July 23, 1957 J. H. BRYANT ET AL 2,800,603

TRAVELING WAVE ELECTRON DISCHARGE DEVICES

Filed Aug. 23, 1952 2 Sheets-Sheet 1

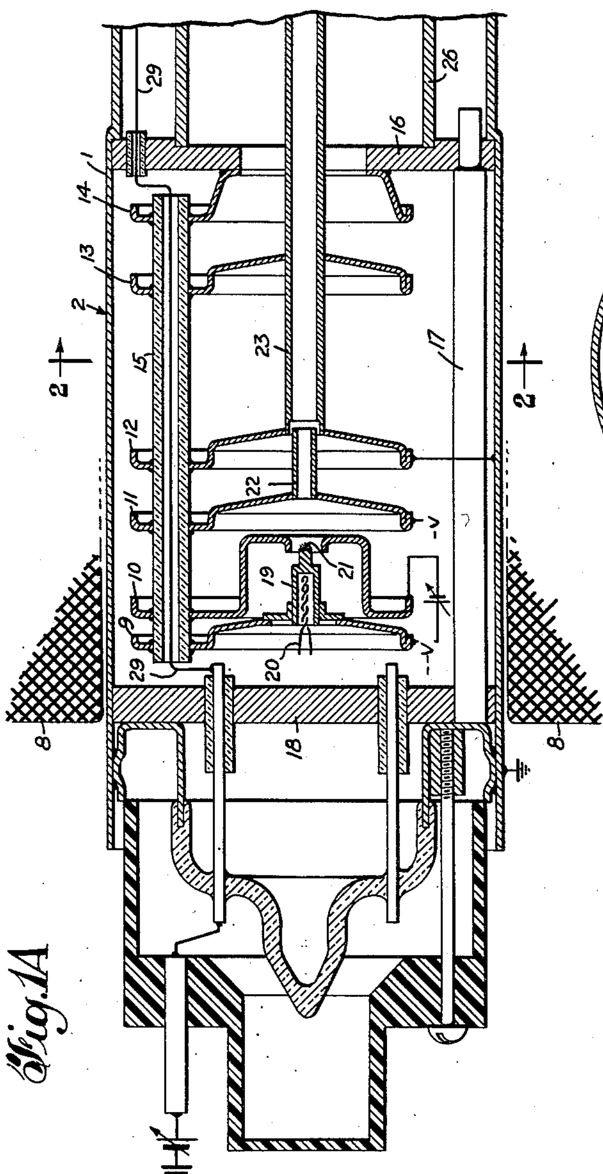


Fig. 1A

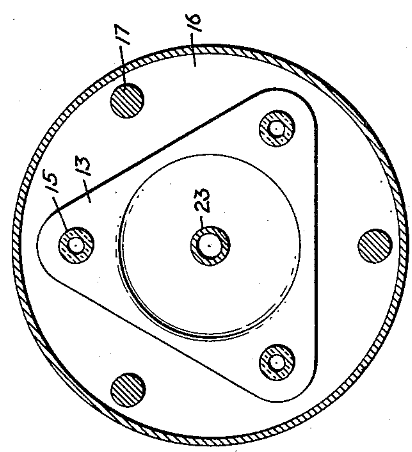


Fig. 2

INVENTORS
JOHN H. BRYANT
ALBERT G. PEIFER
ROBERT W. WILMARTH
BY Percy P. Lantzy
ATTORNEY

July 23, 1957 J. H. BRYANT ET AL 2,800,603

TRAVELING WAVE ELECTRON DISCHARGE DEVICES

Filed Aug. 23, 1952 2 Sheets-Sheet 2

Fig. 1B

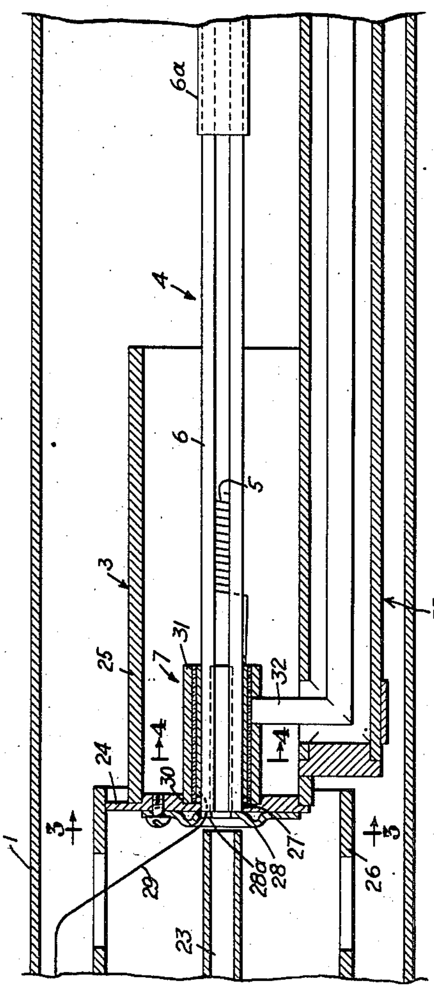


Fig. 4

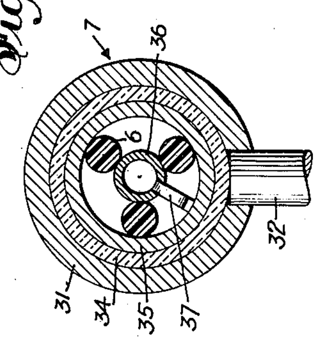
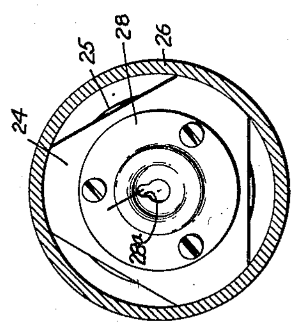


Fig. 5



INVENTORS
JOHN H. BRYANT
ALBERT G. PEIFER
ROBERT W. WILMARTH

BY Percy P. Lantzy
ATTORNEY

United States Patent Office

2,800,603

Patented July 23, 1957

2,800,603

TRAVELING WAVE ELECTRON DISCHARGE DEVICES

John H. Bryant and Albert G. Peifer, Nutley, and Robert W. Wilmarth, Rutherford, N. J., assignors to International Telephone and Telegraph Corporation, a corporation of Maryland

Application August 23, 1952, Serial No. 306,012

11 Claims. (Cl. 315—3.5)

This invention relates to traveling wave electron discharge devices and more particularly to the radio frequency propagating structure, the electron gun and coupling arrangements therefor.

The traveling wave type of tube is particularly useful in wideband microwave systems since it is capable of amplifying radio frequency energy over an unusually wideband of frequencies. The tube includes a form of propagating structure, usually a helix, for transmission of microwave energy for interaction with an electron beam closely associated with the structure. The helical characteristic of the propagating structure is such that the helix velocity of microwave signals conducted along the helical path is approximately the same as or slightly slower than the velocity of the electrons of the beam, whereby the electrical field of the microwave signals interacts with the electron beam for amplification of the microwave signals.

