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PULSE MODULATOR

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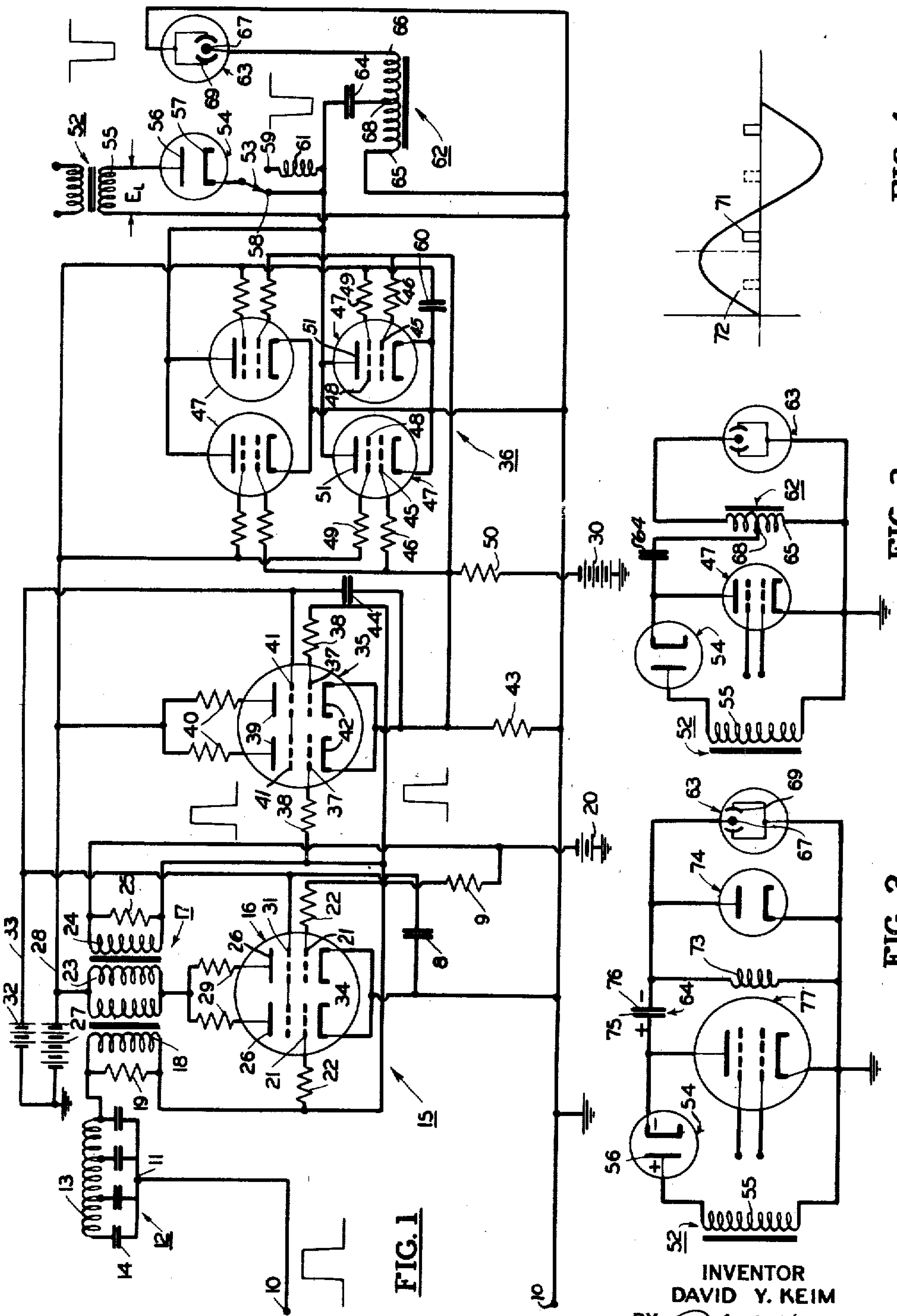

FIG. 1 FIG. 2. FIG. 3. FIG. 4.

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PULSE MODULATOR

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9 Claims. (Cl. 250—36)

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My invention relates broadly to modulators and, more specifically, to pulse modulators for ultra high frequency oscillators.

Modern ultra high frequency technique requires in some applications the operation of certain types of ultra high frequency oscillators such as the magnetron at comparatively high power levels. Since the maximum power level at which continuous operation of these oscillators may be safely maintained is limited by design, it is common practice to operate the apparatus with high power inputs for short periods only, thereby keeping the average operating conditions within the limits of safety.

