April 19, 1960 L. BRÜCK ET AL 2,933,637

TRAVELING WAVE TUBE

Filed May 25, 1954 3 Sheets-Sheet 1

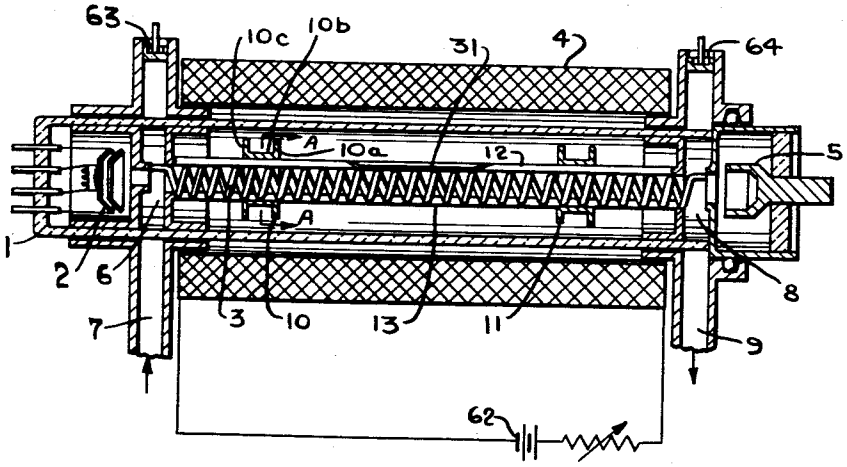


Fig 1

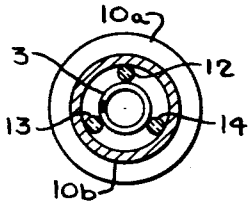


Fig 2

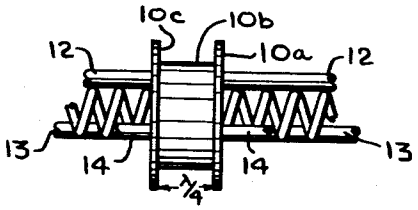


Fig 3

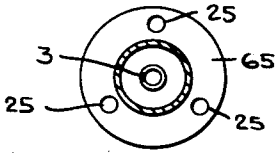


Fig 4

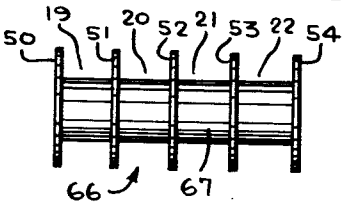


Fig 5

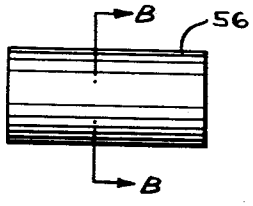


Fig 6

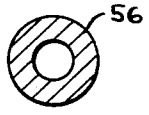


Fig 7

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TRAVELING WAVE TUBE

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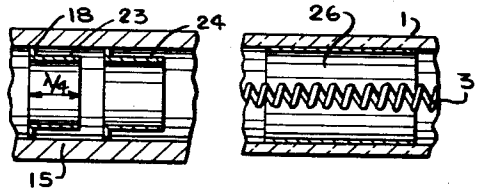


