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Krah et al.

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[45] **May 30, 1972**

[54] **WAVE PROPAGATING STRUCTURE FOR CROSSED FIELD DEVICES**

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[73] Assignee: **Raytheon Company**, Lexington, Mass.

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[21] Appl. No.: **101,678**

[52] **U.S. Cl.** ....**315/3.5**, 315/39.3, 333/31 A, 313/30, 313/32
[51] **Int. Cl.** **H01j 25/34**
[58] **Field of Search** 315/3.5, 3.6, 39.3; 313/30, 313/31, 32, 46

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Assistant Examiner—Saxfield Chatmon, Jr.
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[57] **ABSTRACT**

A wave propagating structure having broad bandwidth capability is disclosed for crossed field electron beam interaction devices. The thermal dissipation characteristics are programmed and customized taking into consideration beam coupling impedance, dielectric loading and suppression of undesired space harmonic modes. A structure such as a modified helix delay line is arranged with groupings of individual elements in parallel and such groupings are serially connected. A fluid coolant is circulated through the delay line and the dielectric constant characteristics of such coolant may be selected to vary the frequency determining dispersion parameters of predetermined portions of the propagating wave.

6 Claims, 11 Drawing Figures

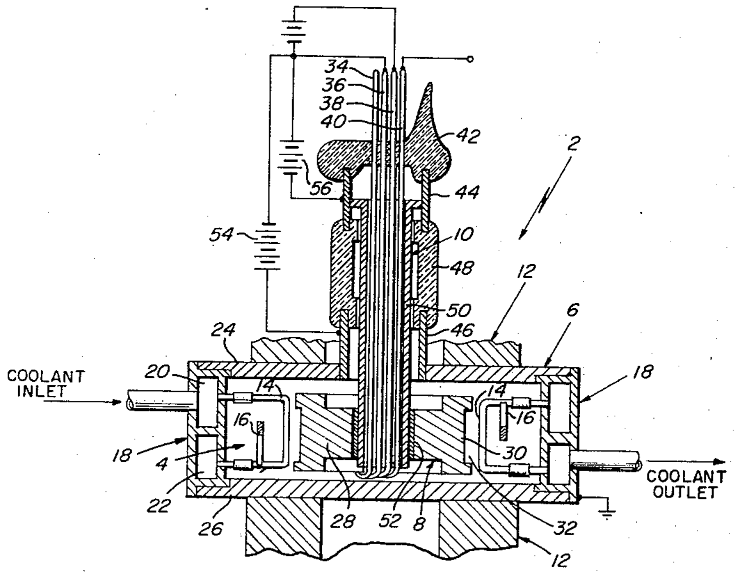
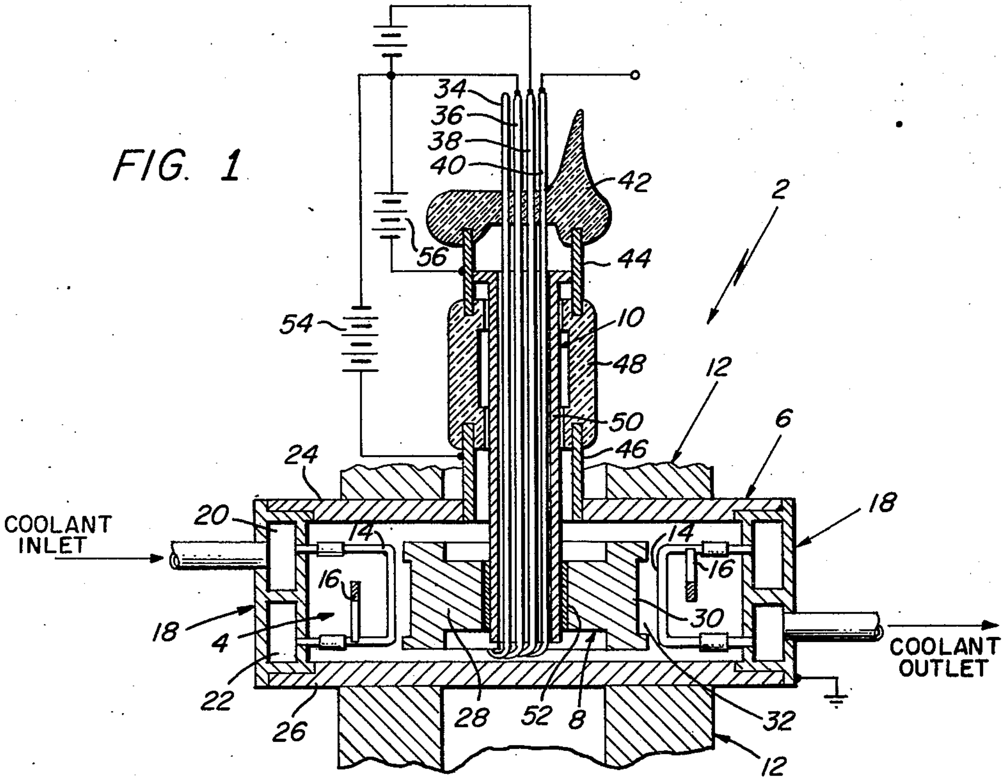


