

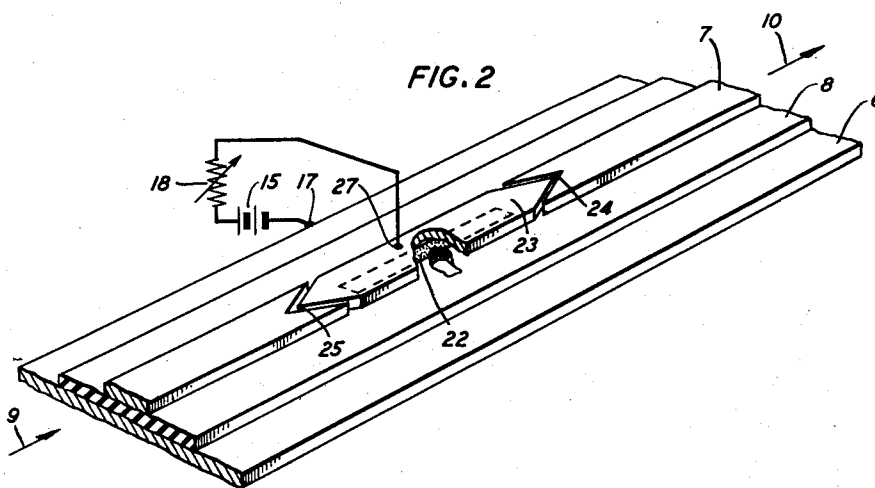
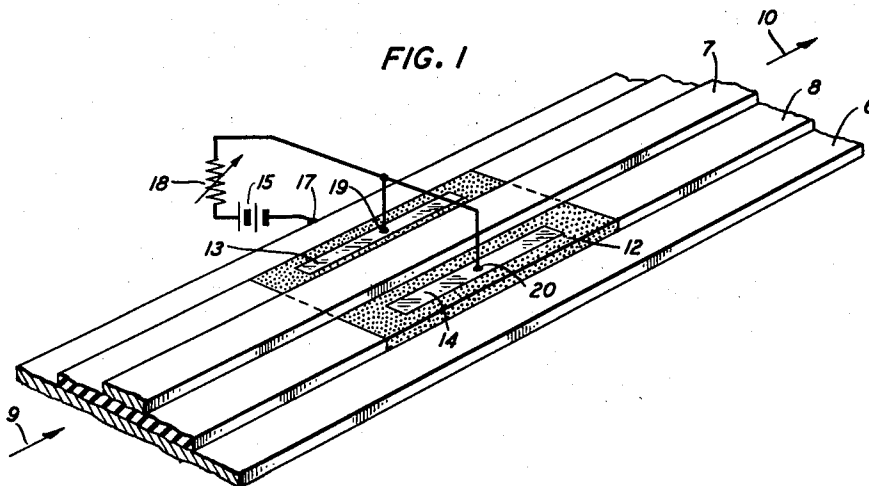
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W. H. HEWITT, JR
ATTENUATOR

