

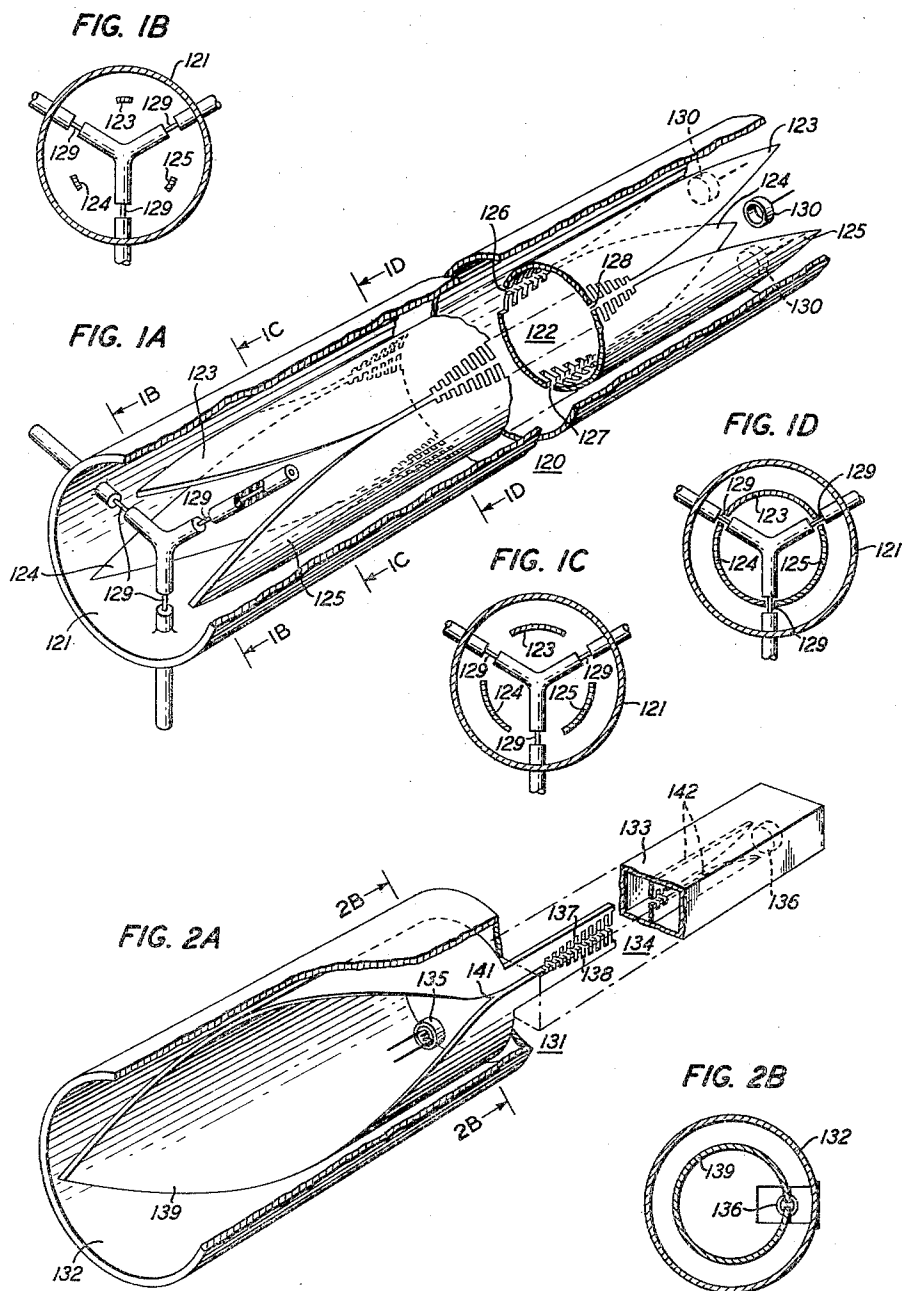
Nov. 20, 1962

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3,065,373

HIGH FREQUENCY APPARATUS OF THE TRAVELING WAVE TYPE

Original Filed Nov. 29, 1955



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3,065,373

HIGH FREQUENCY APPARATUS OF THE TRAVELING WAVE TYPE

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Original application Nov. 29, 1955, Ser. No. 549,820, now Patent No. 2,923,901, dated Feb. 2, 1960. Divided and this application May 29, 1959, Ser. No. 816,860
5 Claims. (Cl. 315—3.6)

This invention is a division of my copending application Serial No. 546,820, filed November 29, 1955, now Patent No. 2,923,901, and relates to finline structure in general and, in particular, to a finline slow wave interaction circuit.