FIG. 1


34
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2
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48
12
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6
46
24
18
20
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COOLANT OUTLET
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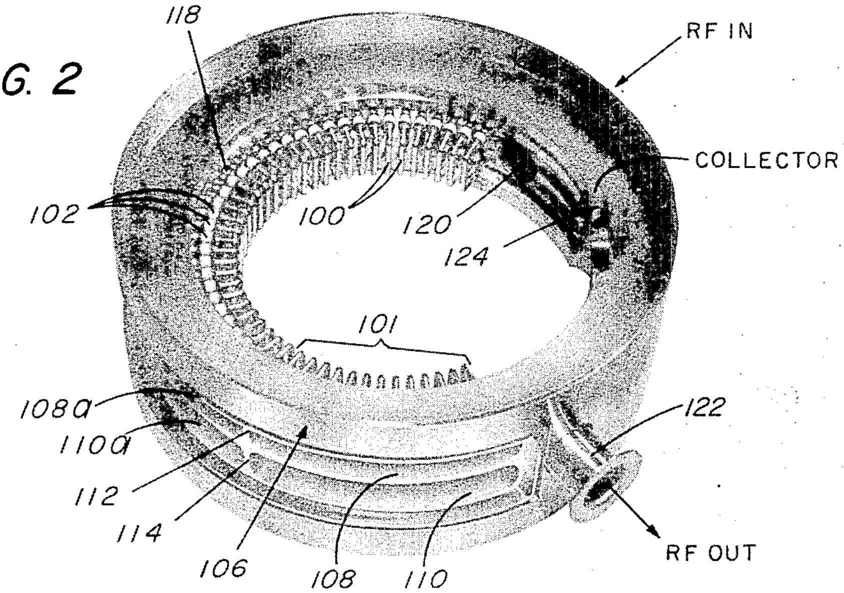
32
12

FIG. 2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101
108a
110a
122
112
114
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110
RF OUT