In applications of such structure it is desirable that noise in the traveling wave tube be as low as possible, such as where employed in receiving equipment for detection of weak signals. The source of noise in a traveling wave tube is the electron beam. At least part of this noise is carried in the space charge by plasma waves which are characterized by alternate maximum of electron velocity and current fluctuations. These waves originate from random emission of electrons from the cathode. One means of achieving a low noise figure may be obtained by beginning the helix, or other wave interaction structure, at a judiciously chosen position along the beam, and that is at the point at which the noise in the beam will couple least effectively to the helix. This position is determined by an optimum relation between velocity and current modulation magnitude and occurs near a current modulation maximum. This position may be theoretically derived from presently available theory by one skilled in the art.

A further improvement in the noise figure can be obtained by employing in the traveling wave tube a potential jump electron gun structure. With such an arrangement, the accelerating potential is applied to the beam in two or more stages. In a two stage arrangement the electrons are accelerated in the cathode-anode region to the first anode potential and then allowed to drift a specified distance at the first anode potential. In a space-charge-limited diode the magnitude of the velocity fluctuations for practical purposes, is independent of the anode potential. Thus, the velocity fluctuations in the first drift tube at low potential are the same as would have been obtained if the same beam current had been achieved at full helix potential. By jumping to the full helix potential at the proper position in this first drift tube, however, a reduction in the magnitude of the velocity fluctuations is achieved. This jump is made to occur at a velocity fluctuation maximum. From conservation of energy considerations the velocity fluctuations are reduced inversely as the square root of the voltage ratio. On the other hand, the noise figure varies as the square of the

