

Sept. 26, 1950

O. E. DOW

2,523,684

STABILIZED OSCILLATOR SYSTEM

Filed July 13, 1946

2 Sheets-Sheet 1

Fig. 1

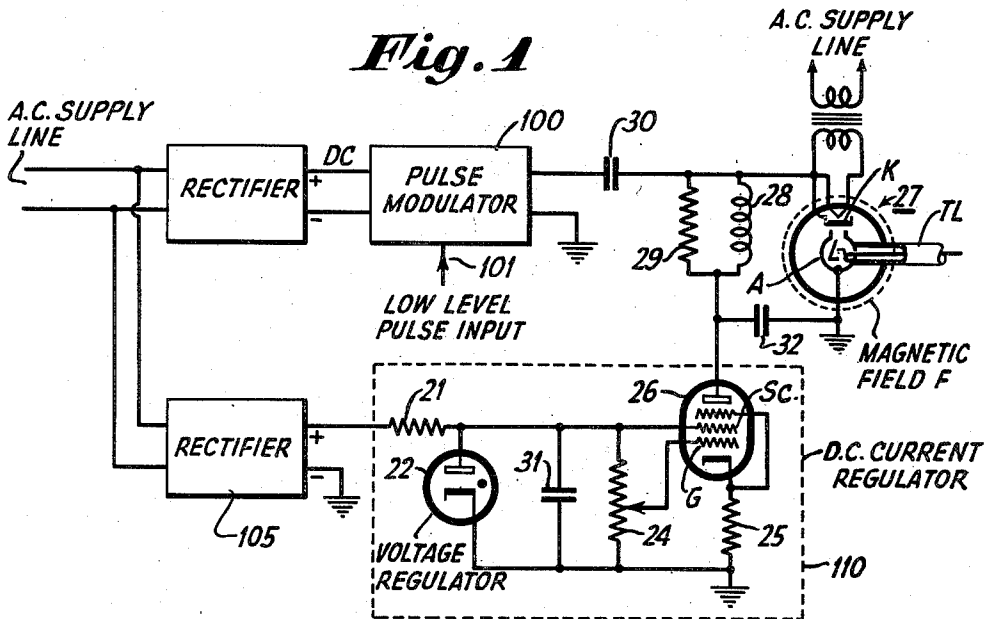


Fig. 2a Fig. 2b Fig. 2c Fig. 2d

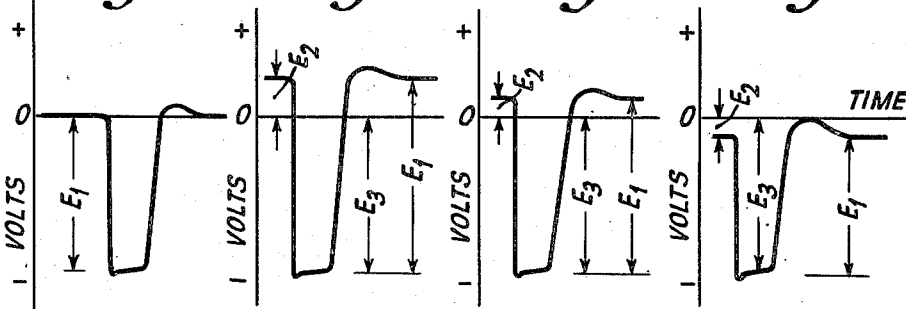
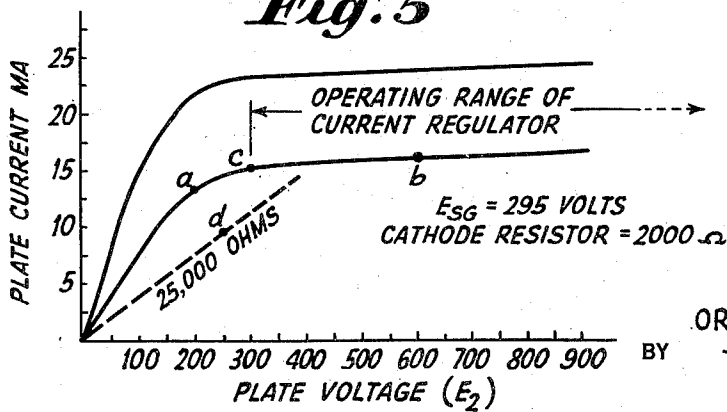


