

Nov. 20, 1962

W. R. JONES

3,065,435

ATTENUATORS

Filed June 29, 1960

2 Sheets-Sheet 1

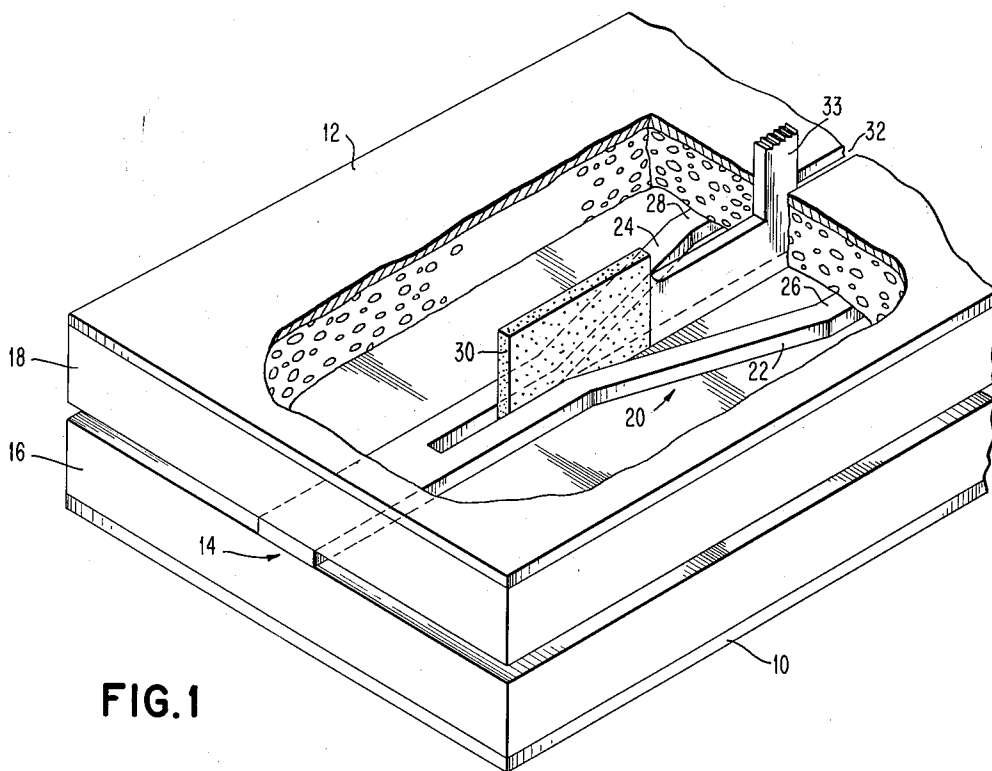
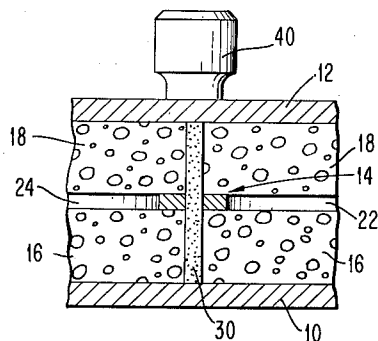


