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BROADBAND WAVEGUIDE TRANSITION FOR A CENTIPEDE SLOW WAVE CIRCUIT AND TUBES USING SAME
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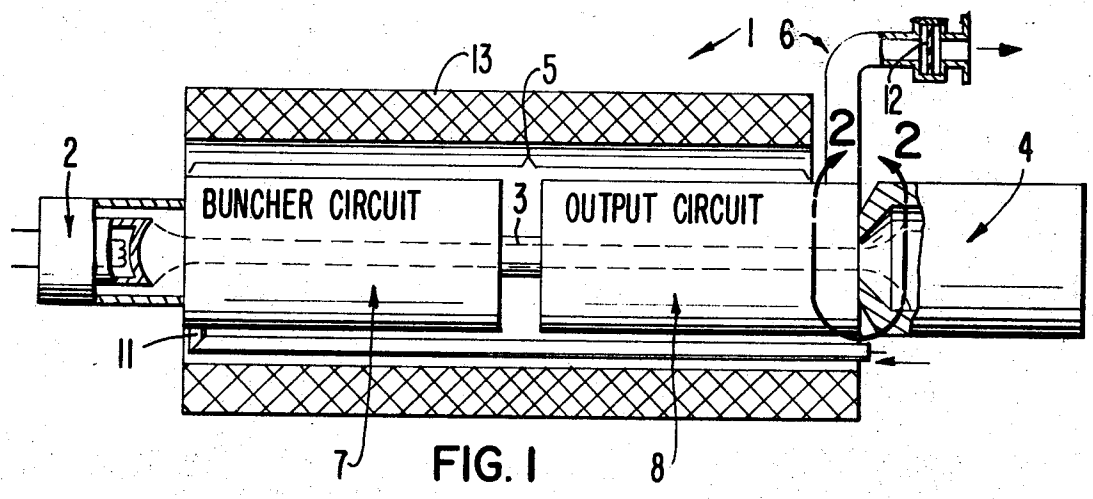


