

Feb. 4, 1958

S. SENSIPER

2,822,502

SLOW-WAVE STRUCTURE

Filed April 5, 1955

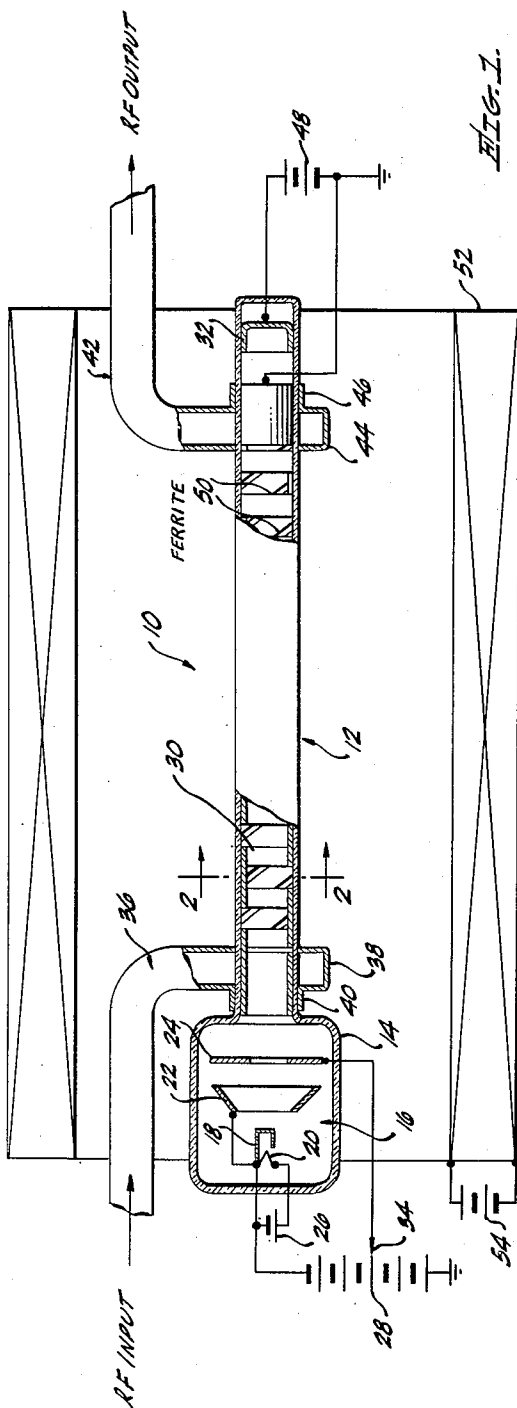


FIG. 1.

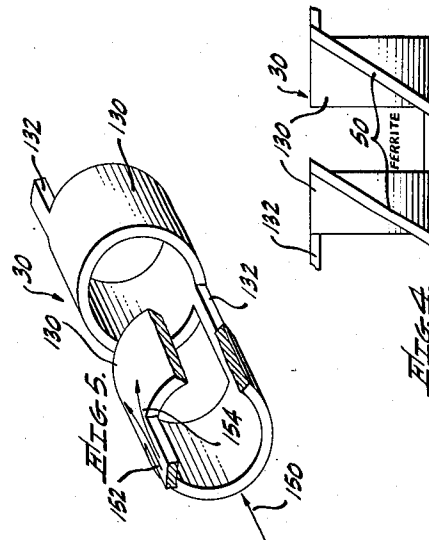


FIG. 2.

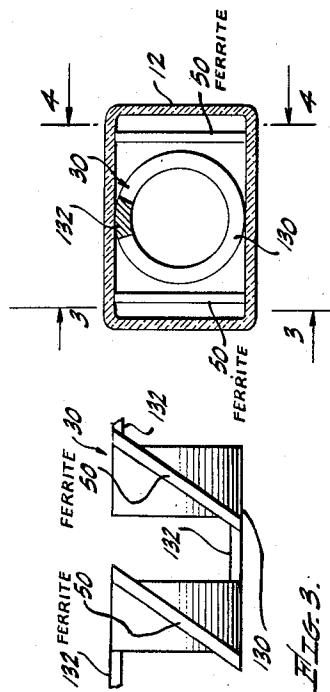


FIG. 3.

