Feb. 23, 1960 R. C. HERGENROTHER 2,926,280

TRAVELING WAVE STRUCTURES

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FIG. 1

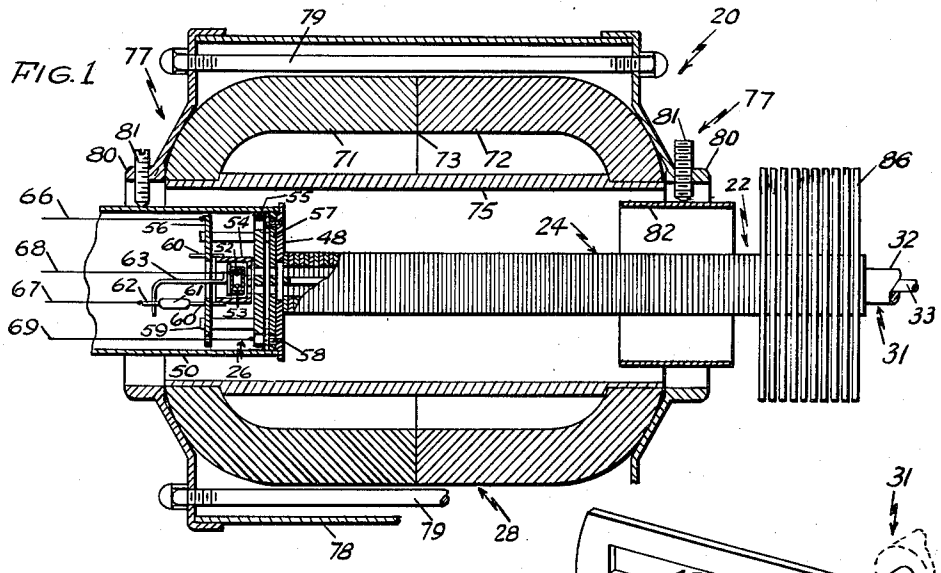


FIG. 2

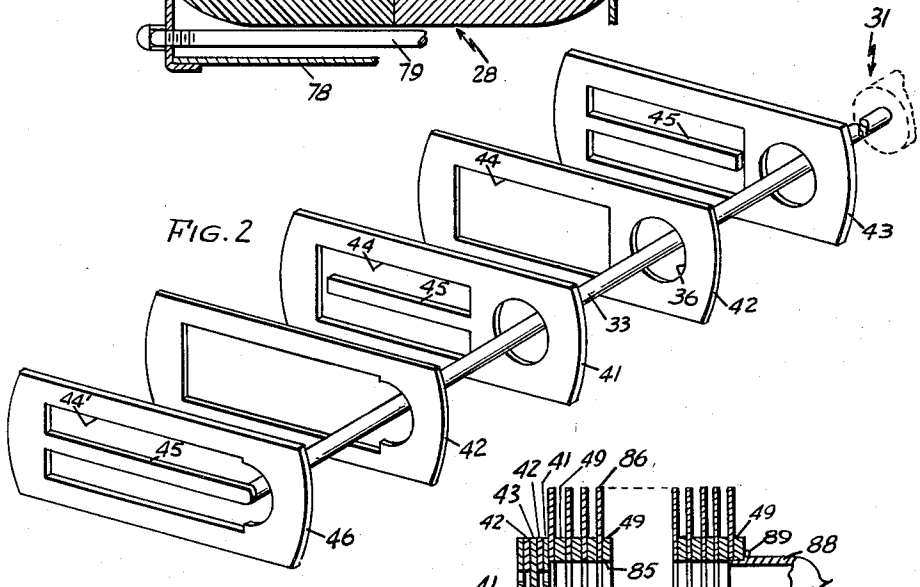


FIG. 3

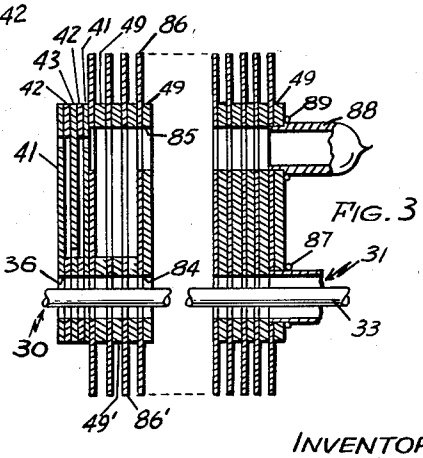
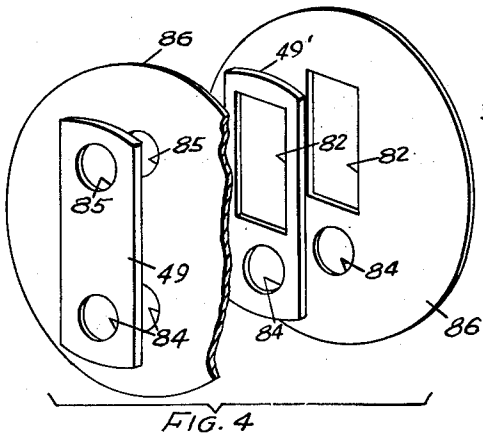


FIG. 4



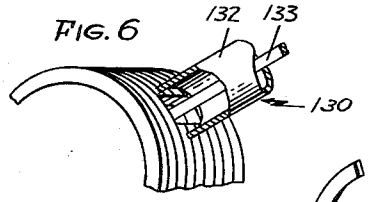
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BY Elmer J. Gorn
ATTORNEY

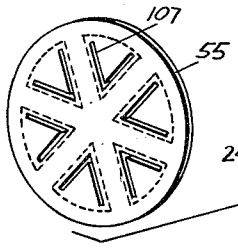
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TRAVELING WAVE STRUCTURES

