Nov. 16, 1965 J. ARNAUD ETAL 3,218,582

DELAY LINE STRUCTURE

Filed April 24, 1961

Fig_1

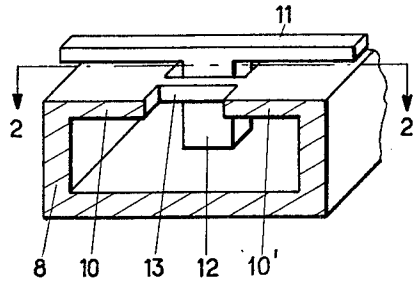
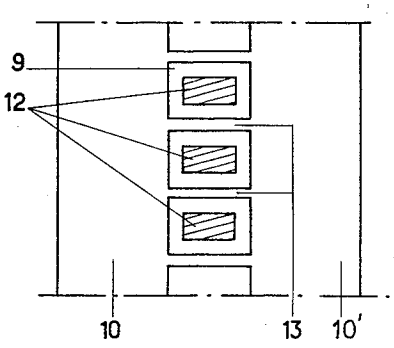


Fig_2



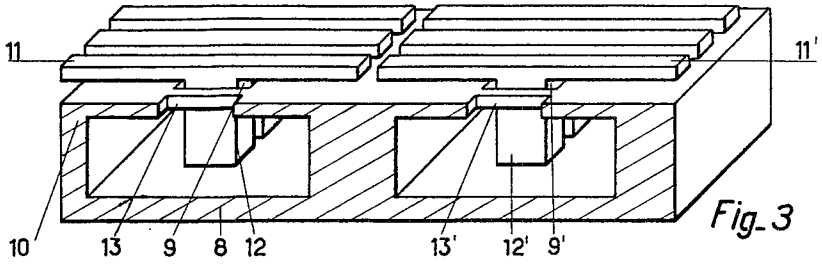


Fig_3

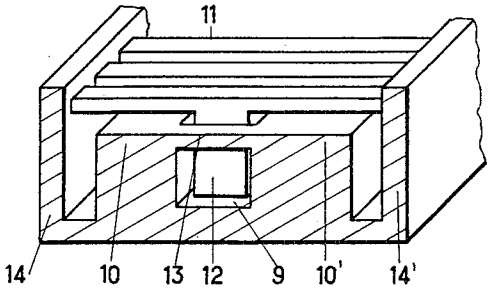


Fig_4

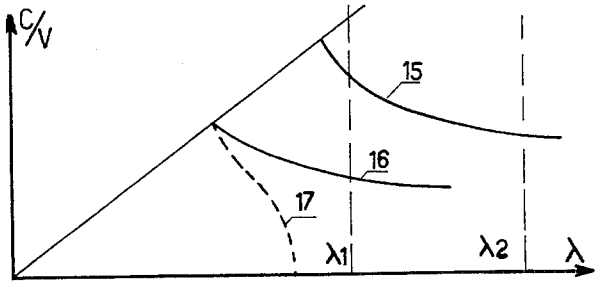


Fig_5

INVENTORS
J. ARNAUD et C. RENAUD

BY Craig and Freudenberg
ATTORNEYS

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DELAY LINE STRUCTURE

Jacques Arnaud and Claude Renaud, Paris, France, assignors to Compagnie Generale de Telegraphie Sans Fil, Paris, France

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15 Claims. (Cl. 333—31)

The present invention relates to delay lines for travelling wave tubes, especially to delay lines constituted by at least one series of parallel bars, disposed parallelly to at least two surfaces usually called back-plates, located in a common plane and effectively separated between themselves by a slot perpendicular to the bars.

The foregoing definition encompasses as well lines of which the individual elements have the shape of a simple or multiple T in conformity, respectively, with FIGURES 4 and 8 of the U.S. patent application Serial No. 793,835, filed by Jacques Arnaud et al., on February 17, 1959, and entitled "Delay Line for Travelling Wave Tubes" now Patent No. 3,086,180, issued April 16, 1963, as lines obtained by juxtaposition alongside one another of several ladder type delay lines with a conducting backplate in conformity with FIGURE 3 of the U.S. Patent No. 2,920,227 of O. Dohler et al., of which the elements then have the form of a multiple π.