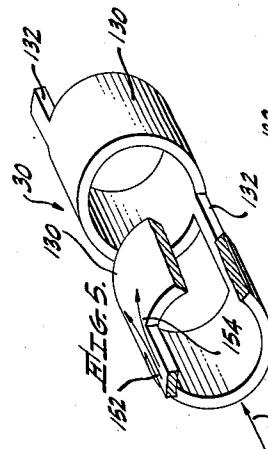


FIG. 4.

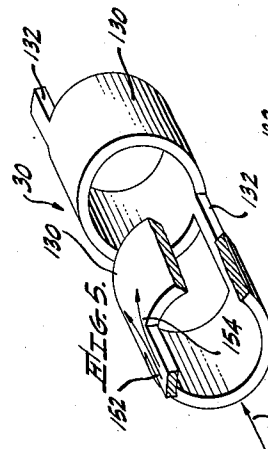


FIG. 5.

INVENTOR.

SAMUEL SENSIPER,

BY

Henry Hyman

ATTORNEY.

1

2,822,502

SLOW-WAVE STRUCTURE

Samuel Sensiper, Los Angeles, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application April 5, 1955, Serial No. 499,330

6 Claims. (Cl. 315—3.5)

This invention relates to microwave tubes and more particularly to a unidirectional wave propagation circuit for a traveling-wave tube.

A traveling-wave tube generally comprises an evacuated envelope, a slow-wave structure, an electron gun for projecting an electron stream through the slow-wave structure, and means for producing a uniform axial magnetic field to focus or confine the stream. A slow-wave structure has recently been developed which may be used in conjunction with a relatively high-powered traveling-wave tube amplifier. Such a slow-wave structure is described and claimed in copending application Serial No. 450,987, entitled "High-Power Microwave Tube," filed August 18, 1954, by C. K. Birdsall.

Although well-known backward-wave self-oscillation is not a severely limiting factor in the use of such slow-wave structures, it is desirable that the amplitudes of reflected wave regeneration and self-oscillation be kept at a minimum or eliminated. One solution to this problem is described and claimed in copending application Serial No. 471,660, filed November 29, 1954, by Samuel Sensiper. It has been previously suggested that a ferromagnetic or ferrite helix be disposed adjacent to the slow-wave structure of a traveling-wave tube to attenuate backward or reflected waves propagated in a direction opposite to that of the electron stream of the tube. In such a case, forward wave propagation is substantially unattenuated. The unidirectional wave propagation properties of a ferromagnetic ferrite are well-known. A ferrite helix is sometimes used with a traveling-wave tube that employs a conductive helix for a slow-wave structure. This is required because it is necessary to obtain an arcuately directed direct-current magnetic field in a ferrite member in a plane transverse to the longitudinal axis of the traveling-wave tube slow-wave structure in order to achieve the desired non-reciprocal attenuation. The ferrite helix with the means which provides the confining axial magnetic field for the electron stream is thus used to divert a portion of the magnetic flux of the axial magnetic field and to provide a transverse component of the magnetic field. This is accomplished by taking advantage of the fact that the magnetic flux of the axial magnetic field tends to follow the relatively low reluctance helical path provided by the ferrite helix.

Substantial reciprocal attenuation is generally encountered along certain portions of the length of the slow-wave structure of the above-mentioned Birdsall application when a ferrite helix is employed. Hence, the use of a ferrite helix with such a high-power slow-wave structure is undesirable.

It is therefore an object of the invention to provide an improved unidirectional wave propagation circuit for a traveling-wave tube.

It is another object of the invention to provide means for selectively attenuating backward and reflected waves normally propagated along the slow-wave structure of a relatively high-powered traveling-wave tube.

