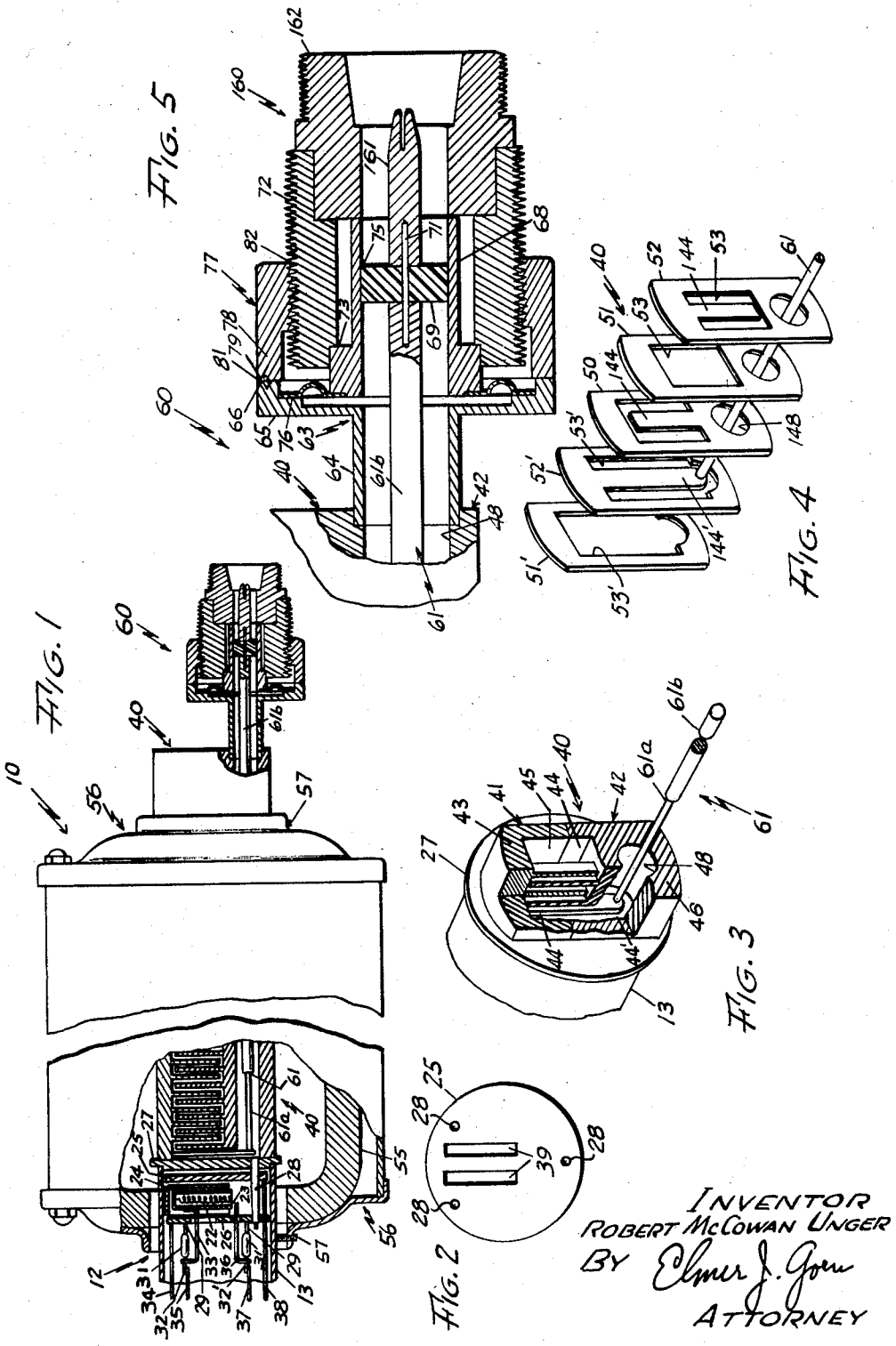
June 3, 1958 R. McC. UNGER 2,837,684

TRAVELING WAVE DEVICES

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TRAVELING WAVE DEVICES

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9 Claims. (Cl. 315—3.5)

This invention relates to a traveling wave electron device and particularly to means for matching the impedance of the periodic slow wave propagating structure of a traveling wave electron discharge device to the impedance of an output coupling means used for removing energy from said device.

Traveling wave oscillators are known in which the electrons in an extended beam are caused to interact with the electromagnetic field of a wave propogating along the path adjacent the periodic slow wave energy propagating structure, which may be an interdigital delay structure. The electromagnetic field along such a structure may be considered to consist of a number of superimposed traveling waves or space harmonics. These harmonics travel with different phase velocities, some of which are characterized in that the phase velocity is in the same direction as the energy or group velocity; such harmonics are referred to as forward waves. Other harmonics, on the other hand, are characterized by a negative phase velocity, that is, a phase velocity in a direction opposite to the energy or group velocity; these waves are referred to as negative space harmonics or backward waves. If, for example, the electron beam is propagated in the direction of one of these backward waves at a velocity substantially equal to the phase velocity of the backward waves, interaction will occur between the electron beam and the traveling wave and the energy will be transferred to the electromagnetic field; the energy given to the backward wave will be transferred along the periodic structure toward the beam source. If the electron beam exceeds a critical value at which oscillations can begin, and when the electron beam velocity is in substantial synchronism with the velocity of one of the space harmonics, such as a backward wave, oscillations may be generated in the tube. These oscillations will propagate along the periodic structure and may be extracted at one end thereof by means of an output coupling means, such as a coaxial line, whose inner conductor is attached to the periodic structure adjacent one end.

In one type of traveling wave tube the electron beam is permitted to pass through the interaction space adjacent the periodic slow wave propagating structure and may be collected at the end thereof remote from the electron source by a collector electrode maintained at a potential positive relative to the electron source. The electron beam is prevented from moving laterally within the tube by a longitudinal focusing magnetic field. In other types of traveling wave tubes the electrons are permitted to move through unidirectional electric and magnetic fields which are transverse to one another and to the mean path of the electron beam.

Interdigital transmission networks have been found to be particularly suitable for use as the periodic slow wave propagating structure of traveling wave tubes. Such interdigital networks comprise a pair of arrays each including a continuous portion or base from which depend several spaced elements or fingers, the fingers of one array extending into the spaces between adjacent fingers of the other

array. The characteristic impedance of an interdigital line is equal approximately to the product of a constant (377 if air is used as a dielectric) and the ratio of the space between adjacent fingers to the width of said fingers. A satisfactory output coupling means comprises a coaxial line having an inner conductor and a concentric outer conductor. In the case of backward wave traveling wave oscillators, the output coupling means it attached to the interdigital line adjacent the upstream end, that is, at one end thereof adjacent to the electron source. Specifically, the inner conductor of the coaxial line may be mechanically and electrically connected to the end finger of the interdigital line while the outer conductor is electrically connected to the base of either array of the interdigital structure.

In order to prevent undesirable reflections of energy from the end of the interdigital structure, that is, from the juncture of the interdigital structure and the coaxial line, it is essential that the impedance of the interdigital structure be matched to that of the coaxial line. It has been found in practice that the characteristic impedance of interdigital networks suitable for use in traveling wave tubes differs from the characteristic impedance of the coaxial transmission line. Some means, therefore, is required to provide the necessary adjustment for obtaining the optimum impedance match. If the end finger of the interdigital structure of the tube is sufficiently flexible, the position of this finger, otherwise referred to as a matching finger, may be adjusted to provide the proper impedance match between the interdigital structure and the coaxial line. This adjustment is often necessary in order to compensate for variations from tube to tube. If the position of the matching finger is adjusted at "cold test," that is, while the tube is operating under other than actual operating conditions desired in practice, the spacing will usually differ appreciably when the tube is actually used in some particular application. This difference results, in part, from differences in thermal expansion of the materials of the lines and from thermal gradients which cannot be predicted in advance of actual operation. It is desirable, therefore, to adjust the position of the matching finger of the interdigital line until the proper impedance is attained during actual operation without breaking the vacuum seal.

