

June 28, 1949.

L. GREENWALD

2,474,243

LINE PULSE MODULATOR

Filed Sept. 14, 1945

2 Sheets-Sheet 1

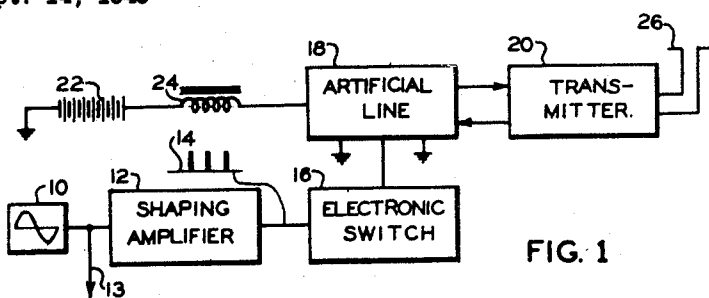


FIG. 1

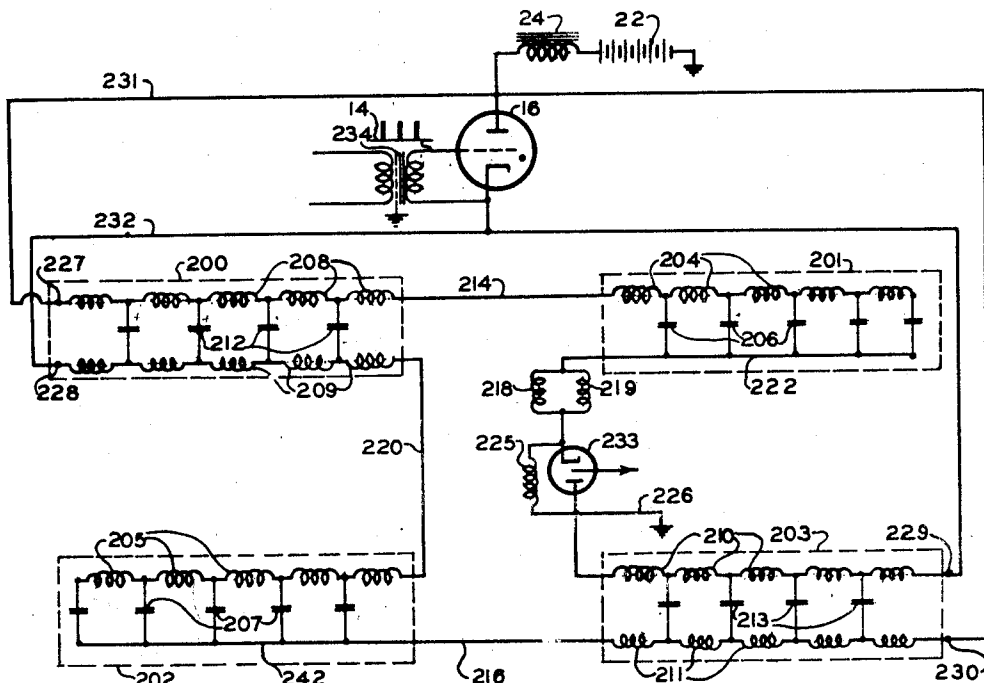


FIG. 2

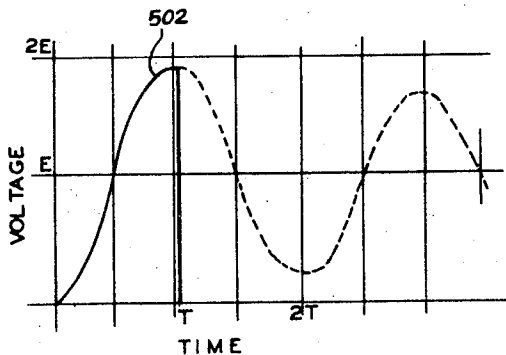


FIG. 5

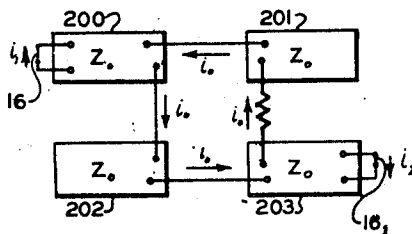


FIG. 4

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2 Sheets-Sheet 2.

