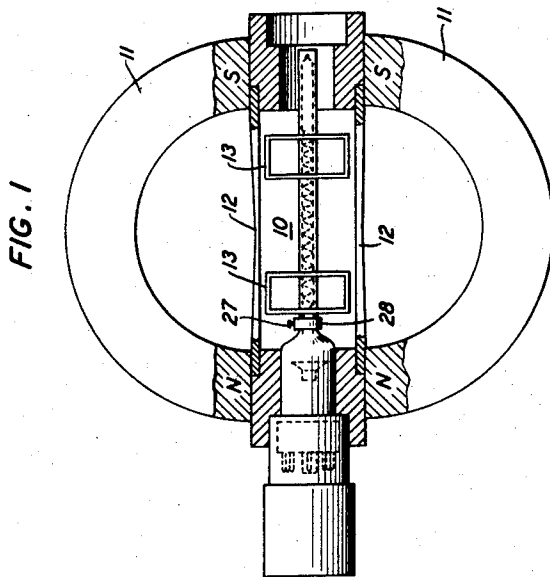
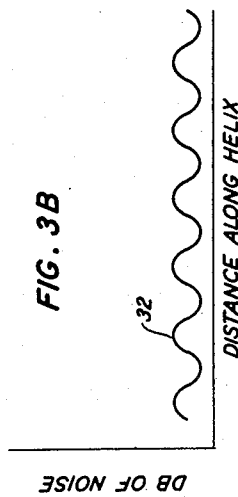
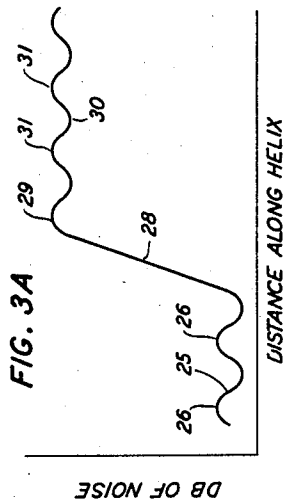
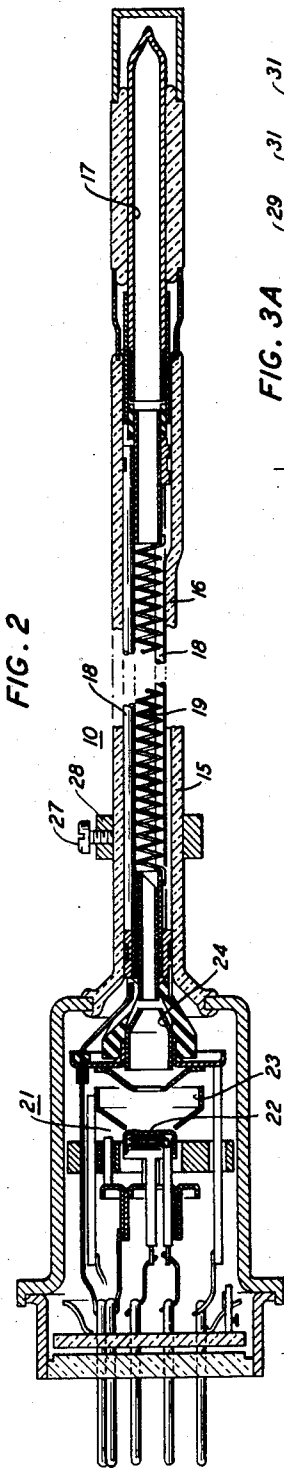


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TRAVELING WAVE TUBES

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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 the 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 United States Patent 2,947,905, issued August 2, 1960, 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 United States Patent 2,828,439, issued March 25, 1958, of R. C. Fletcher.

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 application Serial No. 387,361, filed October 21, 1953, of J. P. Laico, now abandoned. Due to this growing noise wave a very high level of noise may appear at the output of the traveling wave tube and may be sufficient to interfere with the signal being transmitted and amplified by the traveling wave tube.

The reasons for the appearance of this growing noise wave are not presently known but it appears possible that they 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 the traveling wave tube, so that the

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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 beam. 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 the 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 preventing the appearance of a growing noise wave in such tubes.

