May 6, 1952 I. SAGER 2,595,301

LINE PULSE MODULATOR

Filed Aug. 10, 1945 2 SHEETS—SHEET 1

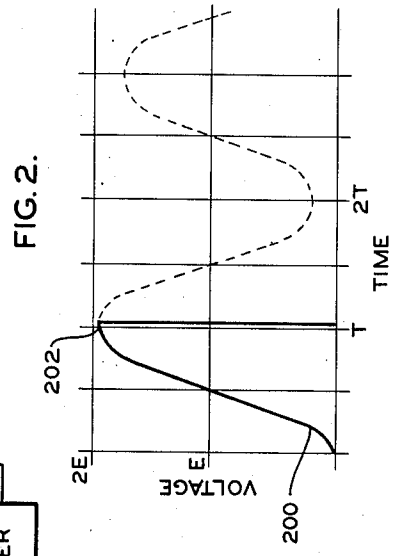


FIG. 2.

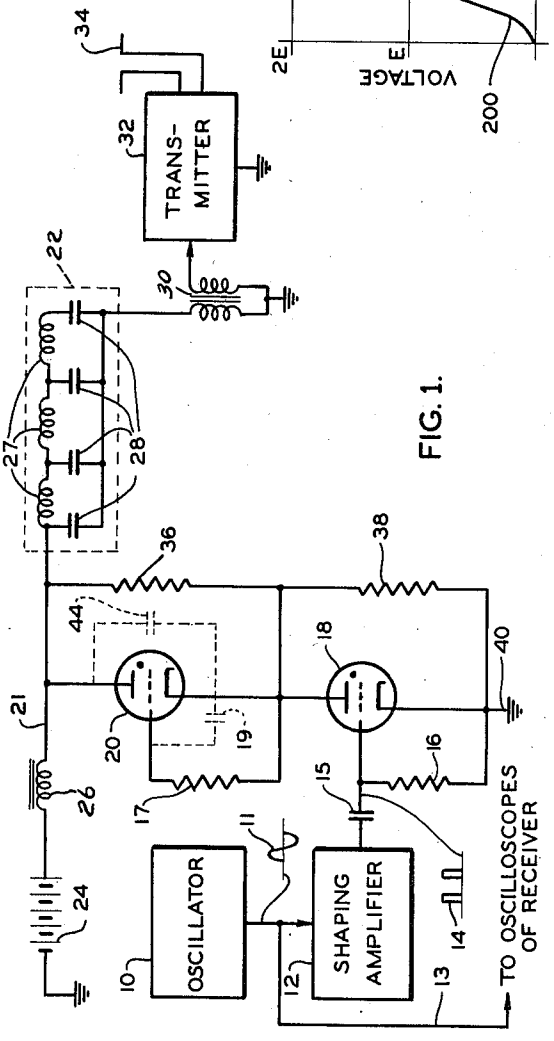


FIG. 1.

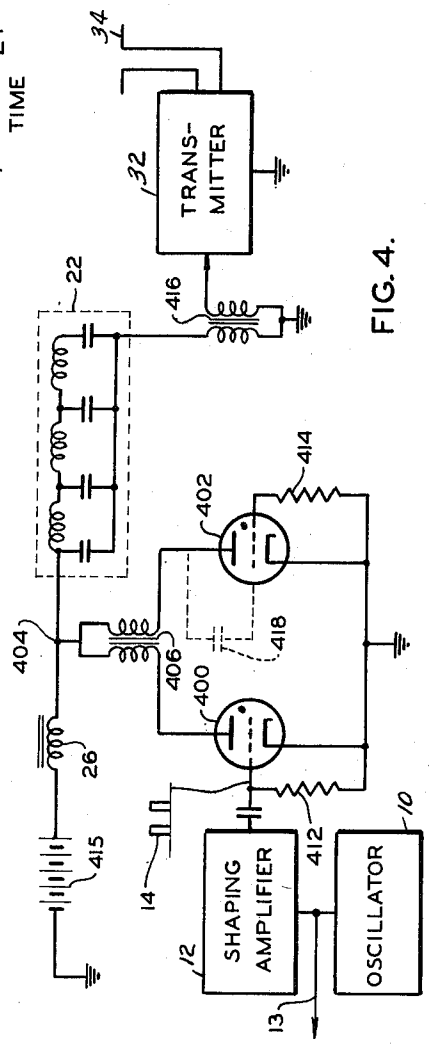


FIG. 4.