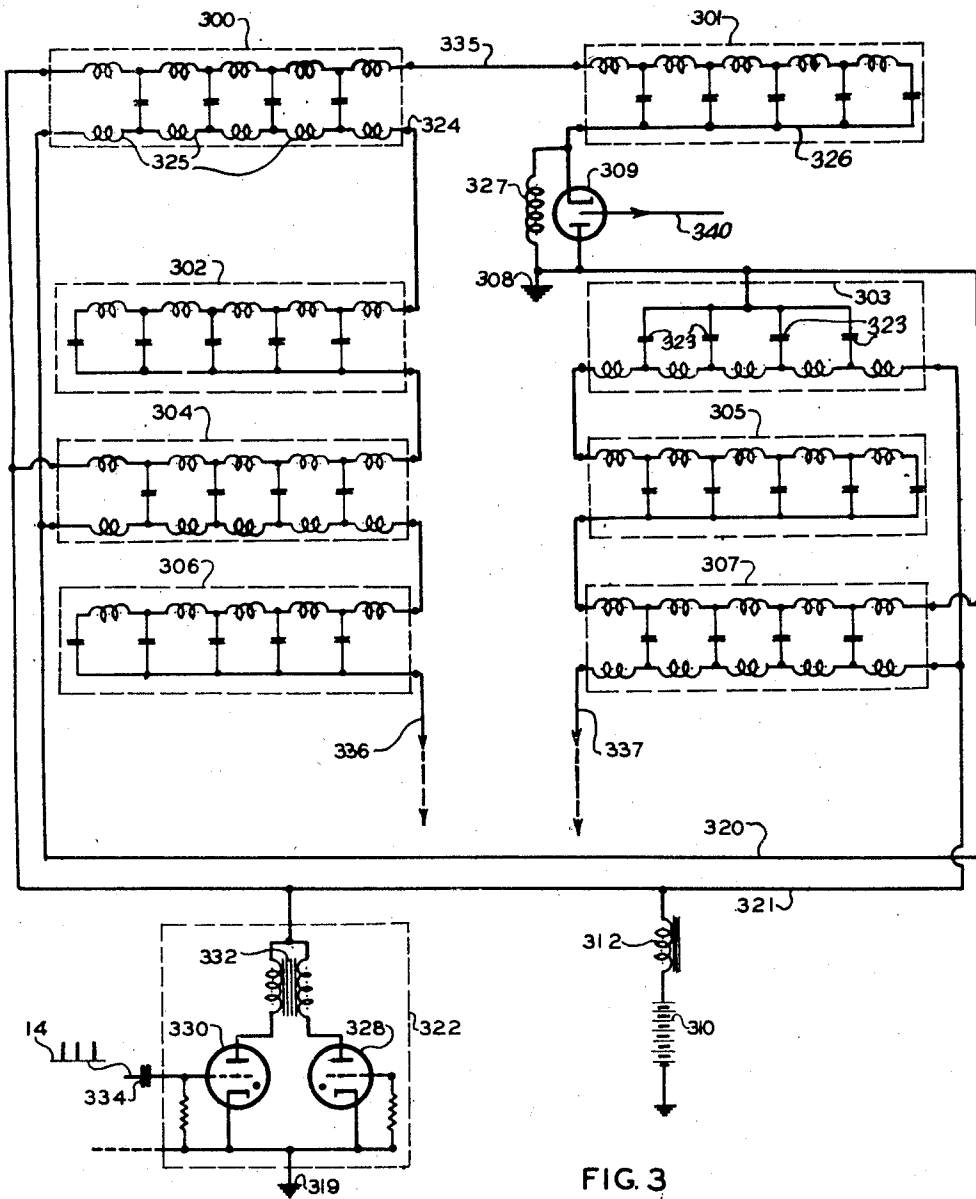


FIG. 3

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2,474,243

LINE PULSE MODULATOR

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Application September 14, 1945, Serial No. 616,440

16 Claims. (Cl. 171—97)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to pulse modulators and more particularly to the so-called line pulse modulators in which an artificial line is charged by resonance charging method and triggered through a gas-filled thermionic tube, the series discharge of the lines furnishing the desired modulating pulse.

The invention will be described by the way of an example in connection with a radio object locating system, but it has a wider utility and application to electrical circuits requiring a source of pulses of short duration and large power.

The line pulse modulators are used very extensively for modulating radio object-locating transmitters, and as is well known in the art the effective range of such systems is a high power function of the transmitted power. In many instances the modulators become the power-limiting links in the radar systems, and the invention discloses an improved line pulse modulator which increases the power delivered by the modulator without any increase in the voltage of the modulator's power supply. The increase in power is accomplished by connecting a plurality of artificial lines in a series circuit which delivers a pulse whose voltage is equal to a voltage of one line multiplied by the number of lines included in the circuit. The configuration of the circuit is such as to allow the use of only one electronic switch for discharging all the lines simultaneously. In the prior art it was known to use two artificial lines in the so-called Blumlein modulators, but any increase in the number of the lines above two required the use of a plurality of electronic switches. Since the electronic switches must use gas-filled tubes or ignitrons in order to satisfy the required current-carrying capacities of the switches, the use of a plurality of switches precluded any multiplication of the number of lines in the Blumlein modulator, and therefore the maximum number of lines that can be used successfully from a practical point of view in the Blumlein modulator is restricted to two lines. The use of a multiplicity of switches is untenable in the modulators of this type because of an impossibility of ionizing the switches simultaneously. All ignitrons and gas-filled tubes are subject to the so-called jitter (for a more detailed discussion of the nature of the jitter phenomenon see applications Serial Number 543,741 and 543,742, filed July 6, 1944) and al-

