Feb. 16, 1960 J. M. OSEPCHUK 2,925,518

TRAVELING WAVE DEVICE

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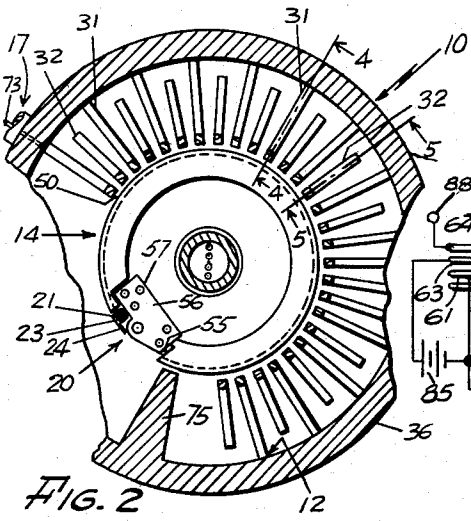


FIG. 2

FIG. 1

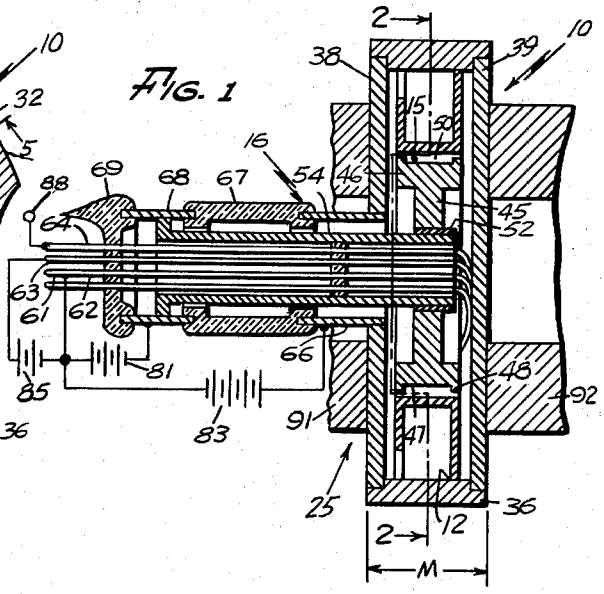


FIG. 3

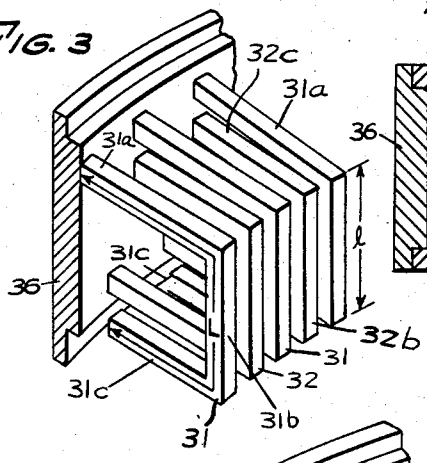


FIG. 4

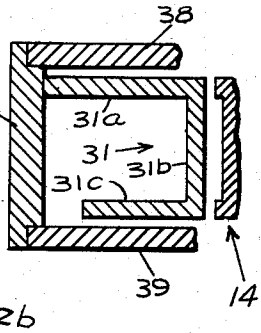


FIG. 5

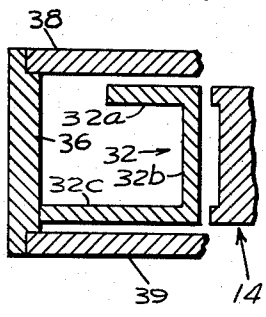
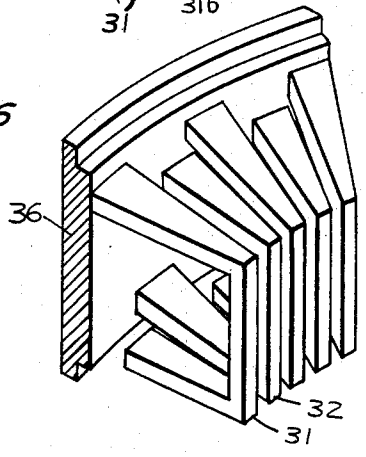


FIG. 6



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TRAVELING WAVE DEVICE

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7 Claims. (Cl. 315—3.5)

This invention relates to a novel slow wave propagating structure for use in a traveling wave oscillator and to a traveling wave oscillator including such a slow wave structure. More specifically, the invention concerns a delay structure for use in a crossed-field traveling wave oscillator having several J-shaped elements wherein the dimension parallel to the magnetic field may be reduced without altering the essential electrical characteristics of the delay line.