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LINE PULSE MODULATOR

Filed Aug. 10, 1945 2 SHEETS—SHEET 2

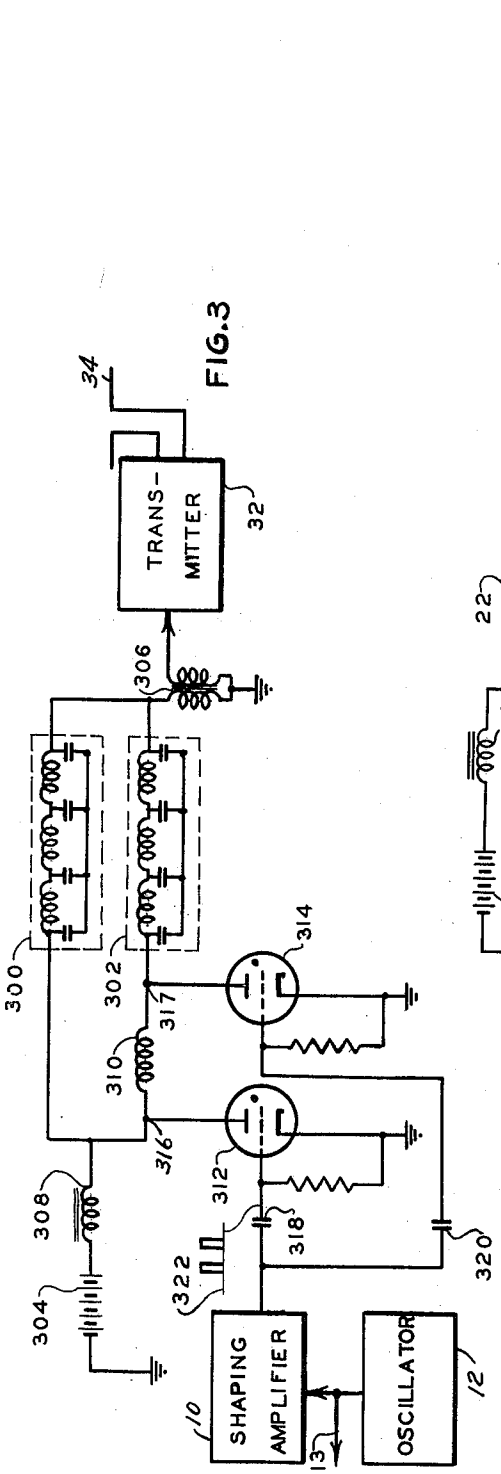


FIG. 3

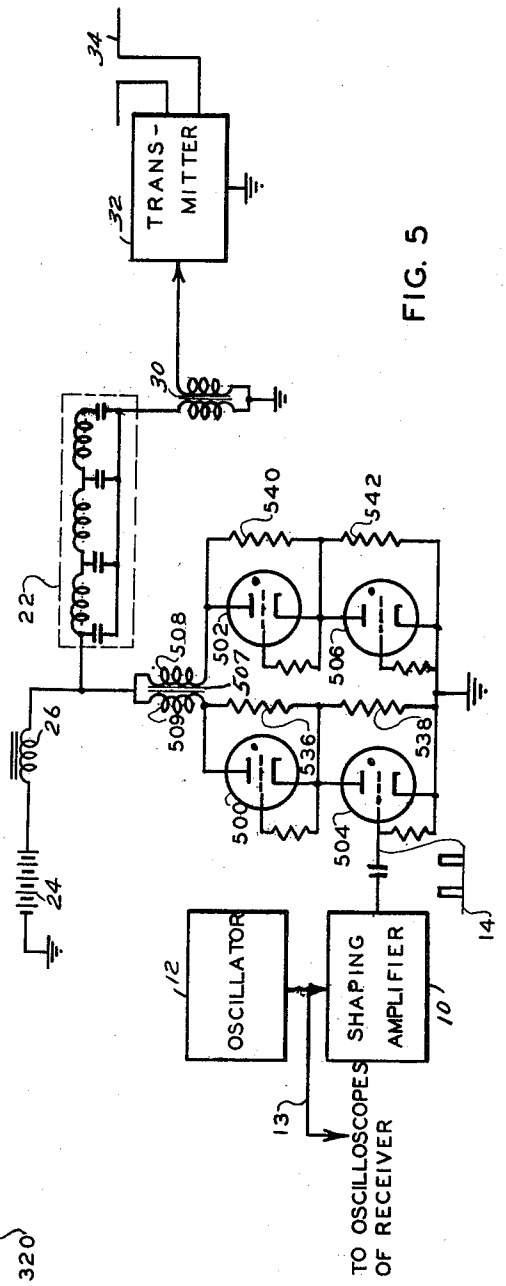


FIG. 5

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LINE PULSE MODULATOR

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Application August 10, 1945, Serial No. 610,163

7 Claims. (Cl. 250—17)

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

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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 keying circuits for radio transmitters and more particularly to the keying circuits which periodically key transmitters by means of pulses of short duration.