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FIG. 6





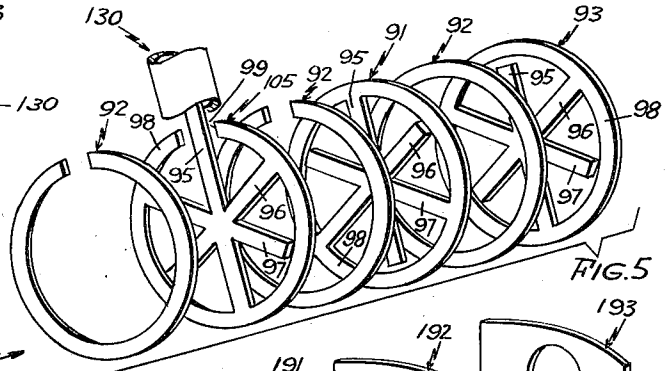


FIG. 5

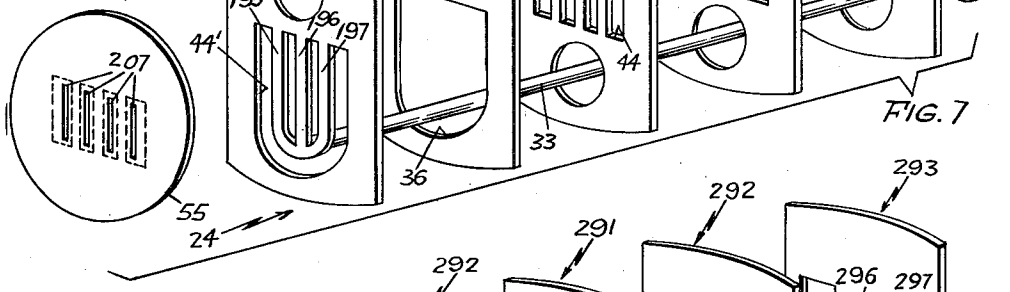


FIG. 7

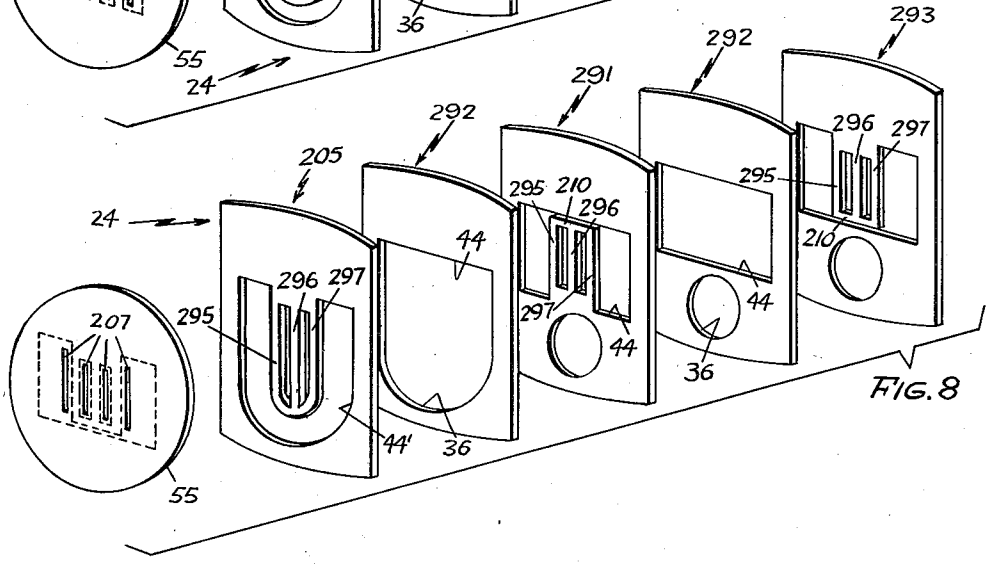


FIG. 8

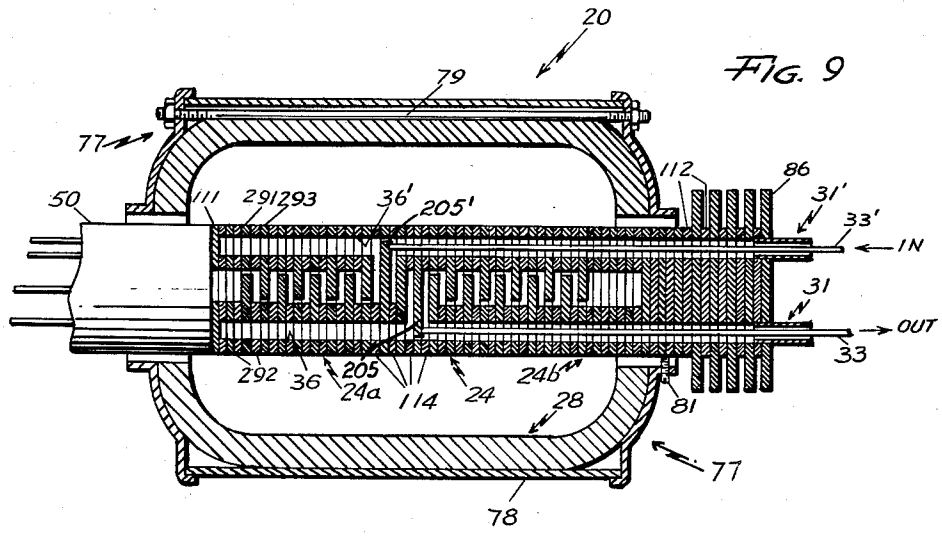
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TRAVELING WAVE STRUCTURES