Fig. 5



INVENTOR
ORVILLE E. DOW

BY *H. S. Brown*
ATTORNEY

Sept. 26, 1950

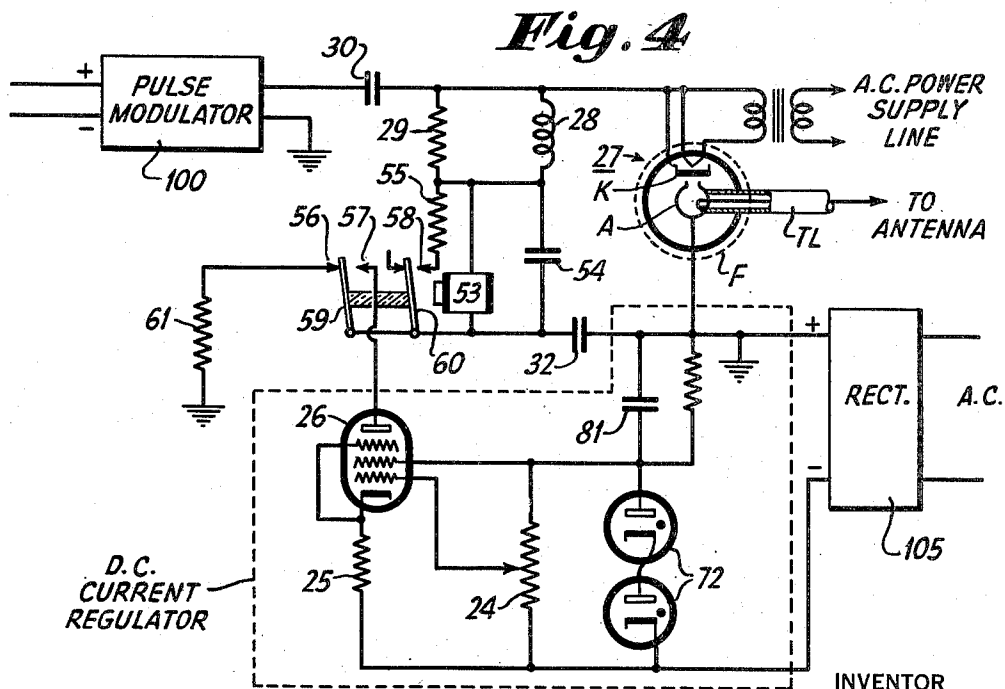
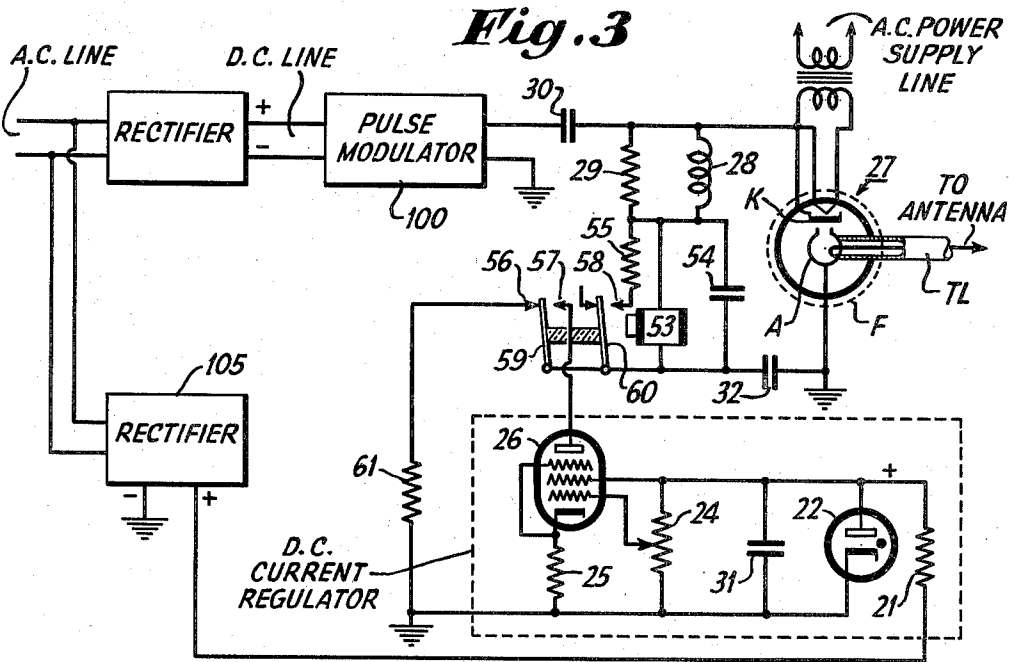
O. E. DOW

2,523,684

STABILIZED OSCILLATOR SYSTEM

Filed July 13, 1946

2 Sheets-Sheet 2



INVENTOR
ORVILLE E. DOW

BY

H. B. Brown

ATTORNEY

UNITED STATES PATENT OFFICE

2,523,684

STABILIZED OSCILLATOR SYSTEM

Orville E. Dow, Port Jefferson, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

Application July 13, 1946, Serial No. 683,295

13 Claims. (Cl. 250—36)

1

The present invention relates to a current regulator scheme for a magnetron oscillator, and particularly for a magnetron which is pulsed to provide output pulses of ultra high frequency energy.