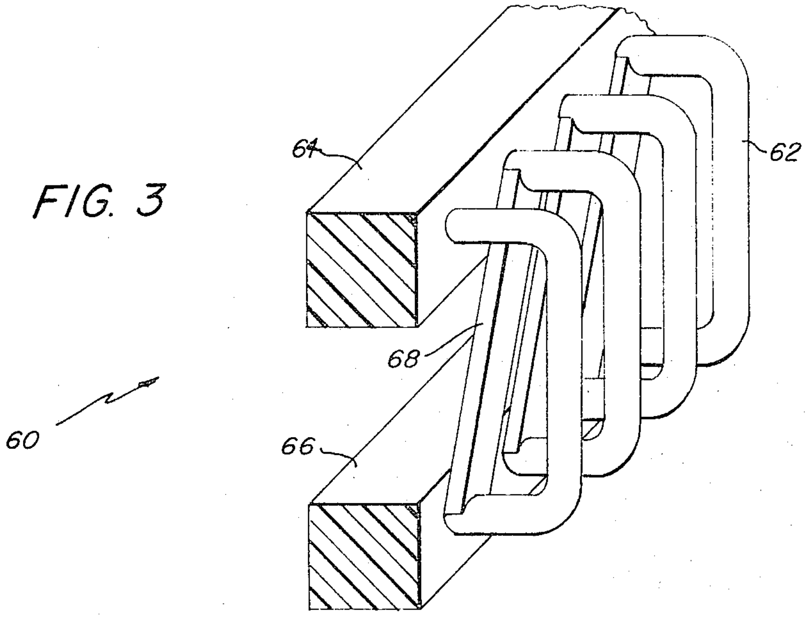


FIG. 3

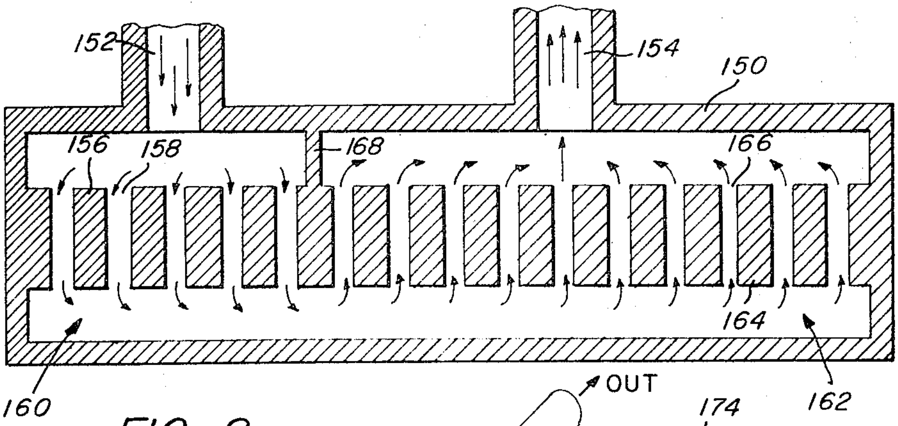


FIG. 8

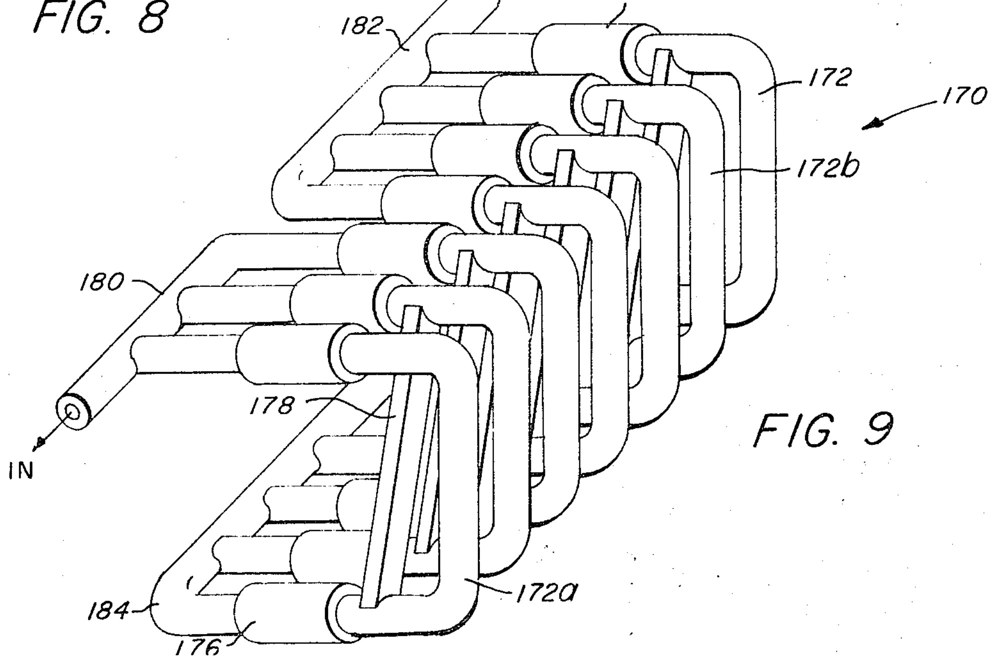


FIG. 9

FIG. 4

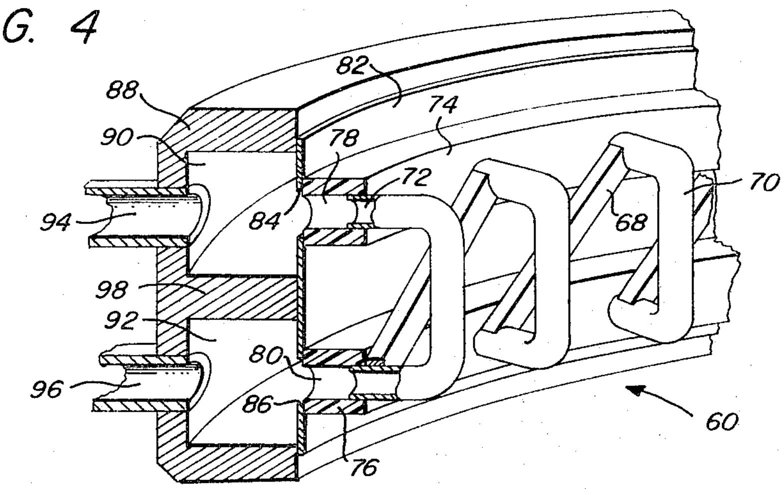
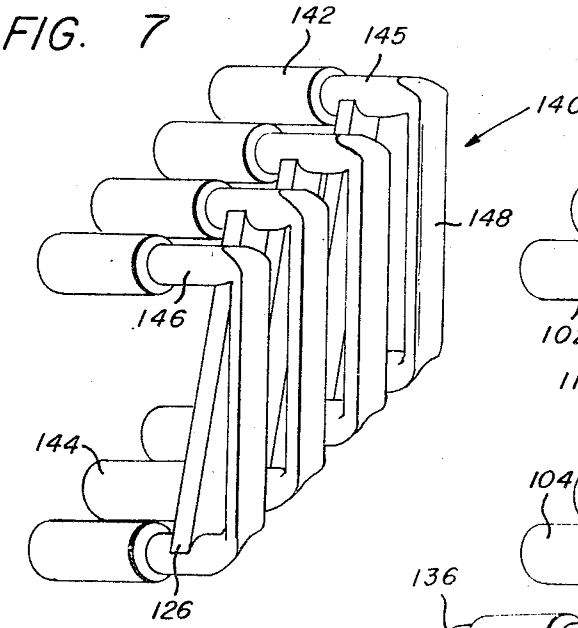


FIG. 7



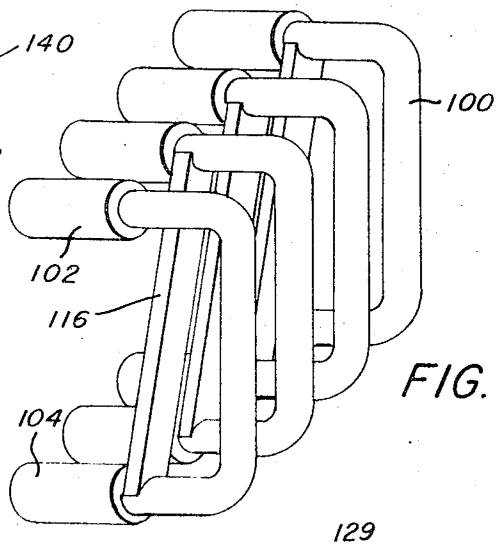


FIG. 5

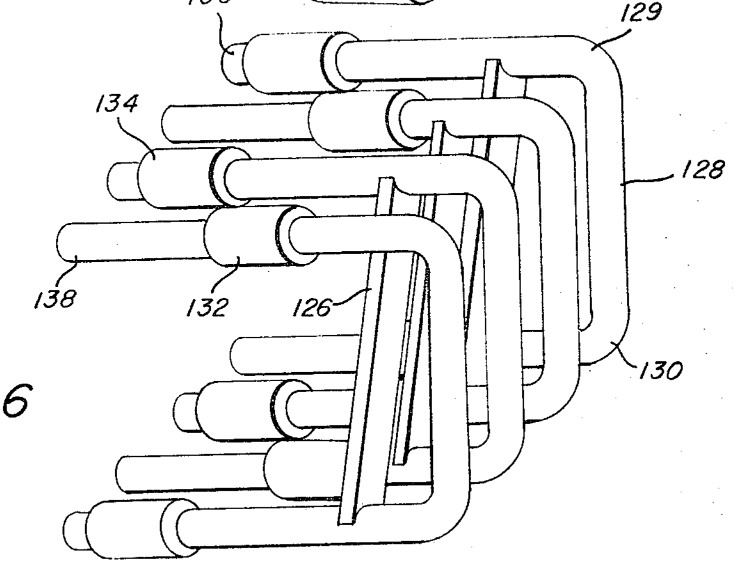
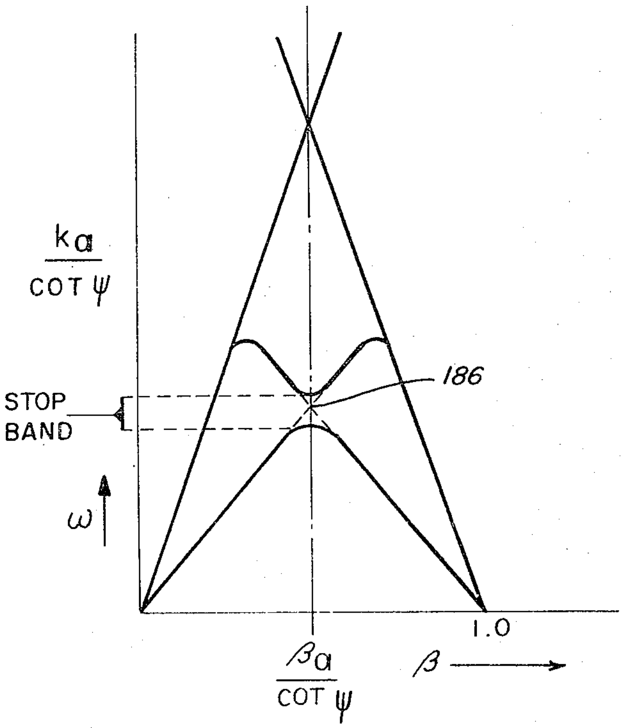