The invention will be described in connection with the radio object locating system, but it is to be understood that the invention has a wider utility and may be used with any type of pulse modulated radio transmitters.

In radio object locating systems the transmitter exploratory pulses are of short duration and high power, effectiveness of the systems depending to a very large extent on the power of the transmitted exploratory pulse. This type of operation requires very large concentration of power in extremely short periods of time, and the task of delivering this power to the transmitters evolves upon the keyers, since plate modulation is assuming a more and more dominant position in the transmitter circuits of the radio object locating systems. In the pending application of John E. Gorham, et al., Serial No. 543,742, filed July 6, 1944, entitled "Line Pulse Modulator," now Patent No. 2,534,261, issued December 19, 1950, circuits are disclosed in which the results are accomplished by using ignitrons; in my application Serial No. 543,741, filed July 6, 1944, entitled "Line Pulse Modulator," now Patent No. 2,533,285, issued December 12, 1950, circuits are also disclosed which use either thyratrons or ignitrons for periodically discharging an artificial line. The outstanding advantage of the line pulse modulators using ignitrons resides in their large peak power rating; a disadvantage of the line pulse modulators of this type is that, because of the inherent ignition characteristics of the ignitrons, there is a certain amount of "jitter" present in the output. This jitter is due to a slight time difference in the actual ionization of the ignitrons, or, more specifically the time between the application of the ignition pulse and the ignition of an arc between the mercury pool and the bracket holding the ignition electrode is not a constant. This is indeed the case even when the ignition pulses impressed on the igniter-electrode are very carefully timed and their magnitudes are very carefully controlled. The arc between the cathode and the anode forms almost immediately upon ignition, closing the anode circuit in a very small fraction of a micro-second after the formation of hot spot on the cathode.

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But the ionization time per se varies from cycle to cycle, the variations following a simple statistical law, and they are known in the art as jitter. As disclosed in the above mentioned applications, the jitter may be reduced to a fraction of a microsecond by properly constructing and positioning the igniter-electrode in the ignitron, but it is nevertheless generally true that a reduction in jitter may be accompanied by a very large increase in the driving power impressed on the igniter circuit which ultimately may reach a required power level in the order of several hundred kilowatts. When very large modulating power, in a form of keying pulses the duration of which is greater than 5 microseconds, is required, ignitrons may offer some advantages. However, when the duration of the keying pulses is in the order of 5 microseconds or less, and it is necessary to reduce the jitter to an absolute minimum, the presence of jitter being more and more objectionable as the duration of the keying pulses decreases, it is preferable to use multiple thyratrons which, under the stated operating conditions, besides minimizing the jitter, are capable of satisfying the required peak power ratings, and at the very same time offer a very important and large saving in the required driving power. In the case of the thyratrons, this required driving power may be only in the order of, at most, 1 kilowatt. The invention discloses several types of line pulse modulators which use thyratrons. According to one embodiment of the invention, an artificial line is discharged through a plurality of thyratrons connected in series, the use of several serially-connected thyratrons permitting employment of high voltage for charging the artificial line. The driving circuit is constructed to produce a substantially simultaneous ionization of all tubes, and hence in a modulator of this type the jitter phenomenon is much less pronounced than is the case with the modulator using ignitrons. Moreover, since the thyratrons are connected in series, each tube will, of necessity, conduct the same current, which insures equal distribution of load between the tubes. Equal division of total voltage among the tubes is safeguarded by means of a voltage-divider, which is adjusted so that each tube takes its part of the line-charging voltage.

According to another embodiment of the invention, the artificial line is discharged through a plurality of thyratrons which are connected in parallel between the artificial line and ground. Since thyratrons, when used in line pulse modulators for keying radar transmitters, may repre-

sent a current-limiting device in the modulator circuit, it becomes very desirable to connect several thyratrons in parallel in order to increase the current carrying capacity of the modulator. Moreover, since in many instances thyratrons also represent the voltage-limiting device in the modulators of this type, the voltage, as well as the current handling capacity of the modulator, may be increased by combining the series and parallel circuits into a single series-parallel circuit.