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FIG. 9



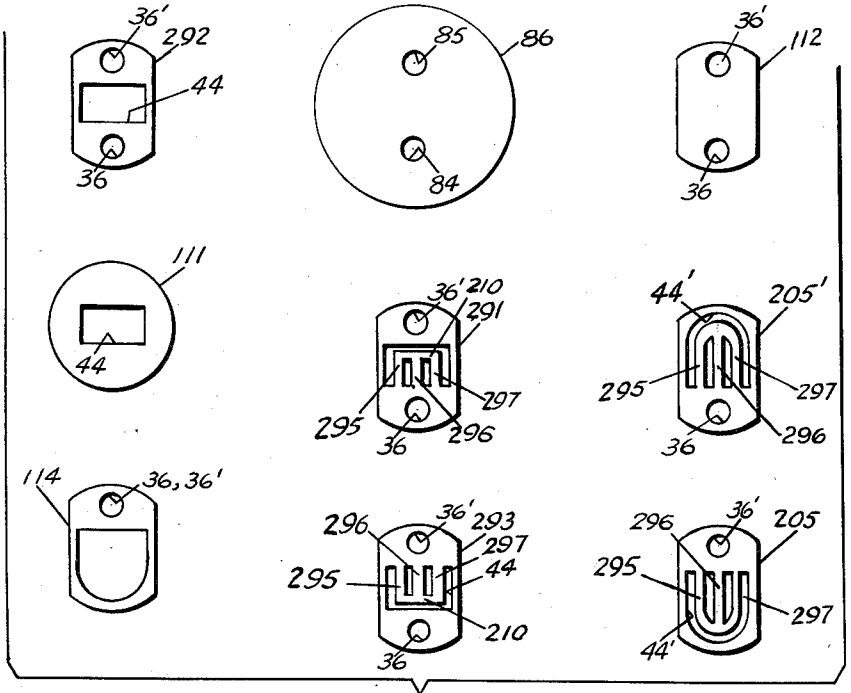


FIG. 10

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Patented Feb. 23, 1960

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TRAVELING WAVE STRUCTURES

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Application April 23, 1956, Serial No. 579,972

12 Claims. (Cl. 315—3.6)

This invention relates to traveling wave tubes of improved construction and, more particularly, relates to interdigital delay networks for use with such traveling wave tubes.

Certain advantages are achieved by constructing the periodic slow wave propagating networks of traveling wave tubes in the form of an interdigital line, as contrasted to networks such as a helix. Some of these advantages are that the interdigital structure may be made more rugged and may be designed to dissipate considerably more power than the helix type of slow wave network.

One of the difficulties inherent in solid interdigital structures of the prior art is that they are somewhat difficult to machine. One of the objects of this invention is to provide a laminated periodic delay structure which may be readily fabricated to a high degree of uniformity, as contrasted with interdigital delay structures of solid construction. The laminations may be stamped out by a punch press and then aligned accurately in a jig. These laminations constitute transverse sections of a complete interdigital delay structure which may be formed by stacking and assembling these laminations along the longitudinal axis of the tube.

When periodic slow wave propagating networks are used in traveling wave electron discharge tubes, it is essential that the impedance of said network be matched to that of the output coupling means, in the case of a traveling wave oscillator, or to the impedance of the input and output coupling means, in the case of a traveling wave amplifier. Coaxial line coupling means, which are particularly suitable for use in traveling wave tubes, have a characteristic impedance of 50 ohms. The characteristic impedance of an interdigital delay network may be shown to be equal approximately to the product of a constant (377 for air) and the ratio to the spacing between adjacent fingers of the network to the width of said fingers. Although theory would indicate that any value of impedance may be obtained by proper choice of finger spacing and finger width, there are limits beyond which it is impractical to vary these parameters.

The period of the interdigital delay network, that is, the sum of the spacing between adjacent fingers and the thickness of the fingers, depends upon the desired velocity of propagation of wave energy along the network and must be established in advance. If the finger spacing is made too small, for a given width, the impedance and the proportion of the stored energy in the fringing field becomes too small; consequently, the efficiency of the network becomes unduly low. On the other hand, if the finger spacing is too large, the fingers become so thin that the network is mechanically fragile; furthermore, the phase angle at which the electron beam passes through the fringing field between adjacent fingers becomes relatively large, and the efficiency thereby is reduced. Therefore, the finger spacing is a matter of compromise between the factors above-mentioned. Having arrived at a practical value for finger spacing, the impedance then becomes dependent upon the finger width, which, like the other

parameters, must be kept within reasonable bounds because of such considerations as mechanical strength, overall tube dimensions, and so forth. It has been found that a practical interdigital delay network suitable for microwave operation can be constructed whose impedance is of the order of 150 ohms. This value is substantially greater than the 50 ohm impedance of a standard coaxial coupling device. If, however, three such interdigital networks are connected in parallel, the resulting impedance will be approximately equal to that of the coaxial coupling device and a good impedance match between the interdigital delay structure and the low impedance coaxial coupling device may be obtained. Another object of the invention, therefore, is to obtain an interdigital delay structure whose impedance is matched to the low impedance output or input coupling device by connecting more than one interdigital network in parallel. The number of shunt-connected networks used will depend upon the approximate impedance of an individual interdigital network. For example, if the impedance of the network is in the neighborhood of 200 ohms, four such networks would be connected in parallel.

