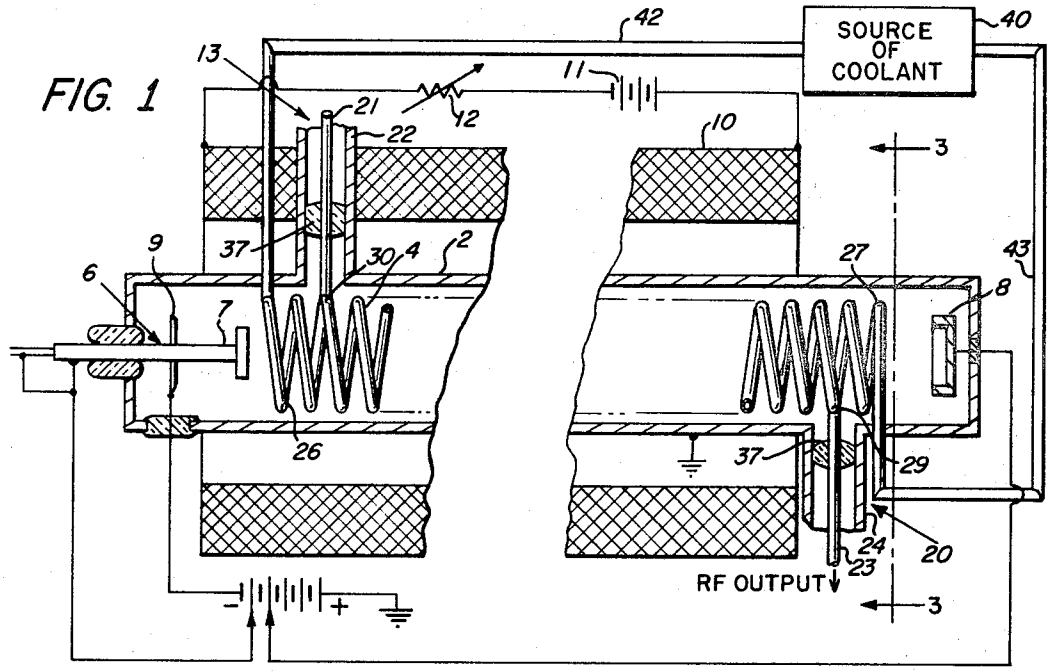
Sept. 3, 1968 H. F. CHAPELL 3,400,295

MATCHED TRANSMISSION LINE COUPLING FOR ELECTRON DISCHARGE TUBE

Filed Nov. 17. 1964 3 Sheets-Sheet 1

FIG. 1



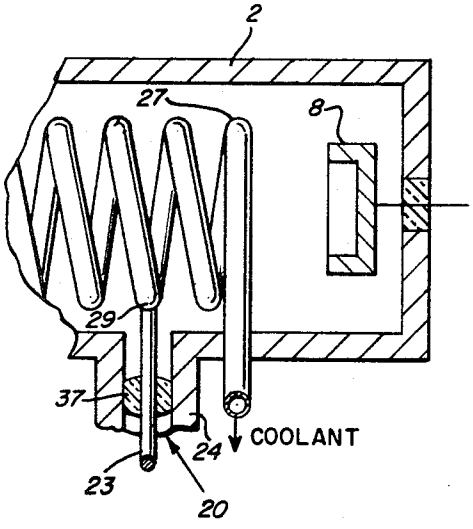


FIG. 2

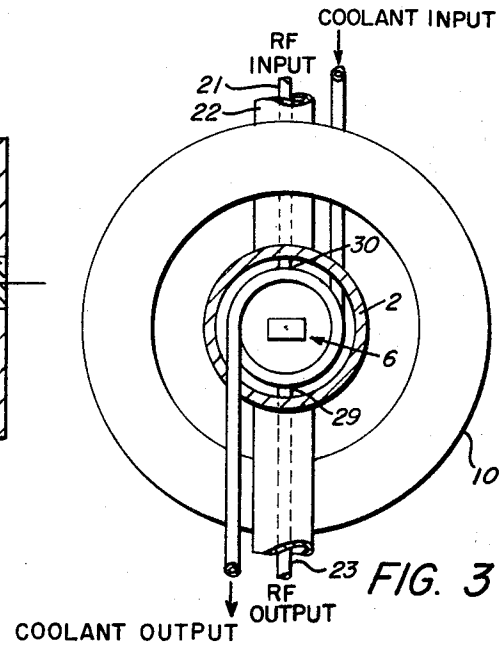


FIG. 3

INVENTOR
HARRY F. CHAPELL

BY Edgar O. Lost
ATTORNEY

MATCHED TRANSMISSION LINE COUPLING FOR ELECTRON DISCHARGE TUBE

Filed Nov. 17, 1964 3 Sheets-Sheet 2

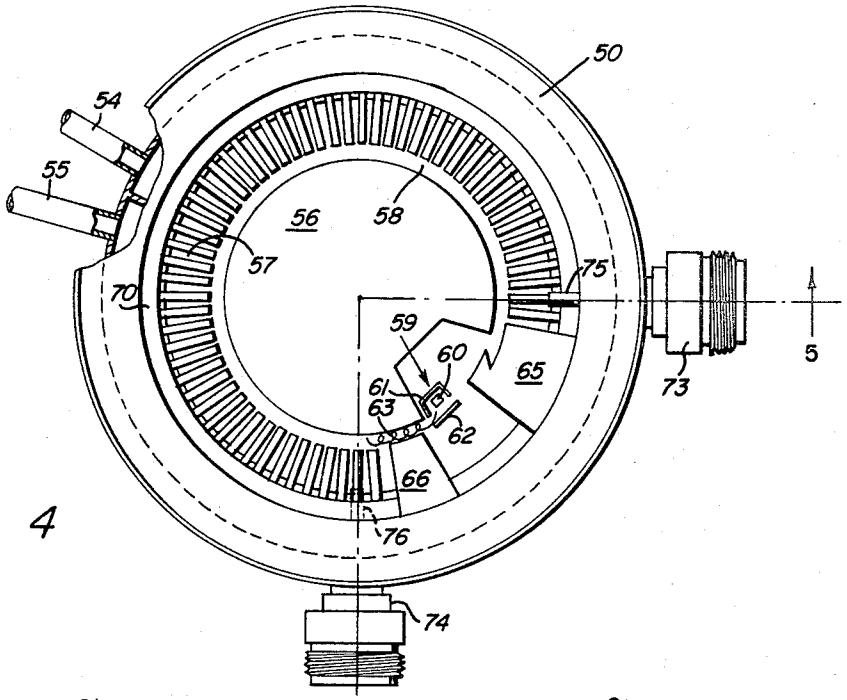


FIG. 4

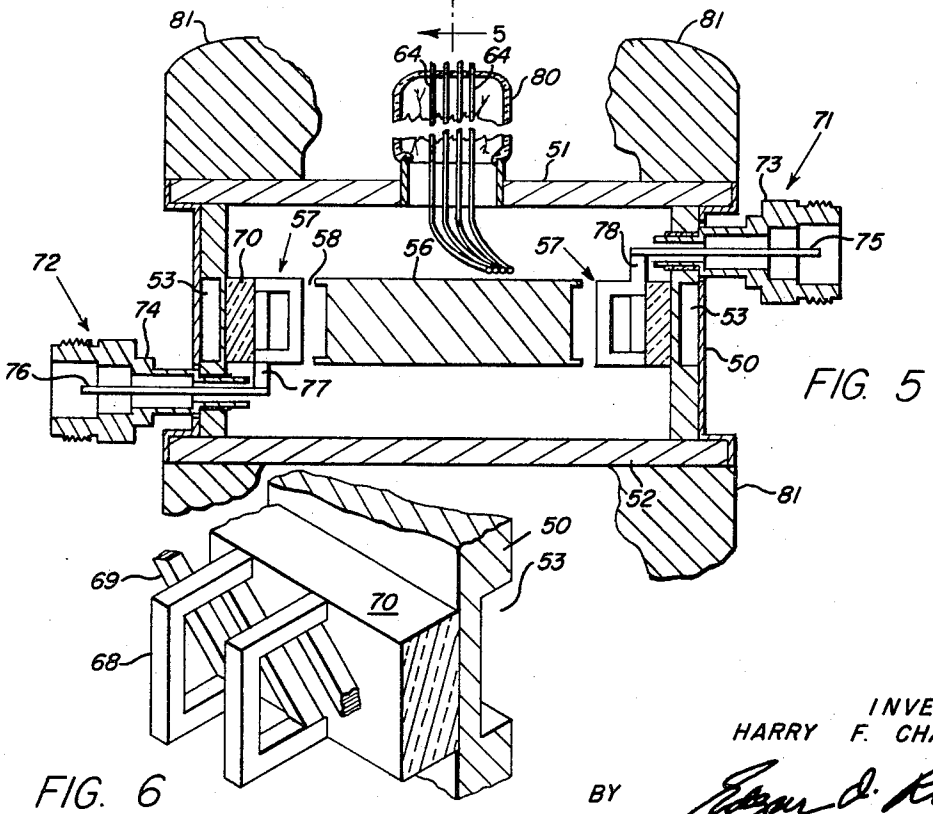


FIG. 5

FIG. 6

INVENTOR
HARRY F. CHAPELL

BY

ATTORNEY

Sept. 3, 1968 H. F. CHAPELL 3,400,295

MATCHED TRANSMISSION LINE COUPLING FOR ELECTRON DISCHARGE TUBE

Filed Nov. 17, 1964 3 Sheets-Sheet 3

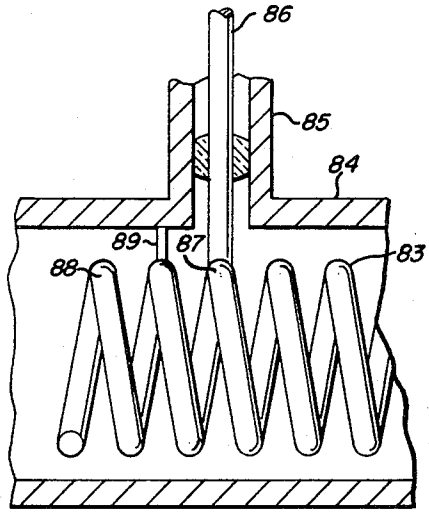


FIG. 7

INVENTOR
HARRY F. CHAPELL

BY Edgar O. Lott
ATTORNEY

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3,400,295

MATCHED TRANSMISSION LINE COUPLING FOR ELECTRON DISCHARGE TUBE

Harry F. Chapell, Maynard, Mass., assignor to Raytheon Company, Lexington, Mass., a corporation of Delaware

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4 Claims. (Cl. 315—3.5)

ABSTRACT OF THE DISCLOSURE