A traveling wave oscillator of the backward wave type is discussed in a copending application for U.S. Letters Patent of Edward C. Dench and Albert D. La Rue, Serial No. 562,472, filed January 31, 1956, now United States Letters Patent No. 2,888,649, issued May 26, 1959, assigned to the same assignee as the present application. Such backward wave oscillators include a non-reentrant slow wave energy propagating structure or delay line, an elongated electrode or sole spaced from and disposed substantially parallel to said structure, and an electron gun mounted adjacent one end of said sole for producing an electron beam which traverses the interaction space bounded by the slow wave structure and the sole. Because of the interaction between the electron beam and the high frequency fields of wave energy propagating along the delay line, energy is generated within the tube and may be removed therefrom by output coupling means coupled to the delay structure adjacent the ends thereof opposite the electron gun. The delay line in such tubes is of the interdigital type, which consists of a first assembly including a first set of fingers each having one extremity attached to a common base arranged substantially along the length of the delay line, and a second assembly including a second set of fingers each of which has one extremity attached to another common base usually arranged more or less parallel to the common base of the first assembly. The fingers of the first and second sets are intermeshed and the free extremities of each finger of a given assembly approaches, but does not contact, the common base of the other assembly. The length of the fingers of such a delay line bears a direct relationship with the operating frequency of the oscillator, and often is made slightly less than one-quarter of a wavelength long at the smallest wavelength in the operating frequency band. This length, in a line such as just described, is measured from the point of attachement to the common base to the free extremity of the finger.

In accordance with the invention, the fingers of the delay line include three mutually perpendicular copolanar portions. Specifically, each finger includes a first portion extending substantially perpendicular to a single uniplanar common base, otherwise referred to as a back wall, and having its extremity attached to said common base, a second portion substantially perpendicular to the first portion and consequently parallel to the common base, and a third portion perpendicular to the second portion and extending toward, but not contacting, the common base. The space between the extremity of the third portion of each of the fingers and the common base preferably is of the same order of magnitude as the space between adjacent fingers, since this best contributes to uniformity of transmission line characteristics. By folding over the ends of the fingers of the conventional interdigital line in the manner just described, the width of the delay line, that is, the dimension of the delay line parallel to the magnetic field in traveling wave tubes using said delay line, is decreased. This permits of a smaller magnet gap and minimization of magnetic weight, for a given magnetic field strength. Moreover, the beam width can be reduced and the space charge density increased so that lower starting currents of crossed-filed type backward wave oscillators can be obtained.

Other objects and advantages of this invention will be more readily apparent as the description thereof progresses, reference being had to the accompanying drawings wherein:

Fig. 1 is a central cross-sectional view of a backward wave oscillator according to the invention;

Fig. 2 is a sectional view, taken along line **2—2** of Fig. 1, of the backward wave oscillator of Fig. 1;

Fig. 3 is a view showing the construction of the delay line of the backward wave oscillator of Figs. 1 and 2;

Fig. 4 is a sectional view, taken along the line **4—4** of Fig. 2, indicating the construction of one of the fingers of a first set of alternate fingers of the delay line of the backward wave oscillator of Figs. 1 and 2;

Fig. 5 is a sectional view, taken along line **5—5** of Fig. 2, indicating the construction of one of the fingers of a second set of alternate fingers of the delay line of the backward wave oscillator of Figs. 1 and 2; and

Fig. 6 is a view showing a modified construction of the delay line of the backward wave oscillator of Figs. 1 and 2 particularly suitable for low frequency tubes.

