March 3, 1959 H. L. McDOWELL 2,876,378

TRAVELING WAVE TUBES

Filed June 10, 1955

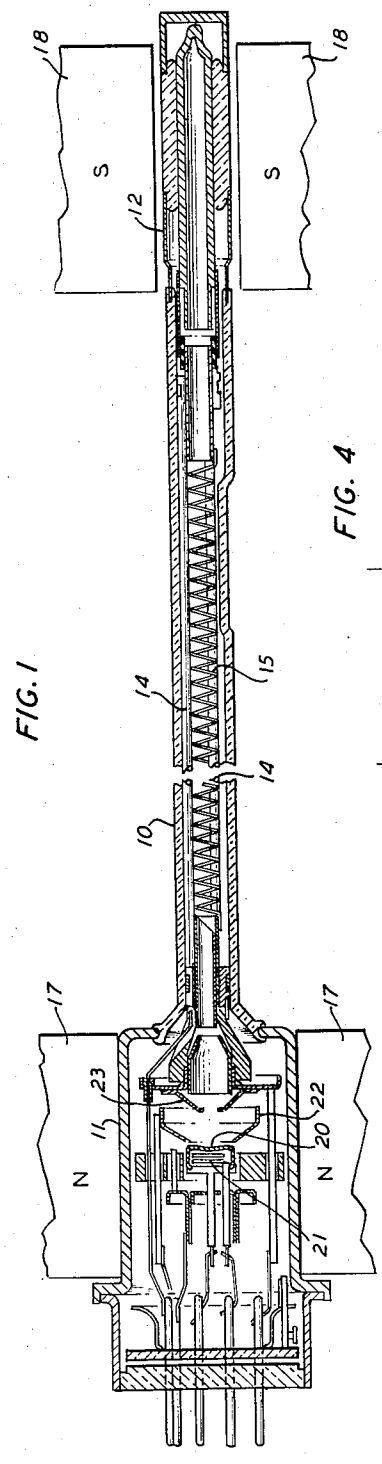

FIG. 1

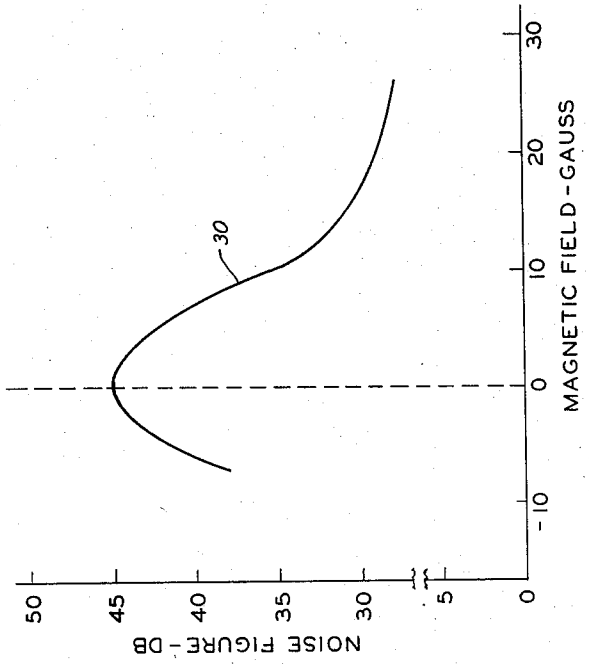

FIG. 4

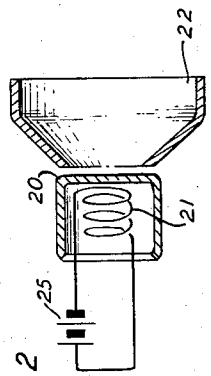

FIG. 2

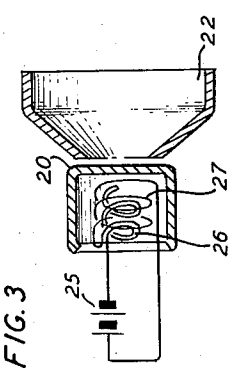

FIG. 3

INVENTOR
H. L. Mc DOWELL
BY
ATTORNEY

United States Patent Office 2,876,378
Patented Mar. 3, 1959

2,876,378

TRAVELING WAVE TUBES

Hunter L. McDowell, Berkeley Heights, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 10, 1955, Serial No. 514,489

3 Claims. (Cl. 315—3.5)

This invention relates to traveling wave tubes and more particularly to reduction of noise in such tubes.

