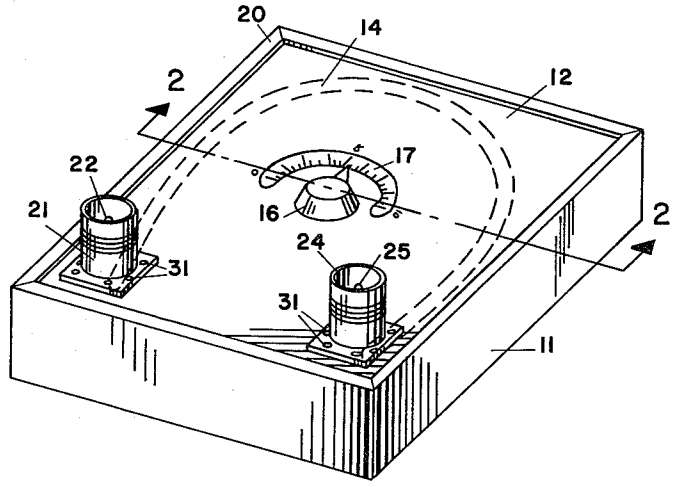
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HIGH FREQUENCY ATTENUATOR

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Fig. 1



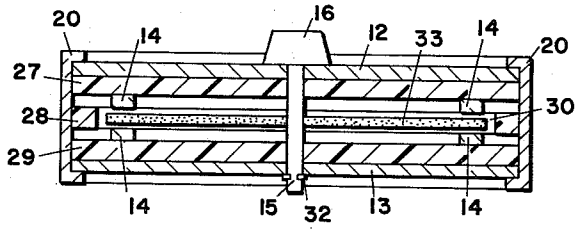
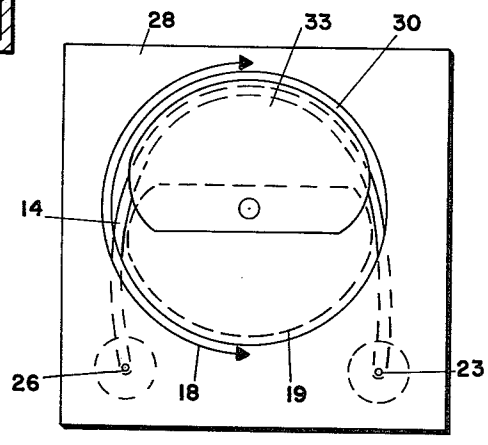


Fig. 2

Fig. 3



William J. Wilson

INVENTOR

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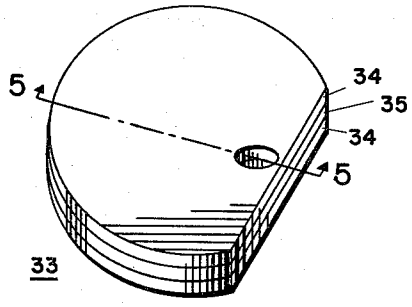


Fig.4

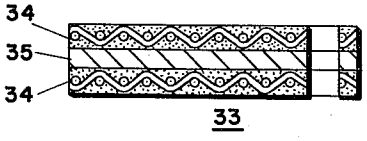
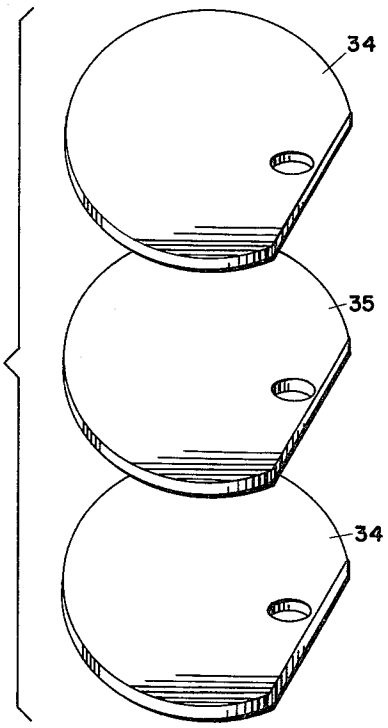