The multiple interdigital networks may consist of a number of separate arrays of spaced interdigital fingers, each array being spaced from the adjacent array. The space between arrays of the multiple network may be relatively small, since it is the fringing field immediately adjacent the fingers of each array that is effective in producing the desired interaction between the electron beam and wave energy traveling along the network. If electrons from an electron gun are directed along multiple paths in the spaces between adjacent arrays, it is possible to achieve efficient interaction between the electron beam and the various arrays without increasing the over-all dimensions of the electron gun or the combined interdigital structure. Since the spacing between arrays may be relatively small, a number of interdigital arrays may be contained within the region of the axial magnetic field which is normally occupied by but a single network, that is to say, the same magnetic field requirements may apply to a multiple interdigital structure as to the usual single interdigital network Another object of the invention, therefore, is to design a multiple interdigital network which will particularly utilize the magnetic field and electron gun for greater power output. By the use of n parallel interdigital networks, the power output of the traveling wave tube may be multiplied approximately n times without increasing the over-all dimensions of the tube or the magnetic field requirements.

In one form of multiple delay structure, adjacent fingers of the n interdigital arrays extend laterally inwardly from a rim portion and intersect one another at an angle of approximately

$$\frac{360^\circ}{n}$$

The networks are coupled together at the intersection of the fingers so that slight individual variations in the separate networks will average out, rather than produce a cumulative effect. If, for example, three interdigital arrays were shunt-connected, the adjacent fingers would intersect at an angle of 120 degrees and laminations would be rotated 60 degrees in assembly.

One objection to the radial design above-mentioned is that the center of the network, which is the most effective for coupling to the electron beam, is not available for use. An improvement may be effected by a linear design, wherein the fingers of the individual network arrays are arranged substantially parallel to one another, and the arrays are spaced laterally with respect to the longitudinal axis of the combined network structures. The electron beam then would be directed into the spaces be-

tween the arrays and into the spaces between the outside arrays and the outer walls of the combined network structure. Because of the proximity of the individual beams to the various fingers, the interaction between the beam and the wave energy traveling along the network is greater than that of the radial type.

In the linear network above described, it sometimes occurs that any inequalities in the individual networks, owing to slight variations in mechanical spacing or to differences in coupling effects of the individual beams, result in discontinuities in the frequency band of operation of traveling wave tubes using such networks. It has been found that a substantially continuous range of frequency of operation may be achieved in such instances by interconnecting the shunt-connected networks together at the free ends of the fingers of the individual interdigital arrays by means of a bridging element or other electrically conductive means.

Although the multiple or parallel interdigital networks of the radial and linear type above-referred to may be of solid construction, in accordance with the invention, a laminated periodic network structure is preferable for reasons initially mentioned. The network laminations of the multiple network, like those of the single network first described, are readily fabricated in a single punching operation and may be assembled easily in accurate alignment, as by a brazing operation, to form a united composite interdigital structure. In all the laminated networks described, the laminations may include apertures whose boundary form a portion of the outer conductor of the coaxial coupling means and into which the inner conductor of the coaxial coupling means may be inserted.

For a better understanding of the invention, together with further objects thereof, reference is made to the following description taken in conjunction with the accompanying drawing wherein:

Fig. 1 is a cross-sectional view of a traveling wave oscillator in accordance with the invention;

Fig. 2 is an exploded view showing the relative position of the laminations comprising the periodic delay network of the device of Fig. 1;

Fig. 3 is a section view illustrating the details of a portion of the tube of Fig. 1 including the external output coupling means and the exhaust tubulation;

Fig. 4 is a view showing some of the laminations of Fig. 3;

Fig. 5 is an exploded view showing a portion of a radial type multiple interdigital network and including one of the slotted elements of the electron gun assembly;

Fig. 6 is a view showing in detail the method of interconnecting a coupling means to the interdigital network of Fig. 5;

Fig. 7 is an exploded view showing the relative positions of the laminations in a linear multiple interdigital structure, including one of the elements of the electron gun assembly;

Fig. 8 is a view showing an arrangement of laminations in a modification of the interdigital network shown in Fig. 7;

Fig. 9 is a view, largely in section, of a traveling wave amplifier using a laminated slow wave propagating network; and

Fig. 10 illustrates the configuration of various ones of the laminations making up the periodic delay network of the tube of Fig. 9.

Referring now to Figs. 1 to 4, a traveling wave oscillator **20** is shown which comprises generally an anode assembly **22** including a periodic interdigital slow wave propagating network **24**, sometimes referred to as a delay network, an electron gun assembly **26**, a magnet assembly **28**, and output coupling means **30, 31**, which comprises a portion **30** located inside the delay network **24** and a portion **31** connected outside said delay network.

The anode delay network **24** comprises a series of laminations, the major portion of which are arranged in sets of four, as indicated in Fig. 2. Each lamination contains a circular aperture **36** near one end whose boundary serves as a portion of the outer conductor of the portion **30** of the coaxial output coupling means. In other words, the periphery of the circular apertures **36** in the assembly of laminations form a continuous outer conductor of diameter equal to the diameter of these apertures. The laminations **41, 42, 43, 42** of each set are further provided with rectangular openings **44**. Lamination **41** includes an elongated electrically conductive element or finger **45** which extends from one edge of opening **44** almost to the opposite edge thereof. Lamination **43** likewise includes an electrically conductive finger **45** which extends from the edge of the opening **44** opposite that of lamination **41** to a point adjacent, but not contacting, the opposite edge of said opening. The elements **45** of laminations **41**, when assembled, are positioned in spaced relationship with adjacent elements **45** of lamination **43**. Proper spacing between successive fingers or elements of the anode network is achieved by means of the spacer laminations **42** which do not contain any fingers. The inner conductor **33** of the coaxial coupling means is attached at one end to an end lamination **46**, which is similar to lamination **43**, except that the finger **45** thereof is slightly longer in order to permit connection to be made directly to the inner conductor **33**; the opening **44'** in lamination **46**, unlike the openings **44** of the other laminations, is continuous with the circular opening forming the boundary of the outer conductor of the coaxial line. The various laminations may be joined together, as by brazing, to form a united periodic interdigital network **24**. The end lamination **46** may be secured, as by brazing, to a disc **48** which is attached, in turn, to a cylinder **50** within which the electron gun assembly **26** is mounted.