Referring to the drawing, a backward wave oscillator **10** is shown in Figs. 1 and 2 which comprises a slow wave energy propagating structure or delay line **12**, a cylindrical electrode **15**, otherwise referred to as a sole, concentric with the delay line **12** and normally maintained negative with respect thereto, a lead-in assembly **16**, an electron gun assembly **20** including at least a cathode **21** and heater **22**, a magnetic field-producing means **25** and an output coupling means **17**. The circular delay line **12** includes several interdigital fingers on elements **31** and **32** attached at one end to a cylindrical electrically conductive ring or base **36**, said base forming a part of an evacuated envelope for tube **10**. The remainder of the tube envelope is made up of two oppositely disposed cover plates **38** and **39** hermetically sealed to base **36**. As shown most clearly in Figs. 2 to 5, the delay line **12** includes one set of interdigital elements represented by the reference numeral **31** and other set of elements represented by the reference numeral **32**. Elements **31** are attached at one end adjacent one edge of the base **36**, while a corresponding end of each of the elements **32** is attached to base **36** along the opposite edge thereof.

Each of the elements **31** are characterized by three successively mutually perpendicular portions **31*a***, **31*b***, and **31*c***. The free extremity of portion **31*a*** is attached to base **36** along one edge thereof, portion **31*a*** extends substantially perpendicular to base **36** and merges with a portion **31*b*** disposed substantially perpendicular to portion **31*a*** and essentially parallel to the base **36**. Portion **31*b***, in turn, merges with a portion **31*c*** which extends substantially perpendicular to portion **31*b*** and base **36** and substantially parallel to portion **31*a***. The free extremity of portion **31*c*** is spaced from base **36**. Each of the elements **32** similarly are characterized by three mutually perpendicular portions **32*a***, **32*b***, and **32*c***, which portions correspond to portions **31*a***, **31*b***, and **31*c***, re-

spectively, of fingers 31. The distance between the extremity of portion 31*c*, or 32*c*, as the case may be, and the base 36 preferably is made of the order of magnitude of the distance between adjacent fingers 31 and 32. The delay line 12 may be considered as the equivalent of a folded parallel wire line wherein the wave energy travels along a J-shaped path between two adjacent fingers, then between the free end of the finger and the base, between the opposed surfaces of the next set of adjacent fingers and then in the space between the free end of finger 32 and the base, etc. If the space between the free ends of fingers 31 and 32 is kept substantially equal to that between an adjacent pair of fingers 31, 32, assuming of course that a uniplanar base 36 is employed, the energy path is of uniform configuration throughout the length of the delay line and this is equivalent to having a parallel wire line of uniform spacing throughout.

The total length L of each finger, that is, the combined length of portions 31*a*, 31*b*, and 31*c* taken along the center line of the cross section, may be of the order of a quarter wavelength at the smallest wavelength in the operating frequency band, while, at the same time, the width *l* of the delay line may be considerably less than the total length L of the fingers. Consequently the distance between cover plates 38 and 39, and, hence, magnetic gap M (see Fig. 1) may be made relatively small.

At relatively low operating frequencies, the total length L of the fingers becomes correspondingly long and, therefore, the radial distance between the inner faces of the portions 31*b* and 32*b* of the respective fingers 31 and 32 increases. The variation of inter-finger spacing along the radial length of the fingers obviously increases with radial length. This causes variation in the electrical characteristics of the network along the length thereof, and extraneous coupling other than the desired inter-finger coupling may result. By making the fingers 31 and 32 of wedge-shaped cross section, as shown in Fig. 6, the spacing between fingers may be maintained essentially constant, and, if the spacing between the free ends of the fingers and the base is made equal to the inter-finger spacing, the characteristics of the delay line may be made quite uniform regardless of finger length L.

It is possible to avoid troublesome effects of direct current and radio frequency fields near the corners of the fingers by making the inside width of the sole 15 (distance between flanges) equal to, or less than, the sum of the length *l* and the distance between adjacent fingers. A good choice is to make the total width of the sole 15, including flanges, equal to the length *l*.

In order to prevent excessive movement of the π and $\pi/2$ cut-off wavelengths in the device, the distance between the portion 31*a* of finger 31 and the cover plate 38 (or the distance between portion 32*a* of finger 32 and cover plate 39) should not be made too small. It has been found that a good choice is to make this distance equal to the distance between adjacent fingers.