FIG. 6

FIG. 10


$\frac{ka}{\cot\psi}$
STOP BAND
ω
186
$\frac{\beta a}{\cot\psi}$
1.0
β

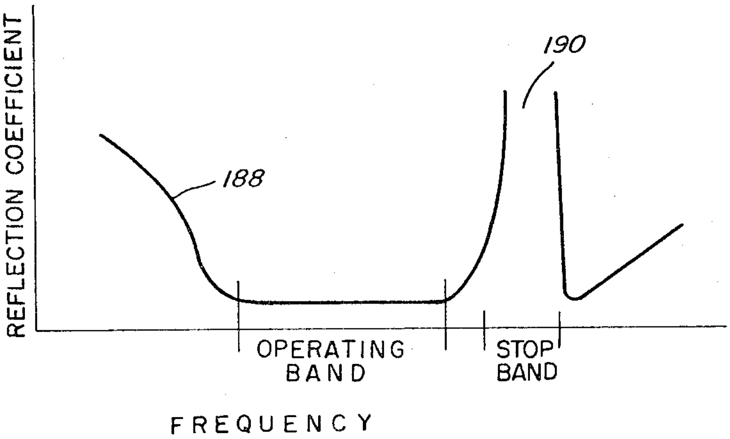

REFLECTION COEFFICIENT
190
188
OPERATING BAND
STOP BAND
FREQUENCY

FIG. 11

WAVE PROPAGATING STRUCTURE FOR CROSSED FIELD DEVICES

The invention herein described was made in the course of a contract with the Department of the Air Force.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to wave propagating structures for traveling wave electron interaction devices.

2. Description of the Prior Art

Devices of the type under consideration utilize wave propagating structures having a plurality of periodic circuit elements to retard the velocity of an electromagnetic wave and permit interaction with resultant net exchange of energy with an electron beam directed along an adjacent path. The establishment of a synchronous relationship between the electron beam velocity and the phase velocity of the desired space harmonic component of the traveling waves determines the interaction characteristics. Devices of the M-type incorporate a sole electrode coextensive with and spaced from the wave propagating structure to define therebetween the electron interaction region. Crossed electric and magnetic fields influence the trajectory of the electron beam traversing this interaction region. Such crossed field devices operate on the principle of transfer of potential energy to result in amplification or generation of high frequency electrical signals. Efficiencies in the order of 70–75 percent and higher are attained together with high average power outputs of many kilowatts and peak powers of megawatts since an appreciably greater portion of the electron beam interacts with the waves on the propagating structure.

Another traveling wave device commonly incorporating a wave transmission structure of a predetermined periodicity is the O-type. Such devices operate on the principle of the transfer of kinetic energy from the electron beam to the fields of the electromagnetic waves. In such devices the combined fields induce the perturbations in the beam to form electron packets or bunches which exchange energy with the electromagnetic waves translated along the length of the propagating structure when the synchronous relationship is achieved. In such devices the coextensive electrode is omitted and the electron beam is directed axially along the length of the device with the wave retardation structure circumferentially disposed about the beam. Efficiencies in the O-type interaction device are notably lower since only a small fraction of the electron beam exchanges energy with the electromagnetic waves. Values in the range of 20 to 40 percent are, therefore, common for these devices which limits the level of power generated by reason of costly on-site power requirements and impractically long dimensions. An exemplary wave propagating structure incorporated in these traveling wave devices is the helix having a plurality of continuously wound circuit elements in both a unifilar or bifilar arrangement. In the field of high frequency electrical signal generation and amplification it is well known that such helical structures have by far the widest bandwidth capability extending many hundreds of megahertz and in numerous instances to octave bandwidths by reason of the high electron beam coupling impedance characteristics.

The adaptation of helix type structures for higher power output devices has been dependent on thermal dissipation problems. Numerous examples of prior art structures exist involving stubs, rods, straps or similar supports combined with a helix to provide the prerequisite thermal dissipation. Such dissipative structures, however, have only resulted in very narrow bandwidth devices which renders them less attractive for high power microwave frequency electromagnetic energy devices. In addition to the thermal dissipation structures incorporated in high frequency traveling wave devices, numerous methods of cooling have been proposed incorporating direct or series cooling of the wave propagating structure or conduction cooling by means of a supporting heat sink member having internal means for circulating a cooling fluid.

It is desirable, therefore, to evolve a wave propagating structure capable of broad bandwidths and high power outputs. High frequency electromagnetic wave energy generators and amplifiers must also be capable of traveling wave-electron interaction in the forward or backward wave mode. The efficiencies of M-type crossed field devices coupled with broad frequency operating ranges will measurably improve modern day electronic systems for communications, surveillance, weather information and the like.