The multiple operation of the thyratrons presents several problems: first, care should be taken that each parallel tube takes its share of the load, which means that each tube must handle an equal amount of current and voltage as compared to those handled by the other tubes connected in parallel; second, the time delay of ionizing a thyratron varies from tube to tube and it also varies during the course of life of any individual tube, hence it is necessary to provide some means which would start each tube conducting power current at the same instant.

The invention discloses a series-parallel circuit for the thyratrons which satisfies the above requirements.

It is therefore an object of this invention to provide a novel keying circuit having a plurality of gas-filled tubes, one tube being ionized by a pulse originating at a master oscillator, while the other tubes are ionized by means of a pulse provided by the ionized tube and a potential furnished by an artificial line.

It is an additional object of this invention to provide a novel keying circuit having a plurality of serially-connected gas-filled tubes, one tube being ionized by a pulse originating at a master oscillator, while the other tubes are ionized by means of potentials provided by the ionized tube and an artificial line.

Another object of this invention is to provide a line pulse modulator using a plurality of serially and parallelly connected gas-filled tubes, one tube being ionized by a pulse originating at a master oscillator, while the other tubes are operated by means of the ionized tube and a potential furnished by an artificial line.

Still another object of this invention is to provide a line pulse modulator using a plurality of serially and parallelly connected gas-filled tubes, one tube being ionized by a pulse originating at a master oscillator, while the other tubes are ionized by means of the ionized tube and a potential provided by an artificial line, the parallel discharge paths being coupled to each other for making the operation of the parallel paths substantially simultaneous.

The novel features which I believe 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 partially block and partially schematic diagram of a line pulse modulator using a plurality of serially-connected thyratrons for periodically discharging an artificial line,

Figure 2 is an oscillogram of a charging voltage for an artificial line circuit,

Figure 3 is a partially block and partially schematic diagram disclosing a line pulse modulator with two thyratrons connected in parallel for discharging two parallelly connected artificial lines,

Figure 4 is a partially block and partially schematic diagram disclosing a line pulse modulator with two thyratrons connected in parallel, the anode circuits of the thyratrons being coupled to each other to insure simultaneous ionization of the thyratrons,

Figure 5 is a partially block and a partially schematic of a line pulse modulator using a plurality of serially and parallelly connected thyratrons, the parallel paths being coupled to each other for insuring their simultaneous ionization.

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 a receiving channel of the radar station thus keeping 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," now Patent No. 2,566,331, issued September 4, 1951. These pulses are impressed on the grid of a thyratron 18 through a condenser 15 and a grid-resistance 16. Thyratron 18 is connected in series with a thyratron 20, whose anode is connected to a conductor 21. Conductor 21 forms a part of a series-resonant circuit including a source of potential 24, with a grounded negative terminal, a high inductance, iron-core choke coil 26, an artificial line 22 consisting of a plurality of inductance coils 27 and condensers 28, and the primary of a pulse transformer 30 with grounded lower terminals. The secondary of this transformer is connected to a transmitter 32 and more particularly to the cathode of a UHF oscillator such as magnetron, the output of which is connected through a transmission line to a directional antenna 34. Thyratrons 18 and 20 are shunted by high resistances 36 and 38 which are connected between conductor 21 and ground 40, and which act as voltage-dividers for the two thyratrons so that normally, when the thyratrons are non-conductive, the voltage appearing between conductor 21 and ground is equally divided between the thyratrons. The grid of thyratron 20 is connected through a resistance 17 to its cathode.

The operation of the line pulse modulator is as follows: normally thyratrons 18 and 20 are not conductive since the control grids are at the cathode potentials. When positive pulse 14 is impressed on the grid of thyratron 18, it is rendered conductive because of the positive potential impressed on its anode through resistance 36. The repetition rate of the keying pulses 14 is adjusted so as to coincide with the maximum positive voltage appearing on line 22 during the oscillatory charging cycle of the line. The oscillatory nature of the charging cycle of the artificial line will be described later. Thyratron 20 is rendered conductive for all practical purposes simultaneously with thyratron 18 because when thyratron 18 becomes conductive its low cathode-anode impedance shunts resistance 38 of the voltage-divider and the cathode of thyratron 20 thus becomes connected substantially directly to ground 40. At this instant full potential between

