United States Patent

[11] **3,566,180**

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[21] Appl. No. **863,135**
[22] Filed **Oct. 2, 1969**
[45] Patented **Feb. 23, 1971**
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[54] **MEANS FOR SUPPRESSING HELIX CURRENT DURING MECHANICAL FOCUSING OF TRAVELING WAVE TUBE**
11 Claims, 2 Drawing Figs.

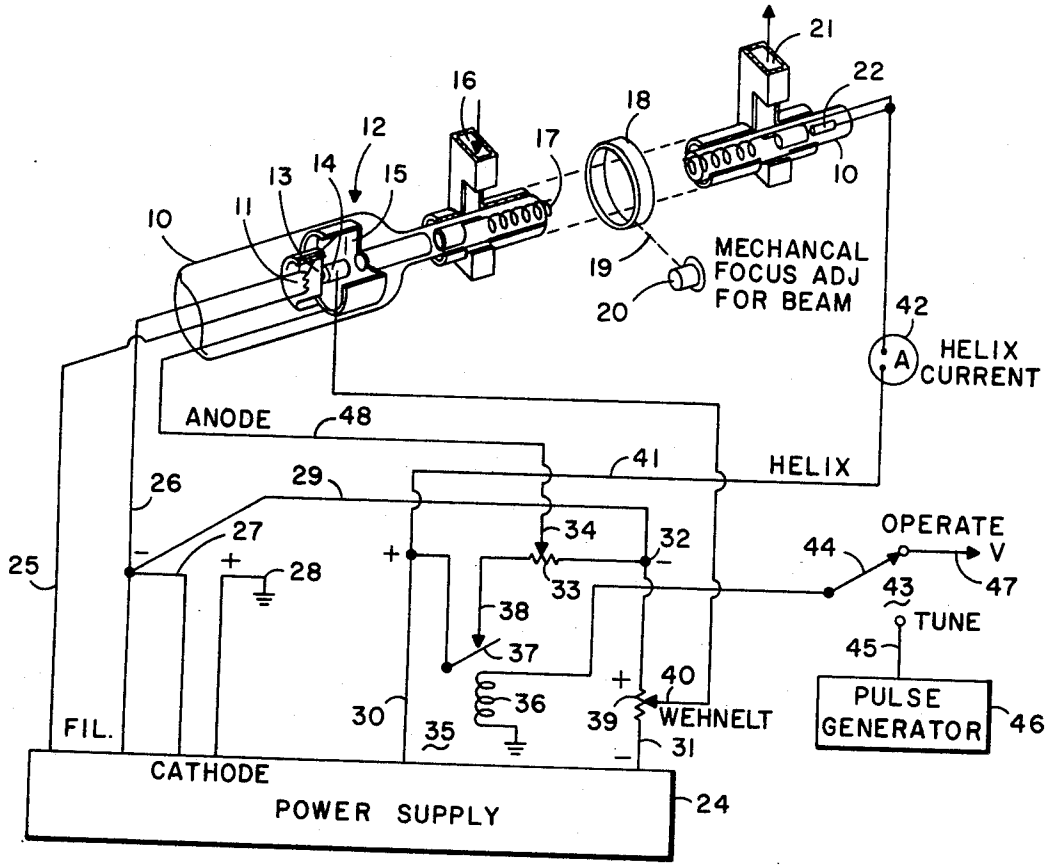
[52] **U.S. Cl.** **315/3.5,** 330/43, 324/26, 315/3.6
[51] **Int. Cl.** **H01j 25/34**
[50] **Field of Search** 315/3.5, 3.6, 39.3; 330/43; 324/20, 23, 44, 24, 26, 27

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ABSTRACT: Application of normal operate supply voltages to a helix-type traveling wave tube may cause, under worst defocused conditions, a helix current due to beam impingement thereon, sufficiently high to destroy the tube. By switching the application of supply voltage to a beam defining electrode between normal value and a beam suppressing value at a predetermined duty cycle, the tube may be focused by monitoring helix current which is prevented under worst defocused conditions from being great enough to cause tube damage.