The propagation of microwave energy in the form of TE_{01} waves in circular wave guides is ideally suited for the long distance transmission of wide band signals since the attenuation characteristics of this transmission mode unlike that of most other modes decreases with increasing frequency. However, one difficulty with this method of transmission is that it is comparatively difficult to operate on energy in the TE_{01} mode. In the past when the energy in the TE_{01} mode was to be operated on, it was found convenient to convert the energy from the TE_{01} mode to the dominant mode, perform the operations and reconvert to the TE_{01} mode. These operations consisted of amplification, modulation, demodulation, etc. Therefore, it is fairly obvious that any structure which can be devised to directly operate on energy while in the TE_{01} mode or to assist in the conversion of the energy from the TE_{01} mode to a dominant mode is highly valuable.

One convenient tool which has been found very useful in operating on microwave energy is the finline. Finline structures are disclosed in my copending application Serial No. 285,671, filed February 2, 1955, now Patent No. 2,922,961, and Serial No. 549,734, filed November 29, 1955, now Patent No. 2,924,797 and in copending application Serial No. 485,672 by H. T. Friis and S. D. Robertson, filed February 2, 1955, now Patent No. 2,921,272. Finline structures comprise two thin conductive fin elements having cooperating edges which are generally spaced apart along their entire length for forming therealong a continuous wave path. The path along the interspace between the cooperating edges of the two fins is advantageously very narrow along the intermediate portion of its length for closely confining the propagating wave energy and is usually tapered at both ends for matching the characteristic impedance of the intermediate portion of the path to the respective characteristic impedances of the waveguiding paths being coupled.

Devices of this type hold considerable promise for microwave transmission applications since they are inherently extremely broad-band devices. Additionally, the finlines are advantageously characterized in that they are polarization-selective, that is, a finline will couple only to electric fields extending in a plane parallel to the plane of its two fins, whereas electric fields polarized transverse to the plane of its fins will pass the finline substantially unaffected by its presence. In order to obtain polarization-selectivity it is to be noted that the fin elements must be extremely thin, for example in the case of a finline positioned within a circular hollow wave guide to form a coupler, the thickness of the fins must be a small fraction of the guide inside diameter, advantageously less than 5 percent of the inside diameter.

In one embodiment of the present invention, finline structure is utilized in a traveling wave tube to provide direct amplification of the microwave energy contained in the TE_{01} mode without the necessity of converting the TE_{01} mode to the dominant mode. In another embodiment of the present invention, finline structure is utilized

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in a traveling wave tube to convert the microwave energy from the TE_{01} mode of a circular wave guide to the dominant mode of a rectangular wave guide while at the same time providing amplification for the converted energy.

The above and other features and advantages of the present invention will be more clearly understood by referring to the following detailed description taken in connection with the accompanying drawing in which:

FIG. 1A is a cutaway perspective view of one embodiment of the present invention wherein direct amplification is provided for the microwave energy in the TE_{01} circular electric mode;

FIGS. 1B, 1C, and 1D are cross-sectional views of the structure of FIG. 1A looking to the left through planes B—B, C—C, and D—D, respectively;

FIG. 2A is a cutaway perspective view of another embodiment of the invention wherein finline structure is utilized to provide a simple transition from the circular electric mode in the round wave guide to the dominant mode in the rectangular wave guide accompanied by amplification during the transition; and

FIG. 2B is a cross-sectional view of the structure of FIG. 2A looking to the left through plane B—B.

Referring more particularly to the drawing, FIG. 1A is an embodiment of the present invention in which a finline having low-pass filter characteristics is used as a slow wave filter-type circuit in a traveling wave tube. In this embodiment, circular hollow wave guide 121 serves as the evacuated envelope housing the elements of the traveling wave tube 120. Along the circular wave guide and concentric therewith is positioned a finline structure 122. This structure comprises arcuately shaped fins 123, 124, and 125, each of which is tapered at both ends to form tapered sections of wave path between adjacent fins. The manner of taper and the shape of the fins can perhaps be understood most clearly by referring to FIGS. 1B, 1C, and 1D which are cross-sectional views of the tube of FIG. 1A taken through planes B—B, C—C, and D—D, respectively. Intermediate the tapered sections of wave path the fins are closely spaced to form narrow wave paths 126, 127, and 128. A succession of periodically spaced slot-like apertures is located in the fins along each of these narrow wave paths to form, in effect, three slow wave circuits in parallel, the apertures of each succession being of equal length along the major portion of the succession but being of gradually decreasing length toward the ends of the succession for impedance matching. At one end of the slow wave circuits thus formed is located an electron gun arrangement having three electron-emissive surfaces 129 and suitable beam focusing and accelerating electrodes (not shown) for directing the electrons from said emissive surfaces along three separate paths each in coupling relation with a different one of the three slow wave circuits. Electrodes 130 are located at the opposite end of the slow wave circuits for collecting electrons passing along the three respective electron paths. Additionally, magnetic focusing apparatus is advantageously provided along the length of the tube for maintaining the electrons focused along the three respective electron paths but has been omitted from the drawing for purposes of simplification.