2

though this jitter may be reduced to a tenth of a microsecond with the ignitrons, and to a hundredth of a microsecond with the hydrogen-filled thyatrons, it can not be eliminated altogether because of the random nature of the ionization phenomenon itself. Yet, strictly simultaneous ionization of the switches is one of the prerequisites in the modulator of this type, since it is only with the simultaneous ionization of the switches that one can obtain the desired waveform of the keying pulse and the concomitant desired modes of resonance in the transmitter's magnetron.

The invention discloses a line pulse modulator capable of generating a voltage $2nE$ with the use of but one electronic switch, n being any integer, $2n$ corresponding to the number of lines used in the modulator, and E is the voltage of the power source connected to the modulator.

It is therefore an object of this invention to provide a line pulse modulator having a plurality of pairs of artificial lines the discharge of all artificial lines being accomplished simultaneously by means of a single electronic switch.

It is an additional object of this invention to provide a line pulse modulator using any desired even number of serially connected lines every other line of the modulator being connected with two terminals to a single electronic switch for triggering all of the lines so as to produce a single simultaneous pulse in the load circuit from all lines.

Still another object of this invention is to provide a line pulse modulator using a plurality of artificial lines, which represent a series circuit during the pulse-generating cycle, and a parallel circuit during the charging cycle, every other line in the series circuit being a two-terminal network, and the remaining lines being the four-terminal networks, the corresponding two-terminals of all four-terminal networks being connected to a single triggering switch.

It is also an object of this invention to provide a line pulse modulator using a plurality of artificial lines, or pulse forming networks, connected to a load, one of the lines on one side of the load being a three-terminal network, while the other is a two-terminal network, and the remaining lines being alternately two- and four-terminal networks.

The novel features which are believed to be characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and methods of operation, together with the further objects and

advantages thereof, may best be understood by reference to the further description in connection with the accompanying drawings, in which:

Figure 1 is a block diagram of the transmitting channel of a radio object locating system,

Figure 2 is a schematic diagram of a line pulse modulator using 4 artificial lines,

Figure 3 is a schematic diagram of a line pulse modulator using n number of artificial lines, n being an integer,

Figures 4 and 5 are explanatory figures.

Referring to Fig. 1, a master oscillator 10 generates a sinusoidal wave 11 which is impressed on a shaping amplifier 12, the output of which is illustrated at 14. The output of the oscillator is also impressed on a conductor 13 which interconnects the transmitting channel with the receiving channel of the radar station thus completing the two in synchronism. The shaping amplifier may consist of a plurality of pulse-shaping overdriven pentodes interconnected through differentiating networks which transform the sinusoidal wave into substantially rectangular pulses 14. For a more detailed description of the shaping amplifiers reference is made to the patent application of William A. Huber et al., Serial No. 506,808, filed October 19, 1943, entitled "Radio object locating system." These are impressed on the grid of a thyatron which is illustrated diagrammatically in the figure as an electronic switch 16. For a more detailed description of the electronic switches suitable for use in connection with the disclosed modulator reference is made to the "Line pulse modulator" applications of John E. Gorham et al., Serial No. 543,742 and Irving Sager, Serial No. 543,741, filed July 6, 1944, and especially Sager's application Serial No. 610,163, filed August 10, 1945. The electronic switch is used for triggering the artificial lines indicated in block 18 which, as mentioned previously, are connected in a series circuit during the duty cycle when they furnish the desired keying pulse for a transmitter 20. The artificial lines 18 form a part of a series resonant charging circuit including a source of potential 22 grounded with its negative terminal, a high inductance iron core choke coil 24 and artificial lines 18 provided with grounds for completing the charging circuits of the lines. The artificial lines, illustrated in the schematic form in Figs. 2 and 3, consist of a plurality of inductance coils and condensers. Transmitter 20 is connected in series with the discharge circuit of the artificial lines as illustrated more fully in connection with Figs. 2 and 4. The output of the magnetron, which represents the UHF oscillator of the transmitter, is connected through a transmission line or a wave guide to a directional antenna 26 which periodically transmits exploratory pulses, the periodicity of these pulses being controlled by the keying pulses 14.