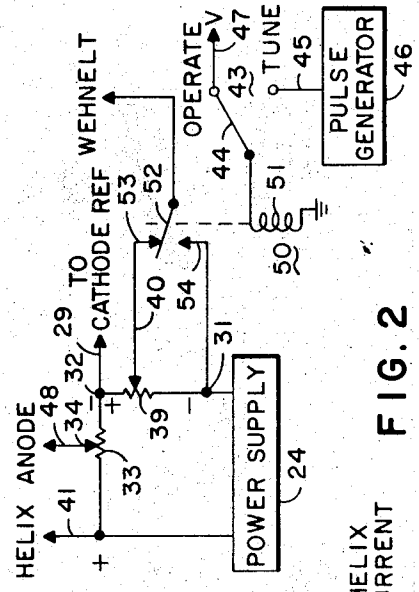


FIG. 2

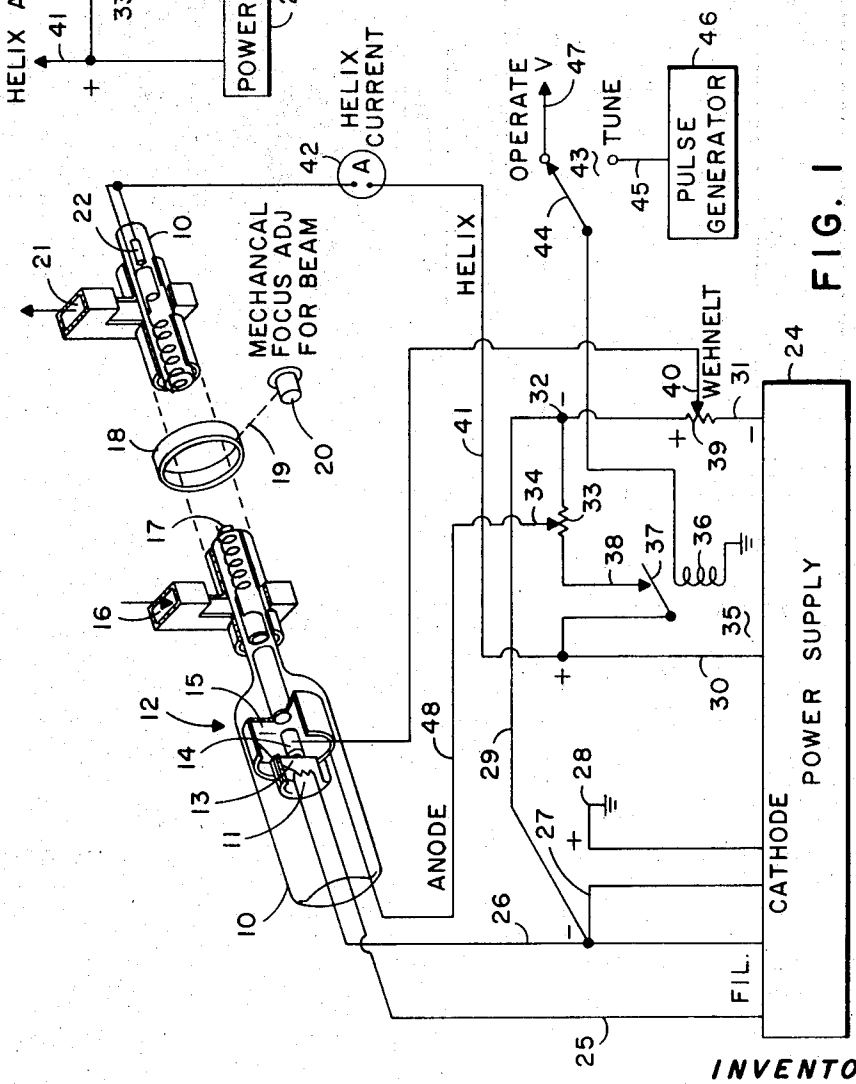


FIG. 1

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MEANS FOR SUPPRESSING HELIX CURRENT DURING MECHANICAL FOCUSING OF TRAVELING WAVE TUBE

This invention relates generally to traveling wave tubes and more particularly to a means permitting traveling wave tube focusing without damage to the tube.

