Feb. 9, 1960 H. F. ENGELMANN ET AL 2,924,793

ADJUSTABLE ATTENUATOR

Filed March 9, 1956 2 Sheets-Sheet 1

Fig. 1

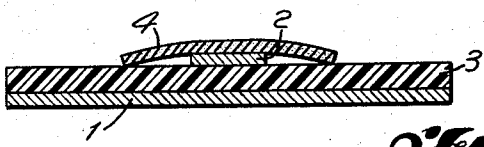

Fig. 2

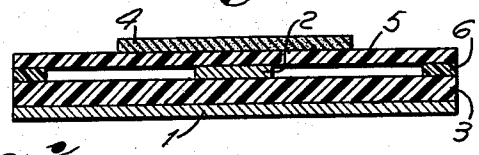

Fig. 3

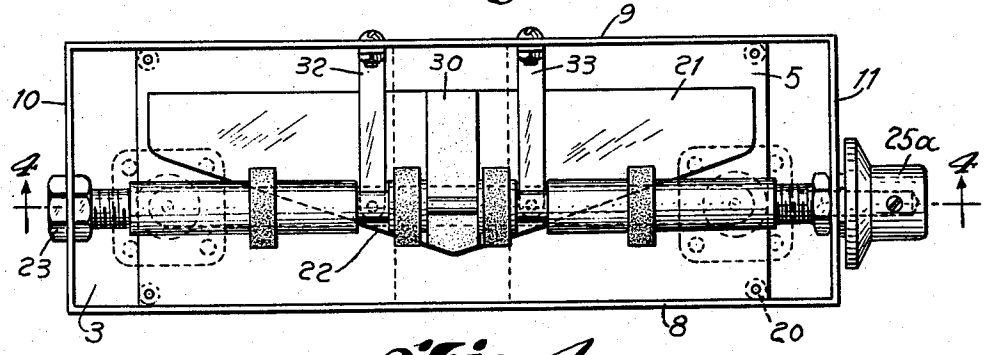

Fig. 4

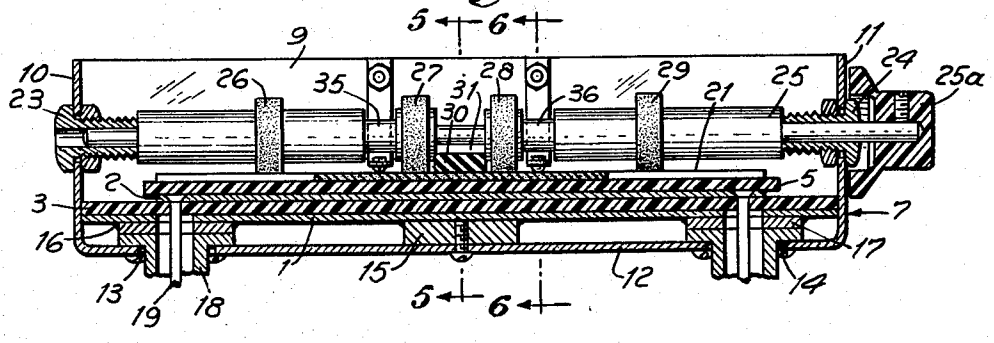

Fig. 5

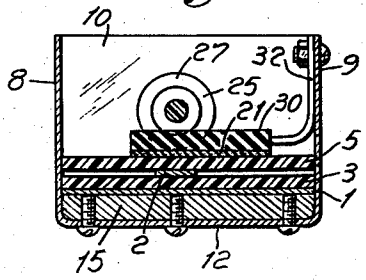

Fig. 6

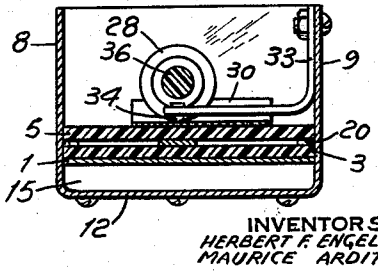

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Fig. 7

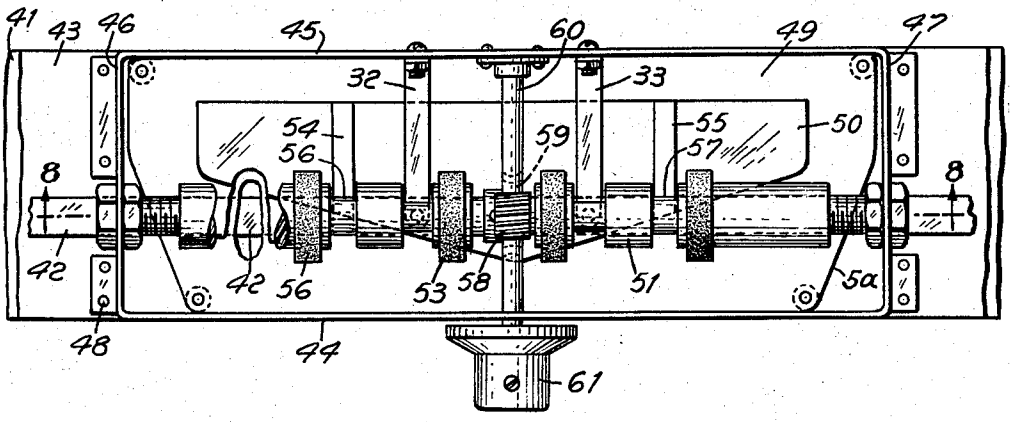
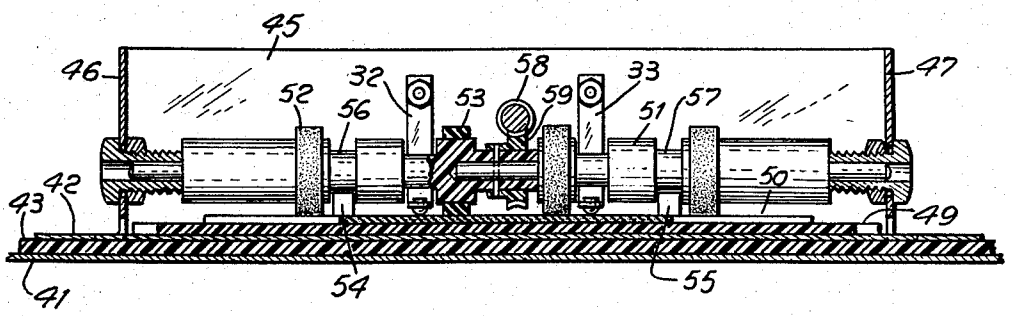


Fig. 8



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ADJUSTABLE ATTENUATOR

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Application March 9, 1956, Serial No. 570,448

10 Claims. (Cl. 333—81)

This invention relates to radio frequency attenuators and more particularly to an attenuator capable of uniform impedance match adjustment over a broad band of frequencies and for different attenuation adjustment.

It has recently been discovered that a simple "line-above-ground" type of transmission line may be employed for propagation of high and ultra high radio frequency energy over a wide range of frequencies. This type of transmission line, which is disclosed in H.F. Engelmann Patent No. 2,654,842, is known as Microstrip. More particularly, the microstrip waveguide comprises a pair of conductors, one wider than the other, dieelectrically spaced apart in parallel relation. The two conductors may be applied to a layer of dielectric material by known printed circuit techniques, one being in the form of a planar conductor and the other a narrow flat strip-like line conductor. The propagation of radio frequency energy is in a manner similar to the TEM mode in that the distribution of the electric field is substantially the same as that which occurs between one conductor and the neutral plane of a truly parallel two-wire transmission line.

Certain types of microstrip attenuators, both fixed and pivoted, are disclosed in the patent of D. D. Grieg, H. F. Engelmann and J. A. Kostriza, No. 2,725,535, and the application of H. F. Engelmann, Serial No. 413,805, filed March 3, 1954. While these disclosures are effective as attenuators for the microstrip line, we have found that it is essential for uniform impedance match over broad band of frequencies and for different attenuation adjustment to provide some means to maintain the attenuator pad truly planar with respect to the microstrip conductors throughout all positions of adjustment. This is necessary since the pad tends to bend and cause the edge thereof to dip into the plane of the strip conductor when it extends beyond the lateral edge of the strip conductor. This dipping of the pad upsets the impedance matching from one adjustment to another.

It is one of the objects of the present invention, therefore, to provide a wide band, relatively simple, sturdy, compact and easily constructed adjustable attenuator having uniform impedance matching characteristics with respect to all of its adjustment positions relative to the conductors of the microstrip type of waveguide. Another object of the invention is to provide an attenuator capable of easy adjustment of the amount of attenuation desired and yet maintain the attenuator pad substantially free of microphonics due to vibrations. Still another object is to provide a novel means for adjusting the position of an attenuator card or pad relative the strip conductors.

One of the features of the invention is the provision, in conjunction with an attenuator pad disposed for lateral sliding movement relative to the strip conductor, of a plate of dielectric material interposed between the strip conductor and the attenuator pad. This plate is maintained truly planar and parallel to the conductors of the microstrip waveguide. Means are provided to adjust the

position of the pad crosswise of this plate, the plate operating as a base which supports the pad in a truly parallel relationship with respect to the planes of the two conductors. Pressure means, including the adjustment control, renders the pad free of microphonics which are normally due to vibration.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a cross-sectional view of a microstrip line and an attenuator pad thereon;

Fig. 2 is a cross-sectional view of a microstrip line with an attenuator pad disposed in a truly planar relationship in accordance with the present invention;

Fig. 3 is a view in plan of an attenuator utilizing the microstrip principle and attenuator pad arrangement illustrated in Fig. 2 for use in a coaxial line;

Fig. 4 is a cross-sectional view taken along line 4—4 of Fig. 3;

Figs. 5 and 6 are cross-sectional views taken along line 5—5 and 6—6, respectively, of Fig. 4;

Fig. 7 is a plan view of a modified form of an attenuator unit according to the present invention; and

Fig. 8 is a view partly in section taken along line 8—8 of Fig. 7.

Referring to Figs. 1 and 2, a cross-sectional view of a microstrip waveguide is shown to include a first or planar conductor 1, a second or strip conductor 2 and a layer of dielectric material 3 which separates the conductors 1 and 2 in parallel relation. The dielectric material may comprise polyethylene, polystyrene, "Teflon," fiber glass or laminations of fiber glass and "Teflon," or other suitable material of dielectric quality, or if microstrip structure permits the dielectric may even be air. The conductor strip 2 comprises a flat conductive strip of definite thickness which is attached to the upper surface of the dielectric layer 3. The strip, for example, may be applied by any of the known printed circuit techniques such as silk screening, electro-plating and/or etching. Fig. 1 shows an attenuator pad 4 resting directly upon the strip 2 with the portions of the pad extending beyond the lateral edges of the strip 2 bending into the plane of the strip. Since the electric field exists between the opposed surfaces of the conductors 1 and 2 and includes a fringe field between the edges of the strip 2 and the top portion thereof adjacent the edges any deviation of the pad 4 from a planar condition upsets the impedance match in adjustment from one position to another of the pad laterally with respect to the strip 2. In Fig. 2 the pad 4 is shown to be supported by a dielectric plate 5 preferably of lossless characteristic which is maintained truly planar with respect to the planes of the conductors 2 and 1. The portion of plate 5 overlying the conductor 2 and located in the fringe field is preferably tapered symmetrically (5a, Fig. 7) to provide for impedance match throughout the frequency range. Where the dielectric constant of the plate is close to unity this taper could be dispensed with. While the plate 5 may extend considerably beyond the edges of the strip 2 and be permitted to rest on the dielectric 3, particularly where the conductor 2 is exceptionally thin, it is best to provide spacers 6 to insure the planar relationship in the area of the pad 4 and its zone of adjustment.

Referring to Figs. 3 to 6, an embodiment of the invention is shown for use with coaxial lines. The unit includes a long rectangular housing 7 having side walls 8 and 9, end walls 10 and 11, and a bottom wall 12. The bottom wall is provided with two openings 13 and 14 adjacent the ends of the housing through which coaxial coupling is made. A section of microstrip is disposed

within the housing and is identified by the reference characters 1, 2 and 3. The ground conductor 1 is supported by the spacer 15 and the coaxial coupling connectors 16 and 17. The outer conductor 18 of the coaxial line is coupled to the bottom wall 12 for extension through the opening therein and in electrical connection with the ground conductor 1. The inner conductor 19 of the coaxial line extends through openings in the ground conductor 1 and the dielectric 3 to the strip conductor 2 to which it is electrically connected. Disposed in planar relation to the planes of the conductors 1 and 2 is the plate 5, the outer edges of which are supported by spacers 20. The attenuator pad 21 of resistive material is disposed for sliding movement on the dielectric plate 5. One edge 22 of the pad 21 is angled from the center thereof to provide a broad angled taper. This edge 22 constitutes the forward edge of the operating portion of the pad and controls the change in attenuation and its symmetrically tapered shape avoids change in impedance match as it is adjusted laterally with respect to the strip 2.

The end walls 10 and 11 are provided with bearings 23 and 24 which support a shaft 25. The shaft 25 carries four resilient rollers 26, 27, 28 and 29, which engage the surface of the pad 21 for friction drive. The pad 21 is provided with a guiding ridge 30 which is receivable in an annular channel 31 formed in the shaft 25. This ridge guide maintains the pad in proper alignment during adjustment. The rollers are driven by a knob 32 for adjusting the attenuator pad. In order to minimize effects of vibration two spring elements 32 and 33 are provided, each being in angular form with one end secured to the side wall 9 and the other end provided with a rounded contacting surface 34 adapted to engage the upper surface of the attenuator pad 21 closely adjacent the axis of the shaft 25 and preferably directly between the shaft and the pad 5. The shaft 25 is provided with annular grooves 35 and 36 to accommodate the spring elements 32 and 33. These spring elements together with the resilience of the roller maintain the attenuator free of microphonics due to vibrations.

Figs. 7 and 8 show an attenuator which is particularly adapted for microstrip circuitry. In this embodiment the microstrip is shown to comprise a first or ground conductor 41, a strip conductor 42 and an interposed layer of dielectric 43. The housing is in the form of a rectangular frame comprising side walls 44 and 45 and end walls 46 and 47. The walls are secured through the dielectric layer 43 to the ground conductor 41 by rivets or other fastening means indicated at 48. Disposed in overlying relation to the microstrip is a dielectric plate 49 onto which the attenuator pad 50 rests. The shaft 51 is mounted in the end walls of the frame similarly as disclosed in Figs. 3 and 4. The shaft includes rollers as indicated at 52 and 53 which frictionally engage the attenuator pad 50. The pad 50 in this embodiment is shown to have two guiding ridge elements 54 and 55 which engage annular grooves formed in the shaft as indicated at 56 and 57. The shaft is driven by a centrally located worm and pinion gearing 58, 59, the worm gear 58 being carried by a shaft 60 mounted on the walls 44 and 45 and controlled by a knob 61. The gear 59 is keyed to the shaft 51.

From the foregoing it will be clear that the attenuator pad may be driven by a shaft extending through either the ends or the sides of the housing. While other means for moving the pad may be arranged, the present shaft and roller arrangement is preferred since it urges with resilient force the pad against the supporting plate. This resilient pressure is supplemented by the spring elements 32 and 33 which are also employed in each embodiment to urge the pad with resilient force against the supporting plate. The attenuator herein disclosed has been used for varying the attenuation for frequencies between 400 and 10,000 megacycles without any significant variation in the impedance match thereof. The attenuation was found to be substantially linear throughout the range of attenuation adjustment, and as an example, a pad of about 4 inches long provided an attenuation range from about 1 to 12 decibels for a frequency of 3,000 megacycles, and the maximum attenuation provided by this pad varied from 2 db to 40 db in the range of frequencies from 400 to 10,000 megacycles. In this range the impedance match gave an input voltage standing wave ratio below 1.3.

While we have described above the principles of our invention in connection with specific structures, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising first and second conductors, means disposing said conductors in close dielectrically spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of said conductors with a fringe field extending from the side edges of said second conductor and the top portions there-adjacent toward said first conductor, a plate of dielectric material disposed in parallel overlying relation to said first and second conductors and in said fringe field, a pad of resistive material disposed on said plate, said pad having an operating portion of symmetrical uniformly tapered shape and means to adjust the position of the operating portion of said pad transversely with respect to said second conductor and said fringe field.

2. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising first and second conductors, means disposing said conductors in close dielectrically spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of said conductors with a fringe field extending from the side edges of said second conductor and the top portions there-adjacent toward said first conductor, a plate of dielectric material disposed in parallel overlying relation to said first and second conductors and in said fringe field, a pad of resistive material disposed on said plate, said pad having an operating portion of symmetrical uniformly tapered shape, means to adjust the position of said pad transversely with respect to said second conductor, and means resiliently urging said pad against said plate to minimize the microphonic effects due to vibration.

3. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising first and second conductors, means disposing said conductors in close dielectrically spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of said conductors with a fringe field extending from the side edges of said second conductor and the top portions there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to the said planar surface and in said fringe field, said plate having the edges thereof which cross said second conductor tapered symmetrically with respect to said second conductor, a pad if resistive material disposed on said plate, said pad having a forward edge tapering at an angle to the center line of said second conductor, means to adjust the position of said pad laterally with respect to said second conductor, and means to maintain said pad in

alignment with a line transversely of said center line during adjustment movement thereof.

4. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising first and second conductors, means disposing said conductors in said dielectrically spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of said conductors with a fringe field extending from the side edges of said second conductor and the top portions there-adjacent toward said first conductor, a plate of dielectric material disposed in parallel overlying relation to said first and second conductors in said fringe field; a pad of resistive material having a symmetrically tapered operating portion disposed on said plate, means to guide said pad for movement crosswise of said plate transversely with respect to said second conductor and said fringe field, and means for moving said pad to adjust the position thereof.

5. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising first and second conductors, means disposing said conductors in close dielectrically spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of said conductors with a fringe field extending from the side edges of said second conductor and the top portions there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to the said planar surface and in said fringe field, a pad of resistive material having a symmetrically tapered operating portion disposed on said plate, a frame, a roller supported by said frame in engagement with said pad and means for rotating said roller to position said pad transversely with respect to said conductor and said fringe field.

6. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising a housing, a microstrip waveguide section in said housing including first and second conductors and a layer of dielectric material disposing said conductors in spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of the conductors with a fringe field extending from the side edges of said second conductor and the top portion there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to said planar surface, a pad of resistive material having a symmetrically tapered operating portion disposed on said plate, said housing having bearing means, a roller supported by said bearing means in engagement with said pad, and means extending outside said housing for rotating said roller to adjust the position of said pad laterally with respect to said second conductor.

7. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising a housing, a microstrip waveguide section in said housing including first and second conductors and a layer of dielectric material disposing said conductors in spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of the conductors with a fringe field extending from the side edges of said second conductor and the top portion there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to said planar surface, a pad of resistive mateiral having a symmetrically tapered operating portion disposed on said plate, said housing having bearing means, a roller supported by said hearing means in engagement with said pad, means to rotate said roller to adjust the position of the operating portion of said pad relative to said second conductor, said roller having a circular groove therein, said pad having a ridge receivable in said groove to maintain said pad in proper alignment with said roller and spring elements carried by said housing having portions adapted to engage and press said pad against said plate of dielectric.

8. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising a microstrip waveguide section including first and second conductors and a layer of dielectric material disposing said conductors in spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of the conductors with a fringe field extending from the side edges of said second conductor and the top portion there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to said planar surface, a pad of resistive material having a symmetrically tapered operating portion disposed on said plate, means to adjust the position of the operating portion of said pad laterally with respect to said second conductor, means for coupling a coaxial line to each end of said section, said last named means including means for coupling electrically the outer conductor of said coaxial line to said first conductor, said first conductor having an opening therethrough coaxially with respect to said outer conductor and means coupling the inner conductor of said coaxial line through said opening to said second conductor.

9. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising a rectangular housing, a microstrip waveguide section disposed lengthwise in said housing including first and second conductors and a layer of dielectric material disposing said conductors in spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electromagnetic field is distributed between the opposed surfaces of the conductors with a fringe field extending from the side edges of said second conductor and the top portion there-adjacent toward said first conductor, a plate of dielectric material disposed in overlying relation to said first and second conductors and in a plane substantially parallel to said planar surface, a pad of resistive material disposed on said plate, said pad having a symmetrically tapered operating portion, the end walls of said housing having bearing means, a roller supported by said bearing means in engagement with said pad, means to rotate said roller to adjust the position of the operating portion of said pad laterally with respect to said second conductor, the bottom wall of said housing having two openings one adjacent each end, means for coupling a coaxial line through each of said openings, said last named means including means for coupling electrically the outer conductor to said first conductor, said first conductor having an opening therethrough coaxially with respect to said outer conductor and means coupling the inner conductor of said coaxial line through said last named opening to said second conductor.

10. An adjustable microwave attenuator of substantially uniform impedance matching characteristics, comprising a housing, a microstrip waveguide section disposed in said housing including first and second conductors and a layer of dielectric material disposing said conductors in spaced parallel relation, said first conductor being wider than said second conductor to present thereto a planar conducting surface whereby the main electro-

magnetic field is distributed between the opposed surfaces of the conductors with a fringe field extending from the side edges of said second conductor and the top portion there-adjacent toward said first conductor, a plate of dielectric material disposed in parallel overlying relation to said first and second conductors and in said fringe field, a pad of resistive material having a symmetrically tapered operating portion disposed on said plate, said housing having bearing means, a roller supported by said bearing means in engagement with said pad, means to rotate said roller to adjust the position of said pad laterally with respect to said second conductor, spring elements carried by said housing having portions adapted to engage and press said pad against said plate of dielectric, the bottom wall of said housing having two openings spaced apart, means for coupling a coaxial line through each of said openings, said last named means including means for coupling electrically

the outer conductor of said coaxial line to said first conductor, said first conductor having an opening therethrough coaxially with respect to said outer conductor and means coupling the inner conductor of said coaxial line through said last named opening to said second conductor.

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