It is known that there is a relatively high noise level in present traveling wave tubes, which makes difficult operation at low input signal levels. The most important sources of noise are the random rate of emission and the Maxwellian distribution of velocities among the electrons emitted from the thermionic cathode of a traveling wave tube. The noise due to the random rate of emission is generally referred to as "shot" noise and that due to the distribution of velocities is generally referred to as "velocity fluctuation" noise. Each of these can induce in the electron stream a convection current component of noise. Convection current noise of this kind ordinarily is wideband in its frequency components; therefore, within the operating band of the traveling wave tube it can induce noise wave energy into the signal circuit. This causes appreciable noise wave energy to appear at the output of the traveling wave tube.

Priorly it has been considered that the shot noise and velocity fluctuation noise cause only standing wave patterns on the electron stream, which patterns exhibit maxima and minima along the path of electron flow. In order to reduce this standing wave noise pattern various arrangements have been proposed. These include the employment of velocity jump electron guns; the provision of a resonant structure adjacent the cathode, the structure being resonant at the mid-frequency of the operating band in the traveling wave tube, as further described in application Serial No. 471,673, filed November 29, 1954, of J. R. Pierce; or the employment of a metallic envelope which itself is scalloped in relationship to the standing wave noise pattern, as further disclosed in Patent No. 2,828,439, issued to R. C. Fletcher on March 25, 1958.

However, when a high density electron beam is employed in a traveling wave tube, as would be desirable in a traveling wave tube capable of delivering a significant power output, it has been found that the noise pattern is not that of a standing wave entirely but instead appears to be composed of a standing wave followed by a growing wave which reaches a saturation value, following which, at this new value of noise, the standing wave pattern reappears. Such a tube may be of the type disclosed in Patent No. 2,772,939, issued to J. P. Laico on December 4, 1956. Due to this growing noise wave a very high level of noise may appear at the output of a tube of this type and may be sufficient to interfere with the signal being transmitted and amplified thereby.

The reasons for the appearance of this growing noise wave are not presently known, but it appears possible that it may be due to the fact that different groups of electrons (which are present in a very dense electron beam) may be given the same velocity in a longitudinal direction but different velocities in a transverse direction. These groups of electrons are confined by the magnetic fields employed in a traveling wave tube, so that the various groups form a single beam in which electrons of the various groups cross over one another in their travel along the helix of the tube. These electrons in crossing over each other interact in such a way that the noise wave may be amplified as the beam travels along the helix of the traveling wave tube. However, it is to be understood that the present invention is not dependent on any explanation of the growth of the noise wave in traveling wave tubes employing a high density electron beam.

It is a general object of this invention to provide an improved traveling wave tube.

More specifically, objects of this invention include reducing the noise in traveling wave tubes and inhibiting or preventing the appearance of a growing noise wave in such tubes.

In one specific illustrative embodiment of this invention the noise level at the output of a traveling wave tube is reduced by employing a heater for the cathode or the electron gun structure which will cause a slight magnetic field to be present at the cathode due to the current flowing through the heater coil. In another specific illustrative embodiment a standard non-magnetic heater coil may be employed and a special magnetic coil connected in series with it to provide the magnetic field linking the cathode. In either case, the current through the heater, which is advantageously a direct current, is utilized to create a magnetic field at the cathode.

By employing a slight magnetic field at the cathode the mobility of the electrons in their travel transverse to the direction of electron beam is impeded and therefore their effect in creating a growing noise wave which can be amplified in the interaction region of the traveling wave tube is considerably lessened. The amount of the magnetic field that should be introduced at the cathode in order most advantageously to prevent this growth of the noise wave is in itself a compromise between introducing a magnetic field for this purpose and the fact that the introduction of the magnetic field has a deleterious effect on the focusing of the electron beam. In one specific embodiment of this invention wherein the focusing magnetic field along the helix was 600 gauss, I found it advantageous to have a magnetic field of 15 gauss at the cathode. This magnetic field at the cathode may advantageously be attained entirely due to the magnetic coil adjacent thereto and the direct heater current flowing therein, or may be due partly to this coil and partly to leakage from the axial magnetic field adjacent the helix. Thus, in this one embodiment, wherein 15 gauss of magnetic field link the cathode, only 6 gauss were actually provided by the heater.

As discussed above, there is a compromise that has to be made in choosing the amount of the magnetic field at the cathode; too much field results in poor electron focusing, while too little field results in a high noise output. I have found that there is a relatively narrow range of fields at the cathode which can give reasonably good focusing and noise performance simultaneously. The exact value of this field or the range of fields for a particular traveling wave tube will depend on a number of facts, including the relative importance for that particular tube of good focusing as opposed to good noise performance. Additionally, the type of gun, its location relative to the helix, and the electrical parameters involved will determine the magnitude of the field for optimum noise characteristics and focusing for that particular tube and circuit.