The primary object of the present invention is to stabilize the performance of a pulsed magnetron oscillator when the power supply line voltage varies.

The invention assures a certain constant peak pulse voltage across the magnetron regardless of power line supply variations and pulse input voltage variations to the magnetron. In accordance with the invention, whenever there is a change in the peak pulse voltage applied to drive the magnetron and which would normally tend to change the peak pulse current flowing in the magnetron and hence, change the average D. C. current, there is applied a compensating D. C. voltage bias to the magnetron of such magnitude and sense as to off-set or counter-balance this change. This compensating D. C. voltage bias is supplied by a D. C. current regulator arranged in series with the D. C. path of the magnetron but not in series with the pulsed D. C. current and whose anode-to-cathode impedance changes a desired amount in the proper direction. In effect, the current regulator of the invention varies the D. C. bias between cathode and anode of the magnetron in such direction and sense as always to maintain the peak negative voltage across the magnetron at a constant value.

One of the advantages of this arrangement of the invention is that the vacuum tube of the D. C. current regulator need only be capable of passing the average D. C. current of the magnetron and not the peak D. C. pulse current which may be about twenty times as large as the average D. C. current.

The expression "voltage across the magnetron" used herein refers to the voltage of the cathode with respect to the anode. Since the anode of the magnetron in the circuit embodiment of the invention, is at ground potential, the cathode potential will be negative when the magnetron is oscillatory and the voltage across the magnetron is referred to as negative.

By peak D. C. pulse current is meant the maximum instantaneous value of unidirectional pulsating current.

In accordance with an embodiment of the invention, the magnetron is enabled always to start on its correct mode of oscillation, thus preventing oscillations from occurring on an unwanted frequency.

2

It is characteristic of a pulsed magnetron that its output power and frequency are critical to variations in the magnetic field and anode voltage. The magnetic field can be made constant by using a permanent magnet. In the operating range of a magnetron, a small change in anode voltage will result in a relatively large change in anode current. For this reason, a current regulator is most effective in stabilizing the magnetron against power supply line variations. If the duty factor of the magnetron is constant, the peak current (and voltage) may be stabilized by maintaining the average current constant. The duty factor is the percent of the time that the magnetron is oscillating. If a magnetron is operating at a 5% duty factor and its peak input current is one ampere, the average current is .05 ampere. By regulating the average current, the maximum current handling requirements are reduced. The invention utilizes an average D. C. current regulator and this average D. C. current regulator fits very conveniently into the circuit of the magnetron as will appear in the description given later in the specification.

A description of the invention follows in conjunction with drawings wherein:

Figs. 1, 3 and 4 illustrate different current regulator circuit arrangements for a magnetron oscillator in accordance with the present invention;

Figs. 2a, 2b and 2c are graphical representations given as an aid in more clearly understanding the operation of the circuit arrangements of the present invention; and

Fig. 5 comprises a series of curves illustrating the anode current versus anode voltage characteristics of a current regulator for the purpose of more clearly explaining the operation of the invention.

Referring to Fig. 1 which shows one embodiment of the present invention, there is shown a magnetron oscillator 27 used in a pulse transmitter system, and provided with a D. C. average current regulator 110. The magnetron 27 comprises a cathode K, a multi-cavity resonant anode structure A, and a magnetic field F acting transversely to the anode-to-cathode path. For the purpose of simplifying the drawing, only a single anode resonant cavity has been shown but it should be understood that in practice, it is preferred that several resonant cavities constitute the anode. Such a magnetron is described in Hansell U. S. Patent 2,217,745 granted October 15, 1940, to which reference is made. The anode may be part of the metal envelope and is shown operated at ground potential. The cathode K is

3

driven by means of negative pulses supplied thereto by a pulse modulator 100 through a blocking condenser 30. Low level input pulses are supplied to the pulse modulator 100 via lead 101 in order to vary the occurrence time of the peak negative pulses supplied to the K of the magnetron. It will be understood that since the anode A is at ground potential, it is necessary to supply a negative voltage to the cathode with respect to ground in order to drive or pulse the magnetron to produce pulses of ultra high frequency energy. Output is derived from the anode via a loop L in the interior of the resonant cavity anode and this loop L is coupled to the inner conductor of a suitable transmission line TL extending to an antenna or other utilization device.