Fig 8 Fig 9

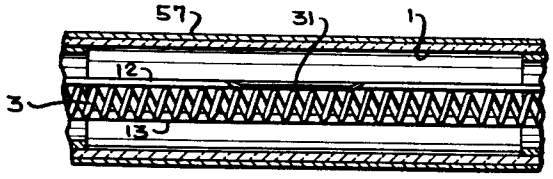


Fig 10

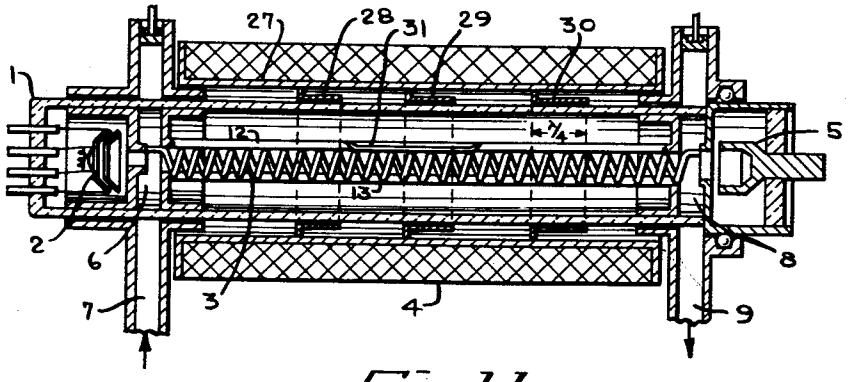


Fig 11

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TRAVELING WAVE TUBE

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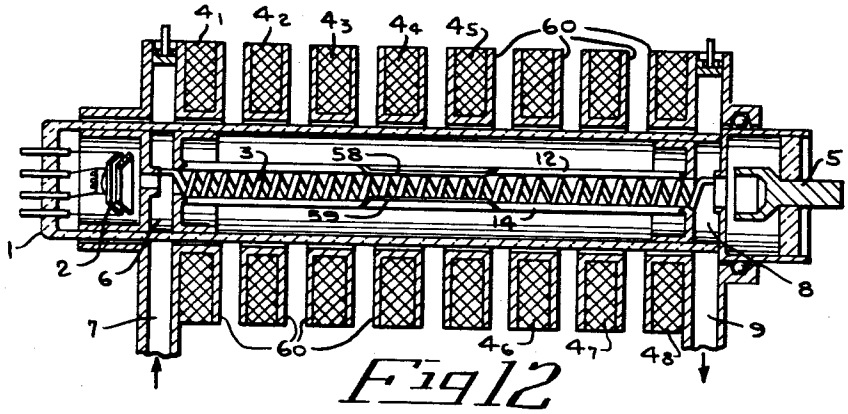


Fig 12

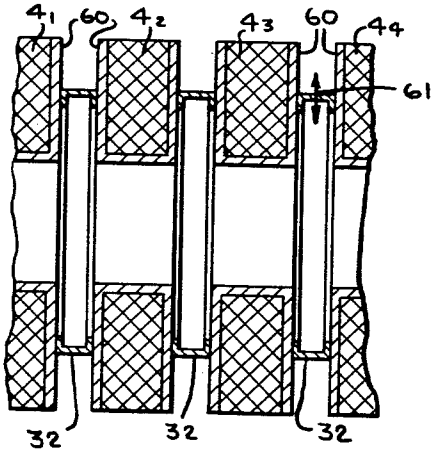


Fig 13

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United States Patent Office 2,933,637 Patented Apr. 19, 1960

2,933,637

TRAVELING WAVE TUBE

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Application May 25, 1954, Serial No. 432,238

Claims priority, application Germany June 5, 1953

10 Claims. (Cl. 315—3.5)

The present invention relates to a traveling wave tube and more particularly to one of improved mechanical stability.

As is well known, a traveling wave tube consists of an evacuated closure containing an electron gun, a delay line means having an input end and an output end, and an electron collector. The delay line means is usually supported by a plurality of ceramic or glass rods. In order to focus the electron beam there is provided an elongated coil coaxial with the evacuated closure which produces an electromagnetic field parallel to the electron stream causing the latter to pass through the delay line.

In order to obtain optimum performance it has been necessary up to the present time to position the envelope of the traveling wave tube relatively close to the delay line and the beam focusing coil very close to the envelope. The resultant tube structure is relatively long and narrow and consequently is very easily damaged.

It might appear that the above disadvantage could readily be overcome by increasing the diameter of the tube envelope. However, attempts in this direction have not met with success. When the diameter of the envelope is increased there is produced an annular space between the delay line and the coil surrounding the envelope which provides a path for the propagation of feedback electromagnetic wave energy from the output end to the input end of the line. This feedback of energy, both periodic and aperiodic, occurs both within and without the operating range of the tube and seriously affects the performance of the traveling wave tube by causing spurious noise and distortion.