More specifically, the present invention relates to a means associated with the operating voltage supply for a traveling wave tube of the helix type which permits tube focusing while suppressing damaging helix current.

The traveling wave tube is a device widely used in the microwave frequency ranges for amplification purposes. It would suffice to state here that the traveling wave tube is a broadband microwave tube which depends for its characteristics upon the interaction between the field of a wave propagated along a waveguide and a beam of electrons traveling with the wave. The electrons in the beam travel with velocity slightly greater than that of the wave and the subsequent loss in kinetic energy of the electrons in the beam appears as increased energy conveyed by the field of the wave.

Generally, the traveling wave tube includes an electron gun for generating a beam of electrons. The most commonly employed wave transmission circuit is comprised of a wire helix which consists of a helically wound wire conductor to which the waveguide energy is coupled. The beam is caused to be directed concentrically within and along the axis of the helix. The length of the winding, that is the length of the wire comprising the helix winding, causes the coupled waveguide energy to be delayed somewhat with respect to the velocity of the beam, and this principle develops the well-known bunching theory which provides amplification of the applied wave.

In the helix-type traveling wave tube under consideration here it is necessary that the beam of electrons from the gun be focused; that is, be precisely directed through the helix to minimize the impingement of beam electrons upon the helix winding. Such impingement generates helix current which results in undesirable shot noise and heating of the tube element. Under badly defocused conditions helix current can be high enough to destroy the tube.

Helix-type traveling wave tubes are accordingly associated with a focusing arrangement by means of which the stream of electrons is held in a tight beam by some sort of magnetic field surrounding the helix. Commonly employed methods to prevent the beam from spreading and thereby impinging upon the helix winding include electrostatic approaches, the employment of electromagnetic focusing means, and the employment of periodic permanent magnet mounts; the latter comprising a plurality of permanent magnets arranged in some periodic manner along the length of the traveling wave tube. Each of these focusing arrangements includes a mechanical positioning system by means of which the relationship between the magnetic field generated by the focusing arrangement and the position of the traveling wave tube envelope may be precisely adjusted. These focusing adjustments have traditionally been made with full operating voltages applied to the tube and are accomplished by monitoring helix current and adjusting the focusing means for a minimum indication of helix current.

Unfortunately with application of full operating voltages to the traveling wave tube, a badly defocused relationship can result in highly damaging helix current. Thus the initial focusing of a tube such as would be encountered in tube replacement in the field has been a highly critical operation ofttimes resulting in the destruction of the traveling wave tube due to initial high helix currents because of worst case defocused conditions.

The object of the present invention is accordingly the provision of a means operating in conjunction with the supply voltage normally applied to a traveling wave tube whereby the beam current may be suppressed during the focusing operation to a degree that focusing is possible but under a controlled arrangement where the worst case defocused condition cannot result in helix current level sufficient to damage the tube.

The invention is featured in the provision of means for pulsing the application of supply voltages to certain beam current defining electrodes in the traveling wave tube during focusing operations.

More precisely the invention is featured in the control of the duty cycle as concerns the application of normal operating voltages to a traveling wave tube in a manner such that average helix current is nondamaging to the tube but is sufficiently high to allow helix current monitoring for focusing purposes.

These and other features and objects of the present invention will become apparent upon reading the following description with reference to the accompanying drawings in which:

FIG. 1 is a functional schematic diagram of a helix-type traveling wave tube in circuit with an operating voltage power supply, and including means to control the duty cycle of anode supply voltage application to the tube; and

FIG. 2 is a functional schematic diagram illustrating an alternate means in association with the traveling wave tube power supply to realize beam current suppression during focusing operations.