velocity fluctuations, so that the noise figure varies inversely as the ratio of the voltages. For example, a voltage jump of 150 volts to 600 volts should give a noise figure reduction of 4 to 1 in power, or 6 db. In practice it is found to give a 3 to 4 db improvement in noise figure. Reasons may be found for this reduction in noise figure improvement. They include finite distance over which the beam voltage changes, finite diameter of the electron beam, and thermal velocity fluctuations in the electron beam.

To assure that the forward end of the propagating structure is maintained at the same potential as the potential on that portion of the last drift tube exending from the last anode it is necessary to apply a D. C. potential to the propagating structure and the element incorporated in the forward end of the helical structure forming the remaining portion of the last drift tube. To accomplish the required D. C. connection thereto it is necessary that the D. C. source be isolated from the radio frequency energy being coupled to the propagating structure, thus assuring that the propagating structure remains an integral part of the radio frequency section of a traveling wave.

It is an object of the present invention to provide a traveling wave tube having an electron gun and propagating structure arrangement which produces an improvement noise figure as hereinabove outlined.

Another object of this invention is to provide a potential jump electron gun to aid in the improvement of the noise figure.

Another object of this invention is the judicious positioning of the propagating structure of a traveling wave tube with respect to the eletcron emission surface to aid in the reduction of noise.

A feature of this invention is to provide an element in the input matching section of the propagating structure as a portion of the drift space aiding in the reduction of noise.

Another feature of this invention is to provide the element in the input matching section employed as a portion of the drift space with a D. C. potential to reduce the possibility of a static charge building up on the forward end of the propagating structure to block the electron beam.

Another feature of this invention is to provide two or more stages in the electron gun, each stage including a drift space, for applying accelerating potential to the beam.

A further feature of this invention is to provide a propagating structure of a traveling wave tube with D. C. isolation and yet remaining a portion of the R.-F. circuit.

The above mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Figs. 1A and 1B are partial longitudinal sectional views of an embodiment of a traveling wave tube illustrating an electron gun and the forward portion of the radio frequency propagating structure thereof in accordance with the principles of our invention;

Fig. 2 is a cross-sectional view taken along line **2—2** of Fig. 1A;

Fig. 3 is a cross-sectional view taken along line **3—3** of Fig. 1B; and

Fig. 4 is a cross-sectional view taken along line **4—4** of Fig. 1B.

Figs. 1A and 1B, when placed end to end, illustrate a partial longitudinal sectional view of an embodiment of a traveling wave tube comprising a metallic housing **1**, a potential jump electron gun **2**, and a radio frequency section **3** including a wave propagating structure **4**, shown herein to be a helical conductor **5** each turn of which is bonded to three dielectric supporting members **6** and having a lossy material *6a* associated therewith at a predetermined location. Coupled at the input end of the structure 4 is a radio frequency input coupling section 7, identical in structure to the output coupling section (not shown). A magnetic field producing means 8 is provided to confine the electron beam in the propagating structure 4. The desired magnetic field may be produced by an electromagnet assembly or a permanent magnet assembly, as may be desired.

Referring more specifically to Figs. 1A and 2, potential jump electron gun 2 is shown to comprise a plurality of electrodes 9—12 and support members 13 and 14, each having a triangular shaped periphery whose central area is circular and disposed coaxially of the electron beam path. The electrodes 9—12 and support members 13 and 14 are secured in position and alignment relative to each other by means of bonding to dielectric rods 15, one each situated at each corner of the triangular area. To properly align electron gun 2 with respect to the housing 1 and the propagating structure 4, support member 14 is brazed to the non-magnetic barrier 16 disposed crosswise of housing 1 in the proper position relative to said housing. Barrier 16, mechanically carrying electron gun 2, is secured in proper alignment by means of bonding to metallic rods 17 extending from magnetic barrier 18 located near the forward end of the housing 1.

