses which are of equal duration but whose spacing is modulated as a function of the instantaneous amplitude of a signal wave, and radiating equal duration pulses of ultra short wave energy of constant power in accordance with the variable spacing between said modulated pulses and at a rate equal to said appreciably lower rate.

10. In a pulse transmission system, a magnetron, and means for supplying said magnetron

with pulses of voltage of constant amplitude, said means including an electron discharge device having a cathode, a grid and an anode, a circuit for biasing said grid negative relative to said cathode to thereby prevent the flow of current through said device, a pulse shaping circuit in the form of a plurality of serially arranged artificial line sections connected between said anode, said line sections comprising series inductance and shunt capacitance, a reactor coil at that end of said pulse shaping circuit farthest removed from said anode, and a source of unidirectional voltage for charging said line sections through said reactor coil, a connection from said cathode to the anode of said magnetron, an inductance coil between ground and the junction point of said last connection with said cathode, and means for supplying to said grid variably spaced relatively positive voltage pulses of a magnitude sufficient for triggering said electron discharge device to pass current at the occurrence of each of said variably spaced positive pulses, said magnetron generating oscillations solely during the time intervals of the pulses of voltage supplied thereto by said device.

11. In combination with an electron discharge device magnetron having a cathode, a surrounding anode constituting a resonant cavity, means for producing a magnetic field parallel to said cathode, a connection from said cathode to ground, means supplying said anode with recurring rectangular wave form pulses of positive polarity and equal duration and of steep starting and trailing edges, said pulses having a magnitude sufficient to cause said magnetron to produce correspondingly positioned pulses of high frequency energy solely during the time intervals of said pulses, and means for varying the spacing between the equal duration pulses supplied to said magnetron in accordance with modulating potentials.

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