In one specific illustrative embodiment of this invention, a traveling wave tube which may be of the type disclosed in the aforementioned application Serial No. 387,361 and in United States Patent 2,772,939, issued December 4, 1956, both of J. P. Laico, is positioned in a magnetic field employing magnetic flux guides, as further described in United States Patent 2,807,743, issued September 24, 1957, of P. P. Cioffi, so that the helix and interaction space are positioned in a region of a completely axial magnetic field. In accordance with one aspect of this invention, a magnetic disturbance is introduced along the helix adjacent the input or cathode end of the traveling wave tube. This small magnetic field disturbance may advantageously, in one specific embodiment, be effected with a screw of iron or other magnetic material positioned on a ring or brass of other non-magnetic material which is secured directly onto the envelope of the traveling wave tube. It has been found that such an arrangement, which disturbs or bows out the axial magnetic field asymmetrically in the region of the magnetic disturber, is particularly conducive to effecting a reduction in the noise content of the beam which includes the prevention of the appearance of a growing noise wave on the beam in accordance with the principles of our invention. In accordance with another aspect of this invention, this small magnetic field disturber is positioned along the helix at a point prior to the growth of the noise wave above the level of the initial standing wave noise pattern of the tube and advantageously close to the anode of the electron gun. Thus the disturber may be directly at the cathode end of the helix or if a drift tube is interposed between the electron gun and the helix, the disturber may in fact be positioned adjacent this drift tube.

We have found that to attain the maximum reduction in the noise level at the output of the traveling wave tube the magnetic field disturber should be positioned before the growth of the noise wave pattern as described above. However, there may still be some reduction in noise if the disturbance is introduced after the start of the growth of the noise wave and it appears that the amount of the reduction in noise is dependent on the distance beyond the initial growth of the wave pattern at which this disturbance is introduced. However, this disturbance, in accordance with this invention, should be introduced before the growing noise wave has attained its saturation value. Further, we have found that there are points of maximum sensitivity at which this small magnetic field disturber should be positioned along the helix to attain the maximum reduction of the noise level at the output. These points of maximum sensitivity are spaced about a cyclotron wavelength apart and appear to correspond to the points of maximum diameter of the electron beam, due to the scalloping present in the focused electron beam, as is known in the art.

It appears that the noise currents or noise electrons present in the electron beam are mainly at the outer

surface of the beam. It seems probable, therefore, that the small magnetic field disturber which is positioned along the helix of the tube in accordance with our invention serves to weaken the field and cause a bowing out of the magnetic flux lines directly adjacent to it and to make it possible to destroy the growing noise phenomena by intercepting only a very small amount of current on the helix, which current may be of the order of only five percent or less of the total beam current in certain specific embodiments of this invention depending on the values of the beam current and voltage. As previously mentioned, we have found that the growing noise wave phenomena advantageously may be prevented from causing an increase in the noise level at the output by the inclusion of only a single small magnetic field disturber designed to bow out the magnetic field asymmetrically in the region thereof in accordance with this invention. It is to be understood that while the above-discussed analysis is believed to be a correct statement of the functioning of the magnetic field disturber in accordance with the aspects of this invention, this invention is not to be considered as limited to the above or any other explanation of the functioning of the invention in the attainment of the meritorious results described herein.

It is a feature of this invention that a small magnetic field disturber be positioned closely adjacent the helix of a traveling wave tube in order to destroy the growing noise wave in the traveling wave tube. More specifically, in accordance with the feature of this invention, the magnetic field disturber is positioned along the helix prior to the growth of the noise wave above the level of the standing noise wave maximum adjacent the input of the traveling wave tube.

It is another feature of this invention that the small magnetic field disturber be positioned closely adjacent the electron gun, as at the input end of the helix, and at a region of closest approach of the electron beam to the helix. In traveling wave tubes wherein the electron beam as focussed and projected along the regions is scalloped within the helix, having alternate regions of maximum and minimum diameters, the magnetic field disturber in accordance with this feature of the invention is positioned at a region of maximum beam diameter.