Fig.5

Fig.6



William J. Wilson
INVENTOR

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Fig. 7

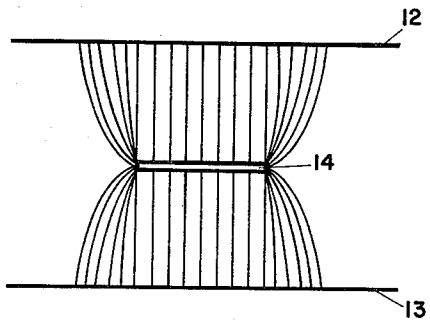


Fig. 8

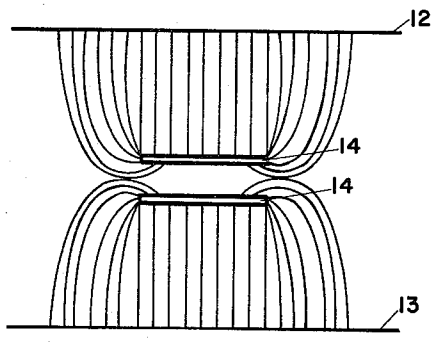
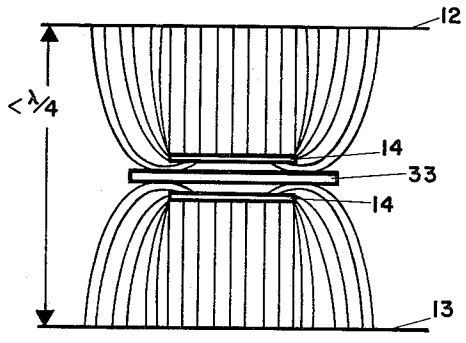


Fig. 9



William J. Wilson
INVENTOR

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3,046,505

HIGH FREQUENCY ATTENUATOR

William J. Wilson, Nashua, N.H., assignor to Sanders Associates, Inc., Nashua, N.H., a corporation of Delaware

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4 Claims. (Cl. 333—81)

The present invention relates to high frequency electric transmission line devices. More particularly, the present invention relates to transmission line attenuating devices and attenuating materials for use therein.

Many of the prior art devices that provide a predetermined degree of attenuation for transmission lines, such as coaxial lines and waveguides, involve relatively complex, heavy, and expensive equipment. Another problem that is particularly perplexing in waveguide applications is the fact that such prior art devices have a band pass characteristic, i.e. ability to pass a range of frequencies, that is very limited.

A recent advance in the field of microwave attenuator technology is described in the copending application of Donald J. Sommers et al., Serial No. 484,406, filed January 27, 1955, which issued October 20, 1959, as Patent No. 2,909,736. This device essentially comprises a pair of signal energy conductors maintained in parallel insulated spaced relation between a pair of ground planes. Attenuation is accomplished by the introduction of a planar card of attenuating material between the inner signal energy carrying conductors. It is now well established that the principle of attenuation in a device of this character is based upon distortion and concentration of the fringe fields produced by splitting the inner conductor. The spacing between the inner conductors is limited because of the requirement that the outer or ground plane conductors be spaced apart substantially less than one-quarter of a wavelength at the highest operating frequency of the line. In the above-mentioned application of Sommers et al., an attenuating card comprising a granular resistive material provides a degree of attenuation which varies inversely as the resistance of the card. One means of decreasing the resistance of the card is by increasing its thickness; however, in view of the quarter wavelength restriction on the separation of the ground plane conductors, the attenuating card thickness is correspondingly limited. A further limitation of such prior art attenuating material is that the attenuation provided by the granular resistive material varies linearly with the frequency. The present invention is directed to an improvement in such attenuators by providing a solution for the problems arising from attempts to achieve a high degree of attenuation using an attenuating card of limited thickness and to achieve a relatively constant degree of attenuation over a range of frequencies.

It is, therefore, an object of the present invention to provide an improved wave translating device for high frequency transmission lines.

It is a further object of this invention to provide an improved wave translating device exhibiting a high degree of attenuation of high frequency energy.

An additional object of the present invention is to provide an improved wave translating device exhibiting a relatively high degree of attenuation over a wide range of high frequencies.

Yet another object of this invention is to provide an improved high frequency attenuating material for use in high frequency attenuators.