SUMMARY OF THE INVENTION

In accordance with the teachings of the invention, a crossed field traveling wave electron interaction device with a broad bandwidth and high power output capability is provided by means of a wave propagating structure having a modified helical circuit format. Improved thermal dissipation is incorporated by a series-parallel grouping arrangement for flow of the circulating cooling fluid with the individual wave circuit elements being continuously electrically connected by an advancing member. The circuit elements are principally cooled by parallel flow to drastically improve cooling efficiency. In addition to the wide bandwidth capability, the wave propagating structure is provided with programmed means for attenuating the propagated electromagnetic wave energy, as well as dissipating generated energy, by altering the dielectric constant of the cooling fluid at selected portions along the length of the propagating structure.

Another characteristic of the electron interaction device of the invention is the efficient suppression of undesired space harmonics such as those of the backward wave type when a forward wave device is desired. The conductive interconnecting element for advancing the circuit waves contacts adjacent periodic elements and provides for electrical parameter considerations independently of the thermal dissipation problems. The embodiments may be of a linear or circular configuration and the periodic circuit elements may be solid or hollow, as well as of a rectangular, square, triangular or circular cross section to adapt the device to the thermal and electrical characteristics for desired bandwidth and power output. There is thus provided a unique and novel device incorporating the high efficiencies and high power outputs of an M-type interaction device with the broad bandwidths of an O-type in a unitary embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, as well as the details for the provision of a preferred embodiment, will be readily understood after consideration of the following detailed description and reference to the accompanying drawings, wherein:

FIG. **1** is a cross-sectional view of an illustrative embodiment of the invention;

FIG. **2** is a perspective view of the wave propagating structure of the illustrative embodiment in a circular configuration;

FIG. **3** is an isometric view of a fragmentary portion of a wave propagating structure of a directly cooled embodiment of the invention in a linear array;

FIG. **4** is a cross-sectional view of a circular structure having a direct cooling fluid circuit;

FIG. **5** is an isometric view of a directly cooled embodiment with each periodic circuit element having a separate insulator support;

FIG. **6** is an isometric view of an alternative embodiment of the wave propagating structure circuit elements;

FIG. **7** is an isometric view of an alternative embodiment of the structure shown in FIG. **5** with the separate insulator support as well as a modified periodic circuit element;

FIG. **8** is a diagrammatic illustration of a series-parallel cooling circuit for an illustrative embodiment of the invention;

FIG. **9** is an isometric view of a series-parallel periodic circuit embodiment of the invention;

FIG. **10** is a$\omega\beta$ diagram of a wave propagating structure displaying stop band space harmonic suppression in accordance with the invention; and

FIG. 11 is a graph of the reflection coefficient versus frequency over the operating range with the wave propagating structure incorporating backward wave suppression.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The crossed field electron interaction device embodiment 2 incorporates a wave propagating structure 4 having broad bandwidth capability and improved thermal dissipation characteristics within an evacuated envelope 6. A sole electrode 8 is disposed concentrically with respect to the wave propagating structure 4 and is normally biased at a negative potential. An input electrical lead assembly 10 provides for the introduction of electron beam generation and electric field producing means. Magnet members 12 provide for the magnetic field distributed perpendicular to the resultant electric fields.

The wave propagating structure 4 includes a plurality of substantially U-shaped parallel periodic circuit elements 14 supported by base member 18 having fluid channels 20 and 22 with the elements interconnected by advancing member 16. The base member 18 together with oppositely disposed end plates 24 and 26 hermetically sealed thereto form the evacuated envelope 6 of the overall embodiment.

The sole electrode 8 comprises a cylindrical member of an electrically conductive material having a web portion 28 defining a channel 30 for confining an electron beam within an interaction space bounded by the channel wall surfaces and the space wave propagating structure 4. A source of electrons is disposed in a recessed portion within the sole electrode 8 with the electrical connections provided through the assembly 10. For the sake of clarity the specific details of the electron source have been omitted, however, the connections will be made to such conventional items as the cathode, heater, grid and accelerating electrodes by means of lead wires 34, 36, 38 and 40 extending through glass bead 42 which is, in turn, supported by sleeve members 44 and 46 having an intermediate glass member 48. The entire electrical lead assembly 10 extends within the hollow supporting member 50 which is inserted within a tubular member 52 in the web portion 28 of sole electrode 8.

The electric field extending between the wave propagating structure 4 and sole electrode 8 is supplied by means of a unidirectional voltage supply such as, for example, a source 54. The sole electrode 8 is biased negatively by means of source 56 connected between the lead 36 extending to the cathode of the electron source and the electrode supporting members 44 and 50. The wave propagating structure 4 is maintained at a positive potential by voltage source 54 connected between sleeve 46 and the base member 18 of the wave propagating structure.

Output coupling means of the well-known coaxial transmission type, as well as a collector electrode, which may be fluid cooled, are disposed adjacent the output ends of the wave propagating structure and the positions of these members will be described in connection with FIG. 2. Specific details have been omitted since these elements are of well-known construction in the interest of specifically describing the wave propagating structure of the present invention.

Reference is now directed to FIG. 3 disclosing a fragmentary portion of an exemplary embodiment of a wave propagating structure 60 having a substantially linear configuration. A plurality of periodic circuit elements 62 are uniformly disposed in parallel by means of bar type base members 64 and 66 of a nonconductive insulating material. The elements comprise substantially U-shaped loop members and fabricated in either a solid or tubular configuration in accordance with the cooling circuit preferred. The base members 64 and 66 are fabricated from any of the well-known ceramic or dielectric materials employed in traveling wave electron interaction devices to provide a minimum of dielectric loading to interfere with the coupling impedance characteristics of the propagating structure relative to the adjacent electron beam. It will be noted that the circuit elements 62 are thereby disposed in a parallel array to measurably enhance higher power capabilities by reason of the increased thermal dissipation efficiency. The base members 64 and 66 may be mounted on a suitable heat sink member to provide the dissipation of the thermal energy by conduction or direct cooling. Alternatively, the base member may comprise a single unitary slab of the applicable material supporting both ends of the circuit loop members or individual sleeve members.

Means for providing electrical continuity and advancing the electromagnetic traveling wave energy propagated along the circuit are provided by a plurality of electrically conductive elements 68 interconnecting adjacent circuit elements 62 to thereby provide a modified helical delay line structure having the electrical properties for deriving broad frequency range outputs of O-type electron interaction devices. Advancing elements 68 provide for the electrical continuity independent of thermal dissipation considerations which are provided principally by the parallel cooling circuit. In a working embodiment each of such elements comprise a solid planar surface member having a substantially rectangular configuration of a highly electrically conductive metal, such as copper. The advancing members 68 thereby provide a flattened asymmetrical surface to suppress undesired space harmonics, as will be hereinafter described, while the U-shaped members have been illustrated in a circular configuration to facilitate cooling fluid circulation. Many other configurations will be possible in either the overall wave propagating structure or portions thereof to customize both the thermal and electrical properties. Such alternative embodiments will also be discussed in relation to subsequent views.

Referring next to FIG. 4 a cooling circuit for the wave propagating structure 60 disclosed in FIG. 3 is illustrated. In this embodiment the periodic circuit loop elements 70 are of a tubular configuration defining a hollow passageway 72. The interconnecting solid advancing elements are similar to that shown and described in relation to FIG. 3 and have been similarly numbered 68. The insulator base members 74 and 76 are provided with a plurality of aligned rows of apertures 78 and 80 to facilitate the circulation of the cooling fluid through each circuit loop element 70 without shorting out these circuit elements to the metalic back wall member 82 which also provides a plurality of aligned apertures 84 and 86. Back wall member 82 abuts a circulating cooling fluid jacket member 88 defining hollow passageways 90 and 92 together with inlet and outlet conduits 94 and 96. The jacket member 88 may be fabricated of a metallic structure to facilitate removal of thermal energy. Partition member 98 separates passageways 90 and 92 to thereby provide for the parallel cooling of the circuit loop elements 70. In the illustrated embodiment the wave propagating structure has been disclosed in the circular configuration and is readily adapted to the crossed field device shown in FIG. 1. The cooling fluid circuit may be arranged in any manner desired as will be hereinafter evident by grouping individual circuit loop elements to handle an increased flow of the cooling fluid in predetermined portions of the wave propagating structure where intense thermal energy is generated by interaction with the adjacent traversing electron beam.

Referring next to FIGS. 2 and 5 an alternative embodiment of the invention is disclosed which may be fabricated in either the linear or circular configuration. The periodic circuit loop elements 100 which again may be of either a solid or hollow configuration, as well as circular or flat or a combination thereof, are supported at their ends by individual insulator base members such as sleeves 102 and 104. The sleeves isolate the traveling wave propagating structure from the metallic envelope body member 106 incorporating the cooling circuit passageways 108 and 110. An upper and a lower partition member 112 and 114 provide for the disposition of a separate cooling circuit to handle the group of parallel periodic circuit loop elements encompassed by the bracket 101. The interconnecting advancing electrically conductive members 116 are again shown as of a solid rectangular cross section. In the embodiment shown in FIG. 2 a short length of metallic conduit **118** has been shown to mate with the ends of the sleeve members **102** and **104** to facilitate the fabrication of the overall wave propagating structure.

In FIG. 2 the passageway **120** in the envelope body member **106** is indicated to receive the structure for coupling input electromagnetic wave energy from an external source for a crossed field amplifier device. The amplified energy after traversing the wave propagating structure is coupled to a utilization circuit through output coupler **122**. In the illustrative device the electron source is disposed within the sole electrode recess previously described in the region of the input end of the structure. In accordance with well-known teachings in the art a collector electrode will be disposed within the body member recess **124** adjacent to the output end to complete the circuit for the interception of the electron beam after interaction with the waves traveling along the propagating structure. The collector may also be fluid cooled in accordance with well-known practices. It will be noted that in this embodiment approximately two-thirds of the overall wave propagating structure will be cooled by a common source communicating with passageways **108***a* and **110***a* terminating in partition members **114** and **116**. The more efficient cooling circuit, therefore, will be disposed adjacent the remaining one-third of the overall wave propagating structure adjacent to the collector and energy output end. Since the electron beam-wave interaction is at its maximum level over this approximate one-third length of the propagating structure, maximum cooling efficiency for the dissipation of the generated thermal energy will be provided with the structure of the invention. In this manner any other desired programmed and customized cooling circuit may be provided tailored to the intended use taking into consideration both electrical, as well as thermal considerations.

The embodiments of the invention shown in FIGS. **1–5** inclusive all provide for the uniform disposition of the periodic circuit loop elements, as well as the disposition of the insulating sleeve members **102** and **104** which will suffice for most of the intermediate frequency ranges in the microwave spectrum of the electromagnetic energy band. In FIG. 6 an illustration of the staggered insulating support technique is shown which is extremely useful in extending the usage of the helix delay line wave propagating structure to other frequency bands within the spectrum. The wave advancing element **126** also has been shown in another alternative configuration with the point of interconnection to the circuit loop elements **128** being disposed intermediate to the bends **129** and **130** and the staggered array of insulator sleeve support members **132** and **134** of a ceramic composition. In this embodiment, which may be directly cooled short, conduit sections **136** and **138** of alternately varying length are affixed to the insulator members **132** and **134** for connection to suitable cooling fluid circulating means. Since in devices of the type under consideration the pitch or turn-to-turn capacitance is controlled by conventional electrical design considerations, a point is reached, particularly at the high microwave frequencies where the insulating sleeve members supporting the individual circuit loop elements have a wall thickness which is mechanically impractical. The staggering of the insulating support members **132** and **134** permits the utilization of much thicker insulating sleeve support members without degrading the electrical properties of the helical delay line structure. In this manner either a low voltage device with its attendant small pitch value or a very high microwave frequency device having exceedingly small wavelengths may be realized. Even at lower or intermediate frequencies the use of this staggered support technique will permit the utilization of much thicker insulating sleeve support walls for directly cooled tubular configurations and thus provide a much stronger assembly. The removal of the wave advancing element **126** from a position adjacent to the insulating sleeve support members will also reduce to a minimum the dielectric loading of the wave propagating structure to further enhance the electron coupling electrical characteristics.

In FIG. 7 still further alternative embodiments are shown. A plurality of periodic circuit loop elements **140** are supported by a uniformly disposed array of insulating sleeve support members **142** and **144** similar to that shown in FIG. 5. Each of the circuit loop elements **140** may be provided with a circular cross section along the portions **145** and **146** adjacent to the insulating sleeve support members and this element may also be provided in the hollow or solid configurations. The intermediate portion of the circuit loop members disposed coplanar to the surface of the sole electrode **8** or parallel to the disposition of the magnetic fields adjacent to the traversing electron beam are provided with a planar surface **148** which may be either square or rectangular. The planar configuration will provide a cross-sectional area which materially affects the electrical characteristics of the propagating waves by maintaining a uniformly controlled spacing between the respective elements. Further, a flat helix loop surface will facilitate the thermal dissipation by increasing the heat transfer interface while a circular cross-sectional area has a tendency to reduce such a heat transfer area. In numerous instances a compromise between the respective desired thermal and electrical parameters may result in a combined structure such as that illustrated in FIG. 7 with the circular and flat sections or in certain instances it may be advantageous to employ complete flat circuit element configuration commencing from the insulator support. In the disclosed embodiment for direct cooling, it will be advantageous to provide a circular passageway through the circuit loop element to enhance the flow rate of the cooling fluid circulating through the circuit. The turn-to-turn capacitance for the planar configurations will be at a maximum for a rectangular cross section and a minimum for a triangular cross section. It is also within the purview of the invention to incorporate various surface configurations exposed to the electron beam in varying regions of the overall interaction region taking into consideration both thermal and electrical considerations.

Referring now to FIGS. **8** and **9** other unique features of the present invention will be described. The individual circuit elements combining to form the overall propagating structure are disposed in a parallel array. The circulating cooling fluid, therefore, will be circulated through the individual turns to thereby provide the maximum thermal dissipation efficiency. A variety of cooling circuits may be employed in the applicable devices to provide a maximum cooling in the region of highest thermal energy generation by grouping certain individual circuit loop elements into programmed groupings with one section of the overall structure such as, for example, one-third and two-thirds with these parallel groupings then being connected in series. In FIG. 8 the fluid cooling jacket member **150** of a metallic or other thermally conductive material has an inlet conduit **152** and outlet conduit **154**. The plurality of circuit loop elements forming the predetermined smaller or one-third section of the overall wave propagating structure are indicated generally by the numeral **156** defining a plurality of passageways **158** within parallel grouping section **160**. An example of the application of the invention would be the disposition of the one-third section having the lower temperature cooling fluid adjacent the output section of the device where much higher thermal energy results from electron beam-wave interaction. The net effect will thereby be the provision of a cooling liquid flow within section **160** at substantially twice the flow rate of the remainder of the wave propagating structure. The parallel grouping section **162** incorporates loop circuit elements **164** defining passageways **166** in a parallel array. A partition member **168** between the sections **160** and **162** will provide for the circulation of the cooling fluid from a common source. In the previously discussed embodiment in FIG. **2**, two such partition members **112** and **114** are provided in the upper and lower passageways which would require the use of two independent cooling systems rather than a single closed loop. It may be advantageous in many instances to incorporate two such complete cooling circuits to provide even higher output powers. The high coolant flow, therefore, can be programmed in any desired manner where required by the high thermal energy dissipation as a result of the high powers generated without unnecessarily high total flow of such fluids.

In FIG. **9** an embodiment of a series-parallel cooling fluid circuit illustrates the thermal dissipation characteristics with individual groupings of the circuit loop elements. The wave propagating structure **170** incorporates the plurality of parallel periodic circuit loop elements **172** with uniformly disposed insulating support members **174** and **176** together with interconnecting wave advancing elements **178** removed from the face of the insulating support members collectively defining a helical delay line structure. Circuit elements **172*a*** are interconnected by means of a conduit **180** to couple the system to the low temperature end of the cooling circuit at the inlet conduit. The remaining or, illustratively, four loop elements designated by the numeral **172*b*** are interconnected by conduit **182** to couple the cooling circuit to the output end. An end of the respective loop element **172*a*** and **172*b*** are, therefore, interconnected in a parallel manner by means of conduits **180** and **182** while the opposing ends of all of the circuit loop elements collectively defining the overall wave propagating structure are interconnected by a common conduit member **184**. This series-parallel cooling circuit arrangement will, therefore, concentrate the highest thermal energy dissipation means utilizing the most efficient coolant temperatures.