FIG. 1

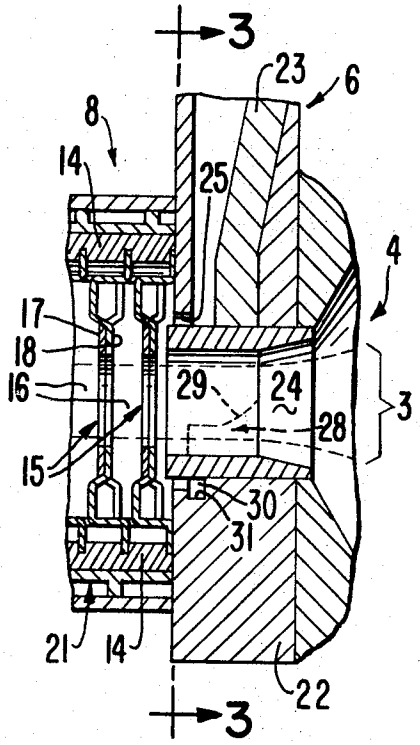


FIG. 2

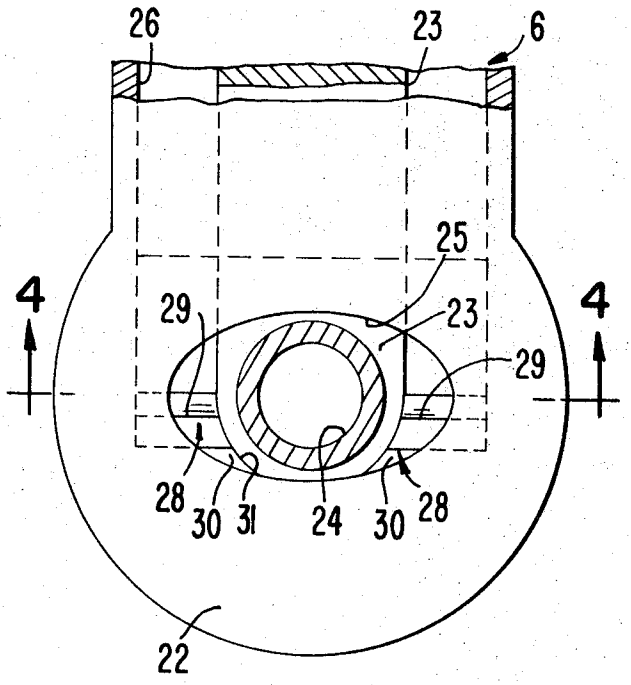


FIG. 3

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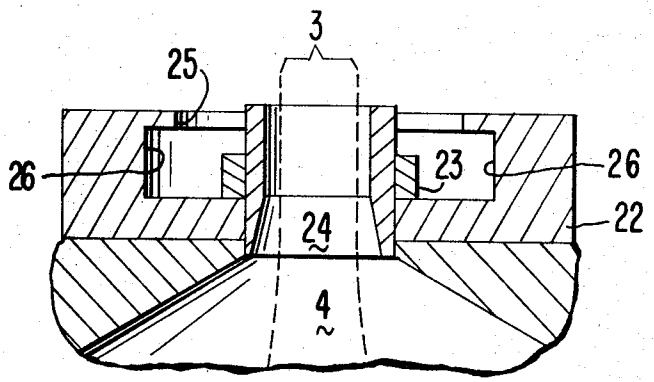


FIG.4

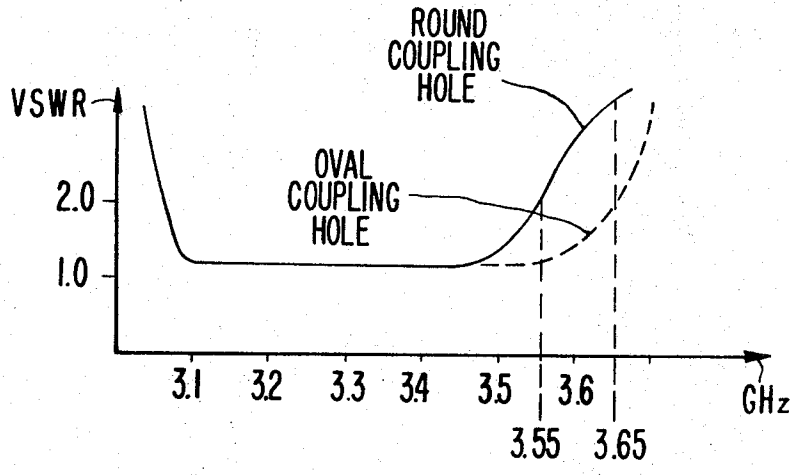


FIG. 5

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BROADBAND WAVEGUIDE TRANSITION FOR A CENTIPEDE SLOW WAVE CIRCUIT AND TUBES USING SAME

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U.S. Cl. 315—3.5 6 Claims

ABSTRACT OF THE DISCLOSURE

A microwave tube is disclosed. The microwave tube includes an electron gun for forming and projecting a beam of electrons over an elongated beam path to a beam collector at the terminal end of the beam. A centipede type slow wave circuit is arranged along the beam path for electromagnetic interaction with the beam to produce an output microwave signal. A broadband waveguide transition is provided at the downstream end of the centipede slow wave circuit for extracting the output microwave signal from the circuit and for transmitting same to a suitable utilization device or load. The broadband waveguide transition includes an output ridged rectangular waveguide disposed in wave energy communication with the downstream end of the centipede slow wave circuit via the intermediary of a centrally apertured conductive wall partitioning off the downstream end of the slow wave circuit. A conductive post extends from the ridged portion of the waveguide into the coupling hole. The coupling hole is elongated in a direction generally perpendicular to the narrow walls of the ridged waveguide to provide heavy wave energy coupling from the centipede slow wave circuit to both the electric and magnetic fields of the waveguide to provide a broadband waveguide transition. A conductive shorting block is provided in the ridged waveguide adjacent the marginal lips of the elongated coupling hole for causing the wave energy to be deflected through a right angle bend between the waveguide and the coupling hole.

DESCRIPTION OF THE PRIOR ART

Heretofore, microwave tubes have been constructed which have employed an output slow wave circuit comprised of an array of cavity resonators having negative mutual inductive coupling therebetween. Examples of such negative mutual inductive coupled cavities include the cloverleaf structure and the centipede slow wave structure described and claimed as equivalents in U.S. Pat. 3,233,-139 issued Feb. 1, 1966 and assigned to the same assignee as the present invention. Output waveguide transitions have been developed for such negative mutually inductively coupled slow wave circuits. Such transitions have included a hollow cylindrical conductive post projecting from a broad wall of the output waveguide coaxially of the beam and coaxially of a wave energy coupling hole communicating through the end wall of the terminal cavity of the coupled cavity circuit. More specifically, the end wall of the terminal cavity of the slow wave circuit is provided with an enlarged central aperture coaxially aligned with the beam path. The conductive post extends from a shallow height rectangular waveguide coaxially of the beam hole and terminates substantially in the plane of the coupling hole. The output coupling hole was made approximately ½ a wavelength in diameter and was of a circular shape. The conductive post was cylindrical and the shallow waveguide was shorted a ¼ wavelength from the center of the conductive post. Such an output waveguide transition is disclosed and claimed in U.S. Pat.