The operation of the transmitting channel of the radar system illustrated in Fig. 1 is as follows: normally the artificial lines are in a discharged condition and therefore no potential is impressed on the cathode-anode circuit of the magnetron. During this period the artificial lines are charged by a source 22 through a choke coil 24 to a voltage 2E, Fig. 5 in a well known resonant charging manner which is twice the voltage of source 22. The repetition rate of the keying pulses 14 is adjusted to coincide with the maximum positive voltage appearing on the artificial lines 18 during the oscillatory resonance charging cycle of the lines. When a positive rectangular

pulse 14 is impressed on electronic switch 16 it acts as a triggering and short-circuiting device for the external terminals of all four-terminal artificial lines (in some embodiments it also includes one three-terminal line) thus initiating the propagation of the pulse waves in the lines and since the oscillator of the transmitter is coupled to the discharged circuit of the artificial lines, a discharged pulse is impressed on the cathode-anode circuit of the oscillator with the concomitant transmission of the exploratory pulse.

The connections of the artificial lines are illustrated schematically in Figs. 2 and 3. Referring to Fig. 2, it illustrates four artificial lines 200, 201, 202, and 203, lines 201 and 202 being two-terminal artificial lines and lines 200 and 203 being four-terminal lines. In the lines 201 and 202 the coils 204 and 205 are all placed along one side of condensers 206 and 207 respectively, and they are connected to the modulator by means of two conductors, this two-terminal connection making them two-terminal artificial lines. In the case of lines 200, 203, the inductance coils 208, 209, 210 and 211 are placed on both sides of condensers 212 and 213, so that, in this case, the inductances are found on both sides of the condenser plates and all four terminals of the lines are used for connecting these lines to the modulator, thus making them four-terminal artificial lines. The inner terminals, closest to the other lines, are used for interconnecting the lines, while the outer terminals are used for connecting the lines to the electronic switch. The parameters of all artificial lines are equal, irrespective of their connections or placing of the inductance coils in the lines, so that the duration of the pulse furnished by the individual lines is the same. As shown later in the specification, the lines discharge simultaneously through a series circuit including all lines and a load 233, the impedance of the load being equal to the characteristic impedance of a single artificial line multiplied by the number of lines in the series circuit. The reason for making two of the artificial lines two-terminal networks and the other two lines four-terminal networks will be given later in connection with the description of the functional cycle of the modulator.

The charging circuit of the lines begins with the grounded source of potential 22 whose positive terminal is connected to a high inductance iron core choke coil 24. The choke coil is connected to a conductor 231, which is also used for shorting the outer terminals 227—228 and 229—230 of the four-terminal lines 200 and 203 through an electronic switch 16. The series-discharge circuit of the lines is completed by conductors 214 and 216, which also complete the positive side of the charging circuit of the lines 200—201 and 202—203 respectively. The charging circuit of the lines on the negative side is completed by means of coils 205, a conductor 220, coils 209, conductor 232, coils 210 and ground 226; the negative side of the charging circuit of line 201 is completed through ground 226, an ultrahigh frequency UHF choke coil 225, magnetron 233, impedance-adjusting coils 218 and 220, and a conductor 222. The outer terminals of the artificial lines 200 and 203 are interconnected over conductors 231 and 232, terminal 227 being connected to terminal 230, and 228 to 229. A gas-filled triode 16, which acts as an electronic switch, is connected with its cathode-anode circuit across the conductors 231 and 232, the grid of this triode

5

being connected to the output of the shaping amplifier 12, Fig. 1, through a transformer 234. Since large currents are carried by the electronic switch, it will, as a rule, require several gas-filled triodes connected in parallel, and, depending upon the maximum voltage impressed on the lines during the resonant charging cycle, the electronic switch may require the connection of several thyratrons in series in each parallel circuit. The construction and operation of such switches will not be described here since it may be found in the previously mentioned publication of Sager, Serial No. 610,163, the disclosure of which is hereby made a part of this disclosure.