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2 Sheets-Sheet 1



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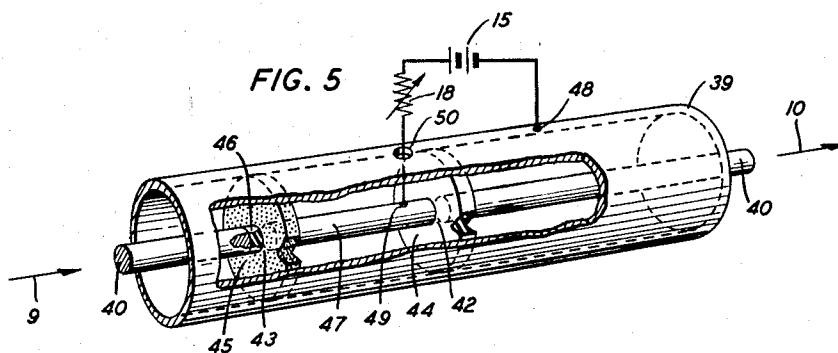
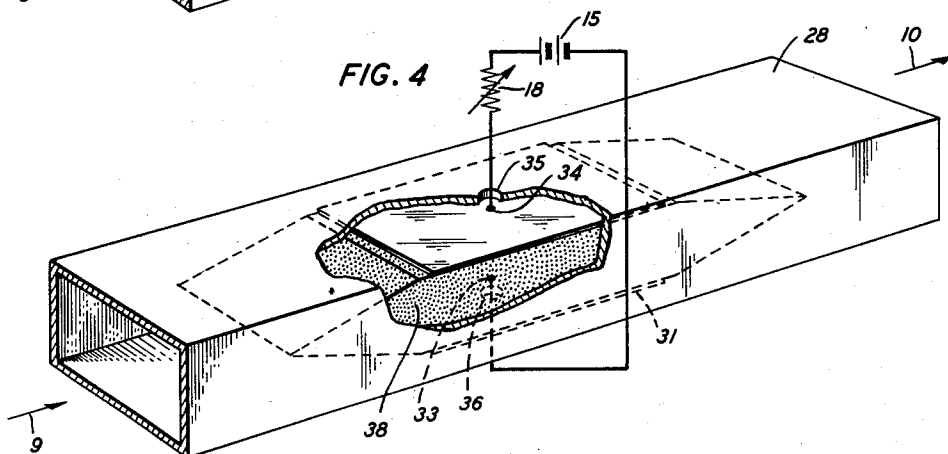
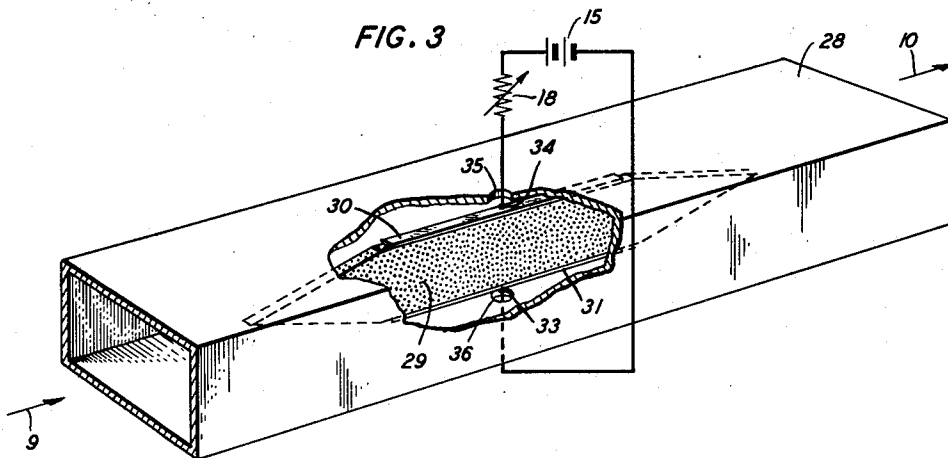
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2,934,723

ATTENUATOR

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1 Claim. (Cl. 333—81)

This invention relates to microwave transmission systems and more particularly to an electrically controllable attenuator.

The general object of the invention is to control the attenuation of electromagnetic waves in a microwave transmission line. A more specific object is to adjust the attenuation electrically.

In microwave transmission systems, it is often required to adjust the attenuation of electromagnetic wave energy which is being transmitted through a transmission line. The adjustable attenuator in accordance with the present invention is applicable to microwave transmission lines of the wave-guide, microstrip, coaxial, or other type which include dielectric material traversed by the electromagnetic field of the waves propagated along the line. The attenuating element is a thermistor, which is a solid, semiconducting body whose electrical resistance varies rapidly with temperature. The thermistor is positioned in the dielectric material so that it extends substantially all the way thereacross and thus constitutes a path in shunt with the line. The attenuation introduced depends upon the impedance of this shunt path which, in turn, is dependent upon the temperature of the thermistor. The thermistor is provided with two or more spaced electrodes which, in the microstrip line, may be portions of the ground plane and the strip conductor and, in the coaxial line, portions of the outer and inner conductors. Heating current from a local source is applied to these electrodes, preferably through an adjustable resistor. Thus, the temperature of the thermistor and, therefore, the attenuation introduced into the transmission line are readily controlled electrically.

Several embodiments of the invention are disclosed, by way of example only. In the case of a microstrip line, the thermistor is inserted in the dielectric between the strip conductor and the ground plane. In a wave-guide, the thermistor may be in the form of a longitudinal vane or block, preferably with tapered ends, inserted in the guide and extending substantially all the way thereacross. In a coaxial line, the attenuating element may be a disc connecting the inner conductor and the outer conductor.

The nature of the invention and its various objects, features, and advantages will appear more fully in the following detailed description of the typical embodiments illustrated in the accompanying drawing, of which

Fig. 1 is a perspective view of a microstrip transmission line incorporating an electrically controllable attenuator in accordance with the invention;

Fig. 2 shows a modified form of the attenuator of Fig. 1;

Fig. 3 is a perspective view, partly cut away, of a wave-guide attenuator in which the thermistor is a longitudinal vane;

Fig. 4 shows a modification of the attenuator of Fig. 3 in which the vane has been expanded into a block which nearly fills the cross section of the guide; and

Fig. 5 is a perspective view, partly cut away, of an

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attenuator for a coaxial transmission line in which the thermistor is in the form of a disc connected between the inner and outer conductors.

Taking up the figures in greater detail, Fig. 1 shows a section of microstrip transmission line comprising a conductive ground plane 6, as strip conductor 7 positioned close to and parallel with the ground plane 6, and an interposed dielectric strip 8. The ground plane 6 may, for example, have a width approximately two or three times that of the conductor 7, and the dielectric 8 is of intermediate width. The spacing between the ground plane 6 and the conductor 7 is preferably only a fraction of the wavelength of the mean operating frequency. Microwave energy from a suitable source, not shown, may be fed to the line 6—7—8 at one end, as indicated by the arrow 9, and transmitted to a load at the other end, as indicated by the arrow 10.

To form the attenuator, a portion of the dielectric 8 is replaced by a thermistor 12 which forms a shunt path between the conductor 7 and the ground plane 6. The thermistor 12 is a solid block or plate having the same width and thickness as the dielectric 8 and a length dependent upon the desired maximum attenuation, which increases with the length. The thermistor 12 comprises semi-conducting, thermosensitive material which may, for example, be germanium or a combination of polycrystalline barium titanate and a small percentage of lanthanum or tungsten. In order to control the temperature of the thermistor 12, two electrodes 13 and 14 are provided on its upper surface, one on each side of the conductor 7. A portion of the ground plane 6 forms a third electrode. Heating current is supplied by a local source, shown as a battery 15. One side of the battery 15 is connected to the ground plane 6 at the point 17. The other side is connected through an adjustable resistor 18 to the top electrodes 13 and 14, at the points 19 and 20, respectively.

The operation of the attenuator is as follows: When the resistor 18 is set at its maximum value, very little heating current from the battery 15 flows from the ground plane 6 through the shunt path to the electrodes 13, 14, the thermistor 12 is at its lowest temperature, and the attenuation introduced is a minimum. However, as the resistance is decreased, more current flows, thus heating the thermistor 12, reducing its resistivity, decreasing the impedance of the shunt path, and increasing the attenuation. There is thus provided an electrically controllable attenuator which may be adjusted for any desired attenuation within wide limits by properly setting the resistor 18.

