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COAXIAL ATTENUATOR HAVING AT LEAST TWO REGIONS OF RESISTIVE MATERIAL

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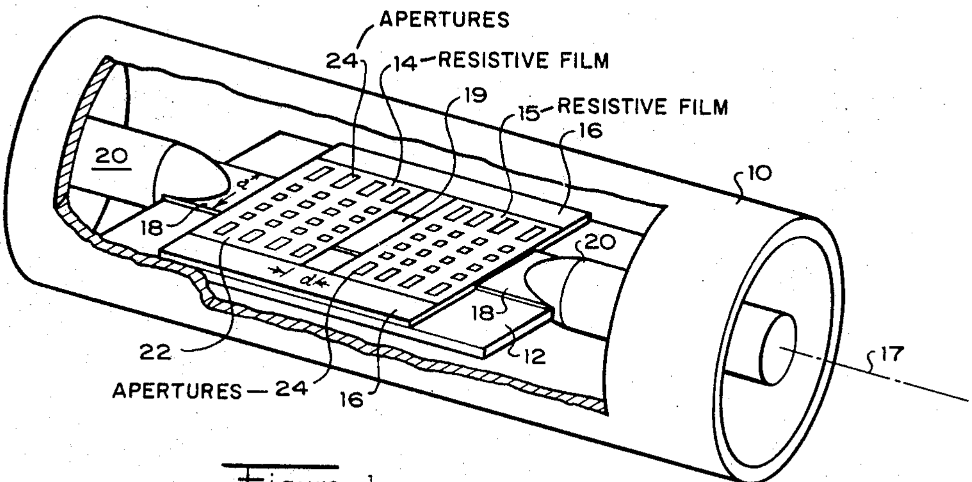

Figure 1

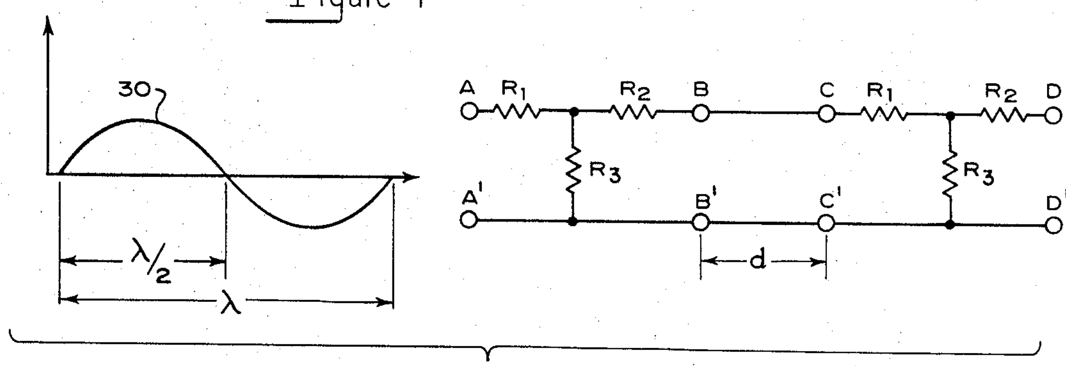

Figure 2