The electron gun assembly includes a cathode **52** including a heater coil **53**, a grid **54**, an accelerating anode **55**, and mounting plates **56** and **57**. The elements **55** to **57** of the electron gun are insulatedly mounted in spaced relationship by means of ceramic support rods **59** which pass through elements **55** to **57**; a ceramic-to-metal braze may be made at the points of insertion of the support rods **59** into the accelerating anode **55** and the mounting plates **56** and **57**. The grid **54** is supported from mounting plate **56** by means of one or more rods **60** spot-welded to the grid and extending through mounting plate **56**. A glass bead **61** is attached to one end of one of the rods **60**, while a wire **62** is secured to glass bead **61**, as shown in Fig. 1. The cathode **52** is supported from mounting plate **56** by means of a rod **63** spot-welded to the cathode and passing through a central aperture in mounting plate **56**; the support rod **63** for the cathode is attached to wire **62**. A grid lead **66** is secured to mounting plate **56** and a cathode lead **67** is connected to the wire **62**. A heater lead **68** is connected to one end of the heater coil **53** and the other end of the heater may be connected directly to the cathode. The accelerating anode **55** is mounted on support rods **59** in spaced relationship with the grid **54** and a lead **69** it attached to the accelerating anode. The mounting plate **57** is attached directly to the disc **48** at the end of cylinder **50** by means of screws **58**. The cylinder **50** is maintained at the same potential as the periodic anode network **24** and an appropriate source of high voltage, not shown, is connected between the anode network and the cathode. Likewise, appropriate sources of potential for the other elements of the electron gun, not shown, are necessarily provided. The leads **66** to **69** extend through a seal, not shown, mounted at the end of cylinder **50** remote from disc **48**. The grid, accelerating anode, and mounting plate **57** contain two aligned slots through which electrons from the cathode may pass. By means of these slots, and by means of an appropriate accelerating voltage between the accelerating anode **55** and the cathode **53**, a pair of flat or ribbon-shaped

beams are directed into the interaction space of the anode delay network 24, said interaction space being made up of those portions of the two spaces between the fingers 45 of each lamination and the long edges of the rectangular openings 44 which are adjacent to the fingers.

The magnet assembly 28 includes a pair of toroidal members 71 and 72 which are adapted to fit together along junction 73. Each of these members is supported at one end by a sleeve 75. A ring-plate assembly 77 is positioned at each end of the magnet assembly and includes a first portion conforming generally to the surface of the respective magnet member and a bracket portion extending radially outward from the first portion. An outer sleeve 78 is positioned between the opposite ring-plate assemblies. The two halves of the magnet assembly are held together by means of through bolts 79 passing through holes in the bracket portions of the assembly 77. Each ring-plate assembly 77 includes a ring portion 80 through which set screws 81 pass. The set screws in the ring portion of one ring-plate assembly are adapted to seat against the cylinder 50 surrounding the electron gun assembly 26, while the set screws in the ring portion of the other ring-plate assembly seat against a tubular member 82 against whose inner periphery rest the curved ends of a portion of the laminations of the anode delay network 24. The magnet assembly 28 provides an axial or longitudinal magnetic field for focusing the electron beam traveling along the length of the anode delay network 24.

In Figs. 3 and 4 a portion of the output end of the anode assembly 22 is shown. The laminations 41, 42 and 43 are followed by a series of laminations 49 and 49', such as shown in detail in Fig. 4. Hole 84 is of the same diameter as that of circular apertures 36 in laminations 41 to 43 and serves as a portion of the outer boundary of the portion 30 of the coaxial output means. The other hole 85 in laminations 49 and the slot 82 in laminations 49' provide means for evacuating the tube. Cooling fins 86 and 86' are disposed between laminations 49 and 49' adjacent the output end of the anode assembly 22 in order to provide improved cooling thereof. Cooling fins 86, like laminations 49, contain holes 84 and 85 which are aligned with similar holes in the laminations 49. Cooling fins 86' contain slots 82 aligned with the slots 82 in laminations 49'. An exhaust tube 88 is positioned within the hole 85 in the last lamination 49 and is secured thereto as by means of a solder ring 89. After evacuation of the tube, the end of the exhaust tube may be pinched off. It should be understood, however, that the tube may be evacuated from the electron gun end, in which case the exhaust tube 88 may be omitted, together with the holes 85 and slots 82 in elements 49, 86, 49' and 86'.

An external coaxial connector 31 includes an outer conductor which is secured to an opening in the endmost lamination 49 as by means of a solder ring 87 inserted as shown in Fig. 3. The inner conductor of coaxial connector 31 may consist of an extension of the inner conductor 33 of the coaxial output means.