Furthermore, in order not to derange greatly the properties of the folded interdigital delay line from those of a linear interdigital line of the prior art, it is desirable that the shortest distance between the inner edges of portions 31*a* and 31*c* of fingers 31 (and between the inner edges of portions 32*a* and 32*c* of fingers 32) be greater than twice the distance between adjacent fingers.

The sole 15 consists essentially of a cylindrical segment of an electrically conductive material, which includes a web portion 45, bounded by an arcuate section 46, whose periphery consists of a major surface 47 and flanges 48. The purpose of the flanges 48 is to confine the electron beam within the interaction space 50 between the surface 47 of sole 15 and the portions 31*b* and 32*b* of interdigital slow wave structure 12. A tubular metallic insert 52 is brazed into position against the inner periphery of a centrally disposed aperture in the web portion of the sole. One end of a hollow supporting member 54 is inserted within insert 52 and is fixedly secured thereto. Supporting member 54, in addition to providing support for the sole 15, forms a portion of lead-in assembly 16 and permits passage of external circuit-connecting leads in a manner to be described later.

Sole 15 contains a slot 55 to accommodate the electron gun assembly 20. The electron gun 20 includes a mounting plate 56 which is attached to the web portion 45 of the sole assembly by means of screws 57. The electron gun 20 includes a cathode 21, heater, not shown, a grid electrode 23, which may be used for control of beam current (as for amplitude modulation), and an accelerating electrode 24 which likewise may be used for control of beam current. The cathode 21 may be a rectangular body provided with a circular base in which a heater wire is inserted and electrically insulated from the cathode; one end of the heater wire may be connected to the cathode. The construction and manner of mounting of the electron gun 20 may be as shown in a copending application of Roy A. Paananen, Serial No. 717,897, filed February 27, 1958, now United States Letters Patent No. 2,914,700, issued November 24, 1959, assigned to the assignee of the present application.

Electrical energy from appropriate sources is supplied to the cathode 21, the heater, grid electrode 23 and accelerating electrode 24 by way of respective lead-in wires 61, 62, 63, and 64, which are brought out from the tube envelope through the lead-in assembly 16.

Lead-in assembly 16 includes an electrically conductive sleeve 66 fixed to the inner periphery of cover plate 38, as indicated in Fig. 1. A section of cylindrical glass tubing 67 interconnects sleeve 66 and a second electrically conductive sleeve 68. The other end of sleeve 68 is provided with a glass seal 69 for sealing the traveling wave tube 10 after evacuation. One end of sole-supporting member 54 contains an outwardly flared portion which is connected to the inner surface of sleeve 68. The leads 61, 62, 63, and 64 are mounted in electrically insulated relation with supporting member 54 by one or more glass beads 71.

The coaxial output coupling means 17 is sealed in an opening of wall 36 of delay line 12 and is impedance-matched to the delay line. The inner conductor 73 of the output coupling means 17 is connected to a finger of delay line 12 at or near the end of the delay line adjacent electron gun 20.

The oscillator 10 may be locked in frequency by an external source, such as shown and described in the aforesaid copending application of Dench and La Rue, Serial No. 562,472, now United States Letters Patent No. 2,888,649, issued May 26, 1959, in which case an additional energy coupling means would be coupled to the end of the delay line 12 opposite output coupling means 17.

Traveling wave tube 10 may be provided with a collector electrode 75, shown in Fig. 2, for intercepting electrons after one traversal of the arcuate interaction space 50. This collector electrode may be in the form of a projection from back wall 36 of delay structure 12. In some instances, however, the collector electrode may be omitted and the electron stream made reentrant.