FIG. 5



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2 Sheets-Sheet 2

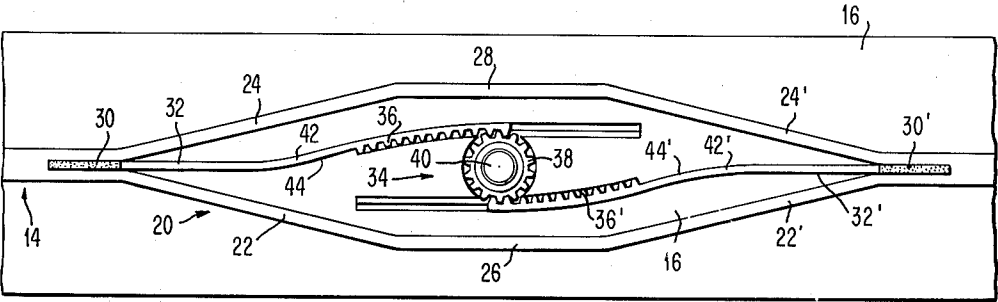


FIG. 2

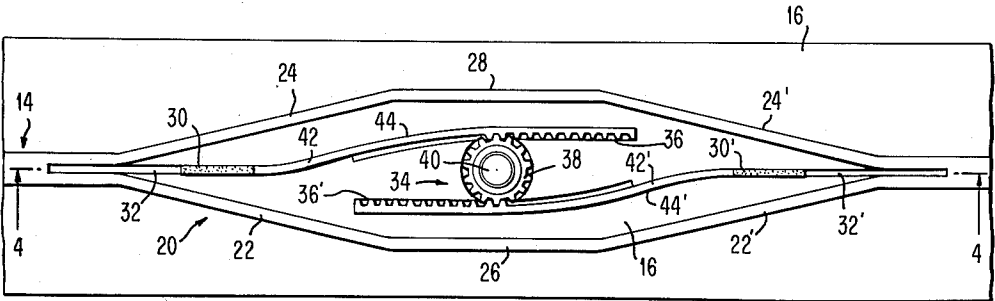


FIG. 3

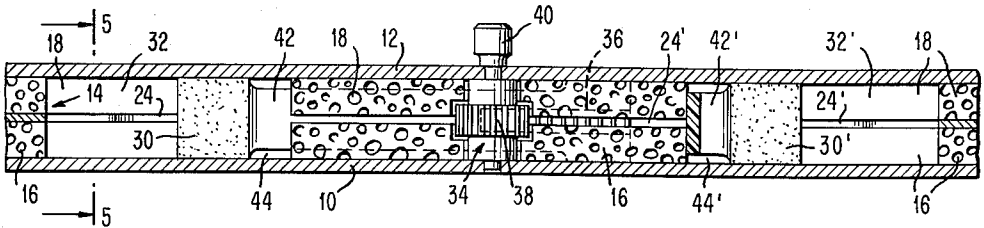


FIG. 4

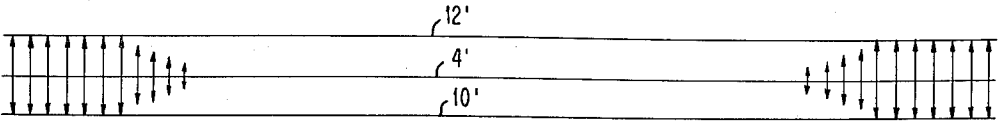


FIG. 6

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ATTENUATORS

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7 Claims. (Cl. 333—81)

This invention relates to attenuators and more particularly to variable attenuators which may be used to vary the power level of the electromagnetic field in a guided wave system employing strip transmission line, e.g., of the type disclosed in U.S. Patent No. 2,913,686, granted November 17, 1959, which includes two spaced apart parallel ground plates, a center conductor disposed midway between the two ground plates and a dielectric material disposed between the center conductor and each of the ground plates.

Satisfactory attenuators are available for use in many types of guided wave transmission lines, e.g., in rectangular, circular and coaxial wave guides employed to transmit high frequencies, particularly in the microwave region of the frequency spectrum. Elements such as carbon-coated cards have been used as attenuators and even as variable attenuators in strip line systems, e.g., as described in Sanders Associates' Handbook of Tri-Plate Microwave Components, 1956, in pages 53 to 57. However, a satisfactory strip line attenuator has not been developed which is suitable for use in all types of presently known strip lines, e.g., strip lines having single or double layer center conductors. One of the main problems in developing a satisfactory strip line attenuator is that encountered in preserving the electrical balance of the transmission system. Prior art strip line attenuators useful in one type of strip line system cannot be readily employed in a second type of strip line system due to electrical unbalance or mechanical fabrication problems that are encountered. Another disadvantage of prior art variable attenuators is that the resistive or lossy material of the attenuating device has been inserted in the fringe of the electric field of the system, therefore, large values of attenuation must be accompanied by the insertion of a large amount of resistive material.

An object of this invention is to provide an improved attenuator.

Another object of this invention is to provide an improved variable attenuator which may be employed in strip transmission lines.

A further object of this invention is to provide an improved variable attenuator which may be used in all types of known strip transmission lines.

Yet another object of this invention is to provide an improved variable attenuator having its lossy or resistive material disposed in the region of the maximum electric field of the strip line system.

Still another object of this invention is to provide an improved attenuator in a strip transmission line which will not produce an electrical unbalance in the line.

Still a further object of this invention is to provide an improved strip line attenuator which will provide a larger amount of attenuation with a given amount of resistive material than can be produced by prior art attenuators.

In accordance with the present invention an attenuator for a strip line system has been provided which includes a center conductor having a section that is bifurcated so as to form two branches which are flared to a distance at which there is no electrical coupling between the branches and a thin lossy sheet disposed between the two branches perpendicularly to a plane passing through each of the two branches of the center conductor.