FIG. 1 illustrates a helix-type traveling wave tube comprised of an envelope **10** which houses an electron gun generally designated by reference numeral **12** **12**. The l electron gun **12** is comprised of a heater or filament element **11**, a cathode **13**, a Wehnelt electrode **14**, a collector element **22**, and an anode **15**. The gun member **12** conventionally generates a beam of electrons which are directed concentrically within a helical winding **17** arranged concentrically within and along the axis of a cylindrical extension of the envelope **10**. The helix winding **17** is thus held concentrically within a wave coupling device depicted as an input waveguide **16** and an output waveguide **21** mounted on a nonmagnetic cylindrical tubelike structure which forms a receptacle for the portion of the tube envelope containing the helix winding. Wave energy to be amplified is coupled through input waveguide **16** to the helical winding and travels along the surface of the helical winding **17** to an output coupling means associated with output waveguide **21**. Normal operating voltages for the traveling wave tube depicted in FIG. **1** might typically be as follows:

cathode, −2,000 volts
anode, +2,500 volts
helix, +3,700 volts
Wehnelt, −50 volts

These typical operating voltages are based on a negative cathode voltage with respect to ground; all other voltages being referenced to the cathode voltage.

The focusing means **18** is functionally depicted in FIG. **1** in the form of a cylindrical magnet such as a coil **18** placed about the tube in proximity with the helix winding. A mechanical linkage **19** is depicted in conjunction with a focusing knob **20** by means of which the position of the coil **18** may be adjusted with respect to the tube envelope to accomplish beam focus. It is understood that the focusing arrangement might be comprised of other means such as the aforementioned electrostatic and periodic permanent magnet mount means. In any event the focusing adjustments influence the direction of the beam of electrons from the tube gun and must be accomplished initially and thereafter as necessary to minimize helix current. The adjustment is made by minimizing the helix current by means of a meter **42** in the helix supply voltage line, it being understood that helix current is the result of the electron beam striking the helix winding **17**.

The means of minimizing or eliminating tube damage due to excessive helix current which may be encountered during focusing is accomplished by reducing the average helix current to a level which is nondamaging to the tube, but is sufficient enough to allow monitoring for tuning purposes. In accordance with the present invention this may be accomplished by controlling average beam current. This may be accomplished by a pulsed application of anode voltage to the elec-

tron gun with a duty cycle sufficiently low that the highest helix current which might be encountered under worst focused conditions is insufficient to damage the tube. As will be described, an alternate method for traveling wave tubes which include a Wehnelt electrode consists in pulsing the application of normal Wehnelt supply voltage to the Wehnelt electrode—more precisely by switching the voltage applied to the Wehnelt electrode between the normal Wehnelt voltage and a voltage highly negative with respect to the cathode potential. In either case, the pulsing technique when applied with the appropriate duty cycle as concerns a given traveling wave tube is successful in suppressing damaging helix current which might be encountered focusing of the tube.

With reference to FIG. 1, the traveling wave tube is shown in conjunction with a typical voltage supply and a pulsing arrangement by means of which the anode voltage is pulsed during tuning operations at a predetermined duty cycle. FIG. 1 illustrates a power supply 24 which might develop on lines 25 and 26 a filament voltage for application to the heater electrode 11 of the tube. Lines 27 and 28 supply the cathode voltage with line 27 being, for example, −2,000 volts with respect to the grounded cathode voltage supply line 28.

Line 41 (referenced to the cathode voltage by means of line 29) supplies helix voltage of, for example, +3,700 volts. A voltage divider, comprised of potentiometers 33 and 39, placed across this high voltage supply, supplies the anode and Wehnelt voltages, respectively. Since terminal 32 is referenced to the cathode voltage by means of line 29, wiper arm 40 of potentiometer 39 supplies a small negative voltage with respect to the cathode for application on line 23 to the Wehnelt electrode 14. Potentiometer 33 supplies, through closed contacts of relay 35, an anode supply voltage as determined by the setting of wiper arm 34.