3,374,390 issued Mar. 19, 1968 and assigned to the same assignee as the present invention.

Although the aforedescribed prior art waveguide transition provides an extremely wide band match between a cloverleaf type coupled cavity slow wave circuit and an output waveguide, such an output transition does not have sufficient bandwidth to provide a match to the wider useable bandwidth of a centipede type coupled cavity slow wave circuit.

Therefore a need exists for an improved waveguide transition for coupling output wave energy from a centipede type coupled cavity slow wave circuit to an output waveguide.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved broadband waveguide transition for a centipede slow wave circuit and tubes using same.

One feature of the present invention is the provision, in a broadband waveguide transition from a centipede slow wave circuit to an output waveguide, of a ridged rectangular output waveguide with a conductive post extending from the ridge into the mouth of a wave energy coupling hole communicating between the terminal cavity of the slow wave circuit and the waveguide, the output coupling hole being elongated in a direction generally perpendicular to the narrow walls of the output ridged waveguide, whereby heavy wave coupling is obtained to both the electric and magnetic fields of the output waveguide.

Another feature of the present invention is the same as the preceding feature wherein a conductive shorting block is provided in the ridged output waveguide, such shorting block being disposed adjacent a portion of the marginal lip of the elongated coupling hole to facilitate a broadband match between the centipede slow wave circuit and the output waveguide.

Another feature of the present invention is the same as the preceding feature wherein the shorting block includes a face which slants into the ridged waveguide for deflecting wave energy through a right angle bend between the waveguide and the coupling hole.

Another feature of the present invention is the same as the preceding feature wherein the shorting block includes a curved face conforming generally to the adjacent curved surface of the conductive post.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal view, partly in section and partly schematic, depicting a microwave tube incorporating features of the present invention,

FIG. 2 is an enlarged longitudinal sectional view of a portion of the structure of FIG. 1 delineated by line 2—2,

FIG. 3 is a transverse sectional view of the structure of FIG. 2 taken along lines 3—3 in the direction of the arrows,

FIG. 4 is a sectional view of the structure of FIG. 3 taken along line 4—4 in the direction of the arrows, and

FIG. 5 is a plot of voltage standing wave ratio vs. frequency which compares the bandpass characteristics of an output waveguide transition employing a round energy coupling hole and an oval energy coupling hole, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a microwave

tube 1 incorporating features of the present invention. The tube 1 includes an electron gun 2 disposed at one end of the tube for forming and projecting a beam of electrons over an elongated beam path 3 to a beam collector structure 4 disposed at the terminal end of the beam path 3. An interaction circuit 5 disposed along the beam path intermediate the gun 2 and the collector 4 for electromagnetic interaction with the beam to produce output microwave energy which is extracted from a downstream end of the interaction circuit 5 via an output waveguide 6 and fed to a suitable utilization device or load, not shown.

The interaction circuit 5 may comprise a single section of centipede type slow wave circuit or may comprise at least two circuit sections, namely, a buncher circuit section 7 and an output circuit section 8. In the latter case, the output circuit section 8 would comprise a centipede slow wave circuit and the buncher circuit 7 may comprise either a severed section of centipede slow wave circuit or some other type of interaction circuit such as, for example, a succession of klystron type cavities tuned near the band edges of the operating band of the tube. Microwave amplifier tubes utilizing a buncher circuit 7 followed by an output circuit 8 wherein the output circuit comprises a succession of negative mutual inductively coupled cavity resonators is disclosed and claimed in the aforecited U.S. Pat. 3,374,390.

The centipede type slow wave circuit is one type of negative mutual inductive coupled circuit as disclosed in the aforecited U.S. Pat. 3,233,139. This type of circuit is also described in an article tilted "A Structure, Using Resonant Coupling Elements, Suitable for a High-Power Travelling-Wave Tube" by A. F. Pearce, appearing in the Proceedings of the Institution of Electrical Engineers, vol. 105, Part B, Supplement II, London, May 1958, pp. 719–726. The centipede slow wave circuit has the advantage of providing extremely wide bandwidth while being capable of operating to very high power levels with reasonable efficiencies.