There are, of course, known in the art means for preventing the reflection of energy from the output end to the input end of the delay line of a traveling wave tube. Such means may comprise a plurality of rods surrounding the delay line, one or more of the rods having a strip of lossy material secured to the outer surface thereof in close proximity to the delay line as described in co-pending application Serial No. 408,965, now Patent No. 2,820,171, dated January 14, 1958, titled Traveling Wave Tube, filed February 8, 1954, by Anton Lauer, one of the joint applicants of the present invention. Such reflection also may be reduced by winding the delay line of a wire having considerable loss, or applying a coating of graphite to a short section of one or more of the non-conducting rods in which the delay line may be supported. None of the above means however are adequate to suppress the feedback of electromagnetic wave energy through the annular space which is present in the tube when the diameter of the envelope is increased and so, up to the present time, it has continued to be necessary to make the tube envelope very narrow and consequently relatively fragile.

It is object of the present invention to provide a traveling wave tube having an envelope of substantially increased diameter and therefore of very sturdy construction without the disadvantage of undesirable feedback of electromagentic wave energy through the increased annular space between the magnetic focusing coil and the delay line.

In accordance with the invention there is provided in a traveling wave tube an elongated delay line means having an input end and an output end. An elongated envelope coaxial with the delay line forms an airtight closure therefor. In a preferred embodiment of the invention the diameter of the envelope is at least three times that of the delay line. The traveling wave tube is provided with an elongated electron beam focusing means such as a coil coaxial with the elongated envelope, the delay line means and beam focusing means defining therebetween an annular space providing a path for the propagation of feedback electromagnetic wave energy from the output end to the input end of the delay line means. And attenuation means are provided located either inside or outside of the tube envelope for substantially eliminating the feedback of electromagnetic wave energy through the annular space.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a cross-sectional view of one embodiment of a traveling wave tube in accordance with the invention;

Fig. 2 is an enlarged cross-section through line A—A of Fig. 1;

Fig. 3 is an enlarged side-view of a portion of the traveling wave tube illustrated in Fig. 1;

Fig. 4 is a cross-sectional view of an attenuation device in accordance with the invention for suppressing the feedback of wave energy through the annular space between the magnetic focusing coil and delay line of a traveling wave tube;

Fig. 5 is a side-view of another type of attenuation device usable with the present invention;

Fig. 6 is a side-view of yet another attenuation device usable with the present invention;

Fig. 7 is a cross-section along line B—B of Fig. 6;

Fig. 8 is a cross-sectional view through a traveling wave tube in accordance with still another embodiment of the present invention;

Fig. 9 is a cross-sectional view through a portion of a traveling wave tube in accordance with yet another embodiment of the present invention;

Fig. 10 is a cross-sectional view through a portion of a traveling wave tube of another embodiment of the present invention;

Fig. 11 is a cross-sectional view of another embodiment of a traveling wave tube in accordance with the present invention;

Fig. 12 is a cross-sectional view of still another embodiment of a traveling wave tube in accordance with the present invention; and

Fig. 13 is a cross-sectional view of a portion of a traveling wave tube which is a modification of the tube illustrated in Fig. 12.

In the figures like reference numerals refer to like elements.

Referring now to the drawings and more particularly to Fig. 1 there is shown a traveling wave tube including a glass envelope 1, an electron gun arrangement 2 located at one end of the glass envelope, and a delay line 3 having an input end close to the electron gun and an output end close to the collector 5. The electron beam produced by electron gun 2 is focused into a beam by means of magnetic focusing coil 4 which is energized by a source of direct current 62. As can be seen from

the drawing, in order to make the tube structure mechanically sturdy, the diameter of the tube envelope is considerably increased, being at least three times that of the diameter of delay line 3.

Electromagnetic wave energy is fed to the traveling wave tube through wave guide 7 and is coupled to the delay line in coupling space 6. For tuning purposes there is provided a conventional tuning plunger 63. The output of the traveling wave tube is taken from space 8 between the discs forming the output coupling structure and is transmitted to a load by means of wave guide 9. As in the case of the input circuit, the output circuit is provided with a plunger 64 for tuning purposes. In order to attenuate the feedback of energy along the delay line itself there is provided a plurality of elongated rods 12, 13, 14 symmetrically arranged about the delay line and one or more of these rods is provided with a strip shaped band of lossy material 31 such as graphite. The function of these rods and the strip or strips of lossy material thereon is explained in more detail in the co-pending application mentioned above.

As can be seen in Fig. 1, because the glass envelope 1 is made of increased diameter, there is a considerable annular space between the delay line and the coaxial magnetic focusing coil 4. This space acts as a wave guide, providing a convenient path for the feedback of electromagnetic wave energy both within and outside of the frequency range of the traveling wave tube from the output end of the delay line to the input end thereof.