In accordance with the present invention, there is provided a unitary, composite, wave translating device for high frequency lines comprising a pair of planar outer conductors providing ground planes. In insulated spaced relation between the outer conductors is a pair of elongated planar inner conductors adjacently disposed in different parallel planes. These inner conductors are connected together to operate electrically as a single conductor while substantially confining high frequency energy between each inner conductor and its adjacent outer conductor. Disposed intermediate the planes of the inner conductors is an attenuating means comprising a composite laminate of a metallic film layer and a layer of granular resistive material. Each of these layers provides a predetermined degree of attenuation of RF energy when placed in a field. The composite laminated material, however, exhibits a degree of attenuation in excess of the predetermined attenuations provided by either of the layers.

Also in accordance with the present invention, there is provided a composite, laminated, high frequency attenuating material having a layer of granular resistive material and a metallic film layer. Each of these layers provides a predetermined degree of attenuation of RF energy when placed in a field. The composite laminated material, however, exhibits a degree of attenuation in excess of the predetermined attenuations provided by either of the layers.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings:

FIG. 1 is a perspective view of a composite, high frequency wave translating device of the present invention;

FIG. 2 is an elevational section of the wave translating device of FIG. 1 taken along the line 2—2;

FIG. 3 is a cross-sectional bottom view of the wave translating device of FIG. 1;

FIG. 4 is a perspective view of an attenuating card of the present invention;

FIG. 5 is an elevational view in section of the attenuating card of FIG. 4 taken along the line 5—5;

FIG. 6 is an exploded view in perspective of the attenuating card of FIG. 4;

FIG. 7 is a schematic illustration of the electric field about a center conductor disposed between parallel ground planes;

FIG. 8 is a schematic illustration of the electric field about a spaced pair of center conductors disposed in register between parallel ground planes; and

FIG. 9 is a schematic illustration of FIG. 8 with the addition of a planar attenuating member between and parallel to the center conductors.

Illustrated in FIGS. 1–3 is a wave translating device 11 for high frequency transmission lines which utilizes an attenuating card such as the attenuating card 33 as more particularly illustrated in FIGS. 4–6. This device comprises a first flat outer conductor 12 and a second flat outer conductor 13 providing electrical ground planes. An inner conductor assembly, for example, a pair of flat elongated conductors 14, is formed into a loop or U-shape and disposed in register in insulated spaced relation between the outer conductors 12 and 13. The attenuating member here shown, e.g. as the attenuating card 33, is disposed between the inner conductor assembly and is so rotatably mounted with respect to the loop formed by the inner conductors 14 as to introduce different areas of the card 33 between the inner conductors 14 with different degrees of rotation of the card 33. Such rotation thereby provides a predetermined degree of attenuation of the high frequency electrical energy passing through the attenuator. More specifically, this operation is carried on by pivotally suspending the card 33 between the conductors 14 by means of a rotatable shaft 15 which is positioned by means of a knob 16 to

indicate the degree of attenuation on a calibrated dial plate **17**. The card may be rotated as indicated by the arrows **18** in FIG. 3 into the position shown by the phantom lines **19**. A conductive means, here illustrated as a copper seal **20**, surrounds the inner conductors **14** and the attenuator card **33** and connects the outer conductors **12** and **13** together to confine electric energy within the outer conductors.

An input transducer means, here shown as coaxial connector **21**, has its center conductor **22** connected to a pair of ends **23** of the inner conductors **14**. An output transducer means, here shown as coaxial connector **24**, has its inner conductor **25** connected to the other pair of ends **26** of the inner conductors **14**.

Dielectric means, here shown as plastic insulating plates **27**, **28** and **29**, hold the conductors in insulated spaced relation as more particularly illustrated in FIG. 2. The plate **28** has a hole **30** formed therein to permit rotation of the card **33**. The coaxial connectors **21** and **24** have their outer conductors connected to the outer conductors **12** and **13** by the conductive pins **31**. The pins may be, for example, brass rivets or screws. The attenuator selecting shaft **15** is inserted through holes (not shown) in the various components and locked in place, for example, with a clamping ring **32**. The center conductors **22** and **25** of the coaxial connectors **21** and **24** are inserted through holes to contact the inner conductors **14** at the respective ends **23** and **26**.

While applicant does not intend to be limited to any particular dimensions in the embodiment of the invention just described, there follows a set of dimensions which is found to be particularly suitable for devices of this character:

The over-all outside dimensions of the device **11** may be, for example, five inches square by 5/32 inch thick. The ground planes **12** and **13** and the center conductors **14** may be made from one mil (0.001 inch) copper laminated to each side respectively of the dielectric layers **27** and **29**. The over-all thickness of the ground plane-dielectric-inner conductor laminate may be, for example 1/16 inch. Separating the ground plane-dielectric-inner conductor laminates is the dielectric spacer **28** which has an aperture formed therein to receive the attenuating card **33**. The dielectric material used in the card **33** may be, for example, polytetrafluoroethylene, such as Teflon, trademark of the E. I. du Pont de Nemours & Company. For convenience, the ground plane dielectric and inner conductors may be formed from commercially obtainable laminates of Teflon-Fiberglas bonded between sheets of one mil copper as, for example, the GB–112T Teflon-Fiberglas as manufactured by the Continental Diamond Fibre Division of the Budd Co., Inc., of Newark, Delaware. The inner conductor configuration may then be formed by conventional chemical etching techniques. The attenuating card **33** may be made, for example, of a polyethyleneterephthalate sheeting, such as Mylar, trademark of the E. I. du Pont de Nemours & Co. of Wilmington, Delaware, metallized on one face and laminated between layers of carbonized fabric. This carbonized fabric may be, for example, USKON, trademark of the U. S. Rubber Company of Rockefeller Center, New York, N.Y. for their carbonized fabric, and may have a resistance of, for example, 377 ohms per square inch. This fabric consists of a linen cloth with carbon granules embedded therein and bonded thereto with some suitable plastic binder in a manner well known in the art. The metallized Mylar may be ½ mil (0.0005 inch) Mylar sheeting having a metallic aluminum film thereon as manufactured, for example, by National Metallizing Corp. of Newark, New Jersey, and may have a resistance of, for example, 6 ohms per square inch. The laminate may be firmly bonded by means of an adhesive as, for example, a thermosetting epoxy adhesive such as Hysol Type 6020 Hardener C as made by Houghton Laboratories, Inc. of Olean, New York. One layer of USKON

and one layer of metallized Mylar may be used in place of the sandwich construction; however, the sandwich construction is preferred for reasons of symmetry. The adhesive bonding of the metallized Mylar between layers of the USKON fabric is not essential but it does tend to protect the metallic film which is very thin and fragile.

Referring now to FIGS. 4–6, there is here illustrated a laminated attenuating card **33** such as that described above. FIGS. 5 and 6 particularly show the carbonized fabric layers **34** and the metallic film layer **35**.

The following table gives a comparison between the attenuation of a device having a laminated attenuating card and the general dimensions and character of the example described above with that of a similar device using a plain carbonized fabric attenuating card in place of the laminated card.

Dial Setting	Standard Attenuator With Plain USKON Card, 3,000 mc. Attenuation	Attenuator With Card of Metallized Mylar Laminated Between USKON Layers, 3,000 mc. Attenuation
0	.4	.6
3	2.8	8.4
6	6.0	14.3
9	8.7	19.5
12	11.6	23.6
15	14.9	31.0
18	17.8	36.1

FIGS. 7–9 of the drawings are schematic illustrations of the mode of operation of the illustrated embodiment. FIG. 7 depicts the electric field lines present when a single center signal energy carrying conductor **14** is disposed between parallel ground planes **12** and **13**, as is characteristic of the transverse electromagnetic or TEM mode of propagation. FIG. 8 shows the character of the field when two center conductors **14** in register and in separate parallel planes are connected electrically to operate as a single conductor. Note that fields which were previously terminated at the ends of the inner conductors, as shown in FIG. 7, here loop over into the space between the inner conductors. FIG. 9 shows the field configuration of the illustrated embodiment with the attenuating card disposed between the separated center conductors. Ordinarily it is a basic rule that the attenuating material be inserted in a plane parallel to the electric lines of force. Here the attenuating card is positioned tangential to the fringe field to distort and concentrate the field. This is, however, in effect equivalent to the insertion of an attenuating member at a point in the electric field parallel to the electric field.