conductor 21 and ground tends to become impressed across the cathode-anode circuit of thyratron 20, and this lowering of the cathode potential is equivalent to impressing a strong negative pulse on the cathode of thyratron 20. The cathode-to-grid interelectrode capacitance of thyratron 20 can not transmit this negative pulse to the grid of this tube instantaneously, the wave-front of this negative pulse reaching its maximum in approximately few hundredths of a microsecond. Therefore, while the cathode of tube 20 is made highly negative with respect to its grid, its grid retains its very high positive potential; so does its anode, and thyratron 20 becomes fully ionized, the power conduction taking place through the two thyratrons in series at the same time. Accordingly, thyratron 20 needs no additional triggering voltage, the interelectrode capacitance 19 and resistance 17 acting as a coupling means and triggering means for making thyratron 20 conductive. Positive potential for making thyratrons 18 and 20 conductive is furnished at this instant by line 22 and particularly by its condensers 28. Thus the two thyratrons become fully conductive, and since they represent a series circuit between ground and the line, the line discharges to ground, the circuit being two thyratrons in series on one side and the primary of transformer 30 on the other side. The duration of this pulse is determined by the time constant of the artificial line and the impedance of the circuit through which it discharges. The discharge impedance, which is the impedance of the two serially-connected thyratrons 18 and 20 on one side and the impedance of the primary of transformer 30 on the other side, must match the impedance of the line to avoid any reflections. Thus pulses of any desired length, from a fraction of one microsecond and up, depending on the selected parameters for the line, may be impressed on the secondary of transformer 30. This results in transmission of an exploratory pulse of corresponding duration by antenna 34.

Line 22 is connected to the D. C. source of potential 24 through an iron-choke coil 26, the line, the choke coil, and the primary of transformer 30, forming a resonant circuit having a large time constant. Accordingly, when the charging period of the line begins, current flows through choke coil 26, 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 in the order of twice the voltage of source 24. This is illustrated in Fig. 2 where time T represents the time required for the charging voltage to reach its peak 202 during the transient oscillatory state which takes place immediately before the line is discharged through the thyratrons. Because of the high inductance of coil 26, which may be in the order of 100–200 henrys the value of inductance 26 depending upon the desired keying rate of the transmitter, the duration T of the rising portion 200 of the voltage cycle, illustrated by a solid line in Fig. 2, may be in the order of 1,000 microseconds. This value is selected so as to establish proper coordination or synchronization between the keying pulses 14 and the charging oscillatory cycle of the artificial line 22, time T, Fig 2, being made equal to the keying rate (spacings between pulses 14). For a more detailed description of the behavior and a design formulae for the artificial line 22, which is sometimes called in the art the Guillemin line, reference is made to chaper 5, Foster's Theorum, in volume 2, of "Communication Networks" by E. A. Guillemin, published by John Wiley and Sons, Inc., 1935.

The reason for using two thyratrons in series in Fig. 1 is to enable one to use higher voltage 2E, Fig. 2, for charging the artificial line, which obviously increases the power impressed on the anode circuit of the magnetron in transmitter 32. This voltage, as mentioned previously, divides itself equally between the two thyratrons. In one embodiment of the invention, the maximum voltage impressed on the two thyratrons in series is in the order of 30,000 volts; thus each thyratron must withstand a maximum voltage of 15,000 volts.

Summarizing briefly the operation of the keying circuit illustrated in Fig. 1, line 22 is charged by source 24 and when the maximum voltage peak 202, Fig. 2, is reached, pulse 14 is impressed on the grid of the lower thyratron 18, which at once etsablishes ionization of this thyratron. Since the anode-cathode circuit of this thyratron is subjected to a voltage E, Fig. 2, appearing across resistance 38, the rendering conductive of thyratron 18 short circuits resistor 38 and connects the cathode of thyratron 20 to ground through the low impedance of thyratron 18. Since the grid of thyratron 18 can not become negative instantaneously, it remains positive long enough to ionize thyratron 20. When thyratrons 18 and 20 are made conductive, condensers 28, which at this instant have been charged to voltage 2E, discharge through the thyratrons and the primary of transformer 30, this discharge furnishing the necessary cathode anode voltage for the oscillator of transmitter 32. The cycle repeats itself upon the deionization of the thyratrons, which takes place upon the discharge of the artificial line. The inductance of choke coil 26 is such that source 24 is incapable of maintaining the ionized state of the thyratrons upon the discharge of the line.