The applicants have discovered that this feedback can be substantially eliminated by positioning one or more elements 10, 11 along the length of the delay line, these elements being shown in greater detail in Figs. 2 and 3. Each of the elements comprises a spool-shaped member such as 10, for example, formed with a body portion 10*b* of a given diameter and a pair of disc-shaped end walls 10*a*, 10*c*, at the respective ends of the body portion having a diameter substantially larger than that of the body portion. Each spool-shaped member is formed with a central, axial aperture therethrough and is located coaxially with the delay line. The end walls are spaced apart a quarter wave length or odd multiple thereof at the frequency of the electromagnetic wave energy fed back through the annular space and form wave traps for attenuating said electromagnetic wave energy.

In the embodiment of the invention illustrated in Fig. 1, only two spool-shaped members are shown. It is to be understood, however, that the invention is equally applicable to three or more spool-shaped members. It is also to be understood that the arrangement may be made extremely broad-banded by tuning each wave trap to a different frequency within the range of feedback energy anticipated. This can be done by adjusting the spacing between end walls so that this spacing is one quarter wave length or an odd multiple thereof at different frequencies within the feedback frequency range.

Instead of the arrangement illustrated in Figs. 1–3 there can be used instead an attenuating device such as shown in Fig. 4. This comprises a plurality of members 65 arranged coaxially about delay line 3 and formed with a plurality of apertures 25 therein to which the ceramic rods 12, 13 and 14 may be attached. These rods form a convenient means for supporting members 65 and also a means on which attenuating strips may be secured. As in the embodiment of Figs. 1–3, members 65 are separated by one quarter wave length or odd multiple thereof at the frequency of, or at different frequencies within, the range of electromagnetic feedback energy propagated through the annular space between the magnetic focusing coil and the delay line. Members 65 act as resonant windows and form a plurality of series resonant circuits.

Fig. 5 illustrates another embodiment of an attenuating device usable in the traveling tube shown in Fig. 1 instead of wave traps 10, 11. This device comprises a member 66 having a hollow cylindrical body portion 67 and a plurality of disc-shaped wall portions 50–54 of a diameter substantially larger than that of the body portion and arranged coaxially with the body portion. Member 66 is arranged symmetrically with the rods 12, 13, 14 when it is in use in the traveling wave tube. End walls 50–54 define therebetween a plurality of cavity resonator structures 19–22 which, depending upon the spacing between the respective walls are tuned to one or more frequencies within the range of the electromagnetic wave feedback energy propagated through the annular space between the magnetic focusing coil and the delay line. As in the previously described embodiments, the various cavity resonators act as wave-suppression devices and eliminate substantially all undesired feedback energy.

Still another embodiment of the present invention is illustrated in Figs. 6 and 7, consisting of a hollow, cylindrical, non-magnetic, conductive element which, in operation, is positioned coaxially about the delay line along the length thereof. The wall thickness of the cylinder is so chosen that the dimensions of the annular space through which feedback of energy would normally occur are reduced beyond the point at which this space will support the propagation of energy.

Fig. 8 illustrates another embodiment of the invention in which a metal envelope 15 is employed. For the purposes of illustration the delay line is not shown. However, the delay line is at the center of the envelope. Symmetrically arranged within the envelope are a plurality of cylindrical members 23, 24, each forming a wave trap. The frequency to which the trap is tuned depends upon the dimensions of the trap, in this case, the axial length of the cylinder. The wave traps may be tuned to one or more frequencies within the feedback range as in the case of the previous embodiments.

Fig. 9 illustrates still another embodiment of the invention, this one used especially advantageously in the case of a traveling wave tube having a glass envelope. Here, in order to attenuate the feedback of energy in the annular space between delay line 3 and glass envelope 1, there is provided an annular coating 26 of a lossy substance such as graphite or the like on the inner surface of the envelope. Coating the envelope on the inner surface has the advantage that the coating is not subject to wear and accordingly has a relatively long life.

The arrangement of Fig. 9 is equally applicable to the case in which the coating of lossy material is applied to the outer surface of the glass envelope. Such an arrangement is illustrated in Fig. 10 wherein it is seen that the outer surface of the glass envelope 1 is provided with a layer 57 of lossy material.