When thus operated, the oscillator is "pulsed" by a high power level surge, the period of which determines the "on" time of the oscillator in which signals are transmitted. The interval between pulses, which is long compared with their period, then fixes the time the apparatus is turned off before signals are again transmitted. Modulators for supplying this high power pulse have taken two forms, namely, the vacuum tube type and the spark gap generator type.

The spark gap generator is not adaptable to systems in which the oscillator is triggered from a synchronizing source, but is used where the transmitter itself delivers the trigger pulse because of one of its inherent characteristics, termed in the art as "jitter," which does not permit accurate timing of the spark. Because of high power requirements, the vacuum tube modulator has heretofore been rather bulky, which is equally objectionable.

It is therefore an object of my invention to provide a vacuum tube pulse modulator which is simple in design, small and compact in structure, and adaptable to portable applications where minimum weight is essential.

Another object of my invention is to provide a method and apparatus for coupling a high power source and an ultra high frequency oscillator which does not require a direct current charging path for the filtering condenser in its power supply nor the damping devices made necessary by such a charging path.

A further object of my invention is the arrangement of a vacuum tube pulse modulator circuit in which a plurality of power pulsing tubes may be reliably triggered without distortion of the triggering pulse.

A still further object of my invention is to provide a pulse modulator in which a power pulsing network is inductively connected to an ultra high frequency oscillator.

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Another purpose of my invention is to provide a high power vacuum tube pulse modulator in which medium power tubes may be used.

It is also an object of my invention to provide apparatus for accurately timing a high power pulse.

Yet another purpose of my invention is to provide a pulse modulator in which the potential of interruptively discharged energy is increased and simultaneously transferred by induction.

These and other objects of my invention will become manifest as the description proceeds.

In carrying out my invention in a preferred embodiment thereof, I employ a line controlled blocking oscillator to drive a plurality of power pulsing tubes for controlling the time duration of pulse modulation. When the pulsing tubes receive a high amplitude pulse from the blocking oscillator, the period of which is determined by the length of a simulated transmission line connected in the grid circuit of the blocking oscillator, a charging condenser in the power supply network of the circuit is caused to discharge through the primary winding of an auto transformer used for coupling the power supply to the oscillator which is to be pulsed. The secondary winding of this transformer then delivers the modulating pulse.

In addition to acting as a coupling means for the power tubes and their load, the auto transformer also performs the function of an impedance-matching device which is necessitated by the number of power tubes employed in the switching network of the circuit. Here the number of tubes used is dependent upon the current-conducting requirements of this branch.

The fact that a number of power pulsing tubes are necessarily used also makes it impossible to drive these tubes directly and reliably by the output of the blocking oscillator. By connecting a cathode follower, which acts as a buffer stage, between these elements of the circuit, it is possible, however, to drive the tubes without distortion of the triggering pulse.

Also by using my improved coupling method, it is possible for me to use medium voltage tubes in the switching network having oxide-coated cathodes and to use these tubes in conjunction with a high-powered system. This makes unnecessary the use of the gas-filled "Thyratrons" and the bulky, less efficient high voltage tubes used in previous systems.

This method of coupling further simplifies the circuit, since it makes it unnecessary to provide a direct current shunt path across the ultra high frequency oscillator. Consequently, I am able to omit the inductance coils and damping devices used in prior systems.

By reducing the size and number of parts, I have produced a vacuum tube modulator which is adaptable to portable needs where the weight of the apparatus must be kept at a minimum.

A more comprehensive understanding of my invention may be obtained from the following detailed description, when taken together with the accompanying drawing, in which like reference numerals have been used throughout to designate like parts and in which,

Fig. 1 is a circuit diagram of an embodiment of my invention.

Fig. 2 is a representative showing of prior art methods of coupling high power sources with ultra high frequency oscillators.

Fig. 3 is a simplified showing of my improved coupling means for coupling power tubes with their load, and

Fig. 4 is a diagram showing the relationship between the power line frequency and pulse repetition rate.

In the embodiment illustrated in Fig. 1, a square trigger pulse is applied to the input terminals 10 of the circuit, from which point it is fed to a connection 11 on the simulated transmission line 12. This line is made up of sections comprising inductance coils 13 and capacitors 14 and is used to control the period of a pulse generated by a pulse amplifier network 15 in whose control grid circuit it is connected.