It is a further feature of one specific illustrative embodiment of this invention that the small magnetic field disturber be a screw of iron or other magnetic material mounted on a ring of brass or other non-magnetic material, the ring being secured to the envelope of the traveling wave tube. Advantageously in accordance with this feature of the invention the ring may be clamped onto the envelope of the tube by the magnetic screw.

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

Fig. 1 is a side view partially in section of one specific embodiment of this invention showing particularly the magnetic field structure and the traveling wave tube;

Fig. 2 is a sectional view of the traveling wave tube of Fig. 1 showing particularly the location and positioning of a small magnetic field disturber in accordance with one aspect of this invention;

Fig. 3A is a graph of the noise current along the helix of a traveling wave tube employing a high current density electron beam in the absence of this invention, showing particularly the growing noise wave that may occur; and

Fig. 3B is a graph of noise current along the helix of a traveling wave tube in accordance with aspects of this invention, showing the standing noise wave pattern that occurs.

In the specific illustrative embodiment of this invention depicted in Fig. 1 a traveling wave tube 10, described further below with reference to Fig. 2, is positioned in a magnetic field provided by two horseshoe magnets 11. The field is maintained perfectly uniform along the in-

teraction circuit of the traveling wave tube, defined advantageously by a helix 19 by the employment of two flux guides 12, as further described in the aforementioned patent of P. P. Cioffi. An input and an output wave guide 13 may be employed for coupling to the helix of the traveling wave tube.

The tube 10 itself may advantageously be of the type described in the aforementioned application and patent of J. P. Laico and comprises an elongated glass envelope 15 having a portion 16 adjacent the collector 17 collapsed onto the support rods 18 for the helix 19 to prevent power fading and low efficiency of operation due to the inability of the helix to transmit the high radio frequency power, which increases exponentially along the helix length, as further discussed in the above-mentioned application and patent. The electron gun 21 may be of any known type capable of providing a high current density beam for medium or high power traveling wave tube operation. In the specific embodiment depicted the gun 21 comprises a cathode 22, an accelerating electrode 23, and an anode 24.

In accordance with this invention a small magnetic field disturber is positioned closely adjacent the helix 19 within the axial or longitudinal magnetic field to cause a bowing out of the flux lines at that point. This magnetic field disturber may be of any of a number of different forms in different embodiments of this invention, however, a magnetic disturber of the type establishing an asymmetrical disturbance or bowing out of the otherwise uniform axial magnetic focusing field has been found to be particularly conducive in combination with other features of the invention to effecting a reduction in the noise content of the beam. Accordingly, in the specific illustrative embodiment depicted in Figs. 1 and 2, the magnetic field disturber is a small screw 27 of iron or other magnetic material positioned in a ring 28 of a non-magnetic material, such as brass, secured onto the envelope 15 of the tube. If desired, the screw 27 may be utilized to clamp the ring 28 onto the envelope 15.

In traveling wave tubes employing high density electron beams, as in the type depicted in Fig. 2 of the drawing, the noise pattern along the helix 18 is as depicted in Fig. 3A; as there seen the noise first shows a standing wave pattern 25, the points 26 of maximum noise amplitude being spaced a half space charge wavelength apart along the electron beam projected through the helix 19. After a few repetitions of the standing wave pattern 25, there is a growing noise wave 28. The noise appears to continue to grow until a saturation value 29 is reached, after which a second standing wave noise pattern 30 is apparent, the points of maximum noise 31 again being spaced a half space charge wavelength apart, but the amplitude of the pattern 30 being smaller than that of the initial pattern 25.

In accordance with our invention the magnetic field disturber 27 is positioned along the helix at a point prior to the commencement of the growing noise wave pattern 28. We have found it advantageous to position the disturber 27 as close to the electron gun 21 as is physically possible; thus in the specific embodiment depicted in Fig. 1 wherein the input wave guide 13 encompasses the start of the helix 19 in the traveling wave tube, the disturber or screw 27 is positioned adjacent the envelope 15 before the wave guide and adjacent the input end of the helix. If a long drift tube is employed between the electron gun and the helix, the disturber may be positioned adjacent it and prior to the start of the helix. Alternatively in another specific embodiment of this invention the magnetic disturber 27 may in fact even be positioned within the input wave guide 13.