The operation of the line pulse modulator illustrated in Fig. 2 is as follows: normally the gas-filled triode 16 is non-conductive since the control grid of this thyatron is at the cathode potential. At this instant the lines are charged by the D. C. source of potential 22 through the iron choke coil 24, the lines and the choke coils 24 and 225 forming a resonant circuit having a large time constant. Accordingly, when the charging period of the lines begins, current flows through choke coil 24, and, because of the stored energy in the iron core of the coil, the maximum voltage that is impressed on the artificial line during the first half of the oscillatory cycle is of the order of twice the voltage of source 22. This is illustrated in Fig. 5, where time T represents the time required for the charging voltage to reach its peak 502 during the transient oscillatory state, which takes place before the lines are discharged through thyatron 16. Because of the high inductance of coil 24, which may be of the order of 100–200 henrys, the value of inductance 24 depending upon the desired keying rate of the transmitter, the duration, T, of the rising portion 500 of the voltage cycle, illustrated by a solid line in Fig. 5, may be of the order of 1000–2000 microseconds. This value is selected so as to establish proper coordination or synchronism between the keying pulses 14, Figs. 1 and 2, and the charging oscillatory cycle of the artificial lines, time T, Fig. 5, being made equal to the keying rate (spacing between pulses 14) of the transmitter. The charging circuit of the artificial lines is as follows: grounded source of potential 22, choke coil 24, conductor 231, then, for the upper lines, coils 208, conductor 214 and coils 204; for the lower lines, conductor 231, coils 211, and conductors 216 and 242. The return is coils 205, conductor 220, coils 209, conductor 232, coils 210, and ground 226; also conductor 222 and coils 218, 220 and 225. Thus, the upper plates of condensers 212 and 206 and the lower plates of condensers 207 and 213 have a positive charge, while the remaining plates of these condensers have a negative charge. Because of very limited inductance of all the line coils, such as 208, 209, etc., charging of some of the lines through the coils of another line is not detrimental because of a large time constant of the charging circuit. Because the parameters of the lines are equal, the charges accumulated by the remaining lines are equal. Therefore during the charging cycle, the outer terminals of the artificial lines 200 and 203 are at the same potential. Thus the potential drop at terminal 229 is equal to the potential drop at terminal 228, and the potential rise at terminal 230 follows the potential rise at terminal 227, as a consequence, there is no cross-circulating current in the conductors 231 and 232. When the charging voltage reaches its maximum peak 502, a positive triggering pulse 14 is im-

6

pressed on the grid of the gas-filled triode 16, and since, at this instant, a voltage 2E, Fig. 5, is impressed across the cathode-anode circuit, the thyatron becomes conductive, shorting conductors 231 and 232.

It can easily be demonstrated that when ideal opencircuited transmission lines are used as pulse lines and the impedance of load 233 is made equal to the characteristic impedance Z_0 of a single line multiplied by the number of lines used in the circuit (i. e. in Fig. 2, Z_L , the load impedance, is equal to $4Z_0$), that upon shorting of conductors 231 and 232, no voltage is impressed across the load impedance 233 for a period of time

$$\frac{\delta}{2}$$

where δ is the length of time required for an electromagnetic wave to be propagated twice the length of a single line. Then, a rectangular voltage pulse of magnitude 4E (Fig. 5) appears across the load impedance Z_L for a period δ , and it is this pulse which is used for actuating the transmitter.

Referring to Fig. 4, it represents a block diagram of Fig. 2 with an instantaneous series current i_0 flowing through four ideal lines 200–203 upon closing of switches 16 and 161, each line has a characteristic impedance Z_0 , and is initially charged to a voltage 2E. The load impedance is equal to $4Z_0$, and the switch currents in switches 16, are i_1 for line 200, and i_2 for line 203.

The Laplace transforms of the circuit equations are:

$$I_0 \left(4Z_0 \coth \frac{s\delta}{2} + 4Z_0 \right) + \quad (1)$$

$$I_1 Z_0 \operatorname{csch} \frac{s\delta}{2} + I_2 Z_0 \operatorname{csch} \frac{s\delta}{2} = 0$$

$$I_0 Z_0 \operatorname{csch} \frac{s\delta}{2} + I_1 Z_0 \coth \frac{s\delta}{2} = -\frac{2E}{s} \quad (2)$$

$$I_0 Z_0 \operatorname{csch} \frac{s\delta}{2} + I_2 Z_0 \coth \frac{s\delta}{2} = -\frac{2E}{s} \quad (3)$$

where I_0 , I_1 , and I_2 are Laplace transforms of i_0 , i_1 , and i_2 .

s is the variable of Laplace transforms.

Z_0 is characteristic impedance of any one of the lines, all lines having equal impedances.

Equations 1 through 3 have the solution:

$$I_0 = \frac{2E \operatorname{csch} \frac{s\delta}{2}}{sZ_0 \left(1 + \cot \frac{s\delta}{2} \right)} = \frac{E}{Z_0} \left(\frac{e^{-\frac{s\delta}{2}}}{s} - \frac{e^{-\frac{3s\delta}{2}}}{s} \right) \quad (4)$$

$$I_1 = I_2 = \frac{-4E}{sZ_0 \left(1 + \cot \frac{s\delta}{2} \right)} = -\frac{2E}{Z_0} \left(\frac{1}{s} - \frac{e^{-\frac{s\delta}{2}}}{s} \right) \quad (5)$$

where E is the voltage of source 22, Figs. 1 and 2, and e is the base of Napierian logarithms.