The following circuit constants and tubes give satisfactory operation of the circuit disclosed in Fig. 1:

Duration of the exploratory pulse.	2 microseconds
Keying rate	300 pulses per second
Thyratrons 18 and 20	5C22
Maximum voltage of pulse 14	200 volts
Resistances 16 and 42	1,000 ohms each
Resistances 36 and 38	10 megohms
D. C. source of potential 24	15,000 volts
Inductance 26	30 henrys
Transformer 30	Output pulse transformer
Artificial line:	
Time constant	2 microseconds
Number of the inductance coils.	Five
Maximum modulation power of the pulse impressed on transformer 30.	4 megawatts

It is to be noted that while in Fig. 1 only two thyratrons are connected in series, the number of the serially connected thyratrons may be increased should the voltage generated by the artificial line be such as to exceed the rated voltage capacity of the thyratrons.

Fig. 3 illustrates a line pulse modulator whose peak power rating is increased by operating two thyratrons in parallel rather than in series. As mentioned previously, the basic problems encountered in multiple operation of the thyratrons are that each tube must take its portion of the load and there must be simultaneous conduction of the tubes. In parallel operation of thyratrons both problems are present to a greater extent than in series operation of thyratrons, since in the latter operation of the thyratrons the series

connection automatically insures equal "division" of current, or expressed more accurately, there is no problem of equal division of current in a series circuit; moreover, since all of the tubes are simultaneously made conductive by the main power pulse, the shape of the output pulse and especially of its leading wave front, does not suffer any distortion. This is not necessarily the case in the parallel operation of thyratrons, unless the circuit is constructed so as to insure simultaneous power conduction in all parallel circuits. Fig. 3 discloses a parallel circuit connection in which no special means are provided for insuring simultaneous ionization of the two parallelly connected thyratrons and therefore simultaneous firing of the thyratrons may be accomplished only when the parameters of the circuits and the constants of the tubes are such as to produce their simultaneous ionization. In Figs. 4 and 5 the circuit of Fig. 3 has been modified so as to insure simultaneous power conduction of the two parallel paths by providing a coupling transformer in the anode circuits of the two thyratrons. In the latter case, the power connection of the two parallel paths will be simultaneous even if there is a difference between the physical characteristics of the tubes.

Referring to Fig. 3, two artificial lines **300** and **302** are connected in parallel between a source of potential **304** and the primary of an output transformer **306**. The circuit also includes a choke coil **308** which performs the same function as choke coil **26** in Fig. 1. A relatively small inductance **310** is inserted between choke coil **308** and line **302** for isolating line **302** from thyratron **312** during the discharge period of line **302**. Thyratrons **312** and **314** are connected in parallel, the anode of thyratron **312** being connected to a junction point **316** while the anode of thyratron **314** is connected to a junction point **317**. The control grids of the thyratrons are coupled through condensers **318** and **320** to a source of rectangular pulses **322** which perform the same function as pulses **14** in Fig. 1.

The functioning of the circuit disclosed in Fig. 3 is as follows: the artificial lines **300** and **302** are periodically charged in the manner described in connection with Fig. 1; the series circuit of source **304**, choke coil **308**, lines **300** and **302**, and the primary of transformer **306** form a long time-constant resonant circuit so that the maximum voltage appearing across the artificial lines approaches voltage 2E illustrated in Fig. 2. At this instant a positive rectangular pulse is simultaneously impressed on the grids of thyratrons **312** and **314** with the result that they are ionized and line **300** discharges through thyratron **312** while line **302** discharges through thyratron **314**, the discharge of line **302** through thyratron **312** being blocked by a small inductance coil **310**. On the right side of the lines, the discharge takes place through the primary of transformer **306**, both lines discharging simultaneously through the same primary with a resultant increase in the power impressed on the oscillator circuit of transmitter **32**. To insure simultaneous firing of the thyratrons **312** and **314**, the thyratrons should be very carefully matched and their characteristics carefully checked periodically throughout their life since the initial matching of the thyratrons does not necessarily insure their simultaneous ionization indefinitely, since, as mentioned before, the triggering potential varies not only from tube to tube, but also during the life of each individual thyratron. The circuit disclosed in Fig. 3 performs satisfactorily for wide exploratory pulses where deviations from the simultaneous ionization of the thyratrons may be tolerated. On very wide exploratory pulses, the effect of one tube firing a fraction of a microsecond before the other is not a serious disadvantage. However, on narrower pulses, which are in the order of 1 microsecond, the variation in firing time of a few tenths or even a few hundredths of a microsecond must be considered, and since such precise matching of the two parallel paths is difficult to maintain, it becomes necessary to provide some method for preventing the main pulse current from flowing until both tubes have been fired. Circuits of this type are disclosed in Figs. 4 and 5.