The network 15 serves as a blocking oscillator transformer and comprises an electronic discharge device 16, which may take the form of a double tetrode, a multiple winding transformer 17, and the delay line 12. A grid winding 18 of the transformer 17 has a resistor 19 connected in parallel therewith and serves as a conductor for transmitting the trigger pulse from the delay line 12 to the grids 21 of the double tetrode 16 through grid resistors 22. A common winding 23 of the transformer 17 is inductively connected with the grid winding 18 and output winding 24, the latter being provided to obtain a positive voltage pulse as the output of the blocking oscillator transformer. Resistors 19 and 25, in parallel with windings 18 and 24, provide fixed loading for these windings and in performing this function improve the wave form of the pulse output of the network.

Positive voltage is supplied to the anodes 26 of tube 16, whose electrodes are parallelly connected, from positive energy source 27 through a common bus 28, transformer winding 23, and plate resistors 29. The screen grids 31 are tied together and positive voltage applied to them from source 32 through line 33. Cathodes 34 are connected directly to ground, and the screen grids by-passed to ground through condenser 8. Bias from negative source 20 is applied to grids 21 through the resistor 9.

The output of the pulse amplifier 15 is used to drive a switching device 36 comprising a plurality of parallelly connected power pulsing tubes 47.

Interposed between the pulse amplifier or line controlled blocking oscillator 15 and the power pulsing tubes 47 is an electronic discharge device 35 which acts as a buffer stage. This device, which may be of the double tetrode type, is parallelly connected and acts as a cathode follower. It receives the output of the blocking oscillator transformer 17 from the output winding 24 thereof upon its grids 37 through grid resistors 38. Anodes 39 are connected to positive energy source 27 through line 28 and plate resistors 40, and the screen grids 41 to positive energy source 32 by line 33. The cathodes 42 are grounded through the cathode resistor 43, and the screen grids coupled thereto through the by-pass condenser 44. Negative grid bias for this stage is derived from source 20 through the output winding 24 of transformer 17. The input impedance of this stage is relatively fixed and is matched with that of the blocking oscillator 15 to provide maximum power transfer.

The pulse developed across the resistor 43 of stage 35 is applied through the grid resistors 46 to the grids 45 of the power pulsing tubes 47 which are connected in parallel and which are biased negatively from source 30 through the resistor 50. Screen grids 48 are by-passed to ground through the capacitor 60 and are supplied with positive energy from source 27 through conductor 28 and resistors 49. The plates 51 of these tubes are coupled in parallel to the high potential source 52 through the double throw switch 53 and the unilateral current-conducting element 54.

One terminal of the secondary winding 55 of transformer 52 is connected to ground and the other terminal to plate 56 of element 54. The cathode 57 of this device, illustrated as a vacuum tube of the diode type, is selectively connected to the plate circuits of tubes 47 through the two-way switch 53. The blade of this switch is normally closed to contact 58, but under certain conditions of circuit operation is closed to contact 59 to couple the inductance coil 61 into the power pulsing network.

An inductive device 62, which may take the form of an auto transformer, serves as a coupling element and impedance-matching device for the power pulsing tubes 47 and their load, the ultra high frequency oscillator 63 illustrated in the drawing as a split anode magnetron.

Coupled in the primary winding circuit of transformer 62 is a condenser 64 which serves the dual purpose of filter and coupling condenser. Common terminal 65 of transformer 62 is connected to ground and its secondary terminal 66 to the cathode and filaments 67 of oscillator 63. Condenser 64 discharges through the power pulsing tubes 47 into the primary winding of transformer 62 through ground and terminal 65. A modulating pulse is therefore induced in the secondary winding of transformer 62 which is impressed upon the ultra high frequency oscillator 63, the circuit being completed from terminal 65 through ground to anode 69, thence to cathode 67 and terminal 66.