Whence, taking inverse Laplace transforms,

$$i_0 = \frac{E}{Z_0} \left[\mu \left(t - \frac{\delta}{2} \right) - \mu \left(t - \frac{3\delta}{2} \right) \right] \quad (6)$$

$$i_1 = i_2 = -\frac{2E}{Z_0} [\mu(t-0) - \mu(t-\delta)] \quad (7)$$

where t is the time variable, and $\mu(t-a)$ represents a function which has the value of

$$\begin{aligned} 0 & \text{ in the interval } 0 \leq t < a \\ 1 & \text{ in the interval } a \leq t < \infty \end{aligned}$$

75 a being any constant.

Hence,

$$\mu\left(t - \frac{\delta}{2}\right) - \mu\left(t - \frac{3\delta}{2}\right)$$

represents a function having the value of

$$0 \text{ in the interval } 0 \leq t < \frac{\delta}{2}$$

$$1 \text{ in the interval } \frac{\delta}{2} \leq t < \frac{3\delta}{2}$$

$$0 \text{ in the interval } \frac{3\delta}{2} \leq t < \infty$$

Thus i_0 is a current pulse of amplitude

$$\frac{E}{Z_0}$$

lasting between the instants

$$t = \frac{\delta}{2} \text{ and } t = \frac{3\delta}{2}$$

and accordingly the voltage pulse appearing across the load impedance 233 has the amplitude

$$4Z_0 i_0 = \frac{4Z_0 E}{Z_0} = 4E \quad (8)$$

during the same time interval between

$$\frac{\delta}{2} \text{ and } \frac{3\delta}{2}$$

The Laplace transforms of the circuit Equations 1, 2, and 3 may be written for $2n$ lines where n is any integer; in this case the load impedance is equal to $2nZ_0$, and therefore the equations become: (using the same terminology)

$$I_0 \left(2nZ_0 \coth \frac{s\delta}{2} + 2nZ_0 \right) + I_1 Z_0 \csc h \frac{s\delta}{2} + I_2 Z_0 \csc h \frac{s\delta}{2} + \dots + I_n Z_0 \csc h \frac{s\delta}{2} = 0 \quad (9)$$

$$I_0 Z_0 \csc h \frac{s\delta}{2} + I_1 Z_0 \coth \frac{s\delta}{2} = -\frac{2E}{s} \quad (10)$$

$$I_0 Z_0 \csc h \frac{s\delta}{2} + I_2 Z_0 \coth \frac{s\delta}{2} = -\frac{2E}{s} \quad (11)$$

$$I_0 Z_0 \csc h \frac{s\delta}{2} + I_n Z_0 \coth \frac{s\delta}{2} = -\frac{2E}{s} \quad (12)$$

The solution of the above equation for I_0 is identical to the solution of Equations 1 through 3, and, as in the previous case where four artificial lines were used, a current pulse i_0 , having an amplitude

$$\frac{E}{Z_0}$$

and the duration δ between

$$t = \frac{\delta}{2} \text{ and } t = \frac{3\delta}{2}$$

is impressed on the load impedance $2nZ_0$, therefore the voltage pulse appearing across the load is:

$$i_0 2nZ_0 = \frac{2nZ_0 E}{Z_0} = 2nE \quad (13)$$

The modulator, using $2n$ lines, is illustrated in Fig. 3. The circuit is identical to the one illustrated in Fig. 2, except that in line 303 all inductances were placed on one side of the line so that it represents a three-terminal network. Conversion of this line into a three-terminal network makes it possible to ground an electronic switch 322 and conductor 320 which connects all nega-

tive terminals of the artificial lines to the negative terminal of source 310.

Proceeding with a more detailed description of Fig. 3, a grounded source of D. C. potential 310 is connected to all artificial lines through a high inductance coil 312, and conductors 321 and 320, the latter being grounded at 308. The lines on the left side are alternately four- and two-terminal networks, lines 300 and 304 being four-terminal networks, and lines 302 and 306 two-terminal networks. The lines on the right side of conductor 335 follow the same alternate succession of two- and four-terminal networks, but in the reverse order, so that lines 301 and 305 are two-terminal networks and line 307 is a four-terminal network; but line 303 is a three-terminal network for the reasons that follow: Since it is convenient to ground electronic switches, such as 322, it becomes very desirable to connect conductor 320 directly to ground. Since the anode of magnetron 309 is also connected to ground, grounding of conductor 320 and of the anode would short-circuit the coils if they were placed above condensers 323 of this line. To avoid this, line 303 is constructed as a three-terminal network, and all the coils transferred to the lower portion of this line, thus making line 303 a three-terminal network. Isolation of terminal 324 of line 300 from ground 308 is accomplished by means of coils 325 of line 300, which prevent shorting of the remaining lines from lines 300 and 301 by conductor 320 during discharge period of the lines. Such isolation is necessary because during the discharge period, when voltage $2nE$ is impressed on magnetron 309, the terminals of the networks are at different potentials. Magnetron 309 may be connected directly in the series discharge circuit of the lines in which case the characteristic impedance of the artificial lines must be equal to

$$\frac{Z_L}{2n}$$

where Z_L is the impedance of magnetron 309, and $2n$ is the number of lines used in the modulator.