Referring to Figs. 5 and 6, the delay network 24 includes three separate interdigital lines intersecting at angles of 120°. The anode network is made up of several sets of laminations, each set comprising three laminations, 91, 92, and 93. Lamination 91 includes fingers 95, 96, and 97 extending from the inner edge of ring portion 98 of the lamination almost to a point on the inner edge of ring portion 98, diametrically opposite. Lamination 93 includes fingers 95, 96, and 97 aligned with fingers 95, 96 and 97, respectively, of lamination 91. The fingers of lamination 93 corresponding to those of lamination 91 extend from opposite portions of the inner edges of ring portion 98. The laminations 91 and 93 are separated by a spacer lamination 92, comprising a ring portion 98, but no fingers. The coaxial output coupling device 130 includes an outer conductor 132, which may contact the periphery of the assembled laminations, as shown in Fig. 6. The inner conductor 133 of the coaxial device 130 is formed by an extension of one of the fingers of a specially designed lamination 105 located at or adjacent the electron gun end of the anode delay network. A slot is cut in the ring portion 98 of lamination 105 through which the central conductor 133 can pass and similar slots are also cut in the spacer laminations 92 on either side of lamination 105, so that the inner conductor is electrically isolated from the outer conductor. More than one spacer may be used on the electron gun side of the coaxial conductor 130 in order to provide the necessary support for the outer conductor 32, as shown in Fig. 6.

The fingers 95 of the various laminations form a first interdigital network or array; the fingers 96 form a second interdigital network; and the fingers 97 form the third interdigital network. These three networks are connected in parallel. In the anode delay network, shown in Figs. 5 and 6, the electron beam is caused to pass through the wedge-shaped spaces between the fingers of the laminated interdigital network. Although the electron beam may occupy substantially the entire space between the fingers, only that portion of the beam immediately adjacent the fingers has an appreciable effect upon the interaction between the electron beam and the wave energy propagating along the delay network. Consequently, a plurality of V-shaped beams provide for the most efficient operation. In order to achieve these V-shaped beams, several V-shaped slots are provided in the appropriate elements of the electron gun. In Fig. 5, a typical accelerating anode 55 is shown, which contains a number of V-shaped slots 107, which will break up the electron stream emanating from the cathode into a plurality of V-shaped beams. The grid of the electron gun, not shown in Fig. 5, also is provided with a similar array of V-shaped slots aligned with those in the accelerating anode. The position of the wedge-shaped interaction spaces between the fingers of the interdigital delay network relative to the corresponding V-slots are indicated by the dotted lines in Fig. 5.

In Fig. 7, another embodiment of a parallel interdigital delay network 24 is shown. Again, the major portion of the anode delay network consists of a plurality of sets of laminations, each set comprising three laminations. Lamination 191 includes three spaced fingers 195, 196, and 197 extending from the lower edge of rectangular opening 44 almost to the opposite edge of said opening. Lamination 193 is similar to lamination 191 except that the fingers 195, 196, and 197 of lamination 193 extend from the opposite edge of the opening 44 from that of lamination 191. The fingers 195 of the various sets of laminations form one interdigital delay network or array, the fingers 196 form a second network, and fingers 197 form a third interdigital network; these three networks are connected in parallel. A spacer lamination 192 provides for necessary spacing between adjacent interdigital fingers of the three parallel interdigital delay networks. The end lamination 105 includes a single opening 44' into which the fingers 195, 196, and 197 extend sufficiently to permit connection of each to the inner conductor 33 of the coaxial output means. The circular apertures 36, like those in the laminations shown in Fig. 2, receive the inner conductor 33 of the coaxial output means. The other circular apertures 36' may be used as an exhaust opening, in the same manner as apertures 85 in laminations 49, shown in Figs. 3 and 4. Alternatively, the circular aperture 36' may be used for receiving the inner conductor of a coaxial input line should the device be used as an amplifier. The tube may be evacuated from the electron gun end of the tube, in which case no exhaust apertures in the laminations are required. The grid and the accelerating anode of the electron gun used with the anode network of Fig. 7 contains several linear slits 207, such that the electrons

from the cathode are directed along a plurality of ribbon-shaped beams in the interaction spaces between the various interdigital networks and adjacent the fingers of said network. A typical accelerating anode **55**, as shown in Fig. 7, includes slits **207** through which the electrons from the cathode are directed. The interaction spaces of the laminations forming the anode network are indicated by dotted lines.

In Fig. 8, a modification of the device of Fig. 7 is shown, wherein the delay network **24** consists of laminations **291**, **292**, and **293**. The laminations **291** and **293** include fingers **295**, **296** and **297**, and the fingers of laminations **191** and **193** extend from opposite edges of the rectangular openings **44**. Laminations **292** provide the necessary spacing between laminations **291** and **293**. The ends of each of the fingers of each of laminations **291** and **293** are electrically interconnected by a bridging element **210**. By means of this bridging element, any tendency of the traveling wave tube to show discontinuities in the frequency band of operation is substantially eliminated. The end lamination **205**, like lamination **105** of Fig. 7, includes an extended opening **44'** to permit fingers **295**, **296**, and **297** to be connected to the inner conductor, not shown, of the coaxial coupling means. The electron gun electrode **55**, like that of Fig. 7, contains several slits **207** whose position relative to the interaction space is indicated by means of a dotted line.

In Fig. 9, a backward wave traveling wave amplifier is shown whose anode assembly includes two delay networks similar to that shown in Fig. 8. The basic principles of this type of amplifier, using a helix rather than the interdigital delay line shown in Fig. 9, is set forth in considerable detail in an article by Currie and Whinnery entitled "The Cascade Backward-Wave Amplifier: A High-Gain Voltage-Tuned Filter for Microwaves" appearing in the November 1955 issue of Proceedings of the IRE at pages 1617 to 1631. This tube includes an electron gun assembly, not shown, mounted within cylinder **50**. This electron gun assembly may be similar to that shown in the device of Fig. 1 except that four slits, rather than two, are provided in the grid and accelerating anode, owing to the fact that three interdigital networks are connected in parallel in Fig. 9.