In these known prior art delay lines, the wave which propagates along the delay line according to the symmetric mode is utilized for the interaction with the electron beam, whereby the symmetric mode refers to a symmetric distribution of the high frequency potential with respect to the median plane of the bar. However, it is known that in addition to this symmetric mode, the delay lines of the type in question are also the seat of propagation of at least one parasitic anti-symmetric mode which propagates on the wave lengths of the useful band corresponding to the utilization of the symmetric mode, and which impairs in an undesirable manner the proper functioning of the tube.

Accordingly, it is an object of the present invention to provide a delay line effectively freed of this inconvenience and shortcoming, which is realized in such a manner that the band of wave lengths of propagation of the anti-symmetric mode or modes essentially do not fall into the band of wave lengths of the symmetric mode.

Another object of the present invention resides in the provision of a delay line structure for high power travelling wave tubes which is mechanically sturdy and robust and which lends itself readily to the dissipation of large quantities of heat normally generated in high power tubes.

A further object of the present invention resides in the provision of a wave retardation structure which effectively displaces the anti-symmetric modes outside the band of wave lengths in which functions the symmetric desired mode.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, several embodiments in accordance with the present invention, and wherein—

FIGURE 1 is a perspective view of a delay line in accordance with the present invention utilizing T-shaped delay elements;

FIGURE 2 is a plan view with the cross section taken along line 2—2 of FIGURE 1,

FIGURE 3 is a perspective view, similar to FIGURE 1, of a modified embodiment of a delay line structure in accordance with the present invention utilizing a double-T arrangement,

FIGURE 4 is a perspective view, similar to FIGURE 1, of still a further modified embodiment of a delay line structure in accordance with the present invention utilizing a double π arrangement, and

FIGURE 5 is a diagram illustrating the dispersion curves for a delay line structure in accordance with the present invention, given herein only to explain the advantages of the present invention.

According to the present invention, a line constituted by at least a series of parallel bars, disposed parallelly to at least two walls or back-plates located in a common plane and effectively separated between themselves by a slot perpendicular to the bars, is characterized by at least one short-circuiting bridge connecting the edges of the slot and disposed in one of the spaces between consecutive bars of the series of the line.

When several bridge portions are provided, the same may form between themselves a periodic sequence, and in one particular case of the present invention, the periodicity thereof may be equal to that of the bars.

The theory as well as experiments have indicated that these bridge portions only affect very slightly the dispersion curve of the symmetric mode, but that, in contrast thereto, they exert a very strong influence on the dispersion curve of each of the anti-symmetric modes, the latter curve or curves becoming more steep and ceasing essentially to fall within the band occupied by the dispersion curve of the symmetric mode.

The bridge portions may be made either of good conductive metal or resistant material, or may also be covered by an attenuation. This resistance or attenuation provides a supplementary contribution to the elimination of the anti-symmetric mode owing to the absorption exercised thereby.

Referring now to the drawing wherein like reference numerals are used throughout the various views to designate corresponding parts, and more particularly to FIGURES 1 and 2 which represent, respectively, a perspective view and a plan view taken along the plane of line 2—2 of FIGURE 1, the delay line illustrated in these figures represents, in its entirety, a T-shaped structure essentially similar to FIGURE 4 of the aforementioned copending application Serial No. 793,835. This delay line includes a rectangular wave guide **8** of which the upper wall **10** is effectively slotted at **9**, and forms also two back-plates **10** and **10'** located in a common plane and effectively separated by the slot **9**. Parallelly to these back-plates **10** and **10'** and perpendicular to the slot **9** extend the bars such as **11**, each forming part of an element in the shape of a T, of which the leg portion **12** extends through the slot **9** and is secured along the bottom of the guide **8** in any suitable manner. The T-shaped elements **11** form a regular sequence or series which imparts the characteristic of geometric periodicity to the delay structure.

According to the present invention, at least one metallic short-circuiting bridge **13** connects the edges of the slot **9**. For example, it is within the purview of the present invention to adopt a periodic series of bridges in which each bridge is disposed within the interval between two consecutive leg portions **12**.

FIGURE 3 which illustrates a modified embodiment of the present invention essentially analogous to the structure of FIGURE 8 of the aforementioned copending application Serial No. 793,835, and which, in effect, represents, next to one another, two delay line systems of FIGURE 1 of the instant application forming an assembly with elements of double-T shape having bars **11** and **11'** and the leg portions **12** and **12'**, also shows the short circuiting bridges **13** and **13'** which connect the edges of each of the slots **9** and **9'**.

FIGURE 4 shows, in perspective view, a delay line resulting from the juxtaposition, alongside one another,

of two ladder-type lines provided with a backplate essentially according to FIGURE 3 of the aforementioned U.S. Patent No. 2,920,227. Consequently, the delay line of FIGURE 4 of the present application also includes bars designated in this figure by reference numeral **11** by analogy with the preceding figures which bars extend parallelly to the back plates **10** and **10'** and are supported again in the center thereof by the leg portions such as leg portions **12**. In contradistinction to the preceding figures, the extremities of the bars **11** are no longer free but are embedded within the lateral wall portions **14** and **14'** which themselves are connected to the back plates **10** and **10'** in any suitable manner. Consequently, the elements of this delay line structure are in the shape of a double π.

As in the preceding figures, the short-circuiting bridges **13** of the embodiment of FIGURE 4 are disposed, in accordance with the present invention, across the slot **9** between the back-plates or wall portions **10** and **10'**.

FIGURE 5 represents a dispersion diagram generally valid for the different embodiments of delay lines described hereinabove and intended to explain the effect of the bridge portions **13**. On this diagram, which indicates the delay ratio c/v (c being equal to the speed of light and v being equal to the phase velocity of the wave) as a function of the wave length λ, there has been plotted as curve **15** the dispersion curve of the symmetric mode of propagation intended for the effective utilization within the tube provided with a delay line in question, while there has been plotted by curve **16** the same curve for one of the anti-symmetric undesirable modes, whereby it is noted that a single anti-symmetric mode exists in the case of a cell in the shape of a simple T as shown in FIGURES 1 and 2 of the present application but three anti-symmetric modes exist in the cases of cells of double T or π shape as shown in FIGURES 3 and 4, and more than that in those cases of possibly multiple cells. The single curve **16** is utilized herein to simplify the explanation and is to be considered typical for each of these undesirable anti-symmetric modes. Without the bridge portions **13**, that is with known delay lines according to the aforementioned patent or patent application, it is noted that the curve **16** falls within the useful band of the curve **15**, defined, for example, between the wave lengths λ_1 and λ_2. Consequently, the anti-symmetric mode or modes impair the proper operation of the tube.

In a delay line provided with the bridge portions **13** according to the present invention, both theory and experiments clearly indicate that the position and shape of the curve **15** is very little influenced in the diagram whereas the dispersion curve of the anti-symmetric mode or modes become much greater, and the curve **16** is replaced, by the effects of the bridge portions **13**, by a curve **17** which essentially does not fall within the useful band of wave lengths. Consequently, the aforementioned shortcomings and inconveniences, namely impairment of the operation of the tube by anti-symmetric mode or modes, disappear owing to the particular arrangement in accordance with the present invention. The elimination of the anti-symmetric mode is even further accentuated if the bridge portions are made of resistant material or are covered with an attenuation as indicated hereinabove.

While the present specification refers to slots **9** and bridge portions **13**, it is understood that such terminology is used only for purposes of convenience. In practice, the bridge portions may be added after machining slots into the conductive back plates or may also be effectively formed by merely producing the apertures into which extend the leg portions **12** of the delay elements thereby providing the same effect.

While we have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of many changes and modifications in accordance with the present invention. For example, the present invention and its particular arrangement as regards the bridge portions **13** may obviously also be combined with the ridged construction of the back plates and the stepped inter-digitation of the ends of the fingers in accordance with the arrangements which form the subject matter of FIGURES 9 to 11 of the aforementioned copending application Serial No. 793,835, and which may be utilized concurrently with the present invention to improve further the separation between the useful and parasitic modes.

Thus, it is obvious that the present invention is not limited to the details shown and described herein but is susceptible of many changes and modifications within the spirit and scope of a person skilled in the art, and we, therefore, do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

We claim:

1. A delay circuit for microwaves, adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least a rung portion, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to the rung portions of said members and provided with at least one slot perpendicular to said rung portions, each delay member including a further portion extending into said slot, and bridging means across said slot for preventing the propagation in said line of an anti-symmetric mode near the operating frequencies of the desired symmetric mode, said bridging means being located between successive delay members in said alignment.

2. A delay circuit adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of essentially similar conductive delay elements providing a periodic structure and each including at least a rung portion and a leg portion, said two portions being disposed at an angle to each other in mutually different directions, plate means extending essentially parallelly to the said rung portions and effectively provided with at least one slot perpendicular to said rung portions and receiving therein the leg portions, and means in said delay structure for effectively preventing the propagation therein of an anti-symmetric mode near the operating frequencies of the desired symmetric mode including bridging means extending across said slot and located between successive delay members in said circuit.

3. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least one rung portion and a leg portion disposed at an angle to said rung portion, the two portions of each delay member being rigidly connected with each other, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to said rung portions of said members and effectively provided with at least one slot essentially perpendicular to said rung portions, bridging means across said slot for preventing the propagation in said lines of an anti-symmetric mode near the operating frequencies of the desired mode, said bridging means being located between successive delay members in said alignment, at least one series of said leg portions being arranged to pass through said slot intermediate two bridging means, and means for effectively interconnecting electrically the free extremities of said leg portions.

4. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least a rung por-

tion, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to the rung portions of said members and effectively provided with a least one slot perpendicular to said rung portions, each delay member including a further portion extending into said slot, and bridging means across said slot for preventing propagation in said line of an anti-symmetric mode near the operating frequencies of the desired mode, said bridging means being located between successive delay members in said alignment, and said delay members and said conductive plate being of highly conductive metal while said bridge means is of relatively resistant metal.

5. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least a rung portion, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to the rung portions of said members and effectively provided with a least one slot perpendicular to said rung portions, each delay member includuing a further portion extending into said slot, and bridging means across said slot for preventing propagation in said line of an anti-symmetric mode near the operating frequencies of the desired mode, said bridging means being located between successive delay members in said alignment, and being coated with an attenuating substance.

6. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least a rung portion having two free extremities and a leg portion disposed at an angle to said rung portion whereby said delay members are of approximately T-shape, the two portions of each delay member being rigidly connected with each other, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate etxending parallel to said rung portions of said members and effectively provided with at least one slot essentially perpendicular to said rung portions, bridging means across said slot for preventing the propagation in said line of an anti-symmetric mode near the operating frequencies of the desired symmetric mode, said bridging means being located between successive delay members in said alignment, at least one series of said leg portions being arranged to pass through said slot intermediate two bridging means, and means for effectively interconnecting electrically the free extremities of said leg portions.

7. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising at least one series of substantially identical conductive delay members each including at least one rung portion, conductive members connected to the extremities of said rung portion and a leg portion disposed at an angle to said rung portion so as to provide delay members of approximately multiple π shape, the two portions of each delay member being rigidly connected with each other, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to said rung portions of said members and provided with at least one slot essentially perpendicular to said rung portions, and bridging means across said slot for preventing the propagation in said line of an anti-symmetric mode near the operating frequencies of the desired symmetric mode, said bridging means being located between successive delay members in said alignment, at least one series of said leg portions being arranged to pass through said slot intermediate two bridging means, and means for effectively interconnecting electrically the free extremities of said leg portions.

8. A delay circuit for microwaves adapted to propagate therealong waves of a predetermined desired mode, comprising a plurality of series of substantially identical conductive delay members each including at least one rung portion having two free extremities and a leg portion disposed at an angle to said rung portion whereby the delay members of each series are of approximately T shape, the two portions of each delay member being rigidly connected with each other, said members being respectively located in essentially parallel periodically spaced planes and aligned in a direction at an angle to said planes, a conductive plate extending parallel to said rung portions of said members and effectively provided with a plurality of slots essentially perpendicular to said rung portions, and bridging means across said slot for preventing the propagation in said line of an anti-symmetric mode near the operating frequencies of the desired symmetric mode, said bridging means being located between successive delay members in said alignment, each respective series of said members being arranged to have its leg portions pass through one of said slots, respectively, intermediate two bridging means, and means for effectively interconnecting electrically the free extremities of said leg portions.

9. A delay line structure adapted to propagate therealong waves of a predetermined desired mode comprising a rectangular metallic wave guide having two broad and two narrow walls, one of the broad walls being provided with a longitudinal slot in the middle thereof, a number of identical equidistant metallic bars disposed outside said wave guide in close, parallel and transverse relationship to said slotted wall, each of said bars being supported in the middle thereof by a metallic support traversing said slot and fixed inside the wave guide to the other broad wall thereof, and electrical bridging means interconnecting the two halves of the slotted wall and disposed between successive bars to prevent the propagation in said lines of an anti-symmetric mode near the operating frequencies of the desired symmetric mode.

10. A delay line structure adapted to propagate therealong waves of a predetermined desired mode comprising a rectangular metallic wave guide having two broad and two narrow walls, one of the broad walls being provided with a longitudinal slot in the middle thereof, a number of identical equidistant metallic bars disposed outside said wave guide in close, parallel and transverse relationship to said slotted wall, each of said bars being supported in the middle thereof by a metallic support traversing said slot and fixed inside the wave guide to the other broad wall thereof, the length of said bars being substantially equal to the width of said broad walls, while the length of said supports is somewhat more than the width of said narrow walls, and electrical bridging means interconnecting the two halves of the slotted wall and disposed between successive bars to prevent the propagation in said lines of an anti-symmetric mode near the operating frequencies of the desired symmetric mode.

11. A delay line as claimed in claim 10, wherein the extremities of the transverse bars are free.

12. A delay line as claimed in claim 9, further comprising lateral support plates disposed on both sides of the wave guide in substantially parallel relationship to the narrow walls thereof, the extremities of the bars being fixed to said lateral support plates, respectively.

13. A delay circuit composed of two juxtaposed delay lines, each delay line being as claimed in claim 11.

14. A delay circuit composed of two juxtaposed delay lines, each of said delay lines being as claimed in claim 12.

15. A delay circuit adapted to propagate therethrough a predetermined desired mode for use in travelling wave tubes or the like, comprising a plurality of substantially similar delay elements arranged to provide a periodic structure, each delay element comprising at least two connected portions disposed at an angle to each other and extending in mutually different directions, and means operatively connected with said delay circuit for prevent-

ing the propagation in said delay circuit of an anti-symmetric mode near the operating frequencies of said desired symmetric mode including first conductive means electrically interconnecting a first portion of each delay element and second conductive means electrically connected to said first conductive means and extending at a relatively small distance from and at least over a major area of the second portion of each delay element to thereby provide a predetermined electric field distribution along both portions of each delay element, and bridging means disposed between successive first portions of said delay elements and operatively connecting said second conductive means within the area located between successive first portions of said delay elements.

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HERMAN KARL SAALBACH, *Primary Examiner.*