The modified form of the attenuator shown in Fig. 2 is the same as the one shown in Fig. 1 except that the thermistor 22 is narrower and has only one upper electrode 23. The thermistor 22 is a solid, rectangular block, as shown by the broken line, and is embedded in the dielectric 8 between the conductor 7 and the ground plane 6 to form a shunt path therebetween. The electrode 23 may be formed by making two cuts 24 and 25 across the conductor 7. These gaps keep direct current from the source 15 out of the rest of the conductor 7 but offer negligible impedance to the propagation of microwaves along the line. The cuts 24 and 25 are preferably V-shaped, as shown, so that the electrode 23 has tapered ends which reduce the reflection of the transmitted energy at these points. The resistor 18 is connected at one end to the electrode 23 at the point 27. Parts of the electrode 23, the thermistor 22, and the dielectric 8 are cut away to show the construction more clearly. The attenuation is varied by adjusting the resistor 18.

Fig. 3 shows an attenuator in accordance with the invention incorporated in a hollow-pipe wave-guide 28 of

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rectangular cross section. The thermistor is in the form of a vane 29, with tapered ends, longitudinally positioned within the guide 28 parallel with the narrower sides. The vane 29 is preferably approximately centered transversely in the guide 28 so that it will be in the maximum electric field of the dominant mode transmitted. The upper and lower edges of the vane 29 are provided with the electrodes 30 and 31, respectively. The width of the vane is such that these electrodes do not make electrical contact with the guide 28, but the vane extends substantially all the way between the wider sides and thus constitutes effectively a shunt path for the energy transmitted through the guide. Heating current is obtained from the battery 15, which is connected at one end to the electrode 31 at the point 33 and at its other end through the resistor 18 to the other electrode 30 at the point 34. The small holes 35 and 36 permit the connections from the battery 15 to pass through the walls of the guide 28, which have been partly cut away to show the vane 29. Here, also, the attenuation is adjusted by means of the resistor 18.

The embodiment of the attenuator shown in Fig. 4 is the same as the one shown in Fig. 3 except that the vane 29 has been increased in thickness to form a block 38 which substantially fills the cross section of the guide 28. With this construction, a higher maximum attenuation is obtainable.

Fig. 5 shows an attenuator in accordance with the invention in a coaxial transmission line comprising a cylindrical outer conductor 39 and an inner conductor 40 concentric therewith. The outer conductor 39 has been partly cut away to show the inner construction more clearly. Portions of the inner conductor 40 have been removed at the points 42 and 43 so that the discs 44 and 45 may be inserted. The disc 44 is an insulator. The disc 45 is the thermistor and provides a shunt path between the inner conductor 40 and the outer conductor 39. A small cylindrical insulator 46 separates the thermistor 45 from the portion of the inner conductor 40 extending to the left thereof. The portion 47 of the inner conductor between the discs 44 and 45 thus constitutes one thermistor electrode and a portion of the outer conductor 39 forms the other electrode. Heating current is supplied to the thermistor 45 by the battery

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15, which is connected at one end to the outer conductor 39 at the point 48 and at the other end through the resistor 18 to the portion 47 of the inner conductor at the point 49. A hole 50 in the outer conductor 39 permits this latter connection to be made. The insulators 44 and 46 keep the direct current supplied by the battery 15 out of the main portions of the inner conductor 40 but offer negligible impedance to the transmission of microwaves through the coaxial line 39-40. As in the other embodiments described above, the attenuation of the signal energy is controlled by adjusting the resistor 18. In an attenuator of this type in which the thermistor 45 was a thin disc of germanium, it has been found by test that changing the heating current from zero to one ampere increases the attenuation by 20 decibels.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

In a microwave transmission system, an attenuator comprising a conductive strip, a conductive ground plane wider than the strip, an interposed dielectric of intermediate width, the dielectric having a portion replaced by a block of germanium which has the same transverse dimensions as the dielectric, two electrodes associated with the block, one on each side of the strip, and a local source of heating current connected between the plane and each of the electrodes.

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