The laminated anode delay network **24**, which includes two separate networks **24*a*** and **24*b***, includes an end lamination **111** which is affixed to the end of cylinder **50**. The amplifier includes a magnet assembly **28** fixedly mounted with respect to the anode assembly in the same manner as shown in the device of Fig. 1. The set-screws **81** in ring-plate assembly **77** at the right hand end of the tube seat against the delay network directly rather than against a tubular member **82**, as in Fig. 1; however, either method for supporting may be used alternatively. The anode assembly of amplifier **20** of Fig. 9 is composed of a plurality of laminations, which, when assembled, form the two separate anode delay networks **24*a*** and **24*b***. These networks are coupled only by the electron beam which passes adjacent both networks in a direction from left to right in Fig. 9. The laminations **112** at the end of the anode assembly remote from the electron gun serve as an electron-collecting electrode. The input connection to the tube for supplying a radio frequency input signal to the amplifier includes a coaxial connector **31'**, whose inner conductor **33'** passes through apertures **85** in cooling fins **86**, and through apertures **36'** in laminations **291**, **292**, and **293**, **112** and **114**, and connects to the juncture of elongated fingers **295**, **296**, and **297** of lamination **205'**. Lamination **205'** is located at the downstream end of the first interdigital anode network **24*a***, that is, at the end thereof toward which electrons are being directed. In the backward wave amplifier, shown in Fig. 9, interaction between the electron beam and the backward wave traveling along network **24*a*** modulates the electron beam, which beam continues on past the second interdigital anode network **24*b***. The amplified output signal is taken out from the last delay network **24*b*** at the beam-entering or upstream end thereof by means of an output coupling device **31**, consisting of a coaxial line whose inner conductor **33** passes through circular apertures **84** in cooling fins **86** and through apertures **36** in laminations **291**, **292**, **293**, **112** and **114**, and connects to the elongated fingers **295**, **296**, and **297** of lamination **205**. The major portion of the anode networks **24*a*** and **24*b***, like those previously described, are made up of several sets of three laminations, that is, laminations **291**, **292**, and **293**. Proper spacing between adjacent fingers of the networks is maintained by means of spacer laminations **292**, as in the previous anode networks.

The upstream end of the first anode network **24*a*** and the downstream end of the last anode network **24*b*** should be properly terminated in order to avoid reflection of energy. Such terminations are well known in the art, and may consist, for example, of an attenuating material such as iron or graphite plated or coated on the fingers at the ends of the line.

It should be understood that the form of delay network shown in Figs. 9 and 10 is merely illustrative and that the number of fingers in each lamination, and hence the number of shunt-connected interdigital lines, may be either less than or greater than three. Furthermore, the delay networks may be of the type shown in Fig. 5 or Fig. 7 of the drawing.

Furthermore, the traveling wave amplifier **20** shown in Fig. 9 may consist of a single anode network, in which case lamination **205'** to which the input connection is attached would be positioned adjacent the electron gun, and lamination **205** to which the output connection is made would be positioned adjacent the collector end of the tube. The backward wave amplifier of Fig. 9, however, has the advantage of being less critical as to the beam current requirements necessary to prevent self-oscillation.

It is also possible to use the anode delay networks previously described in forward wave amplifiers. In this event, the position of the input and output connections to the tube would be reversed.

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 traveling wave tube comprising a periodic slow wave energy propagating means including a plurality of laminations arranged transversely to the longitudinal axis of said propagating means, said laminations including a body portion having an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body portion of said lamination only along said one edge, each of the corresponding ones of said fingers of said laminations forming a portion of a separate interdigital network, the free ends of said fingers being electrically interconnected by a bridging element, and means for forming and directing a beam of electrons along multiple extended paths through the spaces adjacent the fingers in each of said laminations in energy-exchanging relation with fields of wave energy existing along said propagating means.

2. A traveling wave tube comprising a periodic slow wave energy propagating means including a plurality of sets of laminations arranged transversely to the longitudinal axis of said propagating means, said sets including a first lamination including a body portion having an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body portion of said lamination only along said one edge, a second lamination containing an opening therein aligned with the opening of said first

lamination, and a third lamination identical to said first lamination except with said elongated fingers extending from the opposite edge of said opening, said second lamination serving as a spacer between said first and third laminations, each of the corresponding ones of said fingers of the several laminations combining to form a portion of a separate interdigital network, and means for forming and directing a beam of electrons along multiple extended paths through the spaces adjacent the fingers in each of said laminations in energy-exchanging relation with fields of wave energy existing along said propagating means.

3. A traveling wave tube comprising a periodic slow wave energy propagating means including a plurality of sets of laminations arranged transversely to the longitudinal axis of said propagating means, said sets including a first lamination including a body portion having an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body portion of said lamination only along said one edge, a second lamination containing an opening therein aligned with the opening of said first lamination, and a third lamination identical to said first lamination except with said elongated fingers extending from the opposite edge of said opening, said second lamination serving as a spacer between said first and third laminations, each of the corresponding ones of said fingers of the several laminations combining to form a portion of a separate interdigital network, the free ends of said fingers being electrically interconnected by a bridging element, and means for forming and directing a beam of electrons along multiple extended paths through the spaces adjacent the fingers in each of said laminations in energy-exchanging relation with fields of wave energy existing along said propagating means.

4. A traveling wave tube comprising means for propagating electromagnetic wave energy, said means for propagating constituting a united interdigital structure including a plurality of laminations arranged transversely to the longitudinal axis of said propagating means, said laminations including a plurality of spaced elongated fingers which are of uniform configuration, means for directing a beam of electrons along multiple extended paths through the spaces between adjacent fingers in each of said laminations, said means for directing including means for producing a magnetic field axially of said tube in the region of said extended paths, each of said fingers of a given lamination forming a portion of a separate interdigital network, and an output coupling means for removing energy from said means for propagating, said output coupling means having a characteristic impedance substantially equal to that of said means for propagating.