The necessary electric field between the slow-wave structure 12 and sole 14 may be obtained by means of a unidirectional voltage applied therebetween; such a voltage may be supplied by a battery 83. The sole 14 may be biased negatively relative to the cathode 21 by means of a source 81 of voltage connected between cathode lead 61 and sole-supporting member 54 by way of tube 68. The cathode 21 may in some instances, however, be at the same potential as sole 14; in this case, source 81 would be omitted. Similarly, the delay line 12 may be maintained at a potential positive relative to both sole 14 and cathode 21 by means of the source 83 of unidirectional voltage connected between the cathode and sleeve 66, the latter being connected, in turn, to delay

line 12. The accelerating electrode 24 may be maintained at a potential positive relative to cathode 21 by means of a source 85 of unidirectional voltage connected between leads 61 and 64. The control grid lead 63 may be connected by way of terminal 88 to an appropriate energy source for controlling the magnitude of the electron beam current in the traveling wave oscillator 10. A suitable heater voltage from an appropriate source, not shown, may be connected between heater lead 62 and cathode lead 61.

A uniform magnetic field transverse to the direction of propagation of the electron beam is provided by a permanent magnet or electromagnet having cylindrical pole pieces 91 and 92 radially positioned on or adjacent the anode cover plates 38 and 39, respectively. The gap between pole pieces 91 and 92 is indicated as M in Fig. 1. Pole piece 91 is apertured to receive lead-in assembly 15, while pole piece 92 is apertured to maintain symmetry of the magnetic field. The flux lines should be concentrated in the interaction space 50 between sole 14 and delay line 12. By proper adjustment of the magnitude and polarity of the magnetic and electric fields so established, the electron beam may be made to show a more or less circular path along the interaction space 50 under the combined influence of these transversely disposed fields.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A slow wave energy propagating structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, said second portion being disposed substantially parallel to said base member, and said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to said record portion and passing through the intersection of said first portion and said base member, said free termination being disposed on the same side of said reference surface as said second portion, said elements being of uniform cross section throughout the length thereof.

2. A slow wave energy propagating structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, said second portion being disposed substantially parallel to said base member, and said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to said second portion and passing through the intersection of said first portion and said base member, said spacing being substantially equal to the spacing between adjacent elements, said free termination being disposed on the same side of said reference surface as said second portion.

3. A traveling wave electron discharge device comprising a slow wave energy propagating structure producing in the region adjacent thereto fields of electromagnetic wave energy being propagated therebetween, means for directing electrons in a beam along said region in energy-exchanging relation with said fields of wave energy, said structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, said second portion being disposed substantially parallel to said base member, and said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to said second portion and passing through the intersection of said first portion and said base member, said spacing being substantially equal to the spacing between adjacent elements, said free termination being disposed on the same side of said reference surface as said second portion.

4. A traveling wave electron discharge device comprising a slow wave energy propagating structure producing in the region adjacent thereto fields of electromagnetic wave energy being propagated therebetween, means for directing electrons in a beam along said region in energy-exchanging relation with said fields of wave energy, said structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, said second portion being disposed substantially parallel to said base member, said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to said second portion and passing through the intersection of said first portion and said base member, said free termination being disposed on the same side of said reference surface as said second portion.

5. A traveling wave electron discharge device comprising a slow wave energy propagating structure producing in the region adjacent thereto fields of electromagnetic wave energy being propagated therebetween, means for directing electrons in a beam along said region in energy-exchanging relation with said fields of wave energy, said structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, said second portion being disposed substantially parallel to said base member, said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to said second portion and passing through the intersection of said first portion and said base member, said spacing being substantially equal to the spacing between adjacent elements, the length of said second portion being substantially less than that of said first portion, said free termination being disposed on the same side of said reference surface as said second portion.

6. A slow wave energy propagating structure comprising a base member and a plurality of periodically spaced elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, and said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to a second portion and passing through the intersection of said first portion and said base member, said free termination being disposed on the same side of said reference surface as said second portion.

7. A slow wave energy propagating structure comprising a base member and a plurality of periodically spaced

elements each including three successively arranged mutually perpendicular coplanar portions, the first of said portions being disposed substantially perpendicular to said base member and having its free termination attached to said base member, and said third portion extending substantially perpendicular to said base member and having the free termination thereof spaced from a reference surface disposed substantially parallel to a second portion and passing through the intersection of said first portion and the portion of said base member facing said free termination, said spacing being substantially equal to the spacing between adjacent elements, said free termination being disposed on the same side of said reference surface as said second portion.

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