Referring to Fig. 4, all connections in this figure are identical with those in Fig. 3 except that the grid of thyratron **400** is now connected to the output of the shaping amplifier and the anodes of the thyratrons **400** and **402** are connected to a junction point **404** between artificial line **22** and choke coil **26** through a 1:1 phase-reversing pulse transformer **406**. The operation of the circuit disclosed in Fig. 4 is as follows: the grid of thyratron **400** is made positive by means of rectangular pulses **14** which at once ionizes thyratron **400**, which simultaneously produces a strong positive pulse in the right winding of the pulse transformer **406**. The anode potential of thyratron **402** rises to a potential which is higher than the potential 2E, Fig. 2, impressed upon it by the artificial line **22**. The increase in the anode potential of thyratron **402** causes its grid to become positive because of the grid-anode, interelectrode capacity **418** and as a consequence thyratron **402** becomes ionized and there is a simultaneous discharge of line **22** through the two parallel paths provided by the two thyratrons. Hence the firing of thyratron **402** is accomplished in a manner similar to the firing of thyratron **20** of Fig. 1 except that while in Fig. 1 the grid remained positive because of the extremely rapid application of the negative potential to the cathode, in Fig. 4, the same result is accomplished through the anode-to-grid interelectrode capacitance which makes the grid positive. At this instant there is a flow of current through resistance **414** to the grid (electron flow) creating a positive potential drop in the desired direction across this resistance. With the two thyratons conducting, the transformer **406** acts as a means for balancing currents in the two tubes. Because of the unity turns ratio between the two windings of the transformer, the impedance it offers at this instance to the main pulse energy is equal to the leakage inductance plus the D. C. resistance of the winding; the leakage inductance is represented by the leakage flux produced by the action of the current in one winding of the transformer, the leakage flux being that portion of the flux which links the winding in question without linking the other winding. In other words, in the case of single turn coils, the leakage flux consists of those lines of flux produced by the action of the turns in one coil which link this coil but which do not link the other coil. That the impedance the transformer **406** offers to the main pulse energy is equal to the resistive component of the winding plus its leakage inductance follows from the fact that two equal currents flow simultaneously in both windings of the transformer, and therefore, except for the leakage inductance, the two main fluxes produced by the currents neutralize each other. If at any instant there is

no such neutralization then one winding induces the voltage in the other winding which is in the direction of decreasing the current in that other winding to the point until the two currents become equal. The actual added circuit inductance, because of the induction of transformer **406** in the anode circuits of the thyratrons, is equal to ¼ of the sum of the primary and secondary leakage. The following circuit constants are suitable for producing a 4 microsecond exploratory pulse in the order of 2 megawatts:

Thyratrons **400** and **402**	5C22
Pulse **14**	200 volts
Repetition rate of pulse **14**	200 pulses per second
Resistances **412** and **414**	1000 ohms each
D. C. source of potential **415**	5,000 volts
Choke coil **26**	50 henrys
Artificial line **22**:	
Time constant	2 microseconds
Number of inductance coils	five
Maximum modulation power of the pulse impressed on transformer **416**	2 megawatts

Fig. 5 illustrates a combination of the circuits disclosed in Figs. 1 and 4. In Fig. 5, two parallel discharge paths are provided and simultaneous ionization of the discharge paths is insured by introducing a 1:1 ratio transformer **507** between the anodes of thyratrons **500** and **502** and line **22**. The potential impressed on the two parallel discharge paths by the artificial line is equally divided by the thyratrons **500**, **504** on the left side, and thyratrons **502**, **506** on the right side by shunting the serially connected thyratrons with the potential dividers composed of resistances **536**, **538** and **540**, **542**, which perform the same function as the previously described voltage dividing resistors **36** and **38** in Fig. 1. Only the control grid of thyratron **504** is connected to the output of the shaping amplifier which impresses positive rectangular pulses **14** on the grid. The functioning of the circuit disclosed in Fig. 5 is as follows:

Rectangular pulses **14** make thyratron **504** conductive which at once makes thyratron **500** conductive in accordance with the action of the series circuit disclosed in connection with Fig. 1. It may be recalled that this action depends upon the interelectrode capacitance which transmits the positive pulse to the grid of thyratron **500** simultaneously with the ionization of thyratron **504**. Simultaneously with the ionization of the left path, including thyratrons **504** and **500**, a large positive pulse is impressed by transformer **507** on the anodes of the thyratrons **502** and **506** because of the interaction between the windings **508** and **509** of this transformer, and this positive pulse is transmitted to the control grids of thyratrons **502** and **506** through the anode-grid interelectrode capacitances. This produces simultaneous power conduction of the thyratrons **506** and **502**. Transformer **507** from then on acts as a means for equalizing the current in the two parallel paths in the manner described in connection with Fig. 4. Because of the extremely rapid rate of rise of the voltage applied to the grids of the thyratron **500** on the left side and thyratrons **502** and **506** on the right side, substantially simultaneous power conduction of all tubes is obtained with the concomitant steep wave-front of the modulating pulse.