5. A traveling wave tube comprising means for propagating electromagnetic wave energy, said means for propagating constituting a united interdigital structure including a plurality of sets of laminations arranged transversely to the longitudinal axis of said propagating means, each of said sets of laminations including a first lamination having an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body of said lamination only along said one edge, a second lamination identical with said first lamination except with said elongated fingers extending from the opposite edge of said opening, and a spacer lamination inserted between said first and second laminations, means for directing a beam of electrons along multiple extended paths through the spaces between adjacent fingers in each of said laminations and between the spaces between the fingers and the body of said laminations, said means for directing including means for producing a magnetic field axially of said tube in the region of said extended paths, each of said fingers of a given lamination forming a portion of a separate interdigital network, and an output coupling means for removing energy from said means for propagating, said output coupling means having a characteristic impedance substantially equal to that of said means for propagating.

6. A traveling wave tube comprising means for propagating electromagnetic wave energy, said means for propagating constituting a united interdigital structure including a plurality of laminations arranged transversely to the longitudinal axis of said propagating means, said laminations including an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body of said lamination only along said one edge, means for directing a beam of electrons along multiple extended paths through the spaces between said fingers and the spaces between the fingers and the body of said laminations, said means for directing including means for producing a magnetic field axially of said tube in the region of said extended paths, each of said fingers forming a portion of a separate interdigital network, and a coaxial output coupling means having an inner conductor and an outer conductor for removing energy from said means for propagating, said output coupling means having a characteristic impedance substantially equal to that of said means for propagating, said laminations further including a circular aperture whose periphery forms a portion of the outer conductor of said coupling means.

7. A traveling wave tube comprising means for propagating electromagnetic wave energy, said means for propagating constituting a united interdigital structure including a plurality of sets of laminations arranged transversely to the longitudinal axis of said propagating means, each of said sets of laminations including a first lamination having an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body of said lamination only along said one edge, a second lamination identical with said first lamination except with said elongated fingers extending from the opposite edge of said opening, and a spacer lamination inserted between said first and second laminations, means for directing a beam of electrons along multiple extended paths through the spaces between adjacent fingers in each of said laminations and between the spaces between the fingers and the body of said laminations, said means for directing including means for producing a magnetic field axially of said tube in the region of said extended paths, each of said fingers forming a portion of a separate interdigital network, an output coupling means for removing energy from said means for propagating, and an input coupling means for introducing radio frequency energy into said means for propagating, said output and input coupling means having a characteristic impedance substantially equal to that of said means for propagating.

8. A traveling wave tube comprising means for propagating electromagnetic wave energy, said means for propagating constituting a united interdigital structure including a plurality of laminations arranged transversely to the longitudinal axis of said propagating means, said laminations including an opening therein and a plurality of spaced elongated fingers extending from one edge of said opening and attached to the body of said lamination only along said one edge, means for directing a beam of electrons along multiple extended paths through the spaces between said fingers and between the spaces between the fingers and the body of said laminations, said means for directing including means for producing a magnetic field axially of said tube in the region of said extended paths, each of said fingers of a given lamination forming a portion of a separate interdigital network, an output coupling means for removing energy from said means for propagating, and an input coupling means for introducing radio frequency energy into said means for propagating, said coupling means including an inner conductor and an outer conductor, said output and input coupling means having a characteristic impedance sub-

stantially equal to that of said means for propagating, said laminations further including circular apertures whose peripheries form, respectively, a portion of the outer conductor of said input and output coupling means.

9. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy at a velocity substantially equal to that of said electron beam, said means for propagating constituting a united interdigital structure including a plurality of shunt-connected periodic interdigital slow wave propagating networks arranged adjacent said electron beam, and an output coupling means for removing energy from said means for propagating.

10. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy at a velocity substantially equal to that of said electron beam, said means for propagating constituting a united interdigital structure including a plurality of shunt-connected periodic interdigital slow wave propagating networks arranged adjacent said electron beam, and an output coupling means for removing energy from said means for propagating, said output coupling means having a characteristic impedance substantially equal to that of the combined impedance of said shunt-connected networks.

11. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy at a velocity substantially equal to that of said electron beam, said means for propagating constituting a united interdigital structure including a plurality of shunt-connected periodic interdigital slow wave propagating networks arranged adjacent said electron beam, said united structure including a plurality of laminations each of which

includes a portion of all of said shunt-connected networks, and an output coupling means for removing energy from said means for propagating.

12. A traveling wave tube comprising means for directing a beam of electrons along multiple individual extended paths, means for propagating electromagnetic wave energy at a velocity substantially equal to that of said electron beam, said means for directing including means for producing a magnetic field axially of said tube, said means for propagating constituting a united interdigital structure including a plurality of shunt-connected periodic slow wave propagating networks arranged adjacent said electron beam and in the region of said magnetic field, and an output coupling means for removing energy from said means for propagating, said output coupling means having a characteristic impedance substantially equal to that of the combined impedance of said shunt-connected networks, said networks each including an interdigital array of spaced elements spaced from the array of the adjacent network, said electron beam paths being substantially coextensive with and adjacent corresponding ones of said network arrays.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,926,280 February 23, 1960

Rudolf C. Hergenrother

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 60, for "it" read -- is --; column 10, lines 18 and 46, after "fingers", each occurrence, insert -- of a given lamination --.

Signed and sealed this 30th day of August 1960.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents