Sept. 2, 1958 | J. MUNUSHIAN | 2,850,704

WAVEGUIDE COUPLING

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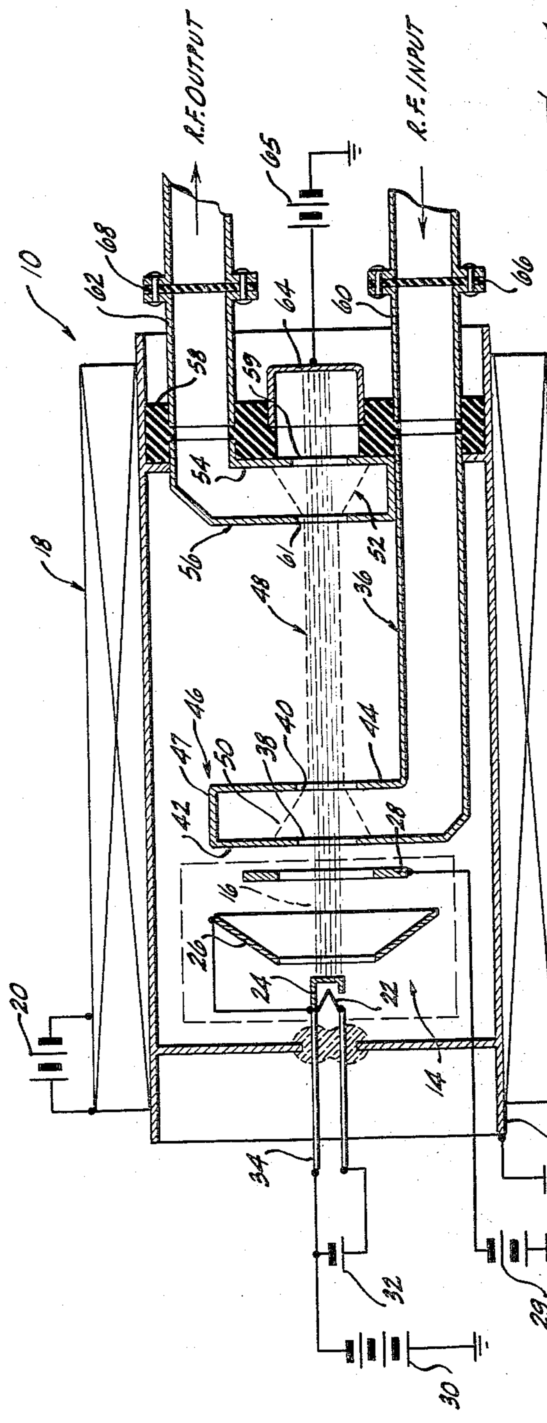

FIG. 1.

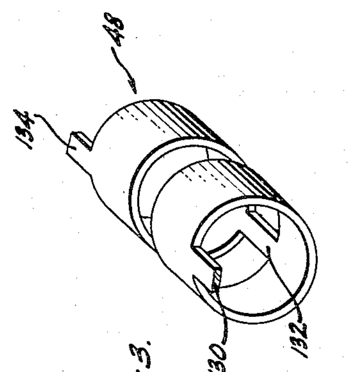

FIG. 3.

INVENTOR.
JACK MUNUSHIAN,
BY
Henry Heyman
ATTORNEY.

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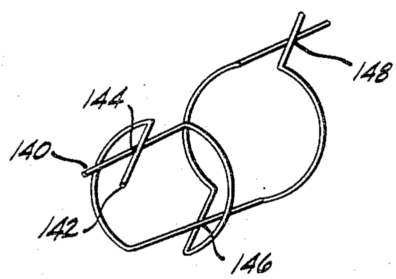

FIG. 4.

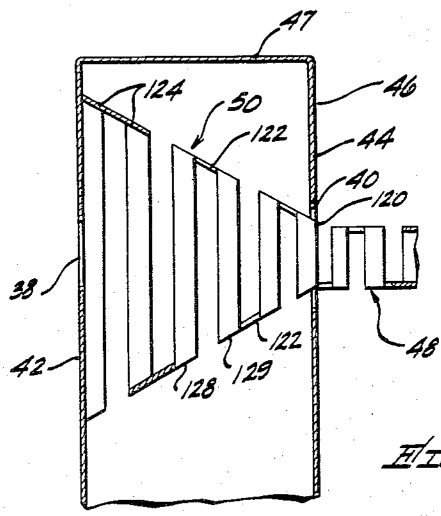

FIG. 2.

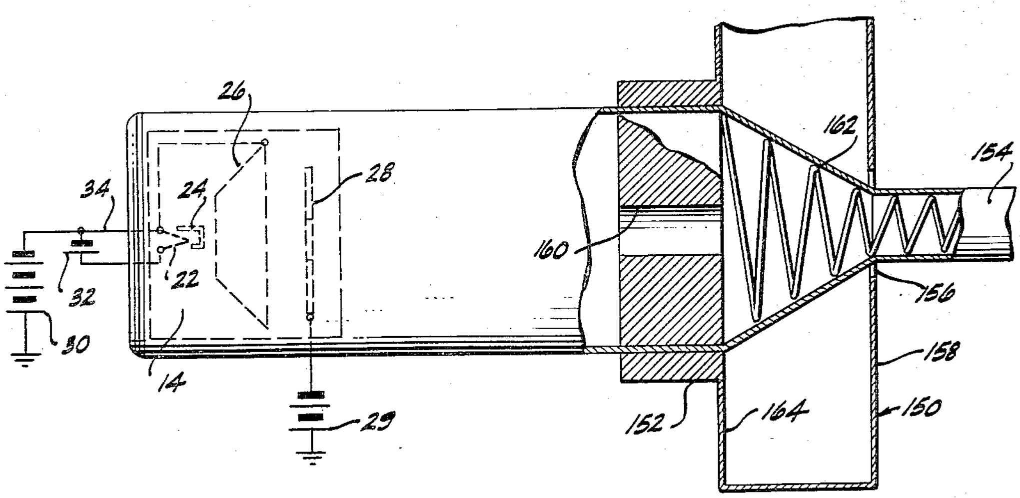

FIG. 5.

INVENTOR.
JACK MUNUSHIAN,
BY
Henry Heyman
ATTORNEY

United States Patent Office

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WAVEGUIDE COUPLING

Jack Munushian, Pasadena, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application February 4, 1955, Serial No. 486,170

4 Claims. (Cl. 333—34)

This invention relates to waveguide transition structures and more particularly to an electromagnetic coupling between a rectangular waveguide and a periodic slow-wave structure providing a broadband impedance match.

A periodic slow-wave structure such as, for example, a conductive helix is frequently employed in traveling-wave tubes. An electron gun is then utilized to project an electron stream in an interacting relationship with an electromagnetic wave which may be propagated along the helix. It is conventional practice to feed the slow-wave structure of a traveling-wave tube with a rectangular waveguide. In order to launch a traveling wave along a helical slow-wave structure, or to extract wave energy propagated therealong, antenna means must be connected between the slow-wave structure and the rectangular waveguide.

It is at present the practice to extend or expand the last few turns on a traveling-wave tube helix to form a dipole antenna, one end of which is grounded to the waveguide wall or an electrical equivalent thereof. A traveling-wave tube has an unusually large operating frequency range. This characteristic makes its use very desirable in a number of applications. However, the radiation resistance of a dipole is relatively frequency sensitive whereby the broadband operating characteristic of a traveling-wave tube is somewhat restricted. The transition from a helical to a linear conductor is not a gradual physical transition. This, in turn, further limits the operating frequency range of a traveling-wave tube.

It is, therefore, an object of the invention to provide a broadband impedance match between a rectangular waveguide and a periodic slow-wave structure.

It is another object of the invention to provide an electromagnetic coupling between a rectangular waveguide and the slow-wave structure of a traveling-wave tube which provides an impedance match over a broad frequency range.