An important advantage of the attenuator of the present invention is that it will provide a large amount of at-

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tenuation with small amounts of resistive material insertion without creating an electrical unbalance in a strip transmission system.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a perspective view of a portion of a strip transmission line in which the attenuator of the present invention is located.

FIG. 2 is a plan view of a strip transmission line similar to that illustrated in FIG. 1, but with the upper plate and upper dielectric layer removed, showing two variable attenuators in a bifurcated section of the center conductor,

FIG. 3 is similar to FIG. 2 except that it shows the two attenuators positioned to provide minimum or zero attenuation,

FIG. 4 is a longitudinal cross sectional view of the strip line shown in FIG. 3 taken along line 4—4 which bisects the center conductor of the transmission line,

FIG. 5 is a transverse cross sectional view of the strip line illustrated in FIG. 4 taken along the line 5—5, and

FIG. 6 is an illustration of the magnitude of the electric field component perpendicular to the center conductor measured along the center line of the center conductor.

Referring to the drawings in more detail, wherein like parts in the various figures are indicated by the same reference numeral, in FIG. 1 there is shown a portion of a strip transmission line which includes a lower electrically conductive plate 10 and an upper electrically conductive plate 12 which is spaced from and arranged parallel to the lower plate 10. A conductive flat center conductor 14 having a width substantially less than that of the plates 10 and 12, is disposed midway between the plates 10 and 12. The center conductor 14 is held in position between the lower and upper plates 10 and 12 by a lower layer 16 of dielectric material and an upper layer 18 of dielectric material disposed between the center conductor 14 and the lower and upper plates 10 and 12. The lower and upper dielectric layers 16 and 18 are preferably made of a solid dielectric foam as described in a commonly assigned application having Serial No. 824,003, filed June 30, 1959, by George F. Bland, now abandoned, and in its divisional application having Serial No. 96,968, filed March 20, 1961. The center conductor 14 may be conveniently made by utilizing well-known printed circuit techniques. The center conductor 14 has a section 20 bifurcated so as to form two branches 22 and 24 which are flared for a distance and then form two parallel lines 26 and 28. Each of the two branches 22 and 24 and each of the two parallel lines 26 and 28 have dimensions such that the even TEM mode impedance of one branch or line in the presence of the other is equal to $2Z_0$, where Z_0 is the impedance of the line or conductor which has been bifurcated. A thin sheet 30, made of material having a low dielectric constant, coated with a lossy material, such as carbon particles, e.g., a metallized mica sheet, is disposed in a groove or slot 32 extending from the top of the upper plate 12 to the lower plate 10 perpendicularly to the plates 10 and 12, and extending longitudinally of the transmission line from a point within and midway between the two parallel lines 26 and 28 to a point on the center line of the center conductor 14 outside the bifurcated section 20 at a distance at least equal to the length of the dielectric sheet 30. The dimension of the dielectric sheet 30 in the direction perpendicular to the plates 10 and 12 is equal to the distance between the lower and upper plates 10 and 12 and the sheet 30 should be sufficiently thin, e.g., .002 inch, so as to present only a small discontinuity when in slot 32. If desired,

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the dielectric sheet 30 or an arm 33 made of low dielectric material connected thereto, may extend out of the upper plate 12, provided the slot in the upper plate is very thin, so that the position of the sheet 30 in the slot 32 may be conveniently controlled.

FIG. 2 is a plan view of a strip transmission line, with the upper plate and dielectric layer removed showing two lossy sheets, the sheet 30 of FIG. 1 and a second sheet 30' similar to sheet 30, in the bifurcated section 20 of the center conductor 14. The sheets 30 and 30' are arranged in the transmission line in the manner described hereinabove in connection with FIG. 1. FIG. 2 shows the bifurcated section 20 having the flared branches 22 and 24 of FIG. 1 at one end of the section 20 and a second pair of flared branches 22' and 24' at the opposite end of the section 20 interconnected by the two parallel lines 26 and 28. Each of the branches 22, 24, 22' and 24' and the parallel lines 26 and 28 in the bifurcated section 20 have dimensions such that the even mode impedance of one branch or line in the presence of the other is equal to $2Z_0$, where Z_0 is the impedance of the line which has been bifurcated. Thus, each of the two transmission paths in the bifurcated section 20 has an impedance of $2Z_0$ so as to properly match the impedance Z_0 of the main line of the central conductor 14 connected to each end of the bifurcated section 20 at the vertices of the flared branches. The lossy sheets 30 and 30' are disposed in slots 32 and 32' between the first pair of flared branches 22 and 24 and the second pair of flared branches 22' and 24', respectively, so as to pass through the vertices of the flared branches. A rack and pinion arrangement 34 has been provided so as to simultaneously adjust the position of the lossy sheets 30 and 30' in the grooves 32 and 32', respectively. The rack and pinion arrangement 34 includes first and second racks 36 and 36', a pinion 38 and a knurled knob 40 coupled to the pinion 38. The lossy sheet 30 is connected to the first rack 36 by any suitable mechanical coupling element 42 made of material with a low dielectric constant and, if desired, may be the same material used in the dielectric sheets 30 and 30'. The coupling element 42 should be sufficiently rigid so as to be able to push the lossy sheet 30 through the groove 32. The coupling element 42 may pass through the slot or groove 32 and an extension 44 thereof to the rack 36, in which case the coupling element 42 should be somewhat flexible, or, alternatively, the coupling element 42 may be a slender rod disposed between the lower and upper layers 16 and 18 of the transmission line dielectric material. The lossy sheet 30' is coupled to the second rack 36' in a manner similar to that disclosed hereinabove in connection with the coupling of the lossy sheet 30 to the first rack 36.