As the amount of the field at the cathode is small and variations in this field strength can seriously and adversely affect the performance of a traveling wave tube, it is important that the value of the magnetic field at the cathode should be very accurately determined. In accordance with this invention that amount of the field can be very accurately determined by proper choice of the

magnetizing coil, which may be the heater, and the current through the coil at the gun structure. If desired the cathode and electron gun may be substantially entirely shielded from the axial magnetic field so that there is substantially no leakage field threading the cathode, the entire field at the cathode being determined by the heater current or the current through the magnetizing coil. Or there may be some leakage field at the cathode and the magnetizing coil current field employed to determine precisely the value of the field at the cathode. While advantageously the heater current is utilized to provide the magnetic field at the cathode, in whole or in part, in certain embodiments of this invention it may be desirable to have, for focusing reasons, a leakage field at the cathode larger than the amount of field desired at the cathode for noise reduction purposes; in such embodiments the field due to the current through the magnetizing coil may be employed to oppose the axial leakage field and in this manner accurately determine the amount of magnetic field at the cathode.

I have found that it is difficult to try to utilize only the leakage field to determine the field at the cathode. Further, for focusing reasons the shape of the magnetic flux lines that emanate from the helix back to the gun structure, as well as the amount of leakage magnetic field at the gun structure, must be maintained within certain requirements. These requirements on the axial magnetic field for focusing reasons may often be incompatible with the desired magnetic field at the cathode for noise reduction purposes. Accordingly, by providing the magnetic field at the cathode by a magnetizing coil independent of the means for providing the axial magnetic field, in accordance with this invention, the design of the leakage magnetic field may be optimized for focusing of the electrons within the helix of the tube.

When there is no field at the cathode, an electron having some transverse thermal velocity can follow a trajectory which takes it back and forth across the electron beam. However, when there is a small magnetic field at the cathode, accurately determined by the current through a magnetizing coil in accordance with this invention, the radial motion of an electron with a given amount of thermal energy is considerably restricted. In this way the small field at the cathode has a large effect on reducing noise, as it appears that, in order to obtain the growing noise wave along the helix, it must be possible for thermal electrons to move back and forth over the cross section of the beam.

It is a feature of this invention that a magnetizing coil be positioned adjacent the cathode of a traveling wave tube through which a direct current flows to provide a small field at the cathode distinct from the leakage axial magnetic field. Thus, it is a feature of this invention that the field threading the cathode be accurately determined, without detriment to the desired lines of magnetic force for focusing purposes, by a magnetizing coil which is distinct from the means providing the axial magnetic field along the interaction circuit of the traveling wave tube.

It is another feature of this invention that the small magnetic field at the cathode of a traveling wave tube to inhibit a growing noise wave in the tube be provided by the heater current associated with the electron gun structure. Thus, it is a feature of one specific embodiment of this invention that the heater itself be a magnetic or inductive heater, the heater current flowing through the heater providing the desired field strength. And it is a feature of another specific illustrative embodiment of this invention that a noninductive heater have connected in series a magnetic coil adjacent the cathode, the heater current flowing through the magnetic coil to provide the desired field strength at the cathode.

In accordance with another feature of this invention the desired field strength at the cathode is accurately determined by the direct current through the magnetizing coil or heater element at the cathode. In certain embodiments of this invention the cathode may be shielded from the leakage axial magnetic field along the interaction space of the traveling wave tube so that the magnetizing current provides the total magnetic field at the cathode; in other embodiments of this invention there may be some leakage field at the cathode and the exact amount of the field at the cathode determined by the magnetizing current field either aiding or in opposition to the leakage field.

A complete understanding of this invention and of these and various other features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a cross sectional view of a traveling wave tube in accordance with one illustrative embodiment of this invention;

Fig. 2 is a schematic representation of the cathode and heater circuit of the embodiment of Fig. 1;

Fig. 3 is a schematic representation of the cathode and heater circuit of another illustrative embodiment of this invention; and

Fig. 4 is a graph depicting the variation of noise with magnetic field at the cathode for one specific embodiment of this invention in accordance with Figs. 1 and 2.