The D. C. average current regulator 110 is provided to assure a certain constant voltage across the magnetron regardless of line supply variations and pulse input voltage variations to the magnetron. It should be noted that the average D. C. current regulator 110 is arranged in series with the D. C. path of the magnetron but not in series with the pulsed D. C. current. The average current from the magnetron from the cathode K is returned to the anode A through a resistor 29 and an inductance 28 in shunt thereto, and through the regulator vacuum tube 26 and cathode resistor 25. The resistor 29 and inductance 28 in shunt thereto provide a circuit from the cathode K to regulator tube 26 which has a low impedance for D. C. currents and a high impedance for the A. C. components of the pulse currents. Although the inductance alone provides the circuit with low D. C. resistance and high A. C. impedance, the shunt resistor serves to damp out transients which are set up across the inductance following the pulse.

Condenser 32 is connected between ground and one terminal of the parallel circuit 28, 29, thus bypassing to ground the A. C. component of the pulse currents which flow through resistor 29 and inductance 28. In effect, the resistor 29 and inductance 28 together isolate the current regulator from the pulse voltages. The path for the pulses of current leaving blocking condenser 30 is through the magnetron to ground rather than through elements 29 and 28. Since the impedance of resistor 29 shunted with inductance 28 is not infinite, some A. C. components of the pulse current will flow through the resistor and the inductance. These small A. C. currents will be shunted to ground through condenser 32.

The D. C. current regulator tube 26 has its screen grid SC supplied with voltage from an auxiliary D. C. voltage supply 105 through a resistor 21. A voltage regulator gaseous tube 22 is connected between the screen grid SC of the tube 26 and ground, as shown, and this voltage regulator tube is shunted by a condenser 31 and a resistor 24. It should be noted that the control grid G of the D. C. current regulator tube 26 is connected to a tap on resistor 24 which is adjustable over this resistor varying the bias supply to the control grid G. The average D. C. current of the magnetron 27 flows through the parallel circuit 28, 29 to the anode of tube 26. If the average D. C. current of the magnetron and the duty factor are constant, the peak D. C. pulse current will be constant. If the peak D. C. pulse is constant, the peak D. C. pulse voltage must also be constant.

The current regulator tube 26 is of the pentode type. Three grids (suppressor, screen, and con-

4

trol) are placed between the anode and the cathode of the tube 26 so the cathode is effectively screened from the anode, that is, variations of the voltage on the anode produce but minor changes of the electric field at the surface of the cathode. This electric field at the surface of the cathode determines the amount of current which will leave the cathode. The screen grid voltage on the screen grid SC and the voltage on the control grid G determine the electric field at the cathode surface. The control grid voltage has more influence than the screen grid voltage. In order for the current emitted from the cathode to remain constant the screen grid and control grid voltage must be constant. It is the function of the voltage regulator gaseous tube 22 to maintain the screen grid and the control grid voltage constant. Any variations of the D. C. output voltage of rectifier 105 will appear across resistor 21 due to the action of voltage regulator tube 22. The constant voltage supply for the control grid is obtained from the potentiometer 24. The normal operating point of the slider on potentiometer 24 is negative with respect to the cathode of tube 26. The value of current at which the current regulator 26 operates is determined by the setting of the tap on resistor 24. This tap is adjusted to suit the operating conditions of a particular magnetron. Thus for a particular magnetic field, pulse voltage, and frequency the tap on resistor 24 is set to obtain stable operation. Once this average current is set the current regulator tube maintains it constant. The two curves on Fig. 5 represent two settings of the tap on resistor 24.

This explanation holds when the anode of tube 26 is sufficiently positive with respect to the screen grid. If the anode is not sufficiently positive with respect to the screen grid, the space charge increases in the anode-screen grid space to a point where a larger percentage of the total emitted current is diverted to the screen grid and the anode current decreases. This corresponds to operation below the "knee" point (a) on Fig. 5.

The cathode resistor 25 for tube 26 results in more constant anode current. If the anode current and hence, cathode current increases, the increased drop across the resistor 25 is in such a direction as to increase the negative voltage from control grid to cathode, which tends to bring the current back to its original value.

The purpose of condenser 31 is to shunt to ground high frequency voltages which may be coupled to the screen grid. The action of voltage regulator tube 22 may be too slow to regulate against high frequency voltages.

The manner in which the current regulator maintains the peak negative voltage supply to the cathode of magnetron 27, may be better understood by referring to the graphical representation of Figs. 2a, 2b, 2c and 2d.