2

In the previously mentioned Birdsall application, a slow-wave structure is disclosed comprising a plurality of conductive rings having conductive means disposed between adjacent pairs of the conductive rings thereby to connect adjacent pairs of the conductive rings alternately at diametrically opposed points. In accordance with the present invention, an elongated ferromagnetic ferrite member is disposed 90 degrees about the slow-wave structure from the diametrically opposed points where the rings are interconnected on at least one side of the slow-wave structure. The ferrite members are disposed in an axial plane and have a certain angle of inclination with respect to a plane transverse to the longitudinal axis of the slow-wave structure. The use of ferrite material at the points where the conductive rings are interconnected is thus avoided and substantial reciprocal attenuation is prevented.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

Fig. 1 is a sectional view of a traveling-wave tube incorporating one embodiment of the slow-wave structure of the present invention;

Fig. 2 is a sectional view taken on the line 2—2 in Fig. 1;

Fig. 3 is a section of the tube shown in Fig. 2 taken on line 3—3 of Fig. 2;

Fig. 4 is another section of the tube taken on line 4—4 in Fig. 2; and

Fig. 5 is an isometric, broken-away section of the slow-wave structure of the traveling-wave tube of Fig. 1.

Referring to the drawing, a traveling-wave tube 10 is shown in Fig. 1 comprising an elongated evacuated envelope 12 having an enlarged portion 14 at its left end. Within the enlarged portion, an electron gun 16 is shown comprising a cathode 18 which is provided with a filament 20, focusing electrode 22, and an accelerating anode 24. One side of the filament 20 is connected to a cathode as is the focusing electrode 22. Filament 20 is provided with a filament source of potential 26, the negative side of which is reference to a potential considerably below ground by means of an accelerating source of potential 28, the positive terminal of which is connected to ground. Focusing electrode 22 is a frusto-conical electrode having an internal surface of revolution disposed at an angle of 67½ degrees from its axis of revolution. Accelerating anode 24 is maintained at a potential somewhat positive with respect to cathode 18 by means of a connection to a tap 34 on accelerating source of potential 28.

In the direction of electron flow from electron gun 16 within the envelope 12 there is shown a slow-wave structure 30 and at the right end of the envelope 12 a collector electrode 32 is provided. Radio frequency or R. F. wave energy is introduced to the tube 10 through a rectangular input waveguide 36 which has a shorted termination 38 and a conductive matching sleeve 40.

A rectangular R. F. output waveguide 42 is shown at the right end of the tube 10 disposed about the right end of slow-wave structure 30 having a shorted termination 44 and a similar conductive sleeve 46 disposed about the envelope 12 to prevent radiation of electromagnetic energy therefrom. Collector electrode 32 is maintained at a potential somewhat positive with respect to that of slow-wave structure 30 in order to prevent the col-

lection of secondary electrons at slow-wave structure 30 produced by primary electrons from the beam developed by the gun 16 causing secondary emission at collector 32. To this end, a source of positive potential 48 is connected between collector 32 and ground. Slow-wave structure 30 is maintained at ground potential by an appropriate connection thereto as shown.

A plurality of ferromagnetic ferrite members 50 are shown disposed on one side of the slow-wave structure 30, another group of members are in fact disposed about the slow-wave structure 30 on the opposite side although they cannot be seen because of the particular broken section taken in Fig. 1. A direct-current axial magnetic field is provided throughout the length of the tube by a solenoid 52 through which direct-current is passed by means of a source of potential 54. Solenoid 52 is employed to provide a direct-current magnetic field coaxially with the slow-wave structure 30 to focus or to confine the electron stream produced by electron gun 16 and in addition to produce a magnetic field through the ferrite members 50 to provide the unidirectional attenuation characteristic of the slow-wave transmission path of the present invention.