Further, we have found that for maximum reduction in the noise level at the output of the traveling wave tube, the magnetic field disturber should be positioned at a specific point or points electrically defined, along the helix. When an electron beam is injected into a

traveling wave tube interaction space, as along the axis of the helix 19, the beam is not perfectly cylindrical but instead has perturbations or scalloping of its outer surface, the electrons being closer to the helix at discrete regions along the beam than at other regions. Accordingly in accordance with an aspect of this invention the magnetic field disturber or screw 27 is positioned on the envelope 15 so as to be adjacent a region of maximum diameter of the electron beam. In certain other traveling wave tubes the electron gun may be slightly misaligned with the axis of the helix so that the center line of the electron stream is not coincident with the axis of the helix. In such tubes the beam has a portion of closest approach to the helix which itself defines a helical path. In such tubes the magnetic field disturber is advantageously positioned along that path.

The noise wave appears to be present in the electron beam mainly in electrons closely adjacent the periphery of the beam. In accordance with our invention growth of this noise wave is prevented by causing those electrons to be intercepted by the helix. This is attained by having the axial magnetic field bowed slightly and, preferably asymmetrically, at one point adjacent the input end of the helix and specifically at a point of maximum electron beam diameter or closest approach of the beam to the helix. By positioning the disturber 27 at a point of maximum electron beam diameter, in the embodiment depicted in the drawing, a smaller magnetic field disturber may be employed and a larger interception of the noise wave electrons attained.

The noise wave pattern in traveling wave tubes, in accordance with our invention, is depicted in Fig. 3B and comprises only the standing wave pattern 32 common to low density electron beam traveling wave tubes, the growing wave pattern having been prevented. The standing wave noise pattern 32 may then be handled in manners known in the art in order to reduce the noise level at the output of the traveling wave tube.

We have found that only a single magnetic disturber positioned along the path of electron flow need be employed to attain the beneficial results of our invention, subsequent magnetic disturbers located at successive regions of electron beam diameter maxima not appreciably changing the noise pattern. Further, while it is advantageous in accordance with our invention, as described above, that the magnetic disturber be located adjacent the helix before the growth of the growing noise wave pattern above the maximum amplitude of the prior standing wave pattern and advantageously, in fact, as close to the input or cathode end of the helix as possible, some improvement in the noise level of the traveling wave tube may be attained by other positioning of the disturber 27. Similarly, while the disturber 27 should advantageously, in accordance with another aspect of our invention, be positioned adjacent to a point of maximum electron beam diameter within the helix, or closest approach of the beam to the helix, prevention of the growth of the growing noise wave pattern may also be attained by positioning the disturber 27 slightly away from these points.

Reference is made to United States Patent 2,876,378, issued March 3, 1959, of H. L. McDowell wherein a related invention is disclosed and claimed.

It is therefore 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.

What is claimed is:

1. A traveling wave tube comprising an interaction circuit, electron gun means for projecting a high density electron beam along said circuit, means providing a uniform axial magnetic field along said circuit, and means for preventing a growing noise wave pattern along said

circuit said last-mentioned means comprising means for causing said axial magnetic field to bow out slightly and asymmetrically at one point to cause the outermost electrons of said beam to be intercepted by said circuit.

2. A traveling wave tube comprising means defining an interaction circuit, electron gun means for projecting a high density electron beam along said circuit, magnetic means providing a uniform axial magnetic field along said circuit, and means for preventing a growing noise wave pattern along said circuit, said last-mentioned means comprising a small magnetic disturber asymmetrically positioned in said axial magnetic field adjacent said circuit to cause the outermost electrons of the beam to be intercepted by said circuit.

3. A traveling wave tube in accordance with claim 2 wherein said small magnetic disturber is positioned adjacent the input to said interaction circuit and before the growth of said growing wave pattern.