A sliding joint is provided on the outer conductor of the coaxial output coupling means and a vacuum seal is retained by means of a resilient diaphragm connected to the movable and stationary portions of the outer conductor of the coaxial output coupling means. The outer conductor may include a part of the base of the interdigital network, that is, the portion of the network to which the fingers are attached. The end of the inner conductor not attached to the matching finger is affixed to the movable portion of the outer conductor through a dielectric vacuum seal. Since the length of the inner conductor is fixed, movement of the movable portion of the outer conductor will cause axial movement of the matching finger and will permit the proper impedance match to be obtained between the coaxial line and the interdigital network. Once the optimum adjustment has been obtained, as determined by measurements indicating optimum output characteristics, the sliding joint may be fixed in position.

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 view, partly in section, illustrating an embodiment of the invention;

Fig. 2 is a plan view of the accelerating anode used in the electron gun assembly of Fig. 1;

Fig. 3 is a fragmentary view showing a portion of the interdigital delay network of Fig. 1;

Fig. 4 is an exploded view of a portion of a laminated interdigital network which may be used in lieu of the solid interdigital network shown in Figs. 1 and 3; and

Fig. 5 is a view showing a portion of the coaxial output means of Fig. 1.

Referring to the drawing, a traveling wave tube **10** is shown which includes an electron gun assembly **12** mounted within a cylindrical housing **13**, an interdigital slow wave propagating structure **40**, a focusing magnet **55**, and a coaxial output assembly **60**. Details of the traveling wave tube, using a laminated interdigital structure, are fully disclosed in a copending application by Rudolf C. Hergenrother, Serial Number 579,972, filed April 23, 1956.

The electron gun assembly comprises a cathode **22** including therein a heater coil **23**, a grid **24**, an accelerating anode **25**, and mounting plates **26** and **27**, the latter of which is secured to one end of housing **13**. The elements **22** to **25** of the electron gun are insulatedly mounted in spaced relationship by means of ceramic support rods **28** which pass through mounting plates **26** and **27** and element **25**. A ceramic-to-metal seal may be made at the points of insertion of the support rods **28** into the accelerating anode **25** and the mounting plates **26** and **27**. The grid **24** is supported from mounting plate **26** by means of one or more wires **29** spot welded to the grid and extending through mounting plate **26**. A glass bead **31** is attached to one end of wires **29**, while wire **32** is secured to the glass beads **31** as shown in Fig. 1. The cathode **22** is supported from mounting plate **26** by means of a support wire **33** spot welded to the cathode and passing through a central aperture in mounting plate **26**. This support wire **33** for the cathode is attached to wire **32**. Grid lead **34** is secured directly to the mounting plate **26**, while a cathode lead **35** is connected to wire **32**. A heater wire **36** interconnects one end of heater **23** and one of the wires **32'**; a heater lead **37** is attached to this wire **32'**. The other end of the heater **23** may be connected directly to the cathode. The accelerating anode **25** is mounted on support rod **28** in spaced relationship with the grid **24**, and a lead **38** is connected to the accelerating anode **25**. The housing **13** is maintained at the same potential as the interdigital network **40** and an appropriate source of high voltage, not shown, is connected between the network **40** and cathode **22**. Likewise, appropriate sources of potential, not shown, for the other elements of the electron gun are necessarily provided. The leads **34**, **35**, **37**, and **38** extend through a seal, not shown, mounted at the end of housing **13** remote from mounting plate **27**. The grid, accelerating anode and mounting plate **27** contain two parallel slots through which electrons from the cathode may pass. A plan view of the accelerating anode **25** containing slots **39** is shown in Fig. 2. By means of these slots, and by means of appropriate accelerating voltage between the accelerating anode **25** and the cathode **22**, a pair of substantially flat beams is directed into the interaction space **45** of the interdigital delay network **40** adjacent the edges of the fingers **44**. A portion of the interaction space **45** is visible in Fig. 3.

The axial focusing field for the electron beam is provided by the magnet assembly **55** which is mounted about the interdigital delay structure **40** by means of a ring plate assembly **56** positioned at each end of the tube. Set screws **57** passing through a portion of each assembly **56** and seating against electron gun housing **13** and the interdigital delay network **40**, respectively, maintain the axial magnetic field producing means **55** in the desired relationship relative to the interdigital delay network **40**.