In operation, a wave traveling from left to right in the fundamental transverse circular electric mode, generally designated TE_{01} , along hollow wave guide 121 will propagate along the tapered wave paths between the fins and continue along the narrow wave paths 126, 127, and 128 in the region of the slow wave circuits along the respective fins. The wave propagating along the succession of apertures of each slow wave circuit is amplified by the now well known process of cumulative interaction with the electron streams from emissive surfaces 129.

This amplified energy is then transferred, via the tapered wave path sections at the right-hand end of the finline structure, and continues along the hollow wave guide 121. It is understood that in practice supports must be provided for maintaining finline structure 122 positioned concentrically within wave guide 121 and, further, that wave guide windows must be provided in wave guide 121 at both ends of traveling wave tube 120 for maintaining evacuated conditions within the tube. It is also understood that wave energy propagating from right to left along hollow wave guide 121 can be amplified by traveling wave tube 120, under appropriate operating conditions, such amplification generally being referred to as backward wave amplification.

FIGS. 2A and 2B illustrate a modification of the embodiment shown in FIG. 1A wherein the three slow wave circuits along the respective wave paths 126, 127, and 128 have been replaced by a single slow wave circuit 134. In this embodiment circular hollow wave guide 132 is abutted against rectangular hollow wave guide 133 and together they form an evacuated envelope for the traveling wave tube 131. As in the tube of FIG. 1A, it is understood that suitable wave guide seals are provided in both these wave guides for maintaining evacuated conditions along tube 131. Traveling wave tube 131 comprises the slow wave circuit 134 positioned along an axial plane of rectangular wave guide 133, an electron gun 135 and collector electrode 136 for projecting an electron stream in coupling relation with the slow wave circuit, and tapered sections of finline at the ends of slow wave circuit 134 for matching to rectangular wave guide 133 at the right-hand end of the circuit and to circular wave guide 132 at the left-hand end. The slow wave circuit constitutes a single pair of fins 137 and 138 having a succession of slot-like apertures along a portion of their length, the apertures being of equal length along the major portion of the succession and being of gradually decreasing lengths at the end portions of the succession for impedance matching. At the right-hand end of the slow wave circuit fins 137 and 138 are tapered to form a tapered finline section 142 for matching to rectangular wave guide 133 and for converting from the finline mode to a rectangular wave guide mode. At the left-hand end of the slow wave circuit the two fins become joined to form a cylindrically shaped conductor 139 having a longitudinal wave path 141 there-through. Conductor 139 extends concentrically within circular wave guide 132 as shown in FIG. 2B, held by dielectric supports (not shown), and is so shaped that the transverse dimension of wave path 141 is increased gradually toward circular wave guide 132 for mode conversion and suitable impedance matching to the wave guide.

In operation a wave propagating in the transverse circular electric mode from left to right along wave guide 132 will pass along the tapered portion of wave path 141, continue through the slow wave circuit along the narrow section of the wave path, being amplified by cumulative interaction with the electron beam along the circuit, and finally pass through tapered finline section 142 to wave guide 133. It can be appreciated that the finline arrangement in the present tube comprising cylindrical conductor 139 and fins 137 and 138 serves effectively as a mode conversion section for transforming from a transverse circular electric mode in a circular wave guide to a rectangular wave guide mode, and further allows amplification of the wave during such conversion. As in the tube of FIG. 1A, the present tube 131 may also be used advantageously under appropriate operating conditions as a backward-wave amplifier for amplifying wave energy passing from right to left therethrough.

It is understood that the above-described arrangements are merely illustrative of the principles of the present invention and various other arrangements can be devised by those skilled in the art in the light of this disclosure without departing from the spirit and scope of the inven-

tion. For example, the traveling wave tubes described can be suitably terminated at their respective downstream ends and operated as backward-wave oscillators in the manner of operation discussed by J. W. Sullivan in an article entitled "A Wide-Band Voltage-Tunable Oscillator" appearing in the Proceedings of the Institute of Radio Engineers, November, 1954, at pages 168 et seq.