In accordance with the invention, a slow-wave structure such as used in a traveling-wave tube and having generally a cylindrical form is disposed transversely through an aperture in a rectangular waveguide, one end of the slow-wave structure being electrically connected to the opposite inside wall of the waveguide or an electrical equivalent thereof. The diameter of the slow-wave structure is then decreased to provide a cone leaving the ends of the slow-wave structure flared radially outward.

A relatively high-power slow-wave structure for microwave tubes is disclosed in a copending application, Serial No. 450,987, entitled "High-Power Microwave Tube," filed August 19, 1954, by Charles K. Birdsall. One embodiment of the present invention is particularly useful for coupling wave energy between that slow-wave structure and a rectangular waveguide.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and

advantages thereof will be better understood from the following description considered in connection with the accompanying drawings in which a number of embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Fig. 1 is a sectional view of a traveling-wave tube employing the broadband impedance match of the present invention;

Fig. 2 is an enlarged broken-away sectional view of a portion of the traveling-wave tube of Fig. 1;

Fig. 3 is an isometric projection of the slow-wave structure shown in Figs. 1 and 2;

Fig. 4 is a schematic view illustrating the electrical equivalent of the slow-wave structure shown in Figs. 1 to 3; and

Fig. 5 is a broken-away sectional view of another embodiment of the coupling of the invention providing a broadband impedance match.

Referring to the drawings, Fig. 1 shows a traveling-wave tube **10** comprising a conductive evacuated envelope **12**, at the left end of which an electron gun **14** is shown for producing an electron stream along a predetermined path **16** within the envelope **12**.

Shown disposed concentrically about the envelope **12** is a focusing solenoid **18** which is employed to constrain or to confine the stream electrons as they are directed along the path **16**. The solenoid **18** is provided with a source of direct current such as a battery **20**.

Electron gun **14** comprises a cathode **24** which is provided with a filament **22**. A focusing electrode **26** is disposed about the path **16** to the right of the cathode **24** and an accelerating anode **28** is disposed about the path **16** adjacent focusing electrode **26**. Focusing electrode **26** may have a frusto-conical configuration with an internal surface of revolution disposed at an angle of 67½ degrees from its axis of symmetry. The cathode **24** is maintained at a potential which may be a few thousand volts negative with respect to ground by means of an accelerating source of potential **30**. Filament **22** is provided with a filament source of potential **32**, the negative terminal of which is connected through a stem lead **34** to the negative terminal of filament **22** and to the cathode **24**, the stem lead being insulated from the conducting envelope **12**. The accelerating anode **28** is maintained at a few hundred volts positive with respect to the cathode **24** by means of a source of potential **29** having its positive terminal grounded.

An internal input waveguide segment **36** is disposed within envelope **12** and is insulated therefrom. The input waveguide segment has registering apertures **38** and **40** disposed in opposite walls **42** and **44** of a waveguide portion **46** which extends transversely to the path **16**. The apertures **38** and **40** thus permit the electron stream to be projected along the path **16** through the transverse portion **46** of the internal input waveguide **36**.

A conductive slow-wave structure **48** having flaring end portions **50** and **52** is mechanically and electrically connected to the internal surface of waveguide walls **42** and to the internal surface of waveguide wall **54** which forms part of an internal output waveguide segment **56**. The slow-wave structure **48** thus comprises a plurality of interconnected conductive rings which decrease progressively in diameter in the axial direction along the slow-wave structure **48** from the internal surface of the waveguide wall **42**. Internal output waveguide **56** is electrically insulated from the envelope **12** and is provided with registering apertures **59** and **61** corresponding to the apertures **38** and **40** in internal input waveguide **36**. A dielectric apertured disc 58 is employed to maintain the internal waveguides 36 and 56 in position and to support external input and output waveguides 60 and 62, respectively, and a collector electrode 64. A high vacuum is maintained within the envelope 12 which is sided by two mica windows 66 and 68 which are disposed transversely within the external input and output waveguides 60 and 62, respectively.

Collector 64 is maintained a few hundred volts positive with respect to waveguide portion 56 by means of a source of potential 65 in order to prevent secondary emission to the waveguide portion 56.