As shown in Figs. 1 and 3, the interdigital delay network **40** may be attached at one end to mounting plate **27** which in turn is affixed to housing **13**; the interdigital network **40** may consist of two solid assemblies **41** and **42** joined together as shown in Fig. 3. The upper assembly **41** includes a body portion **43** from which extends a plurality of spaced fingers **44**. The lower assembly **42** includes a body portion **46** from which extends a plurality of fingers **44** which protrude into the spaces between adjacent fingers **44** of the upper assembly **41**. A circular recess or bore **48** is provided in the body portion **46** of the lower assembly **42** and the periphery thereof serves as a portion of the outer conductor of the coaxial output coupling means **60**. The inner conductor **61**, which includes a reduced portion **61***a* and a larger portion **61***b*, is disposed centrally within the recess **48** and one end thereof is attached to the end of matching finger **44'** of the upper assembly **41**. The matching finger **44'** is longer than the remaining fingers **44** of the upper assembly **41** so that connection may be made directly to the reduced portion **61***a* of inner conductor **61**. The reduced portion **61***a* of the inner conductor **61**, together with the portion of the outer conductor surrounding it, serve as a quarter wave section having a characteristic impedance equal to the square root of the product of the characteristic impedance of the interdigital network **40** and the characteristic impedance of that portion of the coaxial line including the enlarged portion **61***b* of the inner conductor **61**. In this manner, the impedance of the interdigital network may be matched to the impedance of the output line, which normally is different than that of the interdigital network. Although such a quarter wave transformer is frequency sensitive, substantial matching over a considerable range may be provided by virtue of the adjustable matching finger **44'**.

Alternatively, the interdigital network may be made up of several laminations, as shown in Fig. 4. The major portion of the interdigital line then includes a plurality of sets of three laminations **50**, **51**, and **52**, each containing a circular aperture **148** near one end, whose boundary serves as a portion of the outer conductor of the coaxial output coupling means **60** when the laminations have been stacked together and assembled, as by brazing. Each lamination includes a generally rectangular opening **53**. Laminations **50** include an elongated electrically conductive finger **144** which extends from one edge of opening **53** almost to the opposite edge thereof. Laminations **52** likewise include an electrically conductive finger **144** which extends from the edge of opening **53** opposite that of lamination **50** to a point adjacent, but not contacting, the opposite edge of said opening. The elements or fingers **144** of laminations **52**, when assembled, are positioned in space relationship with adjacent fingers of laminations **50** by means of spacer laminations **51** which do not contain any fingers. The matching finger **144'** of lamination **52'** is similar to that of lamination **52** except that the finger **144'** is slightly longer in order to permit connection to be made directly to the inner conductor **61**. The opening **53'** in lamination **52'**, unlike the openings **53** in the other laminations, is continuous with the circular aperture forming the boundary of the outer conductor of that portion of the coaxial output means **60** disposed within the interdigital network **40**. Spacer **51'** is similar to that of spacer lamination **51**, except that it contains an enlarged opening **53'**, like that in lamination **52'**, which may be provided at the end of the interdigital network **40** in order to allow room for sufficient movement of the matching finger **144'**.

As indicated in Fig. 5, the fixed portion of the outer conductor of the output coupling means **60** includes a hollow member **63** having a reduced portion **64** of inner diameter equal to that of the recess **48**, in the case of the solid interdigital construction of Figs. 1 and 3, or equal to that of the circular apertures **148**, in the case of the laminated interdigital construction of Fig. 4. The end of the reduced portion is secured, as by brazing, to the end of the lower assembly **42** of Fig. 3, or into one or more of the apertures **148** in the laminated assembly of Fig. 4. The enlarged portion **65** of member **63** terminates in