What is claimed is:

1. In a device which utilizes an electron stream projected along a predetermined path for interaction with a propagating electromagnetic wave, a slow wave filter-type interaction circuit for propagating an electromagnetic wave in coupling relationship with the electron stream comprising two thin conductive fin elements having a common locus and being transversely spaced apart along the length of the region where interaction takes place for forming a wave path along the interspace therebetween, said wave path and said beam path being on said locus at least one of said fin elements having therein a plurality of slot-like apertures spaced apart in a series extending parallel to the wave path along the interaction space between the fin elements, the long dimension of each of said slot-like apertures extending transverse to said wave path, a circular hollow wave guide for coupling to said slow interaction circuit at one end, said fin elements being coplanar along the interaction region and being joined together at one end to form a cylindrically shaped conductor for coupling to said circular hollow wave guide.

2. In a device which utilizes an electron stream projected along a predetermined path for interaction with a propagating electromagnetic wave, a slow wave filter-type interaction circuit for propagating an electromagnetic wave in coupling relation with said electron stream comprising a plurality of thin longitudinally extending conductive fin elements, said fin elements being arcuate in cross-section shape, longitudinally continuous, and the plurality arranged to lie on a cylindrical locus, adjacent fins being circumferentially spaced apart for defining a wave path along the interspace between said adjacent fin elements, at least one fin along each of said wave paths having therein a plurality of slot-like apertures spaced apart in a series extending parallel to the wave path, the long dimension of each of said slot-like apertures extending transverse to said wave path, and means for coupling to said slow wave circuit including a circular hollow wave guide in energy exchange relation with said circuit and arranged coaxially with said cylindrical locus.

3. In a device which utilizes an electron stream projected along a predetermined path for interaction with a propagating electromagnetic wave, a slow wave filter-type interaction circuit for propagating an electromagnetic wave in coupling relation with said electron stream comprising two thin longitudinally continuous conductive fin elements spaced apart in a direction transverse to the beam path along their entire length for forming a wave path along the interspace therebetween, at least one of said fin elements having therein a plurality of slot-like apertures spaced apart in a series extending parallel to the wave path along the interspace between the fin elements, the long dimension of each of said slot-like apertures extending transverse to said wave path, a first hollow wave guide in energy exchange relation with one end of said slow wave circuit, and a second hollow wave guide in energy exchange relation with the other end of said slow wave circuit, and said two fin elements being closely spaced over the major portion of their length along the series of apertures and being tapered at their ends for matching to said first and second hollow wave guides.

4. In a device which utilizes an electron stream projected along a predetermined path for interaction with a propagating electromagnetic wave, a slow wave filter-type interaction circuit for propagating an electromagnetic wave in coupling relation with said electron stream

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comprising two thin longitudinally extending conductive fin elements spaced apart along the region where interaction takes place for forming a wave path along the interspace therebetween, at least one of said fin elements having therein a plurality of slot-like apertures spaced apart in a series extending parallel to the wave path along the interspace between the fin elements, the long dimension of each of said slot-like apertures extending transverse to said wave path, a circular hollow wave guide in energy exchange relation with one end of said slow wave circuit, a rectangular hollow wave guide in energy exchange relation with the other end of said slow wave circuit, said two fin elements being closely spaced over the major portion of their length along the series of apertures and being joined together at one end to form a cylindrically shaped conductor coaxial with said circular guide for coupling to said circular guide and said two fin elements being tapered at the other end for coupling to said rectangular guide.

5. In a traveling wave tube for direct amplification of the dominant circular electric mode, means for producing a plurality of electron streams lying on a cylindrical locus, a plurality of slow wave filter-type interaction circuits for propagating an electromagnetic wave in coupling relation with said electron streams comprising a plurality of thin longitudinally extending conductive fin

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elements, said fin elements being arcuate in cross-sectional shape and said plurality of interaction circuits also arranged to lie on a cylindrical locus, adjacent fins being spaced apart for defining a wave path along the interspace between said adjacent fin element, at least one fin along each of said wave paths having therein a plurality of slot-like apertures spaced apart in a series extending parallel to the wave path, the long dimension of each of said slot-like apertures extending transverse to said wave path, and means for coupling to said slow wave circuits including a circular hollow wave guide in energy exchange relation at each end of said circuits and arranged coaxially with said cylindrical locus.

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