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

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

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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 intensifies 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 cavity, 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 select the interaction cavities of the traveling-wave tube 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 its 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;
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 an undesired 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 electromagnetic waves traversing the filters. Thus, electromagnetic waves having a frequency above a preselected frequency are directed into the high pass filters and dissipated, while waves having a frequency below the preselected frequency continue to propagate along the slow-wave structure.

As is shown in FIG. 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 waveguides 62 in the waveguide 16. The dimensions of the waveguides 60 are selected so that waves having frequencies less than the upper cutoff frequency 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 $\omega_0$. 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 characteristics. 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 ferrite 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, 19' are provided in the plates 14. Each hole 19' 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 attenuating waveguides 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 36. High pass filters 64, 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 f1.

Although the oscillation suppressing high pass filter arrangements heretofore described are especially suitable for use in sonofocused tubes, where ample space is provided between the sonof and the slow-wave structure to accommodate relatively long waveguides, the present invention is applicable to many other microwave 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 microwave waves traversing the waveguide 70. More specifically, a pair of blocks 74 and 76 of a high dielectric constant material, such as alumina, are contiguous 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 increase 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 at 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 f1 of the used passband of the traveling-wave tube 10 will not propagate along the transmission line 99, whereas the line 90 will support the propagation of waves of frequencies equal to and less than f1. 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 energy 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 cavities 20. More specifically, modified coupling holes 19, similar to those of FIG. 4, are provided in the plates 14 with radially out 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 connected 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 transmission 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 alternating portions of relatively large and small cross-section in a plane passing through the 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 charged and a second portion 109 of uncharged cross-section which are separated 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 $\omega-\beta$ diagram in which the frequency $\omega$ of microwaves traversing the traveling-wave tube 10 is plotted as a function of the phase constant $\beta$ 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 $\omega_0$ and its upper cutoff frequency $\omega_c$. 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 $\omega_0$, but which will leave substantially unimpeded the propagation of microwaves of frequencies below $\omega_0$ 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 $\omega_0$.

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 along 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 high pass filter means coupled to said slow-wave structure means for attenuating electromagnetic wave energy within a pre-determined 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 perpendicularly to said path and externally of each of said selected cavities adjacent the said coupling aperture associated therewith, 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.

3. A traveling-wave tube comprising: means for providing a stream of electrons along a predetermined path, slow-wave structure means for forming 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 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.

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 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 pre-determined 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 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 for forming 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 for forming 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 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.
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 loss means disposed in said transmission line for attenuating the electromagnetic wave energy therein.

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 radial transmission line concentrically disposed about and coupled to at least one of said cavities, 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.

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, axial 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.

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, radial transmission line disposed about and having axially aligned with said tunnel envelope each said coupling aperture in said envelope, radial transmission line having frequency passbands 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 tunnel 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 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.
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.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,221,205

November 30, 1966

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 "energy" read -- energy --;
column 5, line 11, for "62""" read -- 62' --;
column 6, line 48, for "cavities" read -- cavities --;
line 54, for "connected" 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 "alternating" 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

EDWARD J. BRENNER
Commissioner of Patents