an end face 66. The movable portion of the outer conductor of the coaxial output coupling means 60 includes an output supporting element 68 through which the inner conductor 61 extends. The inner conductor 61 is mounted centrally within element 68 by means of a dielectric spacer disc 69 which may be made of ceramic. Since the dielectric constant of the ceramic disc 69 differs from that of air, the impedance of the coaxial line is maintained constant by means of a conductor 71 of reduced diameter which passes through a central aperture in the ceramic disc 69 and fits into recesses in the inner conductor 61 and the inner conductor 161 of a coaxial connector 160 which also includes an outer member 162. An output sleeve 72 whose outer periphery is threaded, as indicated in Figs. 1 and 5, is secured to the supporting element 68, as by a solder ring positioned at 73. The outer member 162 of coaxial connector 160 is secured to one end of the output sleeve 72. The ceramic disc 69 is secured to the inner conductor assembly 61*b*, 71, 161 as by insertion of solder rings, not shown, which may be positioned about conductor 71 and which, after application of heat, flow into the aforementioned recesses. The ceramic disc 69 is attached to the supporting element 68 by means of solder rings placed at 75. A flexible diaphragm 76 is connected between one end of the supporting element 68 and the enlarged portion 65 of member 63. An adjusting nut 77 having a peripheral flange 78 threadedly engages the periphery of output sleeve 72. In order to adjust the position of the matching finger 44' (or 144') of the interdigital delay network 40, the nut 77 is rotated about the threaded output sleeve 72 until the face 79 of the peripheral flange 78 bears against the face 66 of member 63. Since member 63 is fixed in position, further rotation of the nut 77 causes the output sleeve 72 to move toward the right in the drawing, and the inner conductor assembly, including element 61 which is attached to the output sleeve 72 through the ceramic disc 69 and supporting element 68, also moves with the output sleeve. The movement of the inner conductor 61 consequently produces a physical displacement of the flexible matching finger 44' (or 144') attached to the far end of the inner conductor 61. As the inner conductor 61 is moved axially as a consequence of rotation of the adjusting nut 77, the flexible matching finger 44' is bent toward or away from its neutral position, that is, parallel to the adjacent finger of the interdigital delay network 40, by means of cantilever action where the fulcrum is the point of attachment of the finger 44' to the body portion 43 of the interdigital network 40. By varying the spacing between the flexible matching finger 44' and the adjacent finger of the interdigital network 40, the matching impedance may be altered over a considerable range, thereby compensating for variations in impedance of the network 40 owing to slight distortion of the network, such as bent fingers, and for variations in the characteristics of the quarter-wave transformer, previously referred to, with frequency changes. Furthermore, some compensation may be made for slight deviation of the inner conductor of the output coupling means from the center of the coaxial line, and for slight discontinuities in the coaxial output coupling means. In practice, the nut 77 is backed off along the threaded output sleeve 72 and the assembly, including the inner conductor 61, is manually pushed toward the left, as shown in the drawing, as far as possible; the nut is then rotated clockwise until contact is made between the faces 66 and 79 of the member 63 and nut 77, respectively. Once the proper adjustment of the matching finger has been attained, nut 77 may be brazed in position as at points 81 and 82.

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. For example, the supporting element 68 may be omitted in certain instances and the inner conductor 61 may be fixedly supported directly within the output sleeve 72 by means of an insulating disc 69 whose outer periphery engages the inner periphery of the output sleeve 72. In this event, the diaphragm 76 could be connected to the output sleeve 72, rather than to the supporting element 68, as shown in Fig. 5. In most practical applications, however, the method shown in Fig. 5 is preferred by reason of mechanical considerations. 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. In combination, a periodic slow wave energy propagating network including a plurality of interdigital spaced elements, and coaxial output coupling means coupled to said network, said output coupling means including means for adjusting the position of one of said elements of said network, said output coupling means including a stationary portion and a movable portion rigidly connected to said one element, and means for adjusting the position of said one element in response to relative movement of said movable and stationary portions, said output coupling means including a flexible hermetic seal between said stationary and said movable portions.

2. In combination, a periodic slow wave energy propagating network including a plurality of spaced elements, and coaxial output coupling means coupled to said network, said output coupling means including a stationary portion and a movable portion rigidly connected to one only of said elements, said movable portion including an inner conductor, a tubular member whose outer periphery is threaded, and means for fixedly supporting said inner conductor relative to said tubular member in hermetically sealed relationship, flexible means interconnecting said movable portion and said stationary portion and providing a hermetic seal therebetween, and a nut threadedly engaging said member for providing movement of said one element only of said network in response to a force exerted by said nut against said stationary portion of said output coupling means.