In operation, the blocking oscillator network 15 performs the function of timing the plus modulation of oscillator 63. A trigger pulse of suitable characteristics is impressed upon the circuit through input terminals 10 for delivery to device 16 which is normally cut off by the fixed negative grid potential supplied from source 20. When the trigger pulse is received by grids 21, they are driven less negative than the cut-off value, and plate 26 start to draw current. The flow of plate current through plate winding 23 of transformer 17 induces a voltage in grid winding 18 which in turn drives grids 21 more positive with the result that the plates draw more current. When this regeneration starts, a steep negative wave front, that is, negative from the grid side of line to ground, is sent down the blocking line 12. This wave front hits the open end of the line and is reflected back with the same negative phase to the grids of tube 16. When this negative voltage appears on the grids, the grid voltage becomes less positive with a resultant decrease in plate current. As the plate current decreases, regeneration is established in the opposite direction, and the grids are driven negatively beyond plate current cut-off. During the time that the grids are drawing current, a negative voltage is built up across the condensers 14 of line 12 which acts as added negative grid bias to keep the tube shut off during the remainder of the trigger pulse. The time-constant of the grid circuit together with the added time due to trigger input impedance is made short compared to the time between trigger signals so that the grid voltage will have attained its original value before the next trigger signal appears.

Winding 24 is employed in the transformer circuit to deliver a positive pulse output to buffer stage 35 which operates as a cathode follower. Since the current requirements of the switching branch 36 necessitate the paralleling of a plurality of electronic discharge devices, this network draws a relatively high current from the blocking oscillator network 15, and without impedance matching, would distort the output signal of the latter device and make its operation unreliable. Accordingly, the buffer stage is interposed between the networks 15 and 36 to insure reliable operation of the blocking oscillator and to deliver its output to the power pulsing tubes without distortion.

The input impedance of element 35 is relatively fixed and is matched to that of blocking oscillator 15. Its grids 37 are biased to cut-off from negative source 20, and, when the pulse from the blocking oscillator is received on them they are driven positive and a high peak current is drawn through the non-inductive resistor 43. A pulse is therefore developed at the cathodes 42 of element 35 and delivered as a trigger for the tubes 47 of switching device 36, the function of which is best described in connection with the power supply branch.

The circuit is so synchronized that the trigger pulse 71 for tubes 47 is received after the line voltage E_L reaches a positive peak value, as shown in Fig. 4. It follows therefore that the tubes 47 are non-conductive during the positive rise in line voltage in the secondary winding 55 of transformer 52, since these tubes are normally negatively biased to cut-off by source 30, and accordingly they act at this moment as an open switch.

When the line voltage E_L goes positive, plate 56 of tube 54 goes positive, and the tube becomes conducting and current is stored in the filtering condenser 64, the flow being from ground through secondary winding 55, the tube 54, switch 53, condenser 64, and the primary winding of transformer 62, determined by the tap 68 and terminal 65, back to ground.

Thereafter, pulse 71 from line controlled blocking oscillator 15 is received on the grids of tubes 47, driving them positive beyond cut-off. As these tubes become conducting, condenser 64 discharges through them and the primary winding of transformer 62. This develops a pulse, whose period is determined by and equal to that of the triggering pulse received by tubes 47, which is induced in the secondary winding of transformer 62 and transmitted therefrom to the ultra high frequency oscillator as a modulating voltage.

As stated in the description of the circuit, switch 53 is normally closed to contact 58, and the operation of the circuit under these conditions is predicated on the fact that the power supply frequency is substantially equal to the pulse repetition rate.

If this relationship is not maintained, it is necessary to close switch 53 to contact 59 in order to place inductance coil 61 into the power circuit.

From Fig. 4 it will be observed that as the pulse repetition rate is increased with reference to the frequency of E_L, a point of demarcation is reached where pulses, such as 72, appear during the positive rise of line voltage. When this condition obtains, the tubes 47 are triggered and become conducting at a time when current is flowing in the power circuit, since element 54 is conducting only during the positive half cycle of the voltage E_L. Since tubes 47 act as a switch, current flows from power source 52 through them, thence over ground to the secondary winding 55 of transformer 52. This is objectionable, of course, since charging current is diverted from the condenser 64 and since it also results in an unnecessary dissipation of power. The current-conducting capacities of the elements 47 are limited by their inherent characteristics, and the additional current drawn from the power circuit by them is therefore necessarily dissipated in the form of heat energy.

With inductance coil 61 in the power circuit, no appreciable current is drawn by the tubes 47 from the power source, since it offers a high impedance to pulses which are in the order of the triggering pulse delivered to the power pulsing tubes. Thus, current flow from plate 55 to cathode 57 through inductance coil 61 to tubes 47 over ground and back through winding 55 is impeded until tubes 47 are non-conducting, and no appreciable amount of current is drawn by them. This allows the output of the power circuit to be stored in the condenser 64.