An enlarged broken-away sectional view of slow-wave structure 48 and the transverse portion 46 of the internal input waveguide 36 is shown in Fig. 2. The transverse waveguide portion 46 has the aperture 38 in the left wall 42 and the second aperture 40 in the right wall 44. The aperture 38 need be no larger than the path 16 shown in Fig. 1, but should be smaller than the maximum diameter of the slow-wave structure 48 in order that a simple electrical connection may be provided between the transverse waveguide portion 46 and the slow-wave structure 48. The ends of slow-wave structure 48 are accordingly brazed to the internal surfaces of the wave-guide walls 42 and 54 of the waveguide portions 46 and 56, respectively. The width of the transverse waveguide portion 46 should generally be equal to the axial distance along the slow-wave structure 48 from the end brazed to waveguide wall 42 to the portion of the slow-wave structure 48 having a uniform diameter. For example, for the slow-wave structure 48, the right wall 44 of the transverse waveguide portion 46 is positioned about a conductive ring 120 where the taper on the left hand end flare of the slow-wave structure 48 begins. Empirically it has been found that the aperture 40 in the wall 44 of the transverse waveguide portion 46 should be generally one and one-half times as large in diameter as the outside diameter of the slow-wave structure 48. A plurality of axially conductive segments 122 is shown connecting alternate adjacent pairs of conductive rings 124. The slow-wave structure 48 and the structure of bifilar contrawound helices is disclosed and claimed in the previously mentioned Birdsall application.

It has been found that an optimum broadband match will generally occur if the slow-wave structure 48 and the transverse waveguide portion 46 are constructed in the manner shown, i. e. all of the conductive segments 122 lie in a plane substantially parallel to the direction of energy propagation in the waveguide portion 46. The distance between conductive rings may be substantially constant throughout the slow-wave structure 48. The transverse waveguide segment 46 has a shorting termination 47, the position of which may be chosen for an optimum broadband match for a given taper of the flaring end 50 of the slow-wave structure 48. The flaring end 52 of slow-wave structure 48 is constructed in the same manner as flaring end 50. The slow-wave structure 48 is the electrical equivalent of unifilar contrawound conductive helices. Fig. 3 is an isometric broken sectional view of slow-wave structure 48 and Fig. 4 shows two wires 140 and 142 which are in electrical contact twice per turn. The wires 140 and 142 thus simulate the electrical equivalent of the slow-wave structure 48, and the contacts of the wires 140 and 142 at points 144, 146 and 148 are electrically equivalent to axially conductive segments 130, 132, and 134, respectively, in the portion of slow-wave structure 48 shown in Fig. 3.

Fig. 5 illustrates how the broadband impedance match of the present invention may be employed in a traveling-wave tube having a glass envelope. A transverse waveguide segment 150 is thus illustrated in Fig. 5 having an axially extending sleeve 152 which is disposed about an elongated evacuated glass envelope 154. The waveguide segment 150 is provided with an aperture 156 in the right wall 158 thereof. Shown positioned contiguously to and concentrically within the envelope 154 is a matching ferrule 160 to which a helix 162 having a tapering spiral is electrically connected. It will be understood that a glass envelope may be analogously employed with a slow-wave structure similar to or the same as the slow-wave structure 48. The helix 162 may have a constant pitch, i. e., the distance from turn to turn may be the same as is the spacing of the conductive rings of the slow-wave structure 48. The right end of helix 162 may be similarly constructed. The inside diameter of ferrule 160 may be as small as desired depending upon the size of the beam which is employed to interact with electromagnetic waves propagated along the helix 162. The axial length of the ferrule 160 and the sleeve 152 of wave guide 150 may be chosen to produce a vertical shorting plane at the left internal surface 164 of the waveguide 150.