FIG. 3 is similar to FIG. 2 but differs therefrom in that it shows the first and second racks 36 and 36' positioned so as to place the lossy sheets 30 and 30' at locations spaced from the center conductor so as to provide minimum or zero attenuation.

FIG. 4 is a longitudinal cross sectional view of the strip line illustrated in FIG. 3, taken along line 4—4, with the upper plate 12 and upper dielectric layer 18 included. This view clearly shows the lossy sheets 30 and 30' extending between the lower and upper plates 10 and 12 and also the position of the knurled knob 40 of the rack and pinion arrangement 34 on the upper plate 12.

FIG. 5 is a transverse cross sectional view of the strip transmission line illustrated in FIG. 4 taken through the line 5—5. FIG. 5 clearly shows the perpendicular relationship between the lossy sheet 30 and the center conductor 14. This figure also clearly shows that the lossy sheet 30 passes through a line which bisects the center conductor 14 and that equal amounts of the lossy sheet 30 are disposed above and below the center conductor 14.

When a voltage is applied to the strip transmission line illustrated in the above-mentioned figures, a component of the electric field perpendicular to the flat center conductor along the center line of the center conductor, i.e.,

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along line 4—4 of FIG. 3, has a magnitude as indicated in FIG. 6 of the drawing. The arrows shown in FIG. 6 indicate the magnitude of the electric field in the plane passing through the center line of center conductor 14, i.e., line 4—4 of FIG. 3, perpendicularly to the plates 10 and 12, the location of the plates 10 and 12 in that plane being indicated by lines 10' and 12', respectively, and the line midway between the two plates 10 and 12 in that plane being indicated by the line 4'. It can be seen that the electric field in the slots 32 and 32' outside of the bifurcated section 20 is at a maximum value but that it decreases at increasing distances from the vertices of the branch lines 22 and 24 and 22' and 24', since the region of high coupling is near the vertex of the branches 22 and 24 and the vertex of branches 22' and 24' and the coupling decreases as the distance between the two branches 22 and 24 increases and as the distance between the two branches 22' and 24' increases until zero coupling is attained. The lines 26 and 28 interconnecting the branches 22 and 24 and branches 22' and 24' are located outside of the coupling region and, therefore, although shown parallel, need not be positioned with respect to each other in any particular manner but they should have equal lengths. It should also be understood that if each of the resistive or lossy sheets 30 and 30' is not disposed in the transmission line symmetrically with respect to the center conductor 14 the transmission line will become unbalanced and thus undesirable radiations will be produced. Thus, when the lossy sheets 30 and 30' in the slot 32 are spaced the farthest distance apart from each other, as shown in FIG. 2 they are positioned in the portion of the slot 32 which extends into the main line of the central conductor 14 outside of the flared branches 22, 24, 22' and 24' so as to be located within the strip transmission line's maximum electric field and when the lossy sheets 30 and 30' are positioned as shown in FIGS. 3 and 4 they are located in a minimum or zero electric field. When the lossy sheets 30 and 30' occupy positions in the slots 32 and 32', respectively, between the positions illustrated in FIGS. 2 and 3 or 4 the sheets are located in electric fields of intermediate strength. Since it is well known that the attenuation in a transmission line depends upon strength of the electric field through a lossy material it can be readily understood that the present invention provides a variable attenuator yielding attenuation values ranging from zero to maximum by moving the lossy sheets 30 and 30', e.g., by turning knurled knob 40, only a short distance in the grooves 32 and 32', respectively. If desired, the knurled knob 40 may be associated with a convenient scale mounted on the upper plate 12.

The strip line variable attenuators illustrated in FIGS. 2, 3 and 4 may be considered comprising a power divider at one end of the bifurcated section, e.g., flared branches 22 and 24, a power adder at the opposite end of the bifurcated section, e.g., flared branches 22' and 24', if the amplitude and phase of the voltages in the two branches are equal, and a pair of completely uncoupled parallel strip transmission lines, e.g., lines 26 and 28, coupling the power divider to the power adder. By gradually flaring the branches of the power divider and the power adder, the power division and addition is obtained without appreciable reflection in the transmission line. Whenever a power divider is required in a system, a variable attenuator as illustrated in FIG. 1 of the drawing may conveniently be employed, which attenuator does not necessitate the use of a power adder. When a power adder, as defined hereinabove is required in a system a variable attenuator as illustrated in FIG. 1 of the drawing also may conveniently be employed, which attenuator does not necessitate the use of a power divider.

Accordingly, an improved variable attenuator having a wide range of attenuation values in a strip transmission line has been provided in accordance with the present invention which has its lossy material completely within the

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maximum electric field for maximum attenuation or power loss and completely out of the electric field to provide a zero or minimum attenuation or loss.

Although the lossy sheets have been described as adjustable with respect to the center conductor 14, it should be understood that the sheets may be fixed in one position to provide a fixed attenuator.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in forms and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An attenuator comprising a pair of conductive plates spaced from each other in a parallel relationship, a center conductor disposed between said plates so as to be parallel thereto, said center conductor having a section bifurcated so as to form two flared branches, a lossy sheet disposed within the two flared branches perpendicularly to a plane passing through each of said branches and means for moving said lossy sheet between said flared branches along the longitudinal axis of said center conductor.

2. An attenuator comprising a pair of conductive plates spaced from each other in a parallel relationship, a center conductor disposed midway between said plates so as to be parallel thereto, said center conductor having a section bifurcated so as to form two flared branches, a lossy sheet disposed between the two flared branches perpendicularly to a plane passing through each of said branches and extending an equal distance from said center conductor to each of said plates and means for adjusting the position of said lossy sheet between said flared branches along the longitudinal axis of said center conductor.

3. A variable attenuator comprising a pair of conductive plates spaced from each other in a parallel relationship, a center conductor disposed midway between said plates so as to be parallel thereto, said center conductor having a section bifurcated so as to form two flared branches, a lossy sheet having equal areas disposed between said center conductor and each of said plates and means for positioning said lossy sheet perpendicularly to said plates at a plurality of locations between said flared branches along a line which bisects the angle formed by the two flared branches.

4. A variable attenuator comprising a pair of conductive plates spaced from each other in a parallel relationship, a center conductor for carrying electrical energy disposed midway between said plates so as to be parallel thereto, said center conductor having a section bifurcated so as to form two flared branches each having an area separated from each other by a distance at which the areas are electrically uncoupled from each other, a lossy

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sheet having equal areas disposed between said center conductor and each of said plates and means for positioning said lossy sheet perpendicularly to said plates at a plurality of positions along a line extending from a point midway between said two electrically uncoupled areas to a point on the center line of said center conductor at a given distance outside of said bifurcated section.

5. A variable attenuator for a strip transmission line comprising a pair of conductive plates spaced from each other in a parallel relationship, a power divider having a pair of flared branches, a power adder having a pair of flared branches and coupled to said power divider, means made of a dielectric material for supporting said power divider and said power adder midway between said plates, first and second lossy sheets disposed between said power divider and said plates and said power adder and said plates, respectively, and means for positioning said first and second lossy sheets perpendicularly to said plates at a plurality of locations within said power divider and said power adder, respectively, along the line bisecting the angle formed by said divider branches and along the line bisecting the angle formed by said adder branches, respectively.

6. A variable attenuator as set forth in claim 5 wherein said positioning means includes means for simultaneously adjusting the position of said first and second lossy sheets with respect to said power divider and said power adder, respectively.

7. An attenuator comprising a pair of conductive plates spaced from each other in parallel relationship, a center conductor disposed midway between said plates so as to be parallel thereto, said center conductor having a bifurcated section forming two branches, said branches being flared to a given distance so as to form a substantially field free region therebetween, a thin lossy sheet disposed between said two branches perpendicularly to a plane passing through each of the two branches of said center conductor and means for adjusting said lossy sheet at a plurality of positions throughout said bifurcated section along a line which bisects the angle formed by the two flared branches.

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