4. A traveling wave tube in accordance with claim 3 wherein said magnetic field disturber is positioned at a point of closest approach of the electrons of said beam to said circuit.

5. A traveling wave tube comprising means defining an interaction circuit, electron gun means for projecting a high density electron beam along said circuit, said beam being scalloped within said circuit, magnetic means providing a uniform axial magnetic field along said circuit, and means for preventing a growing noise wave pattern along said circuit, said last-mentioned means comprising means for causing the axial magnetic field to bow out slightly and asymmetrically at a point adjacent a maximum diameter of said scalloped electron beam within said circuit whereby the outermost electrons of said beam are intercepted by said circuit.

6. A traveling wave tube in accordance with claim 5 wherein said means of causing said axial magnetic field to bow out comprises a magnetic disturber positioned closely adjacent the end of said circuit nearest said electron gun means.

7. A traveling wave tube comprising an elongated envelope, a helical conductor positioned within said envelope, electron gun means for projecting a high density electron beam along said helical conductor, means providing a uniform axial magnetic field along said helical conductor, and a small magnetic field disturber in said axial magnetic field and attached to said envelope adjacent the input end of said helical conductor, said disturber causing said magnetic field to bow out slightly and asymmetrically adjacent thereto causing the outermost electrons of said beam to be intercepted by said conductor to prevent the growth of a growing noise wave pattern along said helical conductor.

8. A traveling wave tube comprising an elongated envelope, a helical conductor positioned within said envelope, electron gun means for projecting a high density electron beam along said helical conductor, means providing a uniform axial magnetic field along said helical conductor, and a small magnetic field disturber in said axial magnetic field and attached to said envelope adjacent the input end of said helical conductor, said disturber comprising a screw of a magnetic material positioned in a ring of nonmagnetic material clamped onto said envelope, said screw causing said magnetic field to bow out slightly and asymmetrically adjacent thereto causing the outermost electrons of said beam to be intercepted by said conductor to prevent the growth of a growing noise wave pattern along said helical conductor.

9. A traveling wave tube comprising an elongated envelope, a helical conductor positioned within said envelope, electron gun means for projecting a high density electron beam along said helical conductor, means providing a uniform axial magnetic field along said helical conductor, and a small magnetic field disturber in said axial magnetic field and attached to said envelope ad-

jacent the input end of said helical conductor, said disturber comprising a screw of a magnetic material positioned in a ring of a nonmagnetic material clamped onto said envelope, said screw positioned along said helical conductor at a point of closest approach of said electron beam to said helical conductor and causing said magnetic field to bow out slightly and asymmetrically adjacent thereto causing the outermost electrons of said beam to be intercepted by said conductor to prevent the growth of a growing noise wave pattern along said helical conductor.

10. A traveling wave tube comprising an interaction circuit, electron gun means for providing a high density electron beam along said circuit, means providing a uniform axial magnetic field along said circuit, and means encompassing a portion of said interaction circuit for causing said axial magnetic field to bow out slightly and asymmetrically at one point to cause the outermost electrons of said beam to be intercepted by said circuit.

11. A traveling wave tube comprising means defining an interaction circuit, electron gun means for projecting a high density electron beam along said circuit, magnetic means providing a uniform axial magnetic field along said circuit, and means for preventing a growing noise wave pattern along said circuit, said last-mentioned means comprising a small magnetic disturber asymmetrically positioned in said axial magnetic field in encompassing relation to the input end of said interaction circuit defining means.

12. A traveling wave tube comprising an elongated envelope, a helical conductor positioned within said envelope, electron gun means for projecting a high density beam along said helical conductor, means providing a uniform axial magnetic field along said helical conductor, and a magnetic field disturber in said axial magnetic field attached to said envelope at a point along said helical conductor, said disturber causing said magnetic field to bow out slightly and asymmetrically adjacent thereto, thereby causing the outermost electrons of said beam to be intercepted by said conductor, whereby the growth of a growing noise wave pattern along said helical conductor is prevented.

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