The coupling of the present invention providing broadband impedance match may thus be employed with a helical slow-wave structure or an equivalent thereof. A tapered slow-wave structure having end flares connected to the internal surfaces of a rectangular waveguide or an electrical equivalent thereof thus acts as a conical helix radiating toward a ground plane which is one of the internal surfaces of the rectangular waveguide. It has been found that this type of radiation operates over an unusually broad band of frequencies. The broadband impedance match of the present invention therefore is very well adapted for such an application. Because a single tapered conical helix radiates circularly polarized waves in a rectangular waveguide and tapered contrawound conical helices radiate linearly polarized waves, the broadband impedance match provided by the coupling of the present invention may be found to be somewhat more useful in matching to the slow-wave structure 48 or to other such structures, such as, for example, the bifilar contrawound helical slow-wave structure described in the aforementioned Birdsall application. The broadband coupling of the invention still has utility in matching to a unifilar helix because of its broadband characteristics inherent in the gradual physical transition which may be made from a unifilar helix to a helix having a tapering spiral form.

A representative example of a good match from a rectangular waveguide to a unifilar contrawound helical slow-wave structure, such as the slow-wave structure 48, is given in terms of a standing wave ratio over a predetermined frequency band. To thus obtain a standing wave ratio of less than 1.2 over a twenty percent frequency band width is readily possible.

What is claimed is:

1. An electromagnetic coupling providing a broadband impedance match between a rectangular waveguide and a slow-wave structure comprising a rectangular waveguide having a first aperture in one wall and a second registering and concentric aperture in the opposite wall, and a conductive helix having an outward radially flaring end portion forming a helical, conical antenna disposed through said first aperture of said one waveguide wall and connected to said opposite wall of said waveguide, said second aperture in said opposite waveguide wall being smaller in diameter than the maximum diameter of said helix.

2. An electromagnetic coupling providing a broadband impedance match between a rectangular waveguide and a slow-wave structure comprising a rectangular waveguide having at least one aperture in one wall thereof, and a slow-wave structure including a plurality of conductive rings, alternate adjacent pairs of said rings being connected alternately at diametrically opposed points, the diameter of said rings progressively decreasing for a predetermined distance from at least one end of said slow-wave structure to form a conical type of antenna, the

axial distance between said rings being substantially constant over the complete length of said slow-wave structure, the diameter of said conductive rings being approximately equal to two-thirds of the diameter of the aperture of said waveguide wall, the end portion of said slow-wave structure forming said conical type of antenna being disposed through the aperture of said waveguide wall and being electrically connected to the wall of said waveguide opposite the wall defining said aperture.

3. An electromagnetic coupling providing a broadband impedance match between a rectangular waveguide and a slow-wave structure comprising a rectangular waveguide having an aperture in at least one wall thereof, and a conductive helix having a radially progressively decreasing diameter for a predetermined distance from at least one end thereof to form a helical, conical antenna along said distance, the pitch of said helix being substantially constant over its entire length and the diameter of said helix being substantially equal to one-third of the diameter of the aperture in said waveguide wall, the end portion of said helix having said decreasing diameter being disposed through the aperture of said waveguide wall and being electrically connected to the wall of said waveguide opposite the wall defining said aperture.

4. An electromagnetic coupling providing a broadband impedance match between a rectangular waveguide and a slow-wave structure comprising a rectangular waveguide having an aperture in at least one wall thereof, and a slow-wave structure including a plurality of conductive rings having at least one axially conductive segment connecting alternate adjacent pairs of said rings at diametrically opposed points, said rings having progressively decreasing diameters for a predetermined distance from one end of said slow-wave structure to form a conical type of antenna, said end of said slow-wave structure forming said conical type of antenna extending through the aperture in said waveguide wall and being electrically connected to the wall of said waveguide opposite the wall defining said aperture.

References Cited in the file of this patent

UNITED STATES PATENTS

1,945,544	Conklin	Feb. 6, 1934
2,530,171	Okress	Nov. 14, 1950
2,624,859	Smullin	Jan. 6, 1953
2,637,775	Lund	May 5, 1953
2,712,614	Field	July 5, 1955
2,730,647	Pierce	Jan. 10, 1956
2,768,322	Fletcher	Oct. 23, 1956
2,800,605	Marchese	July 23, 1957