3. A traveling wave tube comprising an evacuated envelope containing therein means for directing a beam of electrons along an extended path and means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, an output coupling means for removing energy from said means for propagating, said output coupling means including a stationary member and further including a movable member rigidly connected to a first portion of said means for propagating, and means for adjusting the position of said portion of said means for propagating relative to the remainder of said means for propagating said output coupling means being hermetically sealed to the tube envelope during adjustment of the position of said first portion of said means for propagating.

4. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, an output coupling means for removing energy from said means for propagating, said output coupling means including a stationary portion and including a movable portion rigidly connected to one only of said elements, and means for adjusting the position of said one element only in response to relative movement of said movable and stationary portions said output coupling means being hermetically sealed to the tube envelope during adjustment of the position of said one element.

5. A traveling wave tube comprising an evacuated envelope containing therein means for directing a beam of electrons along an extended path and means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam,

said means for propagating including a plurality of speed elements, an output coupling means for removing energy from said means for propagating, said output coupling means including a stationary portion and further including a movable portion rigidly connected to one of said elements, and means for adjusting the position of said one element in response to relative movement of said movable and stationary portions, said output coupling means being hermetically sealed to the tube envelope during adjustment of the position of said one element.

6. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, output coupling means for removing energy from said means for propagating, said output coupling means including an outer conductor and an inner conductor, said inner conductor being rigidly connected to one of said elements, said outer conductor being isolated from and coaxial with said inner conductor, said outer conductor including a movable portion rigidly attached to said inner conductor and further including a stationary portion, means for effecting a flexible hermetic seal between said stationary and said movable portions, and means for adjusting the position of said one element in response to relative movement of said movable and stationary portions.

7. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, output coupling means for removing energy from said means for propagating, said output coupling means including an outer conductor and an inner conductor, said inner conductor being rigid connected to one of said elements, said outer conductor being isolated from and coaxial with said inner conductor, said outer conductor including a movable portion rigidly attached to said inner conductor and further including a stationary portion, means for effecting a flexible hermetic seal between said stationary and said movable portions, means for providing a fixed hermetic seal between said inner conductor and said movable portion of said outer conductor, and means for adjusting the position of said

one element in response to relative movement of said movable and stationary portions.

8. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, coaxial output coupling means coupled to said network adjacent one end thereof, said output coupling means including a stationary portion and a movable portion, said movable portion including an inner conductor rigidly connected to one of said elements, a tubular member whose outer periphery is threaded, means for fixedly supporting said inner conductor relative to said tubular member in hermetically sealed relationship, flexible means interconnecting said movable portion and said stationary portion and providing a hermetic seal therebetween, and a nut threadedly engaging said member for providing movement of said one element of said network in response to a force exerted by said nut against said stationary portion of said output coupling.

9. A traveling wave tube comprising means for directing a beam of electrons along an extended path, means for propagating electromagnetic wave energy adjacent said path at a velocity substantially equal to that of said electron beam, said means for propagating including a plurality of spaced elements, said output coupling means including a stationary portion and a movable portion, said movable portion including an inner conductor rigidly connected to one of said elements, a tubular member, means for fixedly supporting said inner conductor within said tubular member in hermetically sealed relationship, flexible means interconnecting said tubular member and said fixed portion and providing a hermetic seal therebetween, a threaded sleeve affixed to said tubular member, and a nut threadedly engaging said sleeve for providing movement of said movable portion in response to a force exerted by said nut against said stationary portion of said output coupling.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,837,684 June 3, 1958

Robert McCowan Unger

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 2, line 8, for "it attached" read --is attached--; column 6, line 52, after "propagating" insert a comma; line 67, after "portions" insert a comma; column 7, line 1, for "speed" read --spaced--; line 37, for "rigid" read --rigidly--.

Signed and sealed this 29th day of July 1958.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents