Nov. 30, 1965 S. SENSIPER 3,221,205

TRAVELING-WAVE TUBE WITH TRAP MEANS FOR PREVENTING OSCILLATION AT UNWANTED FREQUENCIES

Filed May 23, 1962 4 Sheets-Sheet 1

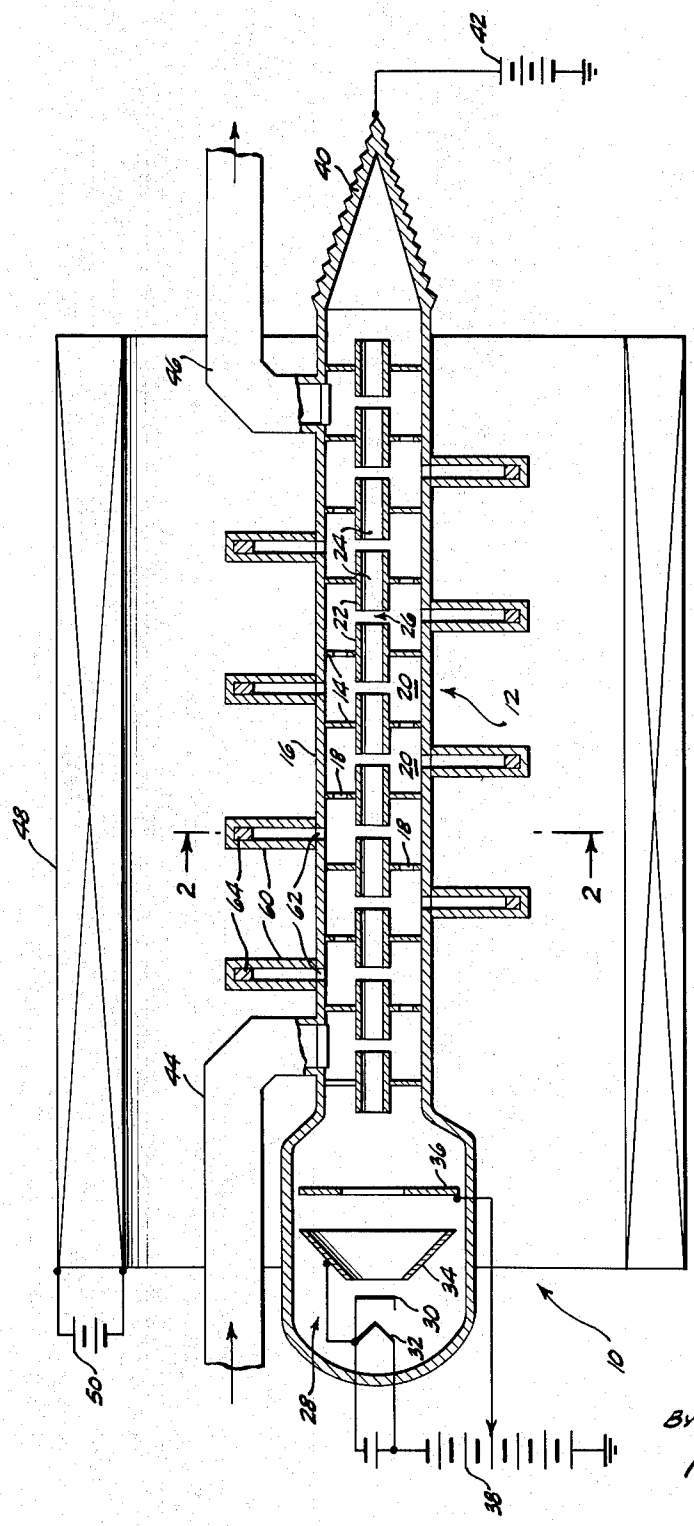


FIG. 1.

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Filed May 23, 1962 4 Sheets-Sheet 2

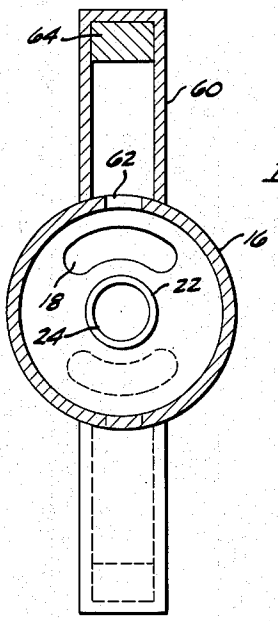


FIG. 2.

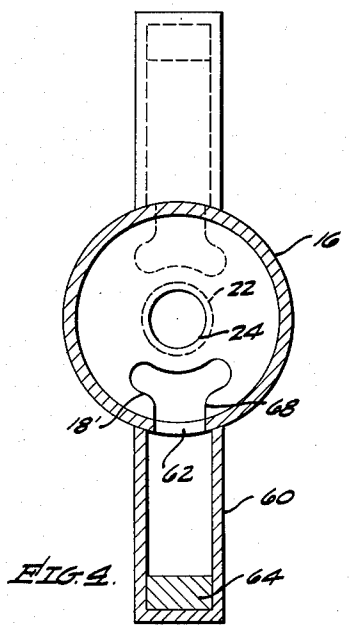


FIG. 4.

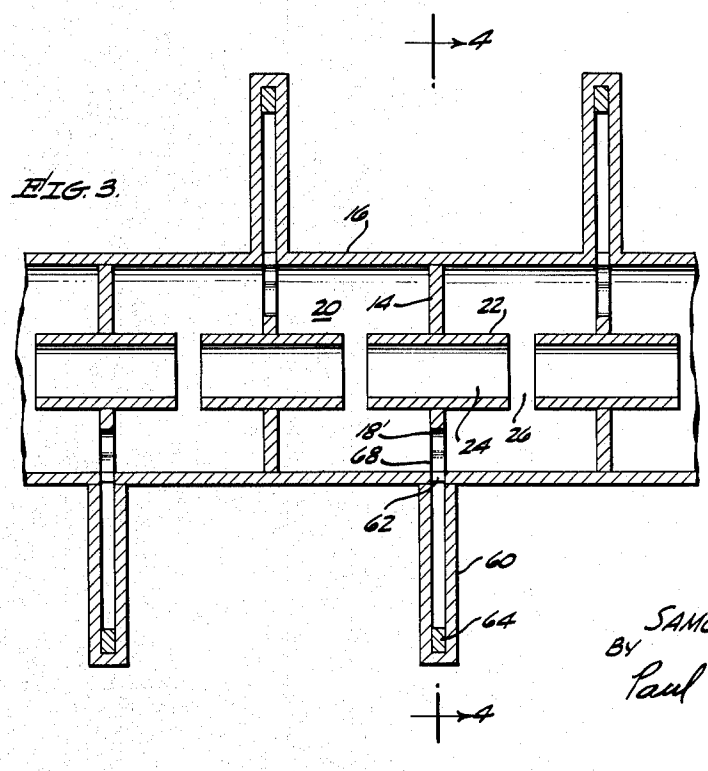


FIG. 3.

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TRAVELING-WAVE TUBE WITH TRAP MEANS FOR PREVENTING OSCILLATION AT UNWANTED FREQUENCIES

Filed May 23, 1962 4 Sheets-Sheet 3

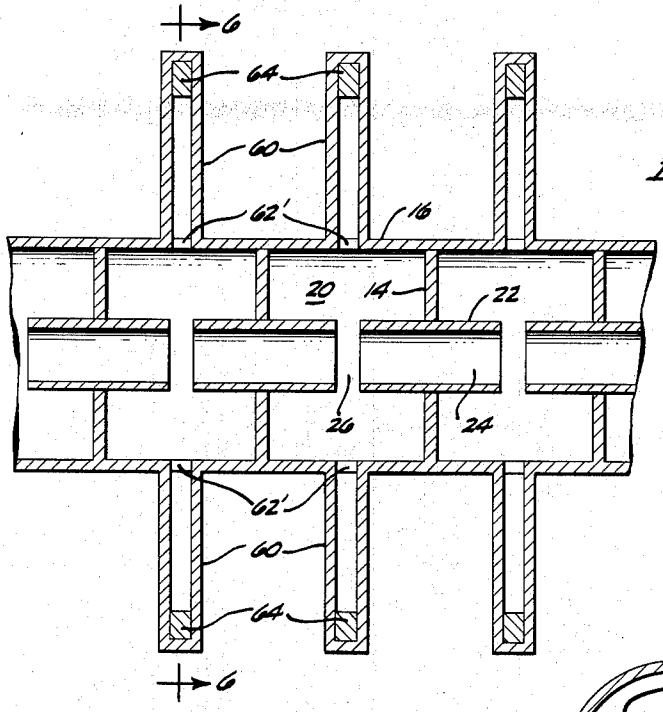


FIG. 5.

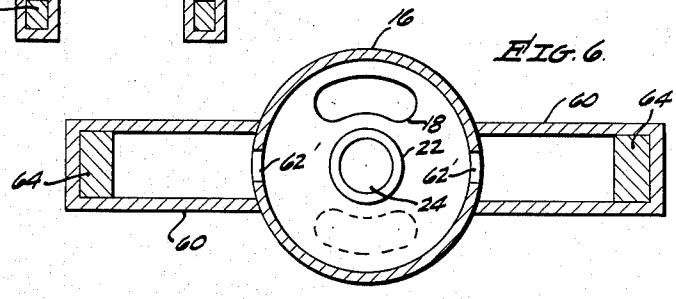


FIG. 6.

FIG. 10.

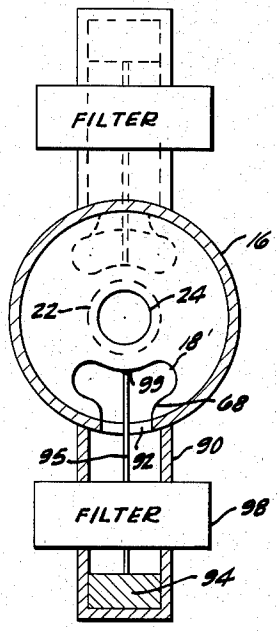


FIG. 7.

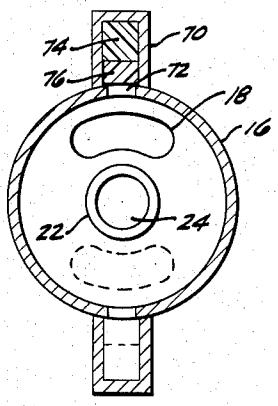
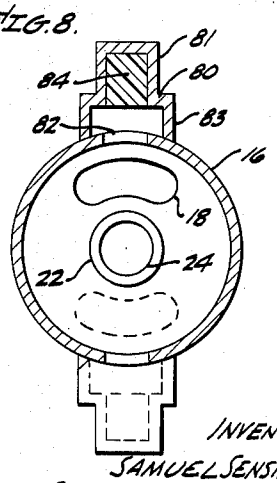


FIG. 8.



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TRAVELING-WAVE TUBE WITH TRAP MEANS FOR PREVENTING OSCILLATION AT UNWANTED FREQUENCIES

Filed May 23, 1962 4 Sheets-Sheet 4

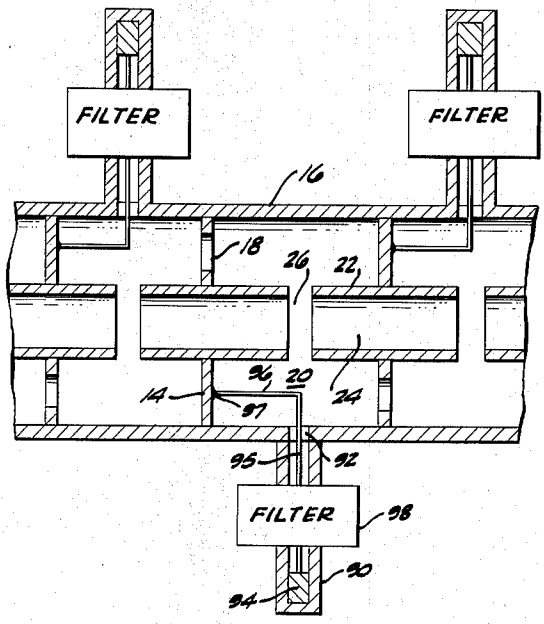


FIG. 9.

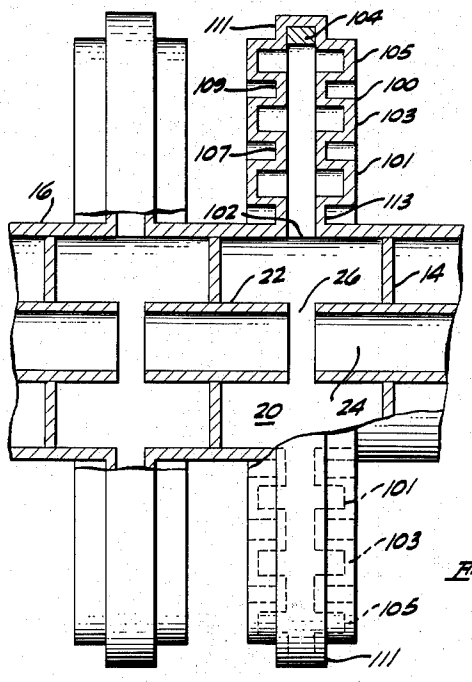


FIG. 11.

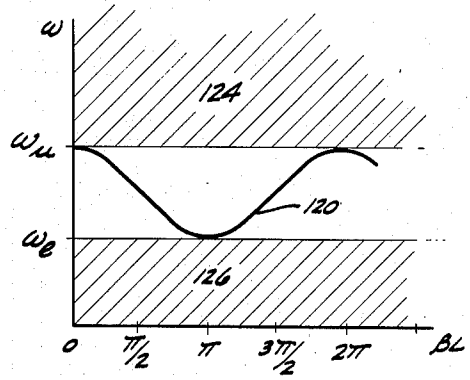


FIG. 12.

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United States Patent Office 3,221,205
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3,221,205

TRAVELING-WAVE TUBE WITH TRAP MEANS FOR PREVENTING OSCILLATION AT UNWANTED FREQUENCIES

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Filed May 23, 1962, Ser. No. 196,937
15 Claims. (Cl. 315—3.5)

This invention relates generally to microwave devices, and more particularly relates to traveling-wave tubes having means for substantially eliminating oscillations throughout a predetermined frequency range, such as frequencies equal to and greater than the upper cutoff frequency of the tube passband, or frequencies equal to and below the tube's lower cutoff frequency.

In traveling-wave tubes a stream of electrons is caused to interact with a propagating electromagnetic wave in a manner which amplifies the electromagnetic energy. In order to achieve such interaction, the electromagnetic wave is propagated along a slow-wave structure, such as a conductive helix wound about the path of the electron stream or a folded waveguide type of structure in which a waveguide is effectively wound back and forth across the path of the electrons. The slow-wave structure provides a path of propagation for the electromagnetic wave which is considerably longer than the axial length of the structure, and hence, the traveling wave may be made to effectively propagate at nearly the velocity of the electron stream. The interactions between the electrons in the stream and the traveling wave cause velocity modulations and bunching of electrons in the stream. The net result may then be a transfer of energy from the electron beam to the wave traveling along the slow-wave structure.

The present invention is primarily concerned with traveling-wave tubes utilizing slow-wave structures of the folded waveguide type, which structures are also known as the coupled cavity, or interconnected cell type. In this type of slow-wave structure a series of interaction cells, or cavities, are disposed adjacent to each other sequentially along the axis of the tube. The electron stream passes through each interaction cell, and electromagnetic coupling is provided between each cell and the electron stream. Each interaction cell is also coupled to an adjacent cell by means of a coupling hole at the end wall defining the cell. Generally, the coupling holes between adjacent cells are alternately disposed on opposite sides of the axis of the tube, although various other arrangements for staggering the coupling holes are possible and have been employed. When the coupling holes are so arranged, a folded waveguide type of energy propagation results, with the traveling-wave energy traversing the length of the tube by entering each interaction cell from one side, crossing the electron stream, and then leaving the cell from the other side, thus traveling a sinuous, or serpentine, extended path.

One of the problems encountered in traveling-wave tubes of the coupled cavity variety, and especially high power tubes of this type, is a tendency for the tube to oscillate at frequencies near the edges of the tube passband, and in particular at the upper cutoff frequency of the passband. This problem arises from the fact that for wideband operation, the phase velocity of the slow-wave circuit wave and the velocity of the electron beam should be essentially synchronized over as large a range of frequencies as possible; hence, these velocities are also close to synchronism near the upper and lower cutoff frequencies of the tube. Since the interaction impedance is high and the circuit-to-transmission line match is poor at and in the vicinity of the cutoff frequencies, the loop gain for the tube, or even for a section of the tube, may be sufficiently large for oscillations to start.

It is, therefore, an object of the present invention to provide a coupled cavity traveling-wave tube in which any tendency for the tube to oscillate in the vicinity of the cutoff frequencies, and in particular the upper cutoff frequency, of the frequency passband of the tube is substantially eliminated.

A further oscillation problem in high power coupled cavity traveling-wave tubes is the prevention of oscillations at frequencies in higher order passbands of the slow-wave circuit which may occur on account of interaction between the electron beam and higher order slow-wave circuit modes.

Accordingly, it is a further object of the present invention to provide a coupled cavity traveling-wave tube having means for suppressing oscillations not only at the upper cutoff frequency of the tube's fundamental passband but also in the higher order passbands of the tube.

It is sometimes desired to operate a traveling-wave tube in a higher order passband of the slow-wave circuit rather than in the fundamental slow-wave circuit mode which is customarily used. When operating in such higher order modes, interaction between the electron beam and slow-wave circuit modes below the mode desired to be used may be troublesome from an oscillation standpoint.

Therefore, it is a still further object of the present invention to provide a coupled cavity traveling-wave tube designed to operate in a higher order slow-wave circuit mode having means for suppressing oscillations not only at the lower cutoff frequency of the operating mode but also in the lower order passbands of the slow-wave circuit.

The above and other objects are achieved by the present invention by providing a traveling-wave tube including means for launching a stream of electrons along a predetermined path of fixed length and a coupled cavity slow-wave structure disposed along and about the electron stream path for propagating an electromagnetic wave in such manner as to provide interaction between the electron stream and the electromagnetic wave. Filters with high, low or bandpass characteristics are coupled to selected interaction cavities of the slow-wave structure for propagating electromagnetic waves of frequencies in desired ranges. Loss is disposed in each filter for attenuating the electromagnetic waves propagating therethrough and thereby terminating the filter. By selectively directing this high or low frequency electromagnetic wave energy out of the slow-wave structure and attenuating it, oscillations in the vicinity of the cutoff frequencies of the desired passband and throughout undesired passbands are suppressed.

Additional objects, advantages, and characteristic features of the present invention will become readily apparent from the following detailed description of preferred embodiments of the invention when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic view, primarily in longitudinal section, of a traveling-wave tube constructed in accordance with the present invention;

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a longitudinal sectional view of a portion of a traveling-wave tube illustrating another embodiment of the present invention.

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 3;

FIG. 5 is a longitudinal sectional view, in a plane rotated 90° with respect to FIG. 1, of a portion of a traveling-wave tube constructed according to a further embodiment of the present invention;

FIG. 6 is a cross-sectional view taken along line 6—6 of FIG. 5;

FIGS. 7 and 8, respectively, are cross-sectional views, similar to FIG. 2, illustrating still further embodiments of the present invention;

FIG. 9 is a longitudinal sectional view, similar to FIG. 3, of a still further embodiment of present invention;

FIG. 10 is a cross-sectional view, similar to FIG. 2, illustrating still another embodiment of the present invention;

FIG. 11 is a longitudinal sectional view, partly in elevation, illustrating a still further embodiment of the invention; and

FIG. 12 is an ω-β graph used in explaining the theory of the present invention.

Referring with more particularity to the drawings, in FIG. 1 there is shown a traveling-wave tube **10** in which a coupled cavity slow-wave structure **12** is utilized for propagating microwave energy in a serpentine path about an electron beam traveling along the longitudinal axis of the tube **10**. The slow-wave structure **12** comprises a series of circular vane members, or plates, **14** which are disposed perpendicular to the longitudinal axis of the tube **10** and are mounted in a cylindrical waveguide **16** which serves as an envelope for the slow-wave structure **12**. The vane members **14**, as well as the envelope **16**, are composed of a nonmagnetic electrically conductive material, such as copper or brass. The vanes **14** are disposed at spaced points along the envelope **16** to provide a series of interaction cells, or cavities, **20**. Each cavity **20** is defined by the walls of the two adjacent vanes **14** and that portion of the inner surface of the waveguide **16** located between these two vanes. Adjacent cavities **20** are interconnected by means of an off-center coupling hole **18** provided through the intermediate vane **14** to permit the transfer of microwave energy from cell to cell along the slow-wave structure **12**. As is illustrated, the coupling holes **18** may be substantially kidney-shaped and may be alternately disposed 180° apart with respect to the longitudinal axis of the tube, although the coupling holes **18** may be of other shapes and may be staggered in other arrangements well known in the art.

Each vane **14** defines a drift tube, or ferrule, **22** in its central region. The drift tube **22** is in the form of a cylindrical extension, or lip, protruding axially along the path of the electron stream from both surfaces of the vane **14**, i.e., in both directions normal to the plane of the vane **14**. The drift tubes **22** are provided with centrally and axially aligned apertures **24** to provide a passage for the flow of the electron beam. Adjacent ones of the drift tubes **22** are separated by an interaction gap **26** in which enregy exchange between the electron stream and microwave energy traversing the slow-wave structure occurs.

At one end of the slow-wave structure **12** there is disposed a conventional electron gun **28** which may include an electron emitting cathode **30** and filamentary heater **32**. The emitted electrons are shaped and focused into a beam by a focusing electrode **34** and are accelerated to a high velocity of accelerating anode **36**. A voltage source **38** is tapped at appropriate potentials, as shown, to provide operating voltages for the electrodes **30**, **34** and **36**.

A collector electrode **40** is disposed at the opposite end of the slow-wave structure **12** to intercept the stream of electrons and dissipate their kinetic energy. A source of potential **42** is connected to the collector **40** to bias the collector **40** positive to prevent secondarily emitted electrons from the slow-wave structure **12** from returning to the interaction region, thereby reducing noise and other interference.

An input waveguide **44** is connected to the input end of the slow-wave structure **12** which, although illustrated as the electron gun end in FIG. 1, may alternately be the collector end if a backward wave device is desired. The waveguide **44** is connected to external circuitry (not shown) and serves to carry microwaves to be amplified to the input end of the slow-wave structure **12**. Similarly, an output waveguide **46** is connected to the opposite end of the slow-wave structure **12** for propagating the amplified microwaves from the slow-wave structure to external circuitry (not shown). A solenoid **48**, energized by a source of potential **50**, is disposed concentrically about and substantially coextensive with the slow-wave structure **12** for providing a longitudinal focusing magnetic field which constrains the electron beam to flow in an axial path toward the collector electrode **40**.

As has been mentioned above, one of the problems in prior art traveling-wave tubes of the type described is a tendency of the tube to oscillate at the upper cutoff frequency of the tube's fundamental passband and in higher order frequency passbands. The present invention solves this oscillation problem by coupling high pass filters to various points along the slow-wave circuit and by providing in the high pass filters sufficient attenuation to substantially dissipate the elctromagnetic waves traversing the filters. Thus, electromagnetic waves having a frequency above a preselected frequency are directed into the high pass filters and dissipated therein, while waves having a frequency below the preselected frequency continue to propagate along the slow-wave structure.

As is shown in FIGS. 1 and 2, waveguides **60**, which are disposed externally of the slow-wave structure **12** and extend in directions perpendicular to the longitudinal axis of the tube **10**, are coupled to respective interaction cavities **20** of the slow-wave structure **12** through respective coupling apertures **62** in the waveguide **16**. The dimensions of the waveguides **60** are selected so that waves having frequencies less than the upper cutoff frequency ω_u of the fundamental pass band of the traveling wave tube **10** will not propagate along the waveguides **60**, whereas the waveguides **60** will support the propagation of waves having frequencies equal to and greater than ω_u. Although the waveguides **60** are illustrated as being rectangular in cross-section, it is to be understood that they may be of other geometry, so long as they possess the desired high pass filter charatceristics. Moreover, the waveguides need not be alternately disposed on opposite sides of the envelope **16** as shown in FIG. 1, but other arrangements are possible, for example, aligning the waveguides **60** on one side of the slow-wave structure **12**.

The waveguides **60** are terminated by locating attenuators **64** in the ends of the waveguides **60** remote from the coupling apertures **62**. The attenuators **64** may be blocks of a lossy ceramic material, such as a mixture of fosterite and silicon carbide, with the percentage of silicon carbide varying from essentially 50% to essentially 80%. The attenuators **64** serve to dissipate the microwave energy traversing the waveguides **60**, with a minimum amount of such energy being reflected back into the interaction cavities **20**. Alternately, the necessary attenuation may be provided by coating the inner walls of the waveguides **60** with a lossy material, for example kanthal.

The location of the coupling apertures **62** along the slow-wave structure **12** may be selected to ensure maximum coupling into the waveguides **60** for those frequencies which it is most desired to attenuate. For example, for maximum excitation in the waveguides **60** of higher order modes originated on account of the coupling holes **18** in the cavity-defining plates **14**, the waveguides **60** may be coupled directly to the coupling holes **18** rather than to the cavities **20**. Such an arrangement is shown in FIGS. 3 and 4. In this embodiment modified coupling holes, or indentations, **18'** are provided in the plates **14**. Each hole **18'** has a portion **68** extending radially outwardly of the kidney-shaped portion to the outer circumference of the plate **14**. The width of the extended portion **68** of the coupling hole **18'** is made equal to that of the coupling aperture **62** in the envelope **16** and is of a value which ensures maximum coupling of electromagnetic waves of the desired frequencies into the adjacent waveguides **60**.

Although the embodiments heretofore described employ only a single high pass filter for each interaction cavity, two or more attenuating waveguides per cavity may be utilized. One arrangement in which two attentuating waveguides **60** are employed for each interaction cavity **20** is illustrated in FIGS. 5 and 6. In this embodiment a pair of coupling holes **62'** are provided at points 180° apart along the circumference of that portion of the envelope **16** which, in conjunction with a pair of adjacent transverse plates **14**, defines an interaction cavity **20**. As is illustrated, the coupling holes **62''** are preferably axially located in the center of the cavity **20**, i.e., aligned with the interaction gap **26**. High pass filter waveguides **60**, containing attenuators **64**, are disposed externally of the envelope **16** adjacent the coupling holes **62'** and extend in directions perpendicular to the longitudinal axis of the tube. The waveguides **60** and attenuators **64** function to propagate and attenuate microwave energy of frequencies equal to and greater than ω_u.

Although the oscillation suppressing high pass filter arrangements heretofore described are especially suitable for use in solenoid focused tubes, where ample space is provided between the solenoid and the slow-wave structure to accommodate relatively long waveguides, the principles of the present invention are also applicable to traveling-wave tubes employing permanent magnetic focusing systems. However, for the latter type of focusing, and especially periodic permanent magnetic focusing, conservation of space becomes an important consideration. In the embodiments shown in FIGS. 7 and 8 the amount of space required for the terminated high pass filters is minimized, and hence, these embodiments are especially suitable for employment in periodically focused tubes.

In the embodiment of FIG. 7 waveguides **70** of shorter length and smaller cross-section than the waveguides **60** of FIGS. 1–6 are coupled to the respective interaction cavities by means of coupling apertures **72** in the slow-wave structure envelope **16**. Each waveguide **70** contains material having a high dielectric constant in order to increase the effective waveguide length as seen by the microwaves traversing the waveguide **70**. More specifically, a pair of blocks **74** and **76** of a high dielectric constant material, such as alumina, are contiguously disposed in the waveguide **70**. The cross-sections of the blocks **74** and **76** are essentially the same as that of the waveguide **70**, and the sum of the lengths of the blocks substantially equals the length of the waveguide **70** so that the waveguide is essentially completely filled with dielectric material. A high percentage of loss is added to the dielectric block **74** more remote from the coupling hole **72** to ensure proper termination of the waveguide **70**, while the block **76** adjacent the coupling hole **72** contains little or no loss to avoid introduction of loss in the tube passband. For example, the block **74** may consist of a mixture of alumina and silicon carbide, with the percentage of silicon carbide varying from essentially 50% to essentially 80%; while the block **76** may consist of a mixture of the same materials, but with the percentage of silicon carbide varying from essentially zero to essentially 10%. It should be understood that more than two dielectric blocks may be disposed in the waveguide **70**, with the percentage of lossy material in the respective blocks increasing with increases in distance from the coupling hole **72**.

The embodiment of FIG. 8 is a design affording a compromise between minimization of space and maximization of coupling into the high pass filters. Each high pass filter comprises a waveguide **80** constructed with a first portion **81** of relatively small cross-section remote from the slow-wave structure and a second portion **83** of larger cross-section adjacent the slow-wave structure cavity to which it is coupled by means of a coupling aperture **82** in the envelope **16**. A block **84**, which may be of the same material as the block **74** of FIG. 7, is disposed in and essentially completely fills the smaller waveguide portion **81** to attenuate the wave energy propagating along the waveguide **80**, thereby terminating the waveguide.

As has been mentioned above, when prior art traveling-wave tubes of the type described are operated in higher order passbands, there is a tendency for the tube to oscillate in lower order slow-wave circuit modes. The present invention solves this oscillation problem by coupling low pass filters to various points along the slow-wave circuit and by providing in the low pass filters sufficient attenuation to substantially dissipate the electromagnetic waves traversing the filters. Thus, electromagnetic waves below a preselected frequency are directed into the low pass filters and dissipated therein, while waves above the preselected frequency continue to propagate along the slow-wave structure.

In the embodiment illustrated in FIG. 9 the oscillation suppression low pass filters comprise coaxial transmission lines **90** coupled to the respective interaction cavities **20** via coupling apertures **92** in the envelope **16**. Each coaxial line **90** is terminated by a lossy ceramic block **94**, which may be of the same material as the terminations **64** of FIGS. 1–6. The inner conductor **95** of each coaxial line **90** is bent within the cavity **20** to provide a portion **96** essentially parallel to the traveling-wave tube axis, and the end of the conductor **96** remote from the termination **94** is connected to a cavity-defining plate **14**, for example by welding or soldering at region **97**. The coaxial transmission line **90** propagates electromagnetic waves between zero frequency and an upper cutoff frequency. Preferably, the upper cutoff frequency of the coaxial line **90** is selected so that waves of frequencies higher than the lower cutoff frequency ω_1 of the used passband of the traveling-wave tube **10** will not propagate along the transmission line **90**, whereas the line **90** will support the propagation of waves of frequencies equal to and less than ω_1. However, in certain cases it may be necessary to insert a conventional high pass or band pass filter **98** in the transmission line **90** between the coupling hole **92** and the termination **94** to ensure that the line **90** will only pass eenrgy in a desired frequency range or ranges.

The embodiment illustrated in FIG. 10, which also employs coaxial transmission lines **90**, is similar to the arrangement of FIG. 9 except that the waveguides **90** are coupled to the slow-wave circuit at points immediately adjacent the interaction cavity coupling holes **18** rather than the interaction cavties **20**. More specifically, modified coupling holes **18'**, similar to those of FIG. 4, are provided in the plates **14** with radially outwardly extending portions **68** located adjacent the coupling apertures **92** in the envelope **16**. The inner conductor **95** of each coaxial line **90** extends directly into the coupling hole **18'** and is conected to the wall of the hole **18'** nearest the drift tube **22** at region **99**. Again, it may be necessary to provide high pass or band pass filters **98** in the coaxial line **90** extends directly into the coupling hole quencies will propagate along the lines **90**.

In the embodiment of FIG. 11 the low pass filters comprise radial transmission lines **100** coupled to the interaction cavities **20** of the slow-wave structure **12**. Each transmision line **100** is disposed about and axially aligned with the tubular envelope **16**. Higher order pass bands in desired frequency ranges are introduced into the radial transmission line **100** by constructing the line **100** with a plurality of alteranting portions of relatively large and small cross-section in a plane passing through thee longitudinal axis of the tube **10**. Thus, in the illustrative example of FIG. 11 each transmission line **100** defines portions **101**, **103** and **105** of enlarged longitudinal cross-section which are separted by portions **107** and **109**, respectively, of smaller cross-section. A termination ring **104** is disposed in outermost small portion **111** of the line **100**, and innermost small portion **113** of the line **100**

is coupled to the interaction cavity **20** by coupling aperture **102** in the envelope **16**.

The theory behind the present invention will now be explained with reference to FIG. 12. In this figure there is shown an ω-β diagram in which the frequency ω of microwaves traversing the traveling-wave tube **10** is plotted as a function of the phase constant β multiplied by the periodic length L of the slow-wave structure **12**. The frequency-phase characteristic of the slow-wave circuit **12** of the traveling-wave tube **10** is represented by the curve **120**, and it will be seen that the slow-wave circuit will propagate microwaves between its lower cutoff frequency ω_l and its upper cutoff frequency ω_u. In order to prevent upper band edge and higher order mode oscillations, a loss band **124** is introduced into the traveling-wave tube by means of the terminated high pass filters described above to attenuate electromagnetic waves of frequencies equal to and above ω_u, but which will leave substantially unimpaired the propagation of microwaves of frequencies below ω_u along the slow-wave structure. Similarly, lower band edge and lower order mode oscillations are suppressed by a loss band **126** which is provided by the terminated low pass filter arrangements described above to attenuate electromagnetic waves of frequencies equal to and below ω_l.

It should be pointed out that the high and low loss bands **124** and **126**, respectively, may be introduced into a traveling-wave tube simultaneously, for example by coupling terminated waveguides (such as **60** of FIG. 1) to some of the interaction cavities of the traveling-wave tube and coupling terminated coaxial transmission lines (such as **90** of FIG. 9) to other interaction cavities.

Although the present invention has been shown described with reference to specific embodiments, numerous modifications or alterations which are obvious to one skilled in the art may be made therein without departing from the spirit, scope and contemplation of the invention as set forth in the appended claims.

I claim:

1. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means disposed along and about said path for propagating electromagnetic wave energy within a predetermined frequency range having an upper cutoff frequency and a lower cutoff frequency in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, and loss-containing high pass filter means coupled to said slow-wave structure means for absorbing electromagnetic wave energy frequencies not lower than substantially said upper cutoff frequency.

2. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means disposed along and about said path for propagating electromagnetic wave energy within a predetermined frequency range having an upper cutoff frequency and a lower cutoff frequency in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, and loss-containing low pass filter means coupled to said slow-wave structure means for absorbing electromagnetic wave energy of frequencies not higher than substantially said lower cutoff frequency.

3. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, an electrically conductive envelope disposed about and axially aligned with said path, a plurality of electrically conductive plates mounted perpendicular to said path at spaced points along said envelope to define therewith a plurality of cavities, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities whereby a propagation path is provided for electromagnetic wave energy within a predetermined frequency range in a manner to provide interaction between said electron stream and said electromagnetic wave energy, said envelope defining coupling apertures adjacent selected ones of said cavities, a waveguide disposed perpendicular to said path and externally of each of said selected cavities adjacent the said coupling aperture associated therewith, each said waveguide having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in each said waveguide adjacent its end remote from said coupling aperture for attenuating the electromagnetic wave energy therein.

4. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, an electrically conductive envelope disposed about and axially aligned with said path, a plurality of electrically conductive plates mounted perpendicular to said path at spaced points along said envelope to define therewith a plurality of cavities, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling indentations in regions radially outwardly of said central regions for interconnecting adjacent cavities whereby a propagation path is provided for electromagnetic wave energy within a predetermined frequency range in a manner to provide interaction between said electron stream and said electromagnetic wave energy, said envelope defining coupling apertures adjacent selected ones of said coupling indentations, a waveguide disposed externally of said envelope and perpendicular to said path adjacent each said coupling aperture therein, each said waveguide having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in each said waveguide adjacent its end remote from the said coupling aperture associated therewith for attenuating the electromagnetic wave energy therein.

5. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled cavities disposed sequentially along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, a waveguide disposed externally of and coupled to at least one of said cavities, said waveguide having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, a first element having a high dielectric constant disposed in said waveguide adjacent the end of said waveguide remote from the region of coupling to said one of said cavities, and a second element having a high dielectric constant disposed in said waveguide between said first element and said region of coupling, said first element containing a lossy material.

6. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled cavities disposed sequentially along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, a waveguide disposed externally of and coupled to at least one of said cavities, said waveguide having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and a plurality of elements of a mixture of dielectric and lossy material disposed in said waveguide in respective regions thereof of differing distance from the region of coupling to said one of said cavities, the percentage of lossy material in the respective ones of said elements increasing with increases in distance from said region of coupling.

7. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled cavities disposed sequentially along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, a waveguide disposed externally of and coupled to at least one of said cavities, said waveguide having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range and having a first portion of given cross-section adjacent the region of coupling to said one of said cavities and a second portion of smaller cross-section than said first portion externally of said first portion, and a loss-containing element having a high dielectric constant disposed in said second portion of said waveguide.

8. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled cavities disposed sequentially along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, a coaxial transmission line disposed externally of and coupled to at least one of said cavities, said transmission line having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in said transmission line for attenuating the electromagnetic wave energy therein.

9. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, an electrically conductive envelope disposed about and axially aligned with said path, a plurality of electrically conductive plates mounted perpendicular to said path at spaced points along said envelope to define therewith a plurality of cavities, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities whereby a propagation path is provided for electromagnetic wave energy within a predetermined frequency range in a manner to provide interaction between said electron stream and said electromagnetic wave energy, said envelope defining coupling apertures adjacent selected ones of said cavities, a coaxial transmission line disposed externally of said envelope adjacent each said coupling aperture therein, the inner conductor of each said transmission line extending through said coupling aperture and into the adjacent cavity and being attached to one of said plates defining said cavity, said transmission line having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in each said transmission line for attenuating the electromagnetic wave energy therein.

10. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, an electrically conductive envelope disposed about and axially aligned with said path, a plurality of electrically conductive plates mounted perpendicular to said path at spaced points along said envelope to define therewith a plurality of cavities, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further definng coupling indentations in regions radially outwardly of said central regions for interconnecting adjacent cavities whereby a propagation path is provided for electromagnetic wave energy within a predetermined frequency range in a manner to provide interaction between said electron stream and said electromagnetic wave energy, said envelope defining coupling apertures adjacent selected ones of said coupling indentations, a coaxial transmission line disposed externally of said envelope adjacent each said coupling aperture therein, the inner conductor of each said transmission line extending through said coupling aperture and the adjacent coupling indentation and being attached to the wall of said coupling indentation nearest said central aperture in said plate defining said coupling indentation, said transmission line having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in each said transmission line for attenuating the electromagnetic wave energy therein.

11. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means defining a plurality of intercoupled cavities disposed sequentially along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, a radial transmission line concentrically disposed about and coupled to at least one of said cavities, said radial transmission line extending outwardly from said slow-wave structure means in a plane perpendicular to said path and having a frequency passband for electromagnetic wave energy substantially different from and not encompassing said predetermined frequency range, and loss means disposed in said radial transmission line for attenuating the electromagnetic wave energy therein.

12. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, an electrically conductive tubular envelope disposed about and axially aligned with said path, a plurality of electrically conductive plates mounted perpendicular to said path at spaced points along said envelope to define therewith a plurality of cavities, said plates defining aligned apertures in their central regions to provide a passage for said electron stream and further defining coupling holes in regions radially outwardly of said central regions for interconnecting adjacent cavities whereby a propagation path is provided for electromagnetic wave energy within a predetermined frequency range in a manner to provide interaction between said electron stream and said electromagnetic wave energy, said envelope defining coupling apertures adjacent selected ones of said cavities, a radial transmission line disposed about and axially aligned with said tubular envelope adjacent each said coupling aperture in said envelope, said radial transmission line having frequency passabands for electromagnetic wave energy within preselected frequency ranges each substantially different from and not encompassing said predetermined frequency range and having alternating portions of smaller and larger cross-section in a plane containing the longitudinal axis of said tubular envelope, and loss means disposed in each said radial transmission line adjacent its end remote from the said coupling aperture associated therewith for attenuating the electromagnetic wave energy therein.

13. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means disposed along and about said path for propagating electromagnetic wave energy within a predetermined frequency range in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, and loss-containing waveguide means coupled to said slow-wave structure means for absorbing electromagnetic wave energy within a preselected frequency range substantially different from and not encompassing said predetermined frequency range.

14. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means disposed along and about said path for propagating electromagnetic wave energy within

a predetermined frequency range having an upper cutoff frequency and a lower cutoff frequency in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, and loss-containing waveguide means coupled to said slow-wave structure means for absorbing electromagnetic wave energy within a preselected frequency range extending substantially from one of said cutoff frequencies to a frequency outside of said predetermined frequency range.

15. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means disposed along and about said path for propagating electromagnetic wave energy within a predetermined frequency range having an upper cutoff frequency and a lower cutoff frequency in such manner as to provide interaction between said electron stream and said electromagnetic wave energy, and non-magnetic reciprocal loss-containing waveguide means coupled to

said slow-wave structure means for absorbing electromagnetic wave energy within a preselected frequency range extending substantially from one of said cutoff frequencies to a frequency outside of said predetermined frequency range.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,221,205 November 30, 196!

Samuel Sensiper

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 50, for "enregy" read -- energy --; column 5, line 11, for "62′′′" read -- 62′ --; column 6, line 48, for "cavties" read -- cavities --; line 54, for "conected" read -- connected --; line 57, for "line 90 extends directly into the coupling hole" read -- lines 90 to ensure that only waves of desired fre- --; line 67, for "alteranting" read -- alternating --; same column 6, line 68, for "thee" read -- the --; column 7, line 33, after "shown" insert -- and --; line 50, after "energy" insert -- of --.

Signed and sealed this 11th day of October 1966.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

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