The envelope 12 is shown in Fig. 2 with the slow-wave structure 30 and the ferrite members 50 disposed on each side of the slow-wave structure 30. The ferrite members 50 are again shown in Fig. 3 with slow-wave structure 30 which comprises a plurality of conductive cylinders 130 which are connected by axially conductive segments 132. The axially conductive segments axially connect adjacent pairs of the conductive cylinders 130 alternately at diametrically opposed points as may be seen in Fig. 3.

In Fig. 4, the slow-wave structure 30 is shown with the ferrite members 50 which are disposed on the side opposite the ferrite members in Fig. 3. For satisfactory tube operation, it is unnecessary to position the ferrite members 50 at each of the conductive cylinders 130 or directly adjacent any of them. The position of a ferrite member 50 adjacent each of the conductive cylinders 130 as shown in Figs. 1 to 4 is not necessarily indicative of a position which will lead to optimum performance. Their position for optimum performance will generally be preferably obtained empirically. The algebraic sign of the vertical angle of inclination of the ferrite members 50 with respect to a plane transverse to the axis of the slow-wave structure will be determined by the direction of the axial magnetic field. Fig. 5 is an isometric broken-away sectional view of the slow-wave structure 30 comprising the conductive rings 130 with the conductive connecting means or rods 132 disposed between adjacent pairs of the conductive cylinders alternately at diametrically opposed points.

The ferrite members 50 may have a circular, triangular, rectangular, or square or other symmetrical or non-symmetrical cross section depending upon the type and the amount of attenuation desired and their dielectric loading characteristics. They generally must be disposed at a predetermined angle with a plane transverse to the axis of the slow-wave structure 30 in order that an arcuately directed or transversely directed magnetic field may be provided through the ferrite members 50. The existence of a ferrite member adjacent to or in the neighborhood of the axially conductive segments 132 is very undesirable in that the existence of a ferromagnetic body in that position causes reciprocal attenuation in the waves propagated along the slow-wave structure 30. That is, in such a case, attenuation of forward waves would be produced in an amount about equal to that of backward and reflected waves. This is obviously undesirable.

It is to be noted that the ferrite members 50 shown in Fig. 4 are disposed at a predetermined angle with respect to a plane transverse to the longitudinal axis of

the slow-wave structure; however, the ferrite members shown in Fig. 3 are disposed at an angle opposite in algebraic sign of that of the ferrite members shown in Fig. 4. This relationship must be maintained between the ferrite members on opposite sides of the slow-wave structure 30 because the axial magnetic field produced by the solenoid 52 will be unidirectional along the axis of the slow-wave structure 30. However, wave propagation about the rings 130 of the slow-wave structure 30 will be in opposite directions. For example, in Fig. 5 currents flowing in the direction shown by the arrow 150 will divide into two portions at the axially conductive segment 132 as indicated by the arrows 152 and 154. Currents flowing according to the arrows 152 and 154 will thus be flowing in opposite arcuate directions. Since the magnetization of the ferrite members 50 will be in the same direction, the ferrite members on opposite sides of the rings 130 of the slow-wave structure 30 must thus be inclined with a plane transverse to the axis of the slow-wave structure 30 approximately at the same angle but in opposite directions, that is, ferrite members 50 on the right side of the slow-wave structure 30 may be inclined at a forward angle as shown in Fig. 4 and the ferrite members on the left side of the slow-wave structure 30 may be inclined at a rearward angle as indicated in Fig. 3.

What is claimed is:

1. In a traveling-wave tube, a substantially unidirectional wave propagation structure comprising a slow-wave structure for propagating electromagnetic waves and having a longitudinal axis, said slow-wave structure including a plurality of conductive rings having apertures disposed in register with each other along said axis, and conductive means disposed between adjacent pairs of said conductive rings connecting said adjacent pairs of said conductive rings alternately at diametrically opposed points, said conductive means lying substantially in a first plane which also includes said axis, and an elongated ferromagnetic ferrite member disposed to at least one side of each of said conductive rings, said ferrite members on said one side of said conductive rings being disposed in a plane parallel to said first plane and each having a predetermined angle of inclination with respect to a plane transverse of said longitudinal axis of said slow-wave structure.

2. In a traveling-wave tube, a substantially unidirectional wave propagation structure having a longitudinal axis and comprising a slow-wave structure propagating electromagnetic waves, said slow-wave structure including a plurality of conductive rings having apertures disposed along said longitudinal axis in register with each other, and conductive means disposed between adjacent pairs of said conductive rings connecting said adjacent pairs of said conductive rings alternately at diametrically opposed points all lying substantially within a first plane containing said longitudinal axis, and an elongated ferromagnetic ferrite member disposed along each side of each of said conductive rings, said ferrite members being disposed in two planes parallel to said first plane and having predetermined angles of inclination with respect to a plane transverse to said longitudinal axis, said ferrite members on one side of said conductive rings having an angle of inclination substantially equal to and in a direction opposite to those ferrite members disposed on the opposite side of said conductive rings.

3. A traveling-wave tube comprising an evacuated envelope, a slow-wave structure having a longitudinal axis and disposed within said envelope for propagating electromagnetic waves, said slow-wave structure including a plurality of conductive rings having apertures disposed along said longitudinal axis in register with each other, and conductive means lying in an axial plane including said axis and disposed between adjacent pairs of said conductive rings connecting said adjacent pairs of said conductive rings alternately at diametrically op-

5

posed points, an electron gun disposed within one end of said envelope for projecting an electron stream through said slow-wave structure along said axis, and an elongated ferromagnetic ferrite member disposed to one side of each of said conductive rings, said ferrite members being disposed in a plane parallel to said axial plane and having a predetermined angle of inclination with respect to a plane transverse to said longitudinal axis.

4. A traveling-wave tube comprising an evacuated envelope, a slow-wave structure having a longitudinal axis and disposed within said envelope for propagating electromagnetic waves, said slow-wave structure including a plurality of conductive rings aligned along said axis and having apertures disposed in register with each other, and conductive means lying in a first plane containing said axis and disposed between adjacent pairs of said conductive rings connecting said adjacent pairs of said conductive rings alternately at diametrically opposed points, an electron gun disposed within one end of said envelope for projecting an electron stream through said slow-wave structure, along said axis, a plurality of pairs of elongated ferromagnetic ferrite members, said members of each pair being disposed in one of two planes parallel to said first plane on opposite sides of one of said conductive rings and each of said ferrite members having a predetermined angle of inclination with respect to a plane transverse to the longitudinal

6

axis of said slow-wave structure, the ferrite members in one of said planes having an angle of inclination substantially equal to and in a direction opposite to that of those ferrite members disposed in the other of said planes.

5. The invention as defined in claim 3, wherein means are provided for producing a magnetic field parallel to said longitudinal axis of said slow-wave structure and through said ferrite members to confine said electron stream and, in conjunction with said ferrite members, to produce substantially non-reciprocal attenuation of waves propagated along said slow-wave structure.

6. The invention as defined in claim 4, wherein means are provided to produce a magnetic field parallel to said longitudinal axis of said slow-wave structure to confine said electron stream and, in conjunction with said ferrite members, to produce substantially non-reciprocal attenuation of waves propagated along said slow-wave structure.

References Cited in the file of this patent

UNITED STATES PATENTS

2,636,948	Pierce	Apr. 28, 1953
2,644,930	Luhrs et al.	July 7, 1953

OTHER REFERENCES

Bell System Tech. Jour., January 1952, pages 22 to 27.
 Jour. of Applied Physics, June 1953, pages 816 to 817.

U. S. DEPARTMENT OF COMMERCE
PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,822,502

Samuel Sensiper

February 4, 1958

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 44, for "of said" read -- to said --; line 48, for "structure propagating" read -- structure for propagating --.

Signed and sealed this 17th day of June 1958.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents