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J. R. WILSON

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TRAVELING WAVE DEVICE

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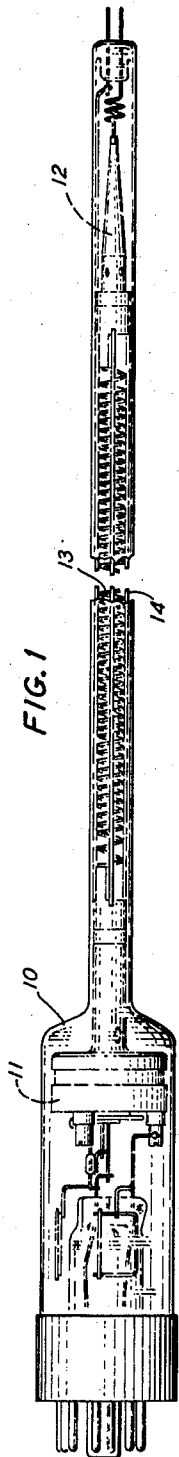


FIG. 1

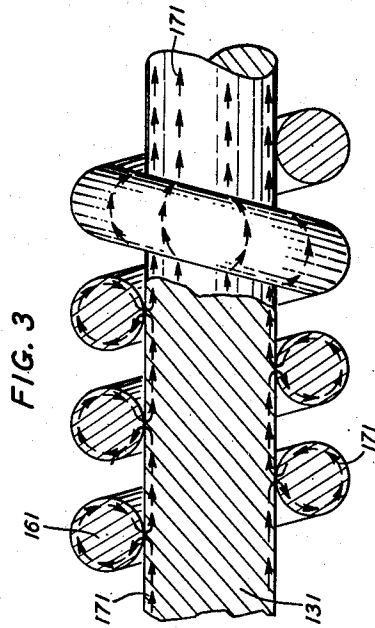


FIG. 3

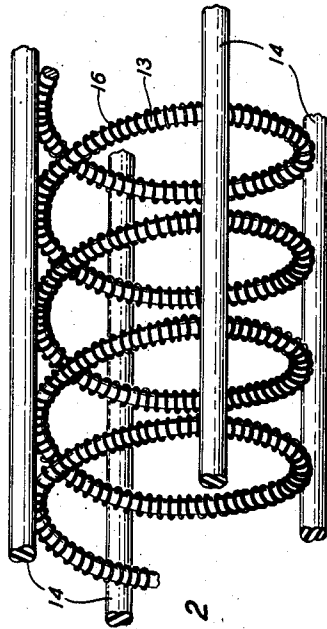


FIG. 2

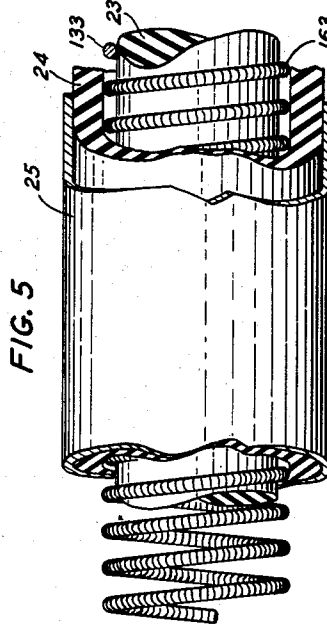


FIG. 5

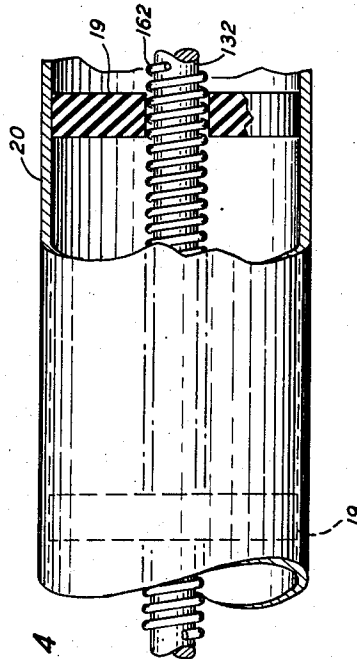


FIG. 4

INVENTOR
J. R. WILSON

BY *A. J. Hunter*
ATTORNEY

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James R. Wilson, Mountain Lakes, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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This invention relates to transmission lines and more particularly to such lines wherein additional loss is introduced.

In certain types of transmission lines, wherein electromagnetic energy is transmitted through an enclosed line, such as coaxial cables, delay lines, or as contained in traveling wave tubes, it may be desirable to introduce loss at certain points for various reasons. Thus in traveling wave tubes, attenuation, or loss, is introduced in the traveling wave tube circuit to inhibit the reverse transmission of components of the radio frequency signal along the circuit. The reverse waves or signals might produce oscillations with resultant tube instability and impairment of the transmitted signal wave. The provision of high frequency attenuation or loss maintains tube stability and avoids these deleterious effects.

Similarly, in coaxial transmission lines or delay lines, the introduction of attenuation may be desirable. Thus, where a delay line is used in measuring circuits, the incoming signal may be too large for the equipment; and it is necessary to weaken the signal before it is applied to the measuring equipment. Such a weakening of the signal can be accomplished by attenuation in the line.

In cases such as those noted above the advantages of the added attenuation are lost unless the attenuation is itself very stable and substantially unvariable at a given frequency during the life of the structure or circuit. Thus, certain prior methods of introducing attenuation into transmission lines for the guidance of electromagnetic energy, such as the employment of lossy dielectric materials, are unsatisfactory, as the materials are unstable with time and the variations, in many cases, are unpredictable. This is particularly of importance when the attenuation added to the transmission line must be accurately controlled, as in measuring circuits, such as employing delay lines, but is also of substantial importance in other applications.

It is, therefore, one object of this invention to provide high frequency attenuation, or loss, in transmission lines. More specifically, it is an object of this invention to introduce such attenuation into traveling wave tubes, coaxial cables, and delay lines.

It is a further object of this invention to provide an attenuation in such transmission lines that is stable and substantially unvariable at a given frequency during the operation of the transmission line and that is easily fabricated in controlled accurate amounts.

It is a further object of this invention to facilitate the attainment of attenuation in such transmission lines.

It is a still further object of this invention to provide improved transmission lines. More specifically it is an object of this invention to provide improved traveling wave tubes, coaxial cables and delay lines.

These and other objects of this invention are achieved in accordance with one specific illustrative embodiment of this invention wherein a fine high resistance wire is wound around an inner conductor within the transmission line. In one specific illustrative embodiment of this

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invention comprising a traveling wave tube, the high resistance wire is an overwound helix wound around the helical inner conductor of the traveling wave tube, through which helical inner conductor the electron beam is projected. In another specific embodiment of this invention comprising a lossy delay line, the attenuation is introduced by the high resistance wire helically wound around the center helical conductor which is positioned on a dielectric member and separated from the outer conductor by a second dielectric member. In a further specific embodiment of this invention comprising a lossy coaxial line, the attenuation is introduced by the high resistance wire helically wound around the straight central conductor.

It is therefore one feature of this invention that a fine wire be wound around an internal conductor within a transmission line. Specifically, it is a feature of this invention that a high resistance wire be helically overwound around the helix of a traveling wave tube, the helical inner conductor of a delay line, or the inner conductor of a coaxial transmission line.

It is a further feature of this invention that the amount of attenuation added can be accurately controlled by varying the pitch of the high resistance wire which is wound around the internal conductor of the transmission line. In accordance with this feature of the invention, the attenuation added at any point along the transmission line can be accurately predetermined, whether the attenuation along the line be uniform or not. Thus, the increased attenuation at any point along the transmission line is dependent on the pitch of the high resistance wire helically wound around the conductor at that point.

A complete understanding of this invention and of the features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a side view of a traveling wave tube illustrative of one specific embodiment of this invention;

Fig. 2 is a perspective view, greatly enlarged, of a portion of the helix and support rods of the traveling wave tube of Fig. 1, illustrating particularly the overwound wire in accordance with this invention;

Fig. 3 depicts a section of an overwound straight inner conductor and illustrates the paths of the high frequency currents;

Fig. 4 is a side view of a portion of a coaxial transmission line illustrative of another specific embodiment of this invention; and

Fig. 5 is a side view of a portion of a delay line illustrative of still another specific embodiment of this invention.

Referring now to Fig. 1, the specific embodiment of this invention there illustratively depicted comprises a traveling wave tube including an envelope 10 in which are positioned an electron gun assembly 11, a collector electrode assembly 12, and an elongated wire helix 13 of substantially uniform pitch throughout most of its length and extending between the electron gun and collector electrode assemblies. The helix 13 is supported by four ceramic support rods 14 which bear against the envelope 10.

As best seen in Fig. 2, the helix 13 has wound around it an overwound helix 16 of a high resistance wire, in accordance with this invention. The high resistance wire 16 is tightly overwound on the helix 13. In one specific embodiment, a .018 inch central wire 13 was overwound with a .005 inch wire 16 at 160 turns per inch, the central wire 13 being itself formed into a helix of .167 inch inside diameter and 20 turns per inch.

The function of the overwound wire 16 in introducing attenuation into the interaction circuit of the traveling wave tube can be best understood with reference to the

representation of Fig. 3 wherein, for simplicity of exposition, the central conductor is shown as straight rather than helical. Referring now to Fig. 3, the fine high resistance wire 161, shown greatly enlarged, is closely helically wound around the central conductor 131. Skin effect causes the conduction currents, indicated by the arrows 171 to be confined to the surface at high frequencies so that the currents must pass over each turn of the overwound wire 161. It has been found that if the turns of the overwound wire 161 are tightly spaced but do not touch each other, the radio frequency currents must traverse a greater length of surface which can be as much as four times, or more, the length of the surface path on a smooth wire. This increased length of path for radio frequency currents gives an increased attenuation expressed in decibels by a factor as great as four for a given length of central conductor. By controlling the pitch of the overwound wire 161 and thus the closeness of the spacing of the turns of the wire 161, the attenuation added can be precisely predetermined and any desired amount of attenuation can accurately be added. This added attenuation further need not be constant over the entire transmission line but may vary along the line, the exact amount of attenuation added being always accurately controlled by the pitch of the overwound wire. Further this attenuation is not variable during the operation of the device, except with frequency, the attenuation increasing approximately in proportion to the square root of the frequency, as the depth of the current path varies with frequency.

It is to be noted in Fig. 3 that the radio frequency currents 171 are not required to travel along the individual turns of the overwound wire 161 but will pass around them down to the central wire 131 and then on to the next turn of the overwound wire 161, always seeking the shortest path. When the wire 161 is overwound on a helix, such as the helical conductor 13 in the traveling wave tube, the path of the currents 171 is considerably more complex. The path is dependent on the relative pitches of the helix of the central conductor and the helix of the overwound wire, and for any given set of conditions the path is apparently always the shortest that the currents can take.

Attenuation introduced into a transmission line by a high resistance wire helically overwound on a straight central conductor, as illustratively depicted in Fig. 3, can be employed in coaxial cables, as shown in Fig. 4. Referring now to that figure, the central conductor 132 may be supported, as by dielectric spacers 19, from the hollow outer conductor 20. A high resistance wire 162 is closely wound on the central conductor 132, whereby the attenuation, or loss, of the cable can be increased.

In still another specific illustrative embodiment of this invention, a lossy delay line comprises, as shown in Fig. 5, a helical central conductor 133 wound on a dielectric core 23 and in turn positioned within a tube 24 of another dielectric. A hollow outer conductor 25 encompasses the dielectric tube 24. A fine high resistance wire 163 is helically overwound around the central conductor 133 to introduce the increased attenuation into the transmission line.

While certain specific arrangements have been described, it is to be understood that these are merely illustrative of the application of the principles of the invention. Numerous other arrangements whereby attenuation may be introduced into transmission lines by an overwound conductor on the inner conductor of the transmission line may be devised by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. In a traveling wave device, a delay line comprising at least one conductor extending in said line and means for increasing the attenuation along said line comprising high resistance wire helically wound directly upon said

conductor and in continuous electrical contact therewith and having a pitch determinative of the attenuation at any point along said line.

2. A traveling wave tube comprising an elongated envelope, a helical conductor, means supporting said helical conductor within said envelope, said helical conductor defining a transmission line, electron gun means for projecting a stream of electrons through said transmission line, collector means for receiving said electrons, and means for increasing the attenuation at any point along said transmission line, said last-mentioned means comprising a high resistance wire helically wound directly upon said helical conductor and in continuous electrical contact therewith and having a pitch determinative of the attenuation at any point along said line.

3. In a traveling wave device, a coaxial cable type delay line comprising a central inner conductor, an outer conductor encompassing said inner conductor, and means for increasing the attenuation along said cable, said means comprising a high resistance wire helically wound around said inner conductor.

4. In a traveling wave device, a coaxial cable type delay line comprising a central inner conductor, an outer conductor encompassing said inner conductor, means supporting said inner conductor from said outer conductor, and means for increasing the attenuation along said cable, said last-mentioned means comprising a high resistance wire helically wound around said inner conductor, the increased attenuation at any point along said inner conductor being dependent on the pitch of said high resistance wire helically wound around said inner conductor at said point.

5. In a traveling wave device, a delay line comprising an inner dielectric support means, an inner conductor helically wound around said support means, an outer conductor encompassing said inner conductor, dielectric means supporting said inner conductor from said outer conductor, and means for increasing the attenuation along said delay line, said last-mentioned means comprising a high resistance wire helically wound around said inner conductor, the increased attenuation at any point along said inner conductor being dependent on the pitch of said high resistance wire helically wound around said inner conductor at said point.

6. In a traveling wave device, a lossy transmission line for the guidance of electromagnetic waves comprising a metallic conductor along the surface of which high frequency currents may flow and means for increasing the attenuation along said line, said means including a high resistance wire helically wound directly around said conductor and in continuous electrical contact therewith, whereby said high frequency currents flowing along the surface of said conductor must flow across the surface of said wire at successive regions of said helically wound wire.

7. A traveling wave tube comprising an envelope, a helical metallic conducting wire extending within said envelope and defining the interaction circuit of the tube, electron gun means for projecting a stream of electrons through the region bounded by said helical conducting wire for interaction with an electromagnetic wave propagating along said helical wire, and means for increasing the attenuation of said region, said means comprising a high resistance wire helically wound directly upon said helical conducting wire and in continuous electrical contact therewith, whereby surface currents due to said electromagnetic wave flowing along the surface of said helical conducting wire must traverse said helically wound high resistance wire at successive regions along said wires.

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