In operation, an input microwave signal to be amplified is fed to the upstream end of the buncher circuit 7 via input coaxial line 11. Input signal energy bunches the beam throughout the buncher circuit 7 and the bunched beam passes into the output circuit 8 wherein it excites a wave on the output circuit which cumulatively interacts with the beam to produce an amplified output signal. The output microwave signal is extracted from the downstream end of the output circuit 8 and fed via waveguide 6 and gas tight wave permeable window 12 to a suitable load. A beam focus solenoid 13 coaxially surrounds the tube to produce an axially directed beam focusing magnetic field over the length of the beam path 3 for confining the electrons to the desired beam path.

Referring now to FIGS. 2–4, the novel broadband waveguide transition from the centipede slow wave circuit 8 to the output waveguide 6 will be more fully disclosed. Briefly, the centipede slow wave circuit 8 includes a hollow tubular conductor 14 as of copper having an array of centrally apertured conductive disc structures 15 axially spaced apart along the length of the tube 14 and transversely mounted therein to define a succession of coupled cavity resonators 16 defined by the spaces bounded by the inside wall of the tube 14 and, on the ends, by adjacent conductive disc structures 15.

The conductive disc structures 15 are conveniently formed by a pair of similarly shaped disc structures 17 and 18, respectively. Each of the disc structures 17 and 18 includes a central ring portion and an outer periphery formed by an array of radially directed legs. The two discs 17 and 18 are placed together with all of the legs of one of the discs being formed into an S shape and all of the legs of the other disc being formed into a reverse S shape. The two central ring portions of the disc structure are then brazed together. The legs are interdigitated to provide negative mutual inductive coupling loops communicating between adjacent cavity resonators 16. A coolant jacket having coolant passageways therein surrounds the tube 14 for carrying away heat generated in the R.F. structure and which is conducted to the jacket via the discs 15 and tube 14.

A circular conductive plate 22, as of copper, closes off the downstream end of the coupled cavity circuit 8. The output waveguide structure 6 is formed in the conductive disc 22 with the axis of the waveguide 6 being transverse to the axis of the beam path 3. The waveguide 6 is tapered in height with decreasing height taken toward the beam axis. In addition, the rectangular waveguide 6 is provided with a central ridge 23 which projects from a bottom broad wall of the waveguide toward the upper broad wall thereof.

A hollow cylindrical conductive post 24, as of copper, surrounds the beam path 3 and projects from the ridge 23 toward the upper opposed broad wall of the guide 6 and also toward the terminal cavity of the slow wave circuit 8. A wave energy coupling hole 25 is provided in the upper wall of the waveguide 6 in coaxial alignment with the beam 3 and the conductive post 24. Beam coupling hole 25 is elongated in the direction transverse or perpendicular to the plane of the narrow walls 26 of the output waveguide 6. In addition, the coupling hole 25 is coaxially aligned with the conductive post 24.

The innermost end of the waveguide 6 is closed off by a conductive shorting plug structure 28 which forms an inner end wall for the ridged waveguide 6. The conductive plug structure 28 includes a pair of spaced rectangular plug portions which fill the portions of the ridged waveguide 6 between the sidewalls 26 and the center ridge 23. In addition, a conductive plate 30 bridges between the pair of rectangular plugs to fill the region of the ridged waveguide between the ridge and the uppermost wall. The inner shorting face 29 of the two rectangular plug portions of the shorting plug structure 28 is slanted into the guide in such a manner as to deflect wave energy traveling down the guide toward the post 24 through a 90° angle and up through the coupling hole 25. The bridging platelike portion 30 of the conductive plug structure 28 is cut in an arc shape 31 to conform to the outer cylindrical surface of the adjacent conductive post 24. The conductive plug structure 28 is disposed generally in the region of the lip portion of the coupling hole 25.

In operation, output wave energy on the centipede slow wave circuit 8 reaches the terminal cavity section 16 and is coupled through the output coupling hole 25 down along the short section of coaxial line formed by the post 24 and the adjacent conductive wall structure including the edge of the coupling hole 25. The wave energy then is deflected through a 90° bend, by plug 28, and travels out the ridged waveguide 6 to a suitable load.

The oval shaped coupling hole 25 facilitates obtaining a broad band transition between the slow wave circuit 8 and the output waveguide 6. More specifically, the elongated portions of the coupling hole 25, which extend over the inductive regions of the waveguide, serve to produce a magnetic coupling between the waveguide 6 and the magnetic fields of the slow wave circuit 8. On the other hand, the capacitive coupling between the post 24 and the regions of closest approach of the marginal lip of the hole 25, i.e., the regions along the minor axis of the oval coupling hole 25, and the center of the disc structure 15 provide a capacitive coupling between the waveguide 6 and the disc structure 15 of the terminal slow wave section 16. This combined electric and magnetic coupling produces a wider band transition than that obtained by use of a circular coupling hole 25.