Magnetron 309 is shunted by a UHF choke coil 327, which is used for connecting conductor 326 of line 301 to ground and source 310. The output of magnetron 309 is connected to an antenna through a transmission line 340. The electronic switch 322 includes two gas-filled tubes 328 and 330, a pulse transformer 332, and a coupling condenser 334 which connects the grid of tube 330 to shaping amplifier 12, Fig. 1 and positive pulses 14. For a more detailed description of switch 322 reference is made to the previously mentioned application 610,163 of Sager.

Conductors 336 and 337, indicated by dotted lines, illustrate the fact that the number of lines may be increased, if so desired, to any number $2n$ (n being any integer) thus increasing the voltage impressed on the load impedance to $2nE$. If the number of the lines is increased, the symmetry of the circuit must be preserved, adding of one line on the right side requiring connection of an additional line on the left side, i. e., the lines must be added in pairs and the indicated alternate order of the two- and four-terminal lines followed during the process.

The operation of the modulator in Fig. 3 is identical to that disclosed in Fig. 1, but the voltage impressed on magnetron 309 is now proportional to the number of lines used in the modulator. The desired rectangular pulse will appear across the magnetron only if proper impedance

matching exists between the characteristic impedance of the individual lines and the load impedance Z_L , which is now equal to $2nZ_0$; it is because of this increase in the Z_L to $2nZ_0$ that there is an increase in the power impressed on the magnetron, the discharge current i_0 remaining constant irrespective of the number of lines used in the circuit. The impedance matching can be very readily accomplished by adjusting the

$$\sqrt{\frac{L}{C}}$$

ratio in the lines. In the prior art, magnetrons, as a rule, were coupled to their modulators through step-up pulse transformers, since this was the only method available for obtaining very high voltages. The invention eliminates the necessity for using step-up transformers, the high voltages now being obtainable directly from the modulator. Thus the wave-form of the pulses does not undergo the distortion introduced by the transformers—an important factor in the pulses of short duration. It is obvious that, if so desired, a pulse transformer may be used either in Fig. 2 or Fig. 3, in which case its primary is substituted for magnetron 233, Fig. 2, or 309, Fig. 3. When, after time T (Fig. 5), the voltage impressed on the lines reaches value $2E$, positive pulse 14 ionizes triode 330, full voltage $2E$ being impressed on triode 330 at this instance. Ionization of triode 330 impresses a strong positive pulse on the plate and the grid of triode 328 through an 1:1 ratio pulse-transformer 332 with the concomitant ionization of triode 328. The two triodes become simultaneously conductive for the power pulse or power conduction (cf., Sager's application 610,163), which short-circuits conductors 320 and 321. Closing of the electronic switch sends the current and voltage waves along the lines whose terminals were shorted by the switch. When these waves, after time

$$\frac{\delta}{2}$$

reach the opposite ends of the shorted lines, they set off current and voltage waves in the adjacent two-terminal lines and simultaneously produce reflected waves in the switch-shortened lines, these waves combine to produce a simultaneous series discharge of all lines, all lines having a current i_0 and voltage E waves traveling back and forth along the lines until time

$$\frac{3\delta}{2}$$

when all current and voltage waves cease and leave all lines in discharged condition.

While the invention has been disclosed in connection with a radar object locating system the invention has a wider utility and may be used in connection with any electrical systems which need a source of powerful short pulses for operating any suitable device. In describing line pulse modulators the load impedance in Figs. 2 and 3 has been represented by a magnetron. The invention is not limited to this type of load impedance and it is to be understood that any other type of load impedance may be used in place of magnetron.

While the invention has been described with reference to several particular embodiments, it will be understood that various modifications of the apparatus shown may be made within the scope of the following claims:

1. A line pulse modulator including a plurality

of pairs of pulse lines having equal characteristic impedances, a source of potential for charging said lines, a load connected to said lines, the impedance of said load being equal to the characteristic impedance of a single line multiplied by the number of said lines, and a single switch for discharging all of said lines through said load.