Fig. 2a represents the voltage versus time on the cathode of the magnetron when the inductance 28 is returned to ground instead of being connected to the current regulator as required by the invention. Stated otherwise, Fig. 2a represents a condition where no current regulator is employed. The peak D. C. voltage applied to the magnetron cathode K by the pulse modulator 100 is represented by E_1 . This voltage E_1 is related to the A. C. supply voltage for the whole transmitter system including the pulse modulator. It will thus be seen that Fig. 2a represents the pulse voltage applied across the

5

magnetron without the use of an average D. C. current regulator.

If the pulsed D. C. voltage from the modulator 100 increases, e. g., due to increase of supply line voltage, the peak negative voltage across the magnetron increases. Now, if there is provided the average D. C. current regulator 110 as indicated in Fig. 1 of the drawing in accordance with the invention, the average current from the magnetron is made to flow through the tube 26, then the voltage at the magnetron cathode will be shown in Fig. 2b. Here again, in Fig. 2b, the peak voltage input from the modulator 100 is represented by E_1 . The D. C. voltage from the anode of tube 26 to ground and hence, from the magnetron cathode to ground is E_2 . Stated otherwise, E_2 is the D. C. voltage drop across the current regulator and is also the D. C. bias on the cathode of the magnetron. Since the magnetron anode A is at ground or zero potential, the negative voltage in the magnetron during the pulse period is now E_3 . It will thus be seen that the effective part of the peak pulse voltage E_1 is that part E_3 which appears or falls below ground or zero potential. If the average current through the magnetron is 15 milliamperes, the operating point for the current regulator may be at point b, Fig. 5. If the magnetron requires 3,000 volts peak (E_3) for proper operation, the peak pulse input will be $E_2 + E_3$ or $600 + 3,000 = 3,600$ volts as evidenced from an inspection of Fig. 5.

Fig. 2c represents the condition where the line voltage decreases below normal but is still above the base line in the case where a system employs the voltage regulator of the invention. A drop in supply line voltage will result in the peak voltage E_1 from the pulse modulator dropping, let us say, to 3,300 voltages. The voltage drop across the current regulator which is the D. C. voltage at the cathode of the magnetron and is represented by E_2 , will decrease by the same voltage that E_1 decreases, thus keeping the peak negative voltage E_3 across the magnetron constant. An inspection of Figs. 2a and 2c will show E_3 as the same value in both cases where the line voltage increases above normal or where the line voltage decreases below normal (but still above the base line) when the average D. C. current regulator of the invention is employed. The operating points of the D. C. current regulator in the condition assumed for Fig. 2c, will move down to point c of Fig. 5. The average current will decrease by one-half milliampere ($\frac{1}{2}$ ma.) so that there will actually be a small decrease in E_3 . If the input pulse amplitude decreases until the current regulator operating point follows below the knee a of Fig. 5, the average current and the peak negative current will decrease more rapidly and the magnetron will cease to operate properly if at all. It should be noted that Fig. 5 indicates the operating range of the current regulator of the invention.

If the pulse output from the pulse modulator 100 is reduced to zero, the average D. C. current and voltage at the magnetron cathode will drop to zero. Now, if the pulse voltage is applied at normal amplitude, the peak negative voltage applied to the magnetron will be E_1 or say 3,600 volts. The following characteristic is normal for most magnetrons. If the magnetic field is constant and the pulse voltage is slowly increased, oscillations will begin at a particular voltage. As the pulse voltage is increased, the radio frequency power output increases until at a critical

6

voltage, oscillations abruptly stop and the output to the magnetron also decreases. If the voltage is still further increased, oscillations may occur on a different mode and a different frequency. Thus, with the current regulator connected as shown in Fig. 1, and the output from the pulse modulator 100 suddenly applied in normal amplitude or greater, under the condition that there is zero D. C. voltage bias on the cathode, then the correct operating point for the magnetron will be overshoot and no oscillations will occur or the magnetron will oscillate at an unwanted frequency. In either case, whether the magnetron does not oscillate or does oscillate at an unwanted frequency, the current regulator will be unable to adjust the peak negative voltage across the magnetron to the correct value. If oscillations fail to occur, the average current will be low. The current regulator will be operating below the knee a of the curve in Fig. 5. The voltage on the anode of the regulator tube 26 is low so that the peak negative voltage on the magnetron cathode K will remain above the correct operating value. If oscillations occur on an unwanted frequency, the average current may be regulated to the correct value, but the voltage at the anode of the regulator will be low, near point c, Fig. 5, when it should be at point b as above. In order for the current regulator 110 to function properly, the magnetron 27 must start on its correct mode. The manner in which I accomplish this desired result of starting the magnetron on its correct mode is described later in connection with the preferred circuit embodiments of Figs. 3 and 4.

In summation, in describing the operation of the system of Fig. 1, it should be understood that a rise in peak pulse voltage applied to the cathode K of the magnetron or condenser 30, tends to increase the peak pulse current flowing in the magnetron and hence, tends to increase the average D. C. current through 28, 29 and the current regulator tube 26. This tendency for increase in the average D. C. current is resisted by the D. C. current regulator which provides an additional D. C. voltage bias to the cathode of the magnetron by virtue of the increased anode-cathode impedance of tube 26. Similarly, a decrease in peak pulse voltage applied to condenser 30 from the modulator 100 tends to decrease the peak pulse current flowing in the magnetron and this is compensated for by the D. C. current regulator which provides a decrease in the D. C. voltage bias to the cathode of the magnetron by virtue of a decreased anode-cathode impedance of tube 26. The anode-cathode apparent D. C. resistance of tube 26 is given by the formula

$$R_p = \frac{E_p}{I}$$

where E_p is the voltage on the anode of the tube 26 and I is the current through this tube. Since the current is maintained constant through tube 26, it will be evident that as the anode voltage E_p changes, there will be a corresponding change in the impedance in the average anode-cathode impedance R_p of the tube.

The system of Fig. 3 is a preferred arrangement of the invention which enables the magnetron to start oscillation always on its correct mode. It should be noted that the system of Fig. 3 differs from the system of Fig. 1, generally speaking, in the addition of the relay 53, a condenser 54 and resistors 61 and 55. With the

7

pulse input to the magnetron 26 zero, the average current through the relay 53 is zero and the relay armatures 59 and 60 are in the position shown. The D. C. circuit from the magnetron cathode K is through the coil 28 shunted by resistor 29, the winding of relay 53, armature 59, break contact 56, and resistor 61 to ground. If the negative pulse into the magnetron is applied at normal or greater than normal amplitude, the peak negative voltage on the magnetron cathode will be greater than the operating value. Whether the magnetron oscillates or not, some average current will flow through the winding of relay 53 and resistor 61. As the voltage across condensers 54 and 32 builds up, the current in the winding of 53 increases until it reaches its operating point, which is less than the normal average current of the magnetron 27. In Fig. 5, the broken line represents the resistance of resistor 61 and the winding of relay 53. The D. C. voltage on the magnetron builds up to 250 volts (point *d* on broken line curve of Fig. 5) when the relay armatures 59 and 60 start to move. As armature 59 leaves contact 56, the total average current from the magnetron flows into condenser 32 resulting in a still further increase of the voltage build-up thereacross. When armature 59 engages contact 57, the D. C. potential at the anode of the current regulator tube 26 will be greater than the voltage corresponding to point *b*, Fig. 5, and thus the peak negative pulse on the magnetron cathode will be lower than required and the current will tend to decrease, thus pushing the operating point back to point *b*. It is necessary to approach point *b*, Fig. 5, from a higher current regulator anode voltage E_2 than from a lower current regulator anode voltage. This is equivalent to approaching the correct peak negative pulse voltage E_3 for the magnetron from the low or stable side. The increase of voltage across condenser 32 during the time of operation of the relay 53 is determined by the magnetron average current, the size of condenser 32 and the time required for armature 59 to travel from contact 56 to contact 57. The magnetron average current may not be constant during the time.

The purpose of condenser 54 in shunt with the winding of relay 53 is to bypass the pulse currents which pass through resistor 59 and inductance 28. The A.-C. impedance of the winding of relay 53 is high so that the A.-C. components of the pulse currents would tend to develop a high voltage across the relay winding.

The conditions of Figs. 2b and 2c can only happen when using the system of Fig. 3. Figs. 2b and 2c show different amplitudes of the pulse with the base line above zero; that is, plus or positive relative to zero. The base line may be defined as the D. C. voltage of the magnetron cathode and regulator tube anode.

The maximum peak pulse voltage which the pulse modulator 100 is required to generate will be reduced if the anode of the current regulator tube 26 is operated negative with respect to ground as represented by E_2 in Fig. 2d. This may be done with the circuit of Fig. 4. The average D. C. current regulator of Fig. 4 differs somewhat from those shown in Figs. 1 and 2 and is designated 110', the difference being primarily in the use of two voltage regulator tubes 72 and 72' (gaseous tubes) which are connected between the screen grid of tube 26 and the negative D. C. supply, e. g. The cathode of the current regulator tube 26 is returned to ground through the

8

resistor 25 to the negative D. C. supply voltage —Eb. The screen grid of tube 26 is negative with respect to ground, and therefore, the anode of tube 26 may be negative with respect to ground. The rectifier 105 supplies power to both the screen grid and anode of tube 26.

In Fig. 4, condenser 81 corresponds to condenser 31 of Fig. 3 and resistor 71 corresponds to resistor 21 of Fig. 3.