Electrode 9 comprises a cylinder 19 extending therefrom to enclose the filament winding 20 and carrying on the end thereof an oxide coated surface 21 for emitting the electrons forming the electron beam. Electrode 10 coaxial of cylinder 19 is the intensity and focusing electrode of the gun assembly. Electrode 11, the first anode of the multi-anode gun assembly 2, has connected thereto electrically and mechanically the first drift tube 22. Electrode 12, the second anode has connected thereto the forward portion of the second drift tube 23 which is electrically and mechanically connected to support member 13 whose primary purpose is mechanical support for said forward portion of the second drift tube. The support member 14 not only provides mechanical support and alignment for electrodes 9—12 and support member 13 but also serves to conduct heat to the plate 16.

Since the electron gun assembly 2 is so arranged to provide an improvement in the noise figure, the drift tubes have a predetermined length to cooperate with the electrode voltages such that each potential jump occurs at a predetermined time corresponding to a velocity fluctuation maximum as set forth hereinabove. Representative voltages that may be applied to the electrodes where the drift tubes have relative lengths substantially as shown, are −600 volts for electrode 9, −350 volts for electrode 11 and drift tube 22, and ground potential for electrode 12 and the forward portion 23 of the second drift tube, the rearward portion of which includes an element of the coupling section 7 extending to the first turn of conductor 5. The intensity electrode 10 has applied thereto a variable negative potential, depending upon the application of the device, with respect to the electrode 9.

Referring to Figs. 1B, 3, and 4, the mechanical and electrical relationship between coupling section 7 and the rearward end of the electron gun 2 is illustrated. The forward end of the radio frequency section 3 carries a triangular shaped element 24 secured to a cylinder 25. To provide proper axial alignment of section 3 with the projected electron beam, element 24 is slidably received in cylinder 26 which abuts barrier 16 and is brazed thereto in the proper position relative to the path of the electron beam. The slidable association between cylinder 26 and element 24 permits differential coefficients of expansion between electron gun 2 and R.-F. section 3.

Element 24 includes an aperture 27 and carries a circular plate 28 thereon having an aperture therein in alignment with aperture 27. The aperture in plate 28 has an offset portion *28a* therein through which the D. C. potential lead 29 is disposed to apply the required D. C. potential to the R.-F. coupling section 7 and hence to the conductor 5, the first turn of which is judiciously positioned to aid in improvement of the noise figure.

Element 24 further provides a recession 30 whereby the coupling section 7 may be secured and axially positioned. Coupling section 7 includes an outer conductive cylinder 31 having therein an aperture for the receipt of the inner conductor 32 of coaxial R.-F. input waveguide 33. Immediately within cylinder 31 is a dielectric sleeve 34 which may be formed, for example, by a glass braid or ceramic glazing material annealed at elevated temperatures. Surrounded by sleeve 34 and encircling dielectric support rods 6 is an inner conductive cylinder 35 to which the required D. C. potential is applied by lead 29 and to which is electrically connected conductor 5. Within the space provided by the arrangement of rods 6 and having a diameter approximately equal to that of conductor 5 is a metallic sleeve 36, electrically connected to cylinder 36 by strap 37. The coaxial arrangement of section 7 not only provides the required D. C. isolation of conductor 5, still coupled from an R.-F. view point to waveguide 33, but provides a means to mechanically support conductor 5 coaxially of the path of the electron beam.

Conductive cylinder 35, considered as an electrode of the device, is maintained at a D. C. potential corresponding to the potential on the forward portion 23 of the second drift tube and at the same time forms a portion of the rearward section of the second drift tube which extends to the first turn of the helix. The radio frequency energy is conducted along inner conductor 32 to cylinder 31, then capacitively coupled to cylinder 35 through insulating sleeve 34, and hence, to conductor 5. Conductive sleeve 36 is maintained at ground potential to prevent a static charge from building up between sleeve 36 and cylinder 35 wherein rods 6 are of dielectric materials. If this charge did build up it would block the electron beam. The dielectric sleeve 34 thus allows the connection of a D. C. potential to the conductor 5 while yet providing the coupling of R.-F. energy to the conductor 5.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. In a traveling wave electron discharge device, an electron beam gun comprising a cathode for emitting electrons, a plurality of electrodes to confine said electrons into an electron beam, one of said electrodes including a first anode surrounding the path of said beam and carrying therewith a first drift tube disposed coaxially of said beam path, another of said electrodes including a second anode disposed closely adjacent the output of said first drift tube and carrying therewith a second drift tube also disposed coaxially of said beam path, means to apply a given direct current potential to said anode, means to apply a direct current potential higher than said given potential to said second anode, means to support said cathode and said electrodes as an electrode unit including an annular conductive member disposed in spaced relation about said second drift tube and means supporting said electrode unit from said member, a conductive cylinder carried by said annular member coaxially of said beam path, a radio frequency propagating structure disposed parallel to said beam path and means carried by said cylinder to support one end of said radio frequency propagating structure for axial movement relative to said annular member.