In the specific illustrative embodiment of this invention depicted in Figs. 1 and 2 the tube is of the type described in Patent No. 2,772,939, issued to J. P. Laico on December 4, 1956 and comprises an elongated glass envelope portion **10** to one end of which is connected a metallic base envelope portion **11** and to the other end of which is connected the collector envelope portion **12**. Positioned within the glass envelope portion **10** are the helix support rods **14** and the helix **15**. The axial or longitudinal magnetic field for the helix **15** may be provided in various ways known in the art and specifically by horseshoe magnets, not shown, extending between pole pieces **17** and **18**. Situated within the base envelope portion **11** is an electron gun comprising a cathode **20**, heater element **21**, as discussed further below, accelerating electrode **22**, and anode member **23**, to all of which suitable connections may be made through the base of the tube. The metallic envelope portion **11** is advantageously of a magnetic material and serves partially to shield the electron gun from the magnetic field due to the pole pieces **17**. Additionally flux guides may be employed between the pole pieces **17** and **18** to assure that the magnetic flux lines are parallel to the axis of the helix, as disclosed further in Patent No. 2,807,743, issued to P. P. Cioffi on September 24, 1957.

In accordance with this specific illustrative embodiment of the invention the magnetic field at the cathode **20**, which field prevents the growth of a growing noise wave along the helix **15**, is assured by providing that the heater coil **21**, as best seen schematically in Fig. 2, is inductive, so that the heater current from a direct current heater voltage source **25** generates a small magnetic field at the cathode. In this specific illustrative embodiment, wherein the axial magnetic field along the helix is 600 gauss, the magnetic shield **11** is so positioned with respect to the electron gun and the size of the aperture in the shield is such as to allow about 9 gauss at the cathode **29**. The exact magnetic field, which is the sum of the leakage and heater fields, is then determined by the heater current from the source **25** through the heater coil **21**.

In the specific illustrative embodiment of this invention depicted schematically in Fig. 3 the heater element **26** is noninductive, and may be of the type priorly employed in traveling wave tubes; however, in accordance with an aspect of this invention a magnetizing coil **27** is connected in series with the heater element **26** and the heater source **25**, the magnetizing coil **27** together with the heater current providing the desired heater magnetic field at the cathode.

The effect of the magnetic field in decreasing the noise at the output of a traveling wave tube and specifically in preventing the growth of a growing noise wave pattern can be seen in Fig. 4, wherein the noise figure of the tube is plotted against the magnetic flux at the cathode for the specific illustrative embodiment depicted in Fig. 1. The noise figure is the degradation in the signal-to-noise ratio of a signal when passed through the tube. As can be seen, the curve 30 has a symmetry centered at zero field at the cathode, at which field the noise figure and thus the noise level at the output is highest. It should be noted that a slight amount of field at the cathode greatly reduces the noise level. Thus, a variation of only 20 gauss on either side of the zero field results in a noise figure decrease of the order of 15 decibels.

It should also be pointed out that this reduction in the noise level is not dependent on the direction of the magnetic field at the cathode. This can be clearly seen in Fig. 4. This apparently is due to the fact that the effect of the magnetic field is merely to restrict the mobility of electrons having transverse thermal velocities, and this restriction is dependent on the magnitude but not the direction of the magnetic field.

Reference is made to application Serial No. 514,488, filed June 10, 1955, of H. E. Elder and H. L. McDowell, wherein a related invention is disclosed and claimed.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. For example, the magnetizing coil may be distinct from the heater element but be connected in parallel therewith, rather than in series; further in other embodiments of this invention, the magnetizing coil may be connected to a current source distinct from that of the heater element.

What is claimed is:

1. A traveling wave tube comprising means defining an interaction circuit, magnetic means for providing an axial magnetic field along said circuit, electron gun means adjacent one end of said circuit for projecting a stream of electrons therealong, said electron gun means including a cathode and a heater element therefor, and means for decreasing the noise level in said traveling wave tube, said last-mentioned means comprising means for causing a direct current to flow through said heater element, said heater element including a non-inductive coil and a distinct magnetic coil electrically connected in series therewith and adjacent to said cathode, whereby flux produced by said magnetic coil threads said cathode.

2. A traveling wave tube comprising an interaction circuit, magnetic means for providing an axial magnetic field along said circuit, electron gun means positioned at one end of said circuit for projecting a stream of electrons therealong, said electron gun means including a cathode and a heater element therefor, shielding means for at least partially preventing said axial magnetic field from linking said cathode, and means distinct from said priorly mentioned magnetic means for causing a small amount of magnetic flux to link said cathode to decrease the noise level in said traveling wave tube, said last-mentioned means comprising a magnetizing coil adjacent said cathode and means for causing a direct current to flow through said magnetizing coil.

3. A traveling wave tube in accordance with claim 2 wherein said shielding means allows a small amount of leakage flux from said axial magnetic field to thread said cathode in addition to the magnetic flux due to said direct current flow through said magnetizing coil.

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