Figs. 4 and 5 disclose the use of two parallel paths for increasing the current-carrying capacity of the shunting path; it is to be understood that the number of the parallel paths may be larger than two by increasing the number of the transformers.

The maximum jitter in the disclosed circuits is limited to the sum of the maximum jitters obtainable under given conditions with the total number of gas-filled tubes used in the circuit; in the disclosed modulators it is in the order of several hundredths of a microsecond, which is a considerably lower value than that obtainable when the gas-filled tubes are substituted for by ignitrons. The circuits used for producing ionization in the thyratrons, i. e., thyratrons **500**, **502** and **506** for example, in Fig. 5, other than the thyratron (**504**, Fig. 5) ionized by pulse **14**, all introduce a certain delay which ordinarily exceeds the jitter. However, this delay is a constant quantity and therefore does not enter into the calculation of the jitter nor does it increase the jitter in practice. That this is the case follows from the fact that the power conduction does not begin until there is complete ionization of all thyratrons, and therefore although the delay element or elements of time are actually positioned between several individual thyratron jitters, the relay elements, being constant, nevertheless do not participate in the summation of the individual jitters. Thus the maximum jitter is limited to the sum of the jitters introduced by the individual thyratrons. Because of the extremely steep wave-front and large magnitude of the triggering pulses impressed on the remaining thyratrons by the ionization of the first thyratron connected to the oscillator, the jitter introduced by the remaining thyratrons—per tube—is as much as 4 or 5 times smaller than the jitter introduced by the first thyratron. Accordingly, the use of a plurality of thyratrons does not mean an increase in the total jitter which is an arithmetical sum of the jitters the individual values of which are equal. For example, if the first thyratron has a maximum jitter of .05 microsecond; the second thyratron in the two-thyratron circuit will have a jitter in the order of .01 microsecond, and the total jitter will be .06 microsecond.

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.

I claim:

1. A keyer connected to a transmitter and including a series circuit of a source of potential, a choke coil, an artificial line, and means for coupling said artificial line to said transmitter; a plurality of parallelly connected gaseous discharge paths each of said paths including a plurality of series-connected gas-filled triodes, each of said triodes having a cathode, a grid, and an anode, the anode of the upper triode of each of said paths being coupled to a conductor interconnecting said choke coil and said artificial line, and the cathode of the lower triode of each of said paths being connected to said means for coupling, a plurality of resistances respectively shunting the cathode-anode circuit of each of said triodes; and a source of pulses connected to the grid-cathode circuit of the lower triode of one of said paths for rendering all of said triodes conductive and discharging said artificial line through said triodes and through said means,

whereby said means for coupling impresses a keying pulse on said transmitter.

2. A keyer as defined in claim 1, wherein the anodes of said upper triodes of said plurality of paths are coupled to said conductor and to one another through a pulse transformer having a corresponding plurality of windings, said windings having a one-to-one ratio.

3. A line pulse modulator connected to a transmitter and including a series circuit of a source of potential, an artificial line, and means for coupling said series circuit to said transmitter, a plurality of parallelly-connected, normally non-conductive gaseous discharge paths shunting said artificial line and said coupling means, one of said paths being receptive of a series of pulses for rendering said plurality of paths conductive.

4. A line pulse modulator as defined in claim 3, which further includes a multiple-winding pulse transformer, the windings of said transformer being connected in series with the respective parallel paths.

5. A line pulse modulator as defined in claim 3, which further includes a multiple-winding pulse transformer, all windings of said transformer having an equal number of turns, and each of said parallel paths including one of said windings.

6. The modulator of claim 3, wherein each of said parallelly-connected gaseous discharge paths includes a plurality of serially-connected gas-filled tubes.

7. A line pulse modulator including an artificial line, means for charging said line, a plurality of parallelly-connected, normally non-conductive gaseous discharge paths shunting said artificial line, and inductive means interconnecting said plurality of paths, one of said paths being receptive of a series of pulses for rendering said plurality of paths conductive.

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