A transition structure for coupling radio frequency energy from a coaxial conductor transmission line to a helical slow wave delay line within a crossed field traveling wave device includes a center conductor attached to the helical delay line at a preselected point to provide for efficient matching of the impedances of the respective lines over a broad band of frequencies. The delay line is conductively coupled to the grounded tube metallic envelope to facilitate the circulation of a coolant through the helical delay line.

This invention relates to improvements in electron discharge devices and more particularly to a transition section for coupling radio frequency transmission lines to wave propagating structures of such devices.

Electron discharge devices such as O-type traveling wave tubes or M-type crossed field devices employing linear or circular electromagnetic wave propagating structures have been relatively limited in power-handling capabilities and have been predominantly cooled by heat radiation. In order to increase the power-handling capacity it is necessary to provide for more rapid heat dissipation. Problems arise, however, in attempting to circulate a coolant in the vicinity of the wave propagating structure since such structure is normally not operated at radio frequency ground potential. Accordingly, the coolant coupling means, which is at ground potential, must be insulated in some manner from the wave propagating structure. In addition, transition coupling means must be efficiently matched to the wave propagating structures to permit operation over a relatively broad band of frequencies. In the present apparatus, these and other problems are solved by providing an extension which is frequency dependent in electrical length at the ends of the wave propagating structure. Coolant may then be introduced from the ground plane either through the extension and thence through the structure or immediately adjacent thereto without the grounding of radio frequency energy on the propagating structure since the extension acts as a resonant choke.

An illustrative embodiment of the invention comprises a conductor such as a helical wave propagating structure; a grounded metallic envelope enclosing the structure; and a coaxial radio frequency transmission line having inner and outer conductors directly coupled to the helix. The outer conductor is conductively coupled to the metallic envelope, and at least one end of the helix is terminated at said metallic envelope. The inner conductor is coupled to said helix structure adjacent to the end thereof at a predetermined point dependent upon the center frequency of the electromagnetic energy transmitted through the helix. Since the helix is conductively coupled to the grounded envelope, coolant may be introduced at radio frequency ground level to the terminated end of a linear helix or may be circulated in close proximity to a circular helical conductor.