The resistor 55 in Figs. 3 and 4 reduces the current in the winding of the relay 53 after the relay has closed (operated). If the normal average current from the magnetron 27 is greater than the maximum rating of the relay winding, the value of the shunting resistor 55 is adjusted so that only the rated current flows through the winding of the relay.

The circuit condition of Fig. 2d can only happen when using the system of Fig. 4, and cannot happen in using the system of Fig. 3. In Fig. 2d, the base line falls below zero.

It should be noted that by means of the circuit arrangement of the present invention, the vacuum tube 26 of the D. C. current regulator need only be capable of passing the average D. C. current of the magnetron and not the peak D. C. current which is considerably greater, often twenty times as great, as the average D. C. current of the magnetron.

What is claimed is:

1. In combination, a magnetron having a cathode and an anode, a connection from said anode to ground, means for supplying pulses of negative polarity relative to ground to said cathode, a parallel combination of a resistor and an inductor having one terminal connected to said cathode and another terminal connected through a by-pass condenser to ground, a D. C. current regulator having a vacuum tube having an anode and a cathode, a lead from said last anode to said other terminal, and a resistor connecting the cathode of said vacuum tube to ground, whereby said D. C. current regulator is in series with the D. C. path of said magnetron but not in series with the pulsed D. C. current.

2. In combination, a magnetron having a cathode and an anode, a connection from said anode to ground, a pulse modulator for supplying pulses of negative polarity relative to ground to said cathode, a source D. C. voltage supply for said modulator, a parallel combination of a resistor and an inductor having one terminal connected to said cathode and another terminal connected through a by-pass condenser to ground, a D. C. current regulator having a vacuum tube having an anode and a cathode, a lead from the anode of said vacuum tube to said other terminal, and a resistor connecting the cathode of said vacuum tube to ground, whereby said D. C. current regulator is in series with the D. C. path of said magnetron but not in series with the pulsed D. C. current, and an auxiliary source of D. C. voltage supply for an electrode of said vacuum tube of said current regulator.

3. In combination, a magnetron having a cathode electrode and a resonant anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, an impedance capable of passing direct current connected at one point to said one electrode and at another point to said other electrode through a condenser of such value as to by-pass the A. C. component of pulse currents, a D. C. current regulator having a vacuum

tube comprising an anode and a cathode, a connection from the anode of said vacuum tube to said other point, and a connection from the cathode of said vacuum tube to said other electrode through a D. C. impedance, whereby said D. C. current regulator is in series with the D. C. path of said magnetron but not in series with the pulsed D. C. current.

4. In combination, a magnetron having a cathode electrode and a resonant anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, an impedance capable of passing direct current connected at one point to said one electrode and at another point to said other electrode through a condenser of such value as to by-pass the A. C. component of pulse currents, a D. C. current regulator having a vacuum tube comprising an anode, a screen grid, and a cathode, a connection from the anode of said vacuum tube to said other point, and a connection from the cathode of said vacuum tube to said other electrode through a D. C. impedance, an auxiliary D. C. voltage supply for said screen grid, whereby said D. C. current regulator is in series with the D. C. path of said magnetron but not in series with the pulsed D. C. current.

5. In combination, a magnetron having a cathode electrode and a resonant anode electrode, a driving source of energy connected to one of said electrodes, a D. C. voltage supply for said driving source, a resistor shunted by an inductance having one terminal connected to said one electrode and another terminal connected to said other electrode through an A. C. by-pass condenser, a D. C. current regulator having a vacuum tube comprising an anode, a cathode and a screen grid, a connection from the anode of said vacuum tube to said other terminal, a connection from the cathode of said vacuum tube to said other electrode, and an auxiliary D. C. voltage supply connected to said screen grid, whereby said vacuum tube is in series with the D. C. path of said magnetron but not in series with the pulsed D. C. current.

6. In combination, a magnetron having a cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, a resistor shunted by an inductor connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to by-pass the A. C. component of pulse currents, a relay having a winding, one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having an armature, a make and a break contact, said armature normally engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to the anode of said magnetron, a connection from said armature to that end of said winding which is connected to said bypass condenser, a D. C. current regulator comprising a vacuum tube having an anode and a cathode, a connection from the anode of said vacuum tube to said make contact, and a resistor connecting the cathode of said vacuum tube to the anode of said magnetron.

7. In combination, a magnetron having a

cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, a resistor shunted by an inductor connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to bypass the A. C. component of pulse currents, a relay having a winding one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having an armature, a make and a break contact, said armature normally engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to the anode of said magnetron, a connection from said armature to that end of said winding which is connected to said bypass condenser, a D. C. current regulator comprising a vacuum tube having a cathode, an anode and a screen grid, a connection from the anode of said vacuum tube to said make contact, a resistor connecting the cathode of said vacuum tube to the anode of said magnetron and a connection from the screen grid of said vacuum tube to an auxiliary source of D. C. supply voltage.

8. In combination, a magnetron having a cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, a resistor shunted by an inductor connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to bypass the A. C. component of pulse currents, a relay having a winding, one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having a pair of armatures, a connection between said armatures, a make and a break contact for one of said armatures, said one armature normally engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to the anode of said magnetron, a connection from said armatures to that end of said winding which is connected to said bypass condenser, a D. C. current regulator comprising a vacuum tube having a cathode, an anode and a screen grid, a connection from the anode of said vacuum tube to said make contact, a resistor connecting the cathode of said vacuum tube to the anode of said magnetron, and a connection from the screen grid of said vacuum tube to an auxiliary source of D. C. supply voltage, said other armature of said relay having a make contact which it engages when said winding is energized, and a resistor connected between said last make contact and said one end of said winding.

9. In a system having a magnetron, a source of pulses for driving said magnetron, and a D. C. voltage supply for said source, the method of maintaining a constant peak signal voltage across said magnetron despite variations in said voltage supply, which comprises providing a flow of space current in series with the D. C. path of said magnetron, bypassing the space current path for the A. C. component of pulse current, and varying the impedance of said space current path in such sense and magnitude as to substantially

11

compensate for variations in the peak voltage of the pulses supplied to said magnetron by said source.

10. In a system having a magnetron and means for supplying driving voltages to said magnetron, the method of maintaining a constant peak signal voltage across said magnetron despite variations in voltage output of said means, which comprises providing a flow of space current in series with said magnetron, bypassing said space current path for the A. C. component of said variations, and varying the impedance of said space current path in such sense and magnitude as to substantially compensate for the variations in voltage output of said means.

11. In combination, a magnetron having a cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, an impedance capable of passing direct current connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to bypass the A. C. component of pulse currents, a relay having a winding one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having an armature, a make and a break contact, said armature normally engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to the anode of said magnetron, a connection from said armature to that end of said winding which is connected to said bypass condenser, a condenser in shunt to the winding of said relay, a D. C. current regulator comprising a vacuum tube having an anode and a cathode, a connection from the anode of said vacuum tube to said make contact, and a resistor connecting the cathode of said vacuum tube to the anode of said magnetron.

12. In combination, a magnetron having a cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, a resistor shunted by an inductor connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to bypass the A. C. component of pulse currents, a relay having a winding, one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having a pair of armatures, a connection between said armatures, a make and a break contact for one of said armatures, said one armature normally

12

engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to the anode of said magnetron, a connection from said armatures to that end of said winding which is connected to said bypass condenser, a condenser in shunt to the winding of said relay, a D. C. current regulator comprising a vacuum tube having a cathode, an anode and a screen grid, a connection from the anode of said vacuum tube to said make contact, a resistor connecting the cathode of said vacuum tube to the anode of said magnetron, and a connection from the screen grid of said vacuum tube to an auxiliary source of D. C. supply voltage, said other armature of said relay having a make contact which it engages when said winding is energized, and a resistor connected between said last make contact and said one end of said winding.

13. In combination, a magnetron having a cathode electrode and an anode electrode, means for supplying pulses of such polarity and magnitude to one of said electrodes to cause said magnetron to produce pulses of radio frequency energy, a D. C. voltage supply for said means, a resistor shunted by an inductor connected at one terminal to said one electrode and at another terminal to said other electrode through a condenser of such value as to bypass the A. C. component of pulse currents, a relay having a winding, one end of which is connected to said other terminal and the other end of which is coupled to said bypass condenser, said relay having a pair of armatures, a connection between said armatures, a make and a break contact for one of said armatures, said one armature normally engaging said break contact in the absence of energizing current in said relay winding, a resistor connecting said break contact to said magnetron anode electrode, a connection from said armature to that end of said winding which is connected to said bypass condenser, a D. C. current regulator comprising a vacuum tube having a cathode, an anode, and a screen grid, a connection from the anode of said vacuum tube to said make contact, a resistor connecting the cathode of said vacuum tube to the negative terminal of an auxiliary source of D. C. supply voltage, and a connection from the screen grid of said vacuum tube to said auxiliary source of D. C. supply voltage, and a connection from the positive terminal of said auxiliary source of D. C. supply voltage to said magnetron anode electrode, said other armature of said relay having a make contact which it engages when said winding is energized, and a resistor connected between said last make contact and said one end of said winding.

ORVILLE E. DOW.

No references cited.