Where pulse repetition rates exceed approximately two and one-half times the power supply frequency, it is advisable to resort to an alternate power supply method such as a voltage doubling circuit. This arrangement lends itself more readily to proper synchronization for these conditions.

Thus far in describing the operation of the circuit, reference has not been made to the functions of transformer 62 other than that of stepping up the modulating pulse delivered to the ultra high frequency oscillator 63. In addition to this function, it also serves as an impedance-matching device and coupling means for the tubes 47 and their load 63.

Previously, the power tubes of vacuum tube modulators for ultra high frequency oscillators were connected directly to their load in a manner similar to that shown in Fig. 2, which fact necessitates the use of large tubes. In actual practice, a number of these tubes are necessary, although only one, 77, is shown in the figure. This tube is greatly enlarged for the purpose of comparing it with tube 47 in Fig. 3 to symbolize, though not to scale, the reduction in size of these elements made possible by my improved coupling, diagrammed in Fig. 3.

In the old coupling method illustrated in Fig. 2, attention is directed to two elements, coil 73 and unilateral current-conducting device 74, whose functions may be described by first considering the operation of the circuit without them.

As the line voltage E_L starts positive, plate 56 of tube **54** goes positive and so does plate **75** of condenser **64**. Since plate **76** is therefore necessarily negative, anode **69** of element **63** is also negative, and the polarity of this device is reversed. Accordingly, no current flows and condenser **64** is not charged but is left floating in the line. In order that charging may be effected, it is therefore necessary to provide a shunt path for the direct current and accordingly an element such as the coil **73** is placed in the circuit. When this is done, the resistance of the shunt path together with the capacitance of element **64** form a tuned circuit, and as soon as condenser **64** discharges, oscillations are set up in the circuit which cause an over-shooting in the pulse. To damp out these oscillations and to prevent over-shooting, the unilateral current-conducting element **74** is placed across the coil **73**.

In applying my improved coupling means, which is shown in Fig. 3, I am able to simplify the circuit by omitting both of the elements **73** and **74**. Here the primary winding of the inductive coupling means **62**, defined by the tap **68** and terminal **65**, in addition to other functions provides a direct current path and no coil, such as **73** (Fig. 2), is necessary. Likewise, element **74** (Fig. 2) is unnecessary, since the direct current resistance and the inductance of this primary winding is low, and the objectionable oscillations found in the prior art circuit are not present. Of itself, this is a marked improvement, since element **74** must be specially constructed to withstand the high inverse voltage impressed on it and also to meet the high current-conducting requirements of the circuit.

Further, since the power pulsing elements **47** are inductively connected to their load, it is possible to use medium voltages tubes and thereby further reduce the size of the apparatus.

To summarize the salient features of the circuit's operation, it may be pointed out that the coupling device employed embodies in one single element, illustrated as an auto transformer **62**, a means for directly performing the multiple functions of coupling tubes **47** with their load **63**, of providing a direct current shunt path for the filtering condenser **64**, of providing an impedance-matching element for tubes **47** and oscillator **63**, and that of stepping up the modulating pulse supplied to this latter element. Collaterally, it permits the use of medium voltage tubes in the place of high voltage tubes heretofore necessary under direct connected operation.

Likewise, the interpositioning of the buffer stage **35** between the line controlled blocking oscillator **15** and the switching network **36** serves several purposes by providing for the accurate pulsing of the oscillator, by acting as an impedance-matching means for the networks **15** and **36** and by providing for the delivery of an undistorted trigger pulse to the tubes **47**, irrespective of the fact that the high current-conducting requirements of this branch of the circuit necessitate the paralleling of a plurality of these devices.

Modifications of my invention are, of course, possible and may suggest themselves from the foregoing disclosure. Accordingly, the embodiment herein described and represented in the accompanying drawing is to be regarded as illustrative, and the spirit and scope of my invention to be limited only by the appendant claims.

What is claimed is:

1. In combination with an ultra high frequency oscillator, a blocking oscillator having connected in the grid circuit thereof a simulated transmission line, a buffer stage comprising an electronic discharge device connected as a cathode follower for receiving the output of said blocking oscillator, a power pulse switching device comprising a plurality of electronic discharge elements, each with a separate control grid driven by the output of said blocking oscillator, an energy storage condenser, a sinusoidally varying power-supply source, and interconnections between said switching device, said condenser and said source whereby said condenser is alternately charged from said source and discharged through said switching device to release energy to said oscillator, said discharge being synchronized to occur after the peak value of said source has been attained.