2. A line pulse modulator including a plurality of pairs of artificial lines having equal parameters and equal characteristic impedances, said lines being connected in a parallel circuit for charging and in a series circuit for discharging, a load included in said series circuit, said load having an impedance equal to the sum of the characteristic impedances of said lines and an ionizable gaseous discharge path connected to every other line, said path—when ionized—producing the series discharge of all of said lines through said load.

3. A line pulse modulator including a plurality of pairs of artificial lines all connected in a series circuit during discharge, every other line in said series circuit being a four-terminal network and the remaining lines two-terminal networks, a load included in said series circuit and a single electronic switch for simultaneously discharging said lines through said load.

4. A line pulse modulator including a plurality of pairs of artificial lines, said lines being alternately two- and four-terminal networks connected in a series discharge circuit, a load impedance serially included in said series circuit, a source of D. C. potential for charging said lines, and an electronic switch connected across the remaining two terminals of the four-terminal lines for producing a simultaneous series discharge of all of said lines through said load impedance upon the actuation of said switch.

5. A line pulse modulator including a plurality of four- and two-terminal artificial lines connected in a series circuit with two-terminal lines alternating with said four-terminal lines in said series circuit, a load impedance included in said series circuit, a D. C. source of potential connected across the two remaining terminals of all of said four-terminal lines to charge all of said lines in a resonance-charging manner, and an electronic switch connected across said remaining terminals for shunting said terminals upon the appearance of maximum voltage across said lines, thereby discharging all of said lines simultaneously through said series circuit.

6. A line pulse modulator as defined in claim 5 in which the characteristic impedances of said lines, Z_0 , are all equal, and the impedance of said load is equal to $2nZ_0$ where $2n$ is the number of lines in said modulator.

7. A line pulse modulator as defined in claim 5 in which all of said networks are of ladder type with the four-terminal lines having impedance on both sides of the ladders.

8. A line pulse modulator including $2n$ of artificial lines, where n is any integer greater than one, one of said lines being a three-terminal network, and the remaining lines being alternately two- and four-terminal networks, said three-terminal network taking the place of one of the four-terminal networks in the alternate series of said two- and four-terminal networks, said lines being connected in a series-discharge circuit, a grounded load impedance included in said series circuit between said three-terminal network and an adjacent two-terminal network, and a single grounded switch for shorting the remaining terminals of said four-terminal networks and the

11

remaining terminal of said three-terminal network to ground thereby serially discharging all of said lines through said load impedance.

9. A line pulse modulator as defined in claim 8 in which the common terminal of said three-terminal network is connected to the grounded end of said load impedance.

10. A line pulse modulator as defined in claim 8 which further includes a source of D. C. potential connected to said lines for parallel charging of said artificial lines.

11. A line pulse modulator as defined in claim 8 in which said switch includes a plurality of parallelly connected gas-filled triodes, and means for rendering all of said triodes simultaneously conductive.

12. A line pulse modulator including a plurality of pairs of pulse lines, a source of direct potential, a circuit for parallelly charging said lines, a load connected between two equipotential sides of two lines, and a single switch connected across said circuit for serially discharging all of said lines through said load.

13. A line pulse modulator including a plurality of pairs of pulse lines, a source of potential, a circuit for charging said lines, a load connected to said lines and in series with a portion of said circuit, and a single switch connected across said circuit for serially discharging all of said lines through said load upon reversal of potentials at the terminals of some of said lines.

14. A line pulse modulator including a plurality of pairs of pulse lines, a source of potential, a circuit between said source and said lines for simultaneously charging said lines, a load connected between two lines, and a second circuit including a single switch for serially discharging

12

all of said lines through said load a predetermined period of time after the operation of said switch, said period of time being equal to the time required for the propagation of the wave initiated, at the time of the operation of said switch, to travel from one end of any one of said lines to its other end.

15. A line pulse modulator including a plurality of pairs of pulse lines directly connected to each other to form a series discharge circuit, a load included in said series discharge circuit, a source of potential, a charging circuit between said source and said lines for parallelly charging said lines with said load being excluded from said charging circuit, and a switch connected across said charging circuit and in series with said discharge circuit for serially discharging all of said lines through said load.

16. A line pulse modulator including a plurality of pairs of serially connected pulse lines, a source of potential, connections between said source and all of said lines for charging said lines, said connections and said source charging adjacent junction points of said lines in said series circuit to the same potential, a load included in the circuit of said serially connected lines, and a switch for serially discharging all of said lines through said load.

LEWIS GREENWALD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,408,824	Varela	Oct. 8, 1946

Certificate of Correction

Patent No. 2,474,243

June 28, 1949

LEWIS GREENWALD

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 10, line 55, for "ZO" read Z_0 ; line 56, for "2nZO" read $2nZ_0$; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 27th day of December, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.