2. In a traveling wave electron discharge device according to claim 1, wherein the means carried by said cylinder comprises a conductive plate having peripherally spaced

portions slidably engaging the inner surface of said cylinder.

3. In a traveling wave electron discharge device according to claim 2, wherein said radio frequency propagating structure includes a radio frequency conductor and a radio frequency transition section, said transition section comprising a pair of concentric conductive cylinders spaced apart by a layer of dielectric material, the outer cylinder of said pair being carried by said plate and the inner cylinder of said pair being coupled to said radio frequency conductor.

4. In a traveling wave electron discharge device according to claim 3, wherein the inner cylinder of said pair is electrically isolated with respect to said plate and means are provided to apply potential to said inner cylinder.

5. In a traveling wave electron discharge device having an electrode unit for producing a beam of electrons and a radio frequency propagating structure disposed parallel to the axis of the path of said beam; a conductive housing for said electrode unit, a conductive annular supporting member carried by said housing concentrically of said beam path, means to support said electrode unit on one side of said member, a conductive cylinder carried on the other side of said member coaxially of said beam path and means carried by said cylinder to support one end of said radio frequency propagating structure in parallel relation to said beam path.

6. In a traveling wave electron discharge device according to claim 5, wherein the means carried by said cylinder comprises a conductive plate peripheral portions of which slidably engage the inner surface of said cylinder.

7. In a traveling wave electron discharge device according to claim 6, wherein said radio frequency propagating structure includes a radio frequency conductor and a radio frequency transition section, said transition section comprising a pair of concentric conductive cylinders spaced apart by a layer of dielectric material, the outer cylinder of said pair being carried by said plate and the inner cylinder of said pair being connected to said radio frequency conductor.

8. In a traveling wave electron discharge device having an electrode unit for producing a beam of electrons and a radio frequency propagating structure disposed parallel to the axis of the path of said beam; said structure comprising a helical conductor, a radio frequency transition unit for said helical conductor, said transition unit comprising three concentrically disposed conductive cylinders, a layer of dielectric disposed between the inner and middle cylinders to provide capacitive coupling therebetween, the inner cylinder being connected to said helical conductor, means coupling radio frequency energy between the middle and outer cylinders for propagation along said helical conductor, and means to apply a given D. C. potential to said inner cylinder.

9. In a traveling wave electron discharge device according to claim 8, further including a conductive cylindrical support, a conductive plate peripheral portions of which are receivable in sliding engagement with the inner surface of said cylindrical support and means supporting one end of said radio frequency propagating structure on said plate.

10. In a traveling wave electron discharge device according to claim 9, wherein the means for supporting said radio frequency structure on said plate includes a plurality of ceramic rods disposed to support said helical conductor, a pair of concentrically spaced conductive cylinders, the inner of said cylinders being disposed about said rods and coupled to said helical conductor, and the outer of said cylinders being connected to a radio frequency transmission line.

11. In a traveling wave electron discharge device according to claim 10, wherein the means for supporting one end of the radio frequency structure on said plate includes an abutment to engage the ends of said rods.

References Cited in the file of this patent

UNITED STATES PATENTS

2,139,685	Laico	Dec. 13, 1938
2,293,151	Linder	Aug. 18, 1942
2,406,370	Hansen et al.	Aug. 27, 1946
2,422,695	McRae	June 24, 1947
2,464,349	Samuel	Mar. 15, 1949
2,575,383	Field	Nov. 20, 1951
2,602,148	Pierce	July 1, 1952
2,608,668	Hines	Aug. 26, 1952
2,632,130	Hull	Mar. 17, 1953
2,672,571	Harman	Mar. 16, 1954
2,773,213	Dodds	Dec. 4, 1956