2. In combination, with an ultra-high-frequency oscillator, a blocking oscillator, a buffer stage having an electronic discharge device connected to receive the output of said blocking oscillator, a power pulse switching stage having at least one electron discharge device driven by the output of said buffer stage, a sinusoidal power-supply source, a storage condenser connected to receive energy from said source, said storage condenser being further connected to release energy thereof through said switching device to said oscillator after the attainment of the peak value of said source.

3. In combination, an oscillator to be energized at regular intervals, a pulse generator, a power pulse switching stage having at least one electron discharge device driven by the output of said generator, a sinusoidal power-supply source, a storage condenser connected to receive energy from said source, an inductive device having primary and secondary windings, said secondary winding being connected across said oscillator said storage condenser being further connected to release energy thereof through said switching stage to said primary winding after the peak value of said source has been attained.

4. In combination, an oscillator to be pulsed, a sinusoidal power-supply source, a storage condenser connected to receive energy from said source, an electron tube switching device having grid and plate circuits, a pulse generator connected to control the grid of said switching device and an inductive device having primary and secondary windings, said oscillator being connected to said secondary winding, the plate circuit of said tube switching device being connected between said condenser and said primary winding for periodically releasing the energy of said storage condenser to said oscillator during each positive second quarter cycle of said source.

5. Apparatus for supplying unidirectional electric pulses to a unidirectional voltage responsive radio-frequency energy generator, comprising first transformer means for receiving alternating current primary power and delivering high tension alternating voltage at the terminals of its secondary winding, a rectifier tube and a grid controlled tube connected in series between the secondary terminals of said first transformer means, the cathode of one of said tubes being connected to the anode of the other and the remaining anode and cathode being connected to the secondary terminals, a second transformer having two winding terminals for connection to said radio-frequency energy generator, a capacitor, said second transformer further having a winding portion connected in series with said capacitor, and means connecting said series-connected capacitor and winding portion between

the cathode and the anode of said grid controlled tube.

6. Apparatus as defined in claim 5, further including means for supplying to the control grid of said tube pulses recurring at the frequency of the alternating current in said first transformer means, said pulses being timed with the quarter of each cycle during which the voltage applied to the anode of said rectifier tube is positive but decreasing in magnitude.

7. Apparatus as defined in claim 5, wherein said second transformer is an auto transformer having a terminal at each extremity of said winding and a connection to an intermediate position of said winding, both end terminals being connected to said radio frequency energy generator, a capacitor, and means connecting said capacitor in series with one of said terminals and said connection, thereby series connecting said condenser and a portion of said winding, said means being further connected between the cathode and anode of said grid controlled tube.

8. In combination with a load to be impulsively energized at regular intervals, an inductive device having primary and secondary windings, a sinusoidal power supply source, energy storing means connected to receive energy from said source, and a unidirectional electronic discharge device having a control grid, said device being connected in series with said energy storing means and primary winding, said load being connected to said secondary winding, and said control grid of said electronic device being synchronized with said sinusoidal source for unidirectionally releasing the energy from said storing means to said load during each cycle of the sinusoidal variations of said source after the peak value thereof has been attained.

9. In combination, an oscillator to be pulsed with energy, a sinusoidal power-supply source, a storage condenser connected to receive energy from said source, an inductive element having primary and secondary windings, said ocscillator being connected across said secondary winding, a control device consisting of a pulse generator and a unidirectional electronic discharge device, said electronic device having a plate circuit and a grid circuit, said plate circuit being connected between said condenser and said primary winding, and said grid circuit being connected to said pulse generator for periodically releasing energy to said oscillator after the attainment of the peak voltage of said source.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,978,461	Hoover	Oct. 30, 1934
2,153,756	Hunt	Apr. 11, 1939
2,212,420	Harnett	Aug. 20, 1940
2,276,994	Milinowski	Mar. 17, 1942
2,295,585	Lindquist	Sept. 15, 1942
2,351,439	Livingston	June 13, 1944
2,405,069	Tonks et al.	July 30, 1946
2,405,070	Tonks et al.	July 30, 1946

FOREIGN PATENTS

Number	Country	Date
460,562	Great Britain	Jan. 25, 1937