Radio frequency energy may be introduced through the center conductor of the coaxial transmission line without being shorted to ground due to the extension provided at the ends of the helical conductor. The provision of an extension of a predetermined length will also provide an excellent match of the helix characteristic impedance to

the coaxial transmission line characteristic impedance. By extending or shortening the length of the aforesaid extension, a shunt impedance in parallel with said wave propagating structure will be provided. Alternatively, the impedance may be varied, as by changing the diameter or composition of the extension, to provide the correct admittance for matching purposes.

Accordingly, it is an object of the present invention to provide a simple and efficient broad band transition coupler for electron discharge devices enabling the circulation of coolant at ground level to the wave propagating structure while enabling the high power electromagnetic energy to be introduced to the same wave propagating structure without grounding.

Another object of the present invention is the provision of a new and improved broad band transition coupler having efficient means for matching coaxial transmission line and wave propagating structure characteristic impedances over relatively large frequency bands of operation.

Other objects and advantages of the invention will be apparent to those skilled in the art after consideration of the following detailed description together with the accompanying drawings in which:

FIG. 1 is a cross-sectional view of an O-type traveling wave tube embodiment of the invention;

FIG. 2 is an enlarged view of a portion of FIG. 1;

FIG. 3 is a cross-sectional view of FIG. 1 taken along the line **3—3**;

FIG. 4 is a plan view of an alternative embodiment with the top cover removed to reveal internal structure including a circular helical wave propagating structure;

FIG. 5 is a cross-sectional view along the line **5—5** in FIG. 4, illustrative of the input and output transition coupling means to a coaxial transmission line;

FIG. 6 is a fragmentary view of a portion of the circular helical conductor shown in FIGS. 4 and 5; and

FIG. 7 is a fragmentary view illustrative of another embodiment of the invention.

Referring to FIG. 1, there is shown a broad band traveling wave amplifier tube in which a stream of electrons is in energy coupling relation with a helical slow-wave propagating structure. The tube comprises a tubular nonmagnetic metallic envelope **2** surrounding the helix **4**. Cathode **6** at one end provides a stream of electrons along a path extending axially through the tube envelope. The electron stream is collected by electrode **8** at the other end of the tube. Cathode **6** is shown, by way of example, as comprising a cylinder having a portion **7** thereof sprayed with an electron emissive material. A repeller electrode **9** serves to direct the electrons emitted by the cathode toward the helix **4**. Alternatively, there may be provided an accelerating anode of positive potential to focus the electrons in the manner desired. A magnetic field coil **10** surrounds the tube and is energized by a direct current source **11** in series with a variable resistor **12**. The field coil is so arranged that the lines of flux extend axially and parallel to the path of the electron stream in order to focus the electrons traveling axially along the length of the helix. It should be noted that the repeller electrode **9** is maintained at a negative potential relative to the cathode, while the collector electrode **8** is generally maintained at a slightly positive potential relative to the helix. It may also be desired to bias the collector electrode at the same potential as the cathode for depressed collector operation.

The metallic envelope **2** is at ground potential which is equivalent to a positive potential with respect to the cathode. Coaxial transmission line **13** supplies radio frequency energy to one terminal of the helix, while the amplified energy is abstracted from the other terminal of the helix **4** by an output coaxial line **20**. Coaxial transmission lines **13** and **20** define respectively, inner conduc-

tors 21 and 23 and outer conductors 22 and 24. Dielectric beads 37 are provided in the input and output coaxial transmission lines to assure a vacuum-tight seal in the manner well known in the art.

The linear helix 4 is a plurality of wavelengths long peripherally at the center frequency of the greatest bandwidth of desired operation. The input energy supplied to the helix 4 by input line 13 causes the electrons passing through the interior of the helix 4 to be bunched. The helix 4 has such dimensions as to couple properly with the electron stream passing along the axis thereof. As a result, the axial wave velocity along the helix substantially matches the axial velocity of the electron stream passing therethrough. Interaction occurs between the electron stream and electromagnetic energy on the helix, resulting in amplification of the radio frequency energy.

In order to avoid undesirable reflections of radio frequency energy and provide an efficient transition coupling means from the coaxial transmission lines 13 and 20 to helix 4, an extension 26 and 27 is provided at both ends beyond the points 29 and 30 at which the respective inner conductors 21 and 23 are electrically connected. The respective outer conductors 22 and 24 are conductively connected to the grounded envelope 2. The length of the extensions 26 and 27 is sufficient to provide a shunt impedance which in parallel with the helix impedance matches the characteristic impedance of the coaxial transmission lines. For a helix characteristic impedance equal to the output coaxial transmission line characteristic impedance, the length of the extension will be substantially one-quarter wavelength of the center frequency for the greatest bandwidth over which the tube is operative. For the purposes of the present invention the measurement of the one-quarter wavelength electrical dimension is performed neither axially nor peripherally around the turns of the helix wire but is a spatial measurement of the effective electrical wavelength in the area adjacent to the helix delay line and may be conveniently determined utilizing a probe. Shortening or extending the length of the extensions will successfully match the impedances of the respective lines to the helix. Alternatively, instead of varying the length, the impedance may be varied by changing the diameter or composition of the conductive extensions of the helix.

Coolant may then be conveniently introduced at the grounded end of the extensions 26 and 27 without affecting the impedance matching. For example, coolant such as freon or the like from source 40 may be pumped through tube or pipe 42 to extension 26 of a hollow tubular helix 4. The coolant is then removed at extension 27 which is coupled to tube 43. A heat exchanger, not shown, of conventional structure may be provided to remove the heat from the coolant which is then recirculated. By circulating coolant directly through the helix, such wave propagating structures are enabled to withstand considerably higher temperature extremes encountered in high power applications and to dissipate considerably more heat than by radiation.

Referring next to FIGS. 4, 5 and 6, another embodiment of the invention illustrative of the M-type crossed field device will be described. A cylindrical body member 50 is enclosed by top and bottom end plate members 51 and 52 to define a vacuum-tight envelope. With the body member biased at ground potential, suitable cooling means may be provided encircling body member 50 such as a coolant circulating channel 53 with suitable inlet and outlet port means 54 and 55. Centrally disposed within the envelope is a sole electrode 56 together with a circular helical slow-wave propagating structure 57 comprising a plurality of substantially C-shaped members disposed in an interconnected continuous array. A circular interaction space 58 is defined between the sole electrode 56 and the circular helical conductor 57 with the stream of electrons 63 emitted by the cathode gun structure 59 flowing therein.

Cathode gun structure 59 comprises an emissive cathode member 60 and grid electrode 61. An accelerating anode 62 with a higher negative potential than the emissive cathode is provided adjacent the area wherein the electron trajectory is initiated to assist in the focusing of the electron stream 63. Conventional electrical leads 64 are connected to the members 60, 61 and 62 and extend through a vacuum-tight tubular member 80 secured to the top plate member 51 of the envelope.

A collector 65 is disposed at one end of the circular helix and is connected to the body member 50 as well as the helix to thereby ground same. A so-called dummy anode 66 is disposed adjacent the beginning of the circular helix and is similarly connected to the body member 50 for grounding of this end. The dummy anode is positioned in the critical region near the start of the helical array to thereby further influence the electron beam configuration.

The helix 57 comprises a plurality of C-shaped members 68 interconnected by diagonal members 69 with the over-all array supported by a ceramic member 70 to thereby insulate same from the grounded body member 50. In accordance with the teachings of the present invention, with the ends of the helical conductor grounded to the body member 50, the means for coupling the input and output coaxial transmission lines 71 and 72 will now be described. Each of the coaxial transmission lines comprise respectively, outer conductors 73 and 74 connected to the grounded body member as well as inner conductors 75 and 76. The relatively low impedance of the coaxial transmission lines may be efficiently matched to the high impedance wave propagating structure by electrically connecting the inner conductors 75 and 76 directly as by conductors 77 and 78 to a helical member approximately one-quarter of a wavelength of the center frequency of the bandwidth away from the ends of the array. Such an electrical length of the transition coupling means will provide a shunt impedance in parallel with the helix impedance to match the characteristic impedance of the coaxial transmission lines.

The over-all device will be provided with external magnets 81 disposed adjacent the cover members 51 and 52 to provide a magnetic field transverse to the electric field bounded by sole electrode 56 and the helix 57. Such magnet structure 81 has been only partially illustrated since it is well known within the realm of the art. Accordingly, as the radio frequency energy traverses the circular helical conductor, the velocity of this energy will be slowed sufficiently to provide for a synchronous interaction with the electron beam circulating in the interaction space 58 with resultant amplification of said energy which is coupled to the output coaxial transmission line.

An additional feature and alternative embodiment of the invention will now be described with reference being directed to FIG. 7. Helical structure 83 is disposed within envelope 84 with the inner conductor 86 of the coaxial transmission line electrically connected thereto as at point 87. The outer conductor 85 is similarly directly coupled to the helical structure by member 89 to thereby effectively ground this portion of the helix. Additionally, a free, non-terminated, electrically floating extension 88 is provided having an electrical length selected in accordance with the teachings of this disclosure to thereby match the impedance of the wave propagating structure to the coaxial transmission line and provide a resonant choke. In an experimental embodiment, three-quarters of a turn in electrical length of the free extension successfully matched impedances over a frequency band from 900 to 2100 megacycles. Shortening of the free extension electrical length to three-eighths of a turn resulted in the entire pass band shifting to a higher frequency band of from 2000 to 3750 megacycles. Hence, a novel and simplified structure for shifting of the operating band may be realized utilizing the free helix extension in combination with outer conductor and helix portion adjacent

to the inner conductor connection point being conductively grounded. The free helical extension also performs the impedance matching function and may be utilized in linear or circular helical conductors.

While a specific embodiment of the invention has been illustrated and described herein with respect to linear and circular helical conductors providing continuously interconnected wave propagating networks, the invention will be equally applicable to other such structures as, for example, strip and ladder lines. Numerous modifications or alterations may also occur to those skilled in the art. It is therefore intended that the spirit and scope of the invention be afforded a broad and general interpretation in accordance with the definition thereof in the accompanying claims.

What is claimed is:

1. An electron discharge tube comprising:
a grounded metallic envelope;
an electromagnetic wave propagating structure disposed within said envelope;
means projecting an electron stream within said envelope;
radio frequency transmission means coupled to said structure;
said transmission means comprising inner and outer coaxial conductors with said inner conductor being electrically connected to said propagating structure at an intermediate point along the length thereof;
said outer conductor being similarly connected to said wave propagating structure; and
a free nonterminating extension of said wave propagating structure extending beyond the point of connection of the outer conductor.

2. An electron discharge tube comprising:
a grounded metallic envelope;
a plurality of metallic members continuously interconnected to define an electromagnetic wave propagating structure having a high characteristic impedance disposed within said envelope;
means projecting an electron stream within said envelope;
radio frequency transmission means having a low characteristic impedance;
said transmission means comprising plural inner and outer conductors with said inner conductors being electrically connected to said propagating structure at intermediate points along the length thereof with the distance between said points being determined by the desired operating frequency bandwidth of the device;
said outer conductors being conductively coupled to said envelope and to a wave propagating structure member adjacent to the point of connection of said inner conductors; and
a free nonterminating extension defined at the ends of said wave propagating structure beyond the point of connection of said outer conductors;
the electrical length of said free extension being sufficient to provide a shunt impedance in parallel to match the characteristic impedance of said propagating structure with the characteristic impedance of the transmission means.

3. A crossed-field electron discharge device comprising:
a grounded cylindrical conductive envelope having spaced parallel circular conductors defining therebetween an interaction space bounded by mutually perpendicular electric and magnetic fields;
one of said circular conductors defining a continuous interconnected electromagnetic wave propagating structure having a frequency dependent electrical length;
means projecting an electron stream within said interaction space;
input and output radio frequency transmission means having inner and outer conductors coupled to said wave propagating structure;
said outer conductors and the ends of said wave propagating structure being conductively coupled to said envelope;
said inner conductors being electrically connected to said wave propagating structure at a terminal point spaced from said outer conductor coupling points a distance substantially one-quarter of an electrical wavelength at the center frequency of the operating bandwidth of the device as measured in the interaction space.

4. A crossed-field electron discharge device according to claim 3 wherein a free electrically floating extension of said wave propagating structure is provided beyond the connection point of said inner conductors and said outer conductors coupling point is adjacent to the point of connection of said inner conductors;
said free extension having a predetermined electrical length to shift the operating pass band of the device whereby the shortening of the free extension yields a higher frequency pass band and lengthening the free extension yields a lower operating pass band.

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HERMAN KARL SAALBACH, *Primary Examiner.*
PAUL GENSLER, *Assistant Examiner.*