Referring now to FIG. 5, there is seen a comparison in the voltage standing wave ratio in the output waveguide 6 over the passband of frequencies from 3.1 to 3.65 gigahertz for a tube 1 using either a round coupling hole 25 or an oval coupling hole 25. Utilizing a round coupling hole 25 it is seen that the voltage standing wave

ratio, at the high frequency end of the passband, reaches the unacceptable level of 2 at approximately 3.55 gigahertz. However, when an oval coupling hole **25** is employed the bandwidth between voltage standing wave ratios of 2.0 is extended, at the high frequency end, from approximately 3.55 gigahertz to 3.65 gigahertz.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a microwave tube apparatus, means for forming and projecting a beam of electrons over an elongated beam path, collector means at the terminal end of the beam path for collecting and dissipating energy of the beam, a centipede slow wave circuit disposed along the beam path for cumulative electromagnetic interaction between the microwave energy on said circuit and electrons of the beam, said centipede slow wave circuit comprising a hollow conductive tube structure having an array of axially spaced centrally apertured conductive discs transversely mounted therein to define a coupled cavity slow wave structure, said tube and said discs being coaxially aligned with the beam path with the beam path passing successively through the aligned central apertures in said discs of said array, each of said discs having an array of peripherally spaced radially directed leg portions with adjacent ones of said leg portions being of an S-shape and a reverse S-shape, respectively, to provide negative mutual inductive coupling between adjacent coupled cavities, an output coupling means for extracting microwave energy from said centipede slow wave circuit for transmission to a load, the improvement wherein, said output coupling means includes an output waveguide having a pair of narrow walls and a pair of broad walls, a conductive wall closing off the downstream end of said slow wave circuit and having a centrally disposed coupling hole coaxially aligned with the beam path and communicating through said wall between said slow wave circuit and said waveguide, a hollow conductive post extending into said coupling hole from said waveguide, said coupling hole having a transverse cross section elongated in a direction generally perpendicular to the narrow walls of said waveguide whereby, coupling between the magnetic fields in said slow wave circuit and said waveguide is increased to enhance the bandwidth of said output coupling means.

2. The apparatus of claim **1** wherein said output waveguide is a ridged rectangular waveguide having a ridge structure projecting from the center of one broad wall toward the other broad wall, and wherein said hollow conductive post projects from said ridge in said waveguide toward the opposed broad wall of said waveguide, said post axially extending into said elongated coupling hole from the ridged portion of said ridged waveguide.

3. The apparatus of claim **2** including a conductive shorting block having a conductive face defining a shorting plane and said shorting block being disposed to close off and to provide a wave energy short for said ridged waveguide, said shorting block being disposed adjacent said post with its conductive face disposed adjacent a portion of the marginal lip of said elongated coupling hole.

4. The apparatus of claim **3** wherein said shorting face of said shorting block includes a pair of faces which face into said waveguide from the shorted end thereof, said shorting faces being disposed between the central ridge of said waveguide and the narrow walls thereof, said shorting faces being slanted into said waveguide for deflecting wave energy through a right angle bend between said waveguide and said coupling hole.

5. The apparatus of claim **3** wherein said conductive post is cylindrical and wherein a shorting face portion of said shorting block is curved to conform generally to the adjacent curved surface of said hollow cylindrical conductive post.

6. In a microwave tube apparatus, means for forming and projecting a beam of electrons over an elongated beam path, collector means at the terminal end of the beam path for collecting and dissipating the energy of the beam, a coupled cavity slow wave circuit disposed along the beam path for cumulative electromagnetic interaction between the microwave energy on said circuit and the electrons of the beam, an output coupling means for extracting microwave energy from said coupled cavity slow wave circuit for transmission to a load, the improvement wherein said output coupling means includes an output waveguide having a pair of narrow walls and a pair of broad walls, a conductive wall closing off the downstream end of said coupled cavity slow wave circuit and having a centrally disposed coupling hole coaxially aligned with the beam path and communicating through said wall between said slow wave circuit and said waveguide, a hollow conductive post extending into said coupling hole from said waveguide, said coupling hole having a transverse cross section elongated in a direction generally perpendicular to the narrow walls of said waveguide whereby coupling between the magnetic fields in said slow wave circuit and said waveguide is increased to enhance the bandwidth of said output coupling means.

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