Another feature of the invention resides in the selection of the cooling fluids for use in the variety of cooling circuits and propagating structure configurations. As is known in the art, the cooling fluid has a material effect on the electrical characteristics of the wave propagating structure. The insulating support members of a dielectric or ceramic material together with the circulating fluid comprise a shunt resistance to ground in addition to the dielectric loading. Dependent on the loss tangent characteristic of the cooling fluid, the shunt resistance characteristic varies, as well as the attenuation, along the wave propagating structure. The shunt resistance is also materially affected by the length of the fluid path. If the mechanical and thermal dissipation considerations would permit, the circulating conduits could be made rather lengthy in order that a cooling fluid such as water with its excellent cooling properties but poor loss temperature would not affect attenuation. The dielectric properties of the cooling fluid also affect the frequency determining properties of the wave propagating structure. An increase in the dielectric constant is equivalent to increasing the dispersion and thereby reducing the overall bandwidth of the device. The frequency characteristics are affected if the dielectric constant of the coolant is high compared to that of the dielectric or ceramic materials employed for the insulating supports. In most instances where the space requirements dictate that the insulating support members be relatively short, a very low loss cooling liquid such as silicone oil or any of the flurochemical liquids, for example, Dow Corning's DC–200 or Minnesota Mining and Manufacturing Company's FC–75 may be employed without adversely affecting the electrical properties. The additional advantage incorporated in the present invention is the means for introducing attenuation losses where desired along specific predetermined portions of the wave propagating structure simply by using a lossy coolant such as water in certain sections of the wave propagating structure. Attenuation can also be achieved in an alternative manner by coating the insulating support members with a lossy material which will rapidly absorb any thermal energy. Since the cooling fluid traverses through the insulating members, the exceedingly high thermal energy absorbed therein will be rapidly removed.

A remaining feature of the invention to be discussed comprises a means for introducing an asymmetry in the propagation of the electromagnetic waves to thereby suppress undesired space harmonics such as the backward wave-determining component which may be coupled to the wave propagating along the helical structure. To avoid the interaction which commonly plagues traveling wave devices the wave propagating structure is deliberately dimensioned in such a manner that a stop band is located where the normally backward wave space harmonics would interact with the electron beam. The electrical parameters of the helical propagating structure are designed in such a way that the circumference of the overall helix structure at the half wavelength point has a frequency which is higher than the highest frequency in the band of operation. Referring again to the configuration of the wave advancing members **16**, **68**, **116**, **126**, and **178** in the previous illustrations, it will be noted that a flat electrically conductive member is provided. This configuration in combination with the remainder of the wave propagating structure introduces the asymmetry which results in a stop band at a frequency where the backward wave space harmonic generation adversely affects the operation of the device. In FIG. **10** the curve plotting the $\omega\beta$ characteristics of the wave propagating structure of the invention is shown with the stop band indicated in the region **186**. This stop band design will facilitate the operation of the wave propagating structure at a much higher value for *ka* which is normally at 0.25. In FIG. **11** a plot of the reflection coefficient over the frequency band of operation is shown for a working embodiment of a helical circuit structure having the inherent backward wave suppression feature. The operating range is designated by the curve **188** and the stop band by the space **190**.

There is thus disclosed a unique traveling wave electron interaction device having a propagating structure with broad bandwidth characteristics. Additionally, an external adjacent electron beam in an interaction region commonly employed in crossed field devices with its high power generation capability provides for a very high efficiency device incorporating the inherent advantages of both M- and O-type structures. Thermal and electrical considerations are considered substantially independent of one another with a principally parallel thermal dissipation circuit with its measurably increased cooling efficiency combined with an electrically continuous wave propagating structure for advancing the electromagnetic wave energy to yield power outputs heretofore unattainable in electron discharge devices of the prior art. The periodic wave propagating structure provides a means for the more efficient thermal dissipation over regions of electron interaction yielding the highest thermal problems. Suppression of undesired space harmonics, as well as means for providing attenuation through selective utilization of cooling fluids, provide still further advantages in a unitary device. Some modifications and alterations in the pertinent structures have been heretofore described in detail and numerous other modifications will be readily apparent to those skilled in the art. It is intended, therefore, that the foregoing illustrative embodiments and detailed description be considered in its broadest aspects and not in a limiting sense.

What is claimed is:

1. In combination:

means for directing a beam of electrons along a predetermined interaction path;

means for propagating electromagnetic wave energy adjacent to said path in energy exchanging relationship with said beam;

said propagating means comprising predetermined groupings of a plurality of hollow periodic parallel disposed circuit elements with each of said elements having at least one end supported by nonelectrically-conductive means;

an electrically conductive member interconnecting adjacent elements to advance said wave energy; and

means for circulating a cooling fluid through said circuit elements;

said groupings of circuit elements being serially interconnected to provide programmed thermal dissipation over selected regions of said propagating means.

2. A periodic electromagnetic wave propagating structure comprising:

a plurality of parallel disposed hollow circuit elements in a cooling array with predetermined programmed groupings of said elements for intense thermal energy dissipation over a selected portion of the overall length of the structure;

said elements being supported by nonelectrically-conductive means;

said groupings of circuit elements being serially interconnected;

an electrically conductive member interconnecting adjacent elements to advance said wave energy; and

means for circulating a cooling fluid through said circuit elements.

3. The wave propagating structure according to claim 2 wherein said grouping of elements for more intense thermal energy dissipation covers a minor portion of the overall structure length.

4. A crossed field electron interaction device comprising:

an envelope;

a periodic electromagnetic wave energy propagating structure;

an electrode coextensive with and spaced from said structure to define an interaction path;

means for generating and directing a beam of electrons along said path in energy exchanging relationship with said wave energy traveling along said structure;

crossed electric and magnetic fields disposed with said interaction path;

said wave propagating structure comprising predetermined groupings of a plurality of hollow periodic parallel disposed circuit elements each supported by nonelectrically conductive means; and

an electrically conductive member for providing electrical circuit continuity interconnecting adjacent elements;

output means for coupling energy appended to one end of said propagating structure; and

means for circulating a cooling fluid through said circuit elements;

said groupings of circuit elements being serially interconnected to provide for programmed more intense thermal energy dissipation over selected regions of said propagating structure.

5. The device according to claim 4 wherein one region provides for more intense thermal energy dissipation over approximately one-third of the overall length of said propagating structure adjacent to the output energy coupling end.

6. The device according to claim 4 wherein said region of more intense thermal energy dissipation is coupled to separate means for circulating a cooling fluid independently of the remainder of the wave propagating structure.

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