As pointed out above, the distance between the ground planes **12** and **13** must be less than one-fourth (¼) the wavelength at the highest operating frequency; therefore, the space available for the insertion of the attenuating card **33** is correspondingly limited. The laminated attenuating card structure described above provides a higher degree of attenuation over a wide range of high frequencies than any single material now known in the art. The theory of this is not entirely understood, as the characteristics of the individual materials comprising the laminate apparently do not combine to provide a composite material exhibiting a mathematically predictable degree of attenuation. In the case of the granular resistive material a decrease in the resistance of the material increases its attenuating ability. This is true only within a given range of resistance values, however, as there is a point after which an increase in conductivity will tend to decrease the attenuating ability of the granular material. Likewise, a metallic film exhibits increased attenuating ability as the resistance of the film is decreased. To exhibit any appreciable attenuating ability at all, however, a metallic film must have a thickness less than the cur-

rent penetrating depth in that film at the highest operating frequency of the device. In the case of the granular resistive material, the attenuation varies linearly with the frequency. With the metallic film, attenuation is proportional to the square root of the frequency. The combination laminate provides a curve of attenuation vs. frequency which is irregular in contour and not indicative of any simple mathematical relationship.

The present invention presents an important step forward in the art of wave translating devices by providing a degree of attenuation of high frequency energy not previously available.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A unitary, composite, wave translating device for high frequency transmission lines, comprising: a pair of planar outer conductors providing ground planes; a pair of spaced, planar inner conductors adjacently disposed in different planes in register, and in parallel with and in insulated spaced relation between said outer conductors, said inner conductors being connected together to operate electrically as a single conductor while substantially confining high frequency energy between each inner conductor and its adjacent outer conductor; and attenuating means disposed in a plane intermediate the planes of said inner conductors, said attenuating means comprising a composite laminate of a metallic film layer and a layer of granular resistive material, said metallic film layer being of a thickness less than the penetrating depth of the energy transmitted along said transmission line.

2. A unitary, composite, wave translating device for high frequency transmission lines, comprising: a pair of planar outer conductors providing ground planes; a pair of spaced, elongated, planar inner conductors adjacently disposed in different planes in register, and in parallel with and in insulated spaced relation between said outer conductors, said inner conductors being spaced less than ¼ wavelength apart and being connected together to operate electrically as a single conductor while substantially confining high frequency energy between each inner conductor and its adjacent outer conductor; and attenuating means disposed in a plane intermediate the planes of said inner conductors, said attenuating means comprising a composite laminate of a metallic film layer having a thickness less than a current penetrating depth of the energy transmitted and a layer of granular resistive material.

3. A unitary, composite, wave translating device for high-frequency transmission lines, comprising: a pair of planar outer conductors providing ground planes; a pair of spaced, planar inner conductors adjacently disposed in different planes in register, and in parallel with and in insulated spaced relation between said outer conductors, said inner conductors being connected together to operate electrically as a single conductor while substantially confining high frequency energy between each inner conductor and its adjacent outer conductor; and attenuating means disposed in a plane intermediate the planes of said inner conductors, said attenuating means comprising a composite laminate of a first layer of granular carbon material providing a predetermined degree of attenuation of RF energy when placed in a field, a second layer of granular carbon material providing a predetermined degree of attenuation of RF energy when placed in a field, and a layer of metallic film having a thickness less than the current penetrating depth of the energy transmitted, said composite laminate being less than ¼ wavelength thick.

4. A unitary, composite, wave translating device for high frequency transmission lines, comprising: a first flat outer conductor providing an electrical ground plane; a second flat outer conductor providing an electrical ground plane; a pair of flat, elongated, inner conductors formed into a pair of identical parallel loops connected together to operate electrically as a single conductor and disposed in register in different planes parallel to and in insulated spaced relation between said outer conductors; and attenuator material disposed between said inner conductors and so rotatably mounted with respect to said loops as to introduce different areas of said attenuation material between said inner conductors with different degrees of rotation of said material to provide a pre-determined degree of attenuation to the passing of electric energy through said attenuator, said attenuating material comprising a composite laminate of a first layer of resistive material, a second layer of resistive material, and a layer of metallic film having a thickness less than the penetrating depth of the energy transmitted, said layer of film being disposed between said first and second layers of resistive material.

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