Fig. 11 illustrates a traveling wave tube similar in many respects to the arrangement of Fig. 8. It includes a focusing coil 4 wound upon a non-magnetic conductive spool 27, the spool and delay line 3 defining therebetween an annular space providing a path for the propagation of feedback electromagnetic energy from the output end to the input end of the delay line. In order to attenuate this feedback energy, there are provided a plurality of hollow cylindrical elements 28, 29 and 30 externally of glass envelope 1. As in the foregoing embodiments, the cylinders act as wave traps tuned to a frequency or frequencies in the range of feedback frequencies. The frequency to which each cylinder is tuned depends upon the axial length of the cylinder which should be a quarter wavelength long or odd multiple thereof, at the frequency it is desired to attenuate.

In Fig. 12 the attenuation device consists of the magnetic focusing coil itself. Rather than being wound as a single elongated coil, the coil is formed of a plurality of individual coils 4_1–4_8, each coil being wound upon its own spool 60. The spaces between the individual coil members form a plurality of resonant gaps and act as a plurality of tuned series circuits providing substan-

tial attenuation to the feedback of energy. In the embodiment of Fig. 9, rather than having a single strip shaped band of lossy material on one of the ceramic supporting rods, two of the rods are provided with graphite layers 58, 59. As already explained, these layers have very little effect, however, on the feedback of energy through the annular space between focusing coil sections and the delay line.

For tuning purposes, the arrangement of Fig. 12 may be provided with a plurality of annular rings 32 as illustrated in Fig. 13 which tune the gaps to one or more of the frequencies within the range of the feedback electromagnetic wave energy. In a preferred embodiment of the invention, these rings are made adjustable in radial direction as indicated by the arrow 61. By means of these tuning rings, the traveling wave tube can be made extremely broad-banded with respect to the attenuation of feedback energy.

In some embodiments of the invention actually constructed it has been found possible to attain an attenuation of feedback energy from the output end to the input end of the delay line through the annular space between the delay line and the focusing coil on the order of 15–20 decibels and to obtain traveling wave tube performance substantially equivalent to the performance of conventional long-narrow tubes.

In all of the embodiments of the invention described above the diameter of the tube envelope is at least three or more times greater than that of the delay line.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of traveling wave tubes differing from the types described above.

While the invention has been illustrated and described as embodied in a traveling wave tube employing a helical delay line supported by a plurality of elongated ceramic rods, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a traveling wave tube, in combination, elongated delay line means having an input end and output end for the transmission of electromagnetic waves in a preselected frequency range therethrough; an elongated evacuated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space having an outer diameter substantially larger than that of said delay line means providing a path for the feedback of electromagnetic wave energy from said output and to said input end of said delay line means located within said annular space; and axially adjustable attenuation means and comprising a plurality of wave traps within said annular space tuned to at least one predetermined frequency of said electromagnetic wave energy for substantially suppressing spurious noise and distortion caused by said electromagnetic wave energy propagated at least within said preselected frequency range through said annular space.

2. In a traveling wave tube, in combination, elongated delay line means having an input end and output end for the transmission of electromagnetic waves in a preselected frequency range therethrough; an elongated evacuated envelope coaxial with said delay line means and forming an air-tight closure therefor, said envelope having a diameter throughout its entire extent at least three times that of said delay line means; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable attenuation means located within said annular space and comprising a plurality of wave traps within said annular space tuned to at least one predetermined frequency of said electromagnetic wave energy for substantially suppressing spurious noise and distortion caused by said electromagnetic wave energy propagated at least within said preselected frequency range through said annular space.

3. In a traveling wave tube, in combination, elongated delay line means having an input end and output end for the transmission of electromagnetic waves in a preselected frequency range therethrough; an elongated evacuated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space having an outer diameter substantially larger than that of said delay line means providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable attenuation means located in the portion of said annular space within said envelope and comprising a plurality of wave traps within said annular space tuned to at least one predetermined frequency of said electromagnetic wave energy for substantially suppressing spurious noise and distortion caused by said electromagnetic wave energy propagated at least within said preselected frequency range through said annular space.

4. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable attenuation means located in the portion of said annular space within said envelope for substantially eliminating said feedback of electromagnetic wave energy through said annular space comprising at least one spool-shaped member formed with a body portion of a given diameter and a pair of disc-shaped end walls at the respective ends of said body portion having a diameter substantially larger than that of said body portion, said member being formed with a central, axial aperture therethrough and being coaxial about said delay line means, and said disc-shaped end walls being spaced apart a distance equivalent to one quarter wave length at the frequency of said electromagnetic wave energy.

5. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy within a given frequency range from said output end to said input end of said delay line means; and axially adjustable attenuation means located in said annular space for substantially eliminating said

feedback of electromagnetic wave energy through said annular space comprising a plurality of spool-shaped members, each formed with a body portion of a given diameter and a pair of disc-shaped end walls at the respective ends of said body portion having a diameter substantially larger than that of said body portion, each of said members being formed with a central, axial aperture therethrough and being coaxial about said delay line means, said members being spaced from one another along the length of said delay line means, and said disc-shaped end walls of each of said members being respectively spaced distances apart which are equivalent to one quarter wave length of a frequency within said given frequency range.

6. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor, said envelope having a diameter throughout its entire extent at least three times that of said delay line means; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy within a given frequency range from said output end to said input end of said delay line means; and axially adjustable attenuation means located in the portion of said annular space within said envelope for substantially eliminating said feedback of electromagnetic wave energy through said annular space comprising a plurality of spool-shaped members, each formed with a body portion of a given diameter and a pair of disc-shaped end walls at the respective ends of said body portion having a diameter substantially larger than of said body portion, each of said members being formed with a central, axial aperture therethrough and being coaxial about said delay line means, said members being spaced from one another along the length of said delay line means, and said disc-shaped end walls of each of said members being spaced different distances apart, said distances being equivalent to one quarter wave length at different frequencies within said given frequency range.

7. In a traveling wave tube, in combination, elongated delay line means having an input and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable attenuation means located in the portion of said annular space within said envelope for substantially eliminating said feedback of electromagnetic wave energy through said annular space comprising a member having a hollow cylindrical body portion of a given diameter and a plurality of disc-shaped wall portions of a diameter substantially larger than that of said body portion coaxial with said body portion and extending perpendicularly therefrom along the length of said body portion, said member being coaxial with said delay line means, and said disc-shaped walls being spaced apart in axial direction of said body portion a distance equivalent to an odd multiple of one quarter wave length at the frequency of said electromagnetic wave energy.

8. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy within a given frequency range from said output end to said input end of said delay line means; and axially adjustable attenuation means located in the portion of said annular space within said envelope for substantially eliminating said feedback of electromagnetic wave energy through said annular space comprising a member having a hollow cylindrical body portion of a given diameter and a plurality of disc-shaped wall portions of a diameter substantially larger than that of said body portion coaxial with said body portion and extending perpendicularly therefrom along the length of said body portion, said member being coaxial with said delay line means, and said disc-shaped walls being spaced apart in axial direction of said body portion distances from an odd multiple of one another equivalent to one quarter wave length at different frequencies within said given frequency range.

9. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated evacuated envelope coaxial with said delay line means and forming an air-tight closure therefor, said envelope having a diameter at least three times that of said delay line means, said envelope and delay line means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable quarter wave resonator means comprising a plurality of wave traps within said envelope tuned to at least one predetermined frequency of said electromagnetic wave energy for substantially suppressing spurious noise and distortion caused by said electromagnetic wave energy propagated through said annular space.

10. In a traveling wave tube, in combination, elongated delay line means having an input end and output end; an elongated envelope coaxial with said delay line means and forming an air-tight closure therefor; elongated electron beam focusing means coaxially surrounding said elongated envelope, said delay line means and beam focusing means defining therebetween an annular space providing a path for the feedback of electromagnetic wave energy from said output end to said input end of said delay line means; and axially adjustable attenuation means in said annular space for substantially eliminating said feedback of electromagnetic wave energy through said annular space comprising at least one spool-shaped member formed with a body portion of a given diameter and a pair of disc-shaped end walls at the respective ends of said body portion having a diameter substantially larger than that of said body portion, said member being formed with a central, axial aperture therethrough and being coaxial about said delay line means, and said disc-shaped end walls being spaced apart a distance equivalent to one-quarter wave length at the frequency of said electromagnetic wave energy.

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