The Wehnelt voltage in FIG. 1 is seen to be continuously applied (negative with respect to the cathode voltage by an amount determined by the setting of wiper arm 40 of potentiometer 39). The anode voltage on line 48 to anode 15 of the tube is applied only when contacts 37 and 38 of relay 35 are closed. Relay 35 is controlled by the selective application of energizing voltage to the relay solenoid winding 36. The energization of relay 35 is accordingly controlled on a selective basis by the position of a switch 43 which functionally depicts a first "operate" position which continuously energizes relay 35 by application of an energizing voltage 47. The anode voltage is then continuously applied to the anode electrode on a normal operating basis. A second position of switch 43, the "tune" position, is seen to connect the relay winding to the output 45 of a pulse generator 46. In accordance with the present invention, the pulse generator 46 supplies a train of pulses 45 of a predetermined duty factor such that the anode voltage on line 48 is applied on a corresponding pulsed basis to the anode electrode of the tube.

The pulse generator 46 may then be designed with a particular duty cycle such that the average helix current monitored on meter 42 under worst defocused conditions is below the particular level for the tube employed which would be damaging. By applying the anode voltage in a periodic sense, sufficient beam current is generated on a pulse basis to permit the monitoring during focusing. However, the average beam current, and thus the average possible helix current, can be controlled so as to obviate damage to the tube. It has been found that controlling the duty cycle to approximately 25 percent based on normal operate voltage may keep the average helix current below a damaging value for worst defocused conditions. For example, in a particular application, a duty cycle of 30 percent was found to accomplish the desired control; that is, applying the anode voltage 30 percent of the time with all other voltages being normal.

It should be emphasized that the incorporation of the "tune-operate" switch 43 in FIG. 1 along with pulse generator 46 is intended to be functional in nature. In an operating system, for example, the "operate" position, rather than dictating a constant application of anode voltage might tie into further monitoring equipment associated with the power supplies which under certain conditions could remove the anode voltage to prevent tube damage. The arrangement of FIG. 1 is intended to indicate that in the operate mode, the conventional system application including all interwoven safety factor controls, is effected; while in the "tune" position the application of the anode voltage on line 48 to the tube is based on a precise predetermined duty cycle as determined by the pulse repetition rate and pulse width of the pulses supplied by the generator 46.

FIG. 2 represents a functional arrangement of a second embodiment in accordance with the present invention by means of which the average helix current in a traveling wave tube may be reduced for focusing purposes. FIG. 2 illustrates the portion of the power supply supplying the helix anode, cathode, and Wehnelt electrode supply voltages, along with a pulse switching arrangement by means of which the Wehnelt voltage is pulsed in a fashion so as to control the beam current and hence the maximum helix current. While the embodiment of FIG. 1 is universal in nature for all types of traveling wave tubes, those types including a Wehnelt electrode may be controlled by a pulsing operation on the voltage supplied to this particular electrode. The Wehnelt electrode is a suppressor type of element which forms a part of the electron gun of the tube. Normally the Wehnelt voltage is maintained at a relatively small negative potential with respect to the cathode potential. Thus as illustrated in each of the FIGS. the Wehnelt voltage might be taken from a potentiometer 39 in the helix supply voltage portion of the power supply which is in circuit between the negative-most terminal 31 and the point 32 which forms the cathode reference point. Thus the position of the wiper arm 40 on potentiometer 39 determines a Wehnelt electrode potential negative with respect to the cathode by a preselected amount. As previously indicated, a typical tube employing a Wehnelt electrode might operate with the electrode at −50 volts with respect to the cathode potential. It has been found that the average helix current may be controlled by switching the Wehnelt potential between a highly negative voltage with respect to the cathode potential and the normal Wehnelt operating voltage. As in the case of controlling the duty cycle of the application of the anode potential, this expedient suppresses the cathode and helix current is held to a nondamaging value. FIG. 2 illustrates the incorporation of a relay 50 for this purpose. The fixed contacts 53 and 54 of relay 50 are connected respectively to the wiper arm 40 and terminal 31 of the power supply (the negative-most terminal). Movable contact 52 of relay 50 is connected to the Wehnelt electrode 14. As in the case of switching the anode voltage with the relay in the FIG. 2 embodiment, in the "tune" position of switch 43, an output train of pulses 45 from pulse generator 46 causes the relay to switch between the normal operating Wehnelt voltage (connection 52—53) to a more highly negative voltage with respect to the cathode (connection 52—54). The potential alternately applied to Wehnelt electrode from connection 52—54 of the relay applies to the electrode a sufficiently high voltage to suppress the cathode and helix current to a nondamaging value under worst focused conditions. In a typical operating case it was found that a duty cycle of 15 percent; that is, application of the normal Wehnelt operating voltage 15 percent of the time, was required to keep the average helix current below a damaging level under worst defocused conditions.

In either of the embodiments the pulsing technique is effective in reducing the beam current by a factor sufficient to limit helix current during worst defocused conditions while at the same time permitting sufficient helix current to allow monitoring on the helix current meter 42 for tuning purposes.

I claim:

1. A beam focusing means for a traveling wave tube of the type including a helix and a beam focusing means positionable with respect to said helix by means of which helix current may be minimized to attain beam focusing; means for reducing beam current to a safe average value during focusing whereby

helix current is limited to a predetermined magnitude under worst defocused conditions; comprising, power supply means supplying normal operating voltages of predetermined magnitudes and potentials to the beam defining and controlling electrodes of said traveling wave tube, means for controlling the application of the supply voltage to at least one of said beam defining tube electrodes between the normal operating potential and a second predetermined potential the application of which is instrumental in effecting a predetermined suppression of beam current in said traveling wave tube, whereby the average beam current is reduced to a value such that average monitored helix current may not exceed a predetermined magnitude.

2. Means as defined in claim 1 wherein said traveling wave tube anode supply voltage is periodically applied to the anode of said tube at a rate corresponding to a predetermined duty cycle to effect said beam current suppression.

3. Means as defined in claim 2 wherein the anode voltage supply is selectively connected to said anode electrode of said traveling wave tube through switching means the energization of which is controlled by a source of energizing pulses.

4. Means as defined in claim 3 wherein said source of pulses comprises the output from a pulse generator, said pulses being of a predetermined duty cycle.

5. Means as defined in claim 4 wherein said duty cycle is between the limits of 20 and 30 percent based on normal operating anode voltage application.

6. Means as defined in claim 1 wherein said traveling wave tube includes a Wehnelt suppressor electrode, said power supply including a source of voltage negative with respect to said cathode normal operating voltage for application to said Wehnelt suppressor electrode, and control means for selectively applying said Wehnelt suppressor power supply potential to said Wehnelt electrode alternately with application of a further negative potential substantially more negative than said cathode supply voltage, whereby said average beam current is suppressed to an average value such that average helix current under worst defocused conditions of said traveling wave tube is beneath said predetermined magnitude.

7. Means as defined in the claim 6 wherein said control means comprises a relay a first fix contact of which is connected to the normal Wehnelt electrode operating voltage and a second fixed contact of which is connected to said further negative potential, and means for selectively operating said relay between respective positions thereof.

8. Means as defined in claim 7 wherein said relay comprises an energizing winding selectively connectable to the output of a pulse generator means, said pulse generator means developing a train of pulses the duty cycle of which effects said predetermined beam current suppression.

9. Means as defined in claim 8 including switching means, a first position of said switching means effecting a connection between said relay energizing winding and a source of energizing voltage, a second position of said switching means connecting said relay energizing winding to the output of said pulse generator.

10. Means as defined in claim 8 wherein the periodic switching of said normal and further supply voltages to said Wehnelt electrode establishes a duty cycle in the range of 15 percent based on the application of normal operating voltage to said electrode.

11. In conjunction with a power supply for a traveling wave tube, control means for varying the duty cycle of the application of normal operating voltage to at least one beam current determining electrode at a predetermined rate to reduce average beam current to a value in response to which average helix current under worst tuned conditions is held beneath a predetermined magnitude, whereby damage to said traveling wave tube is prevented during focusing arrangements, said control means comprising switching means, a first position of said switching means effecting continuous application of normal supply voltages to said traveling wave tube and a second position of said switching means effecting alternate application of the normal operating value of a predetermined one of said supply voltages to its associated tube electrode with application of a second potential, the application of said second potential being effective in suppressing beam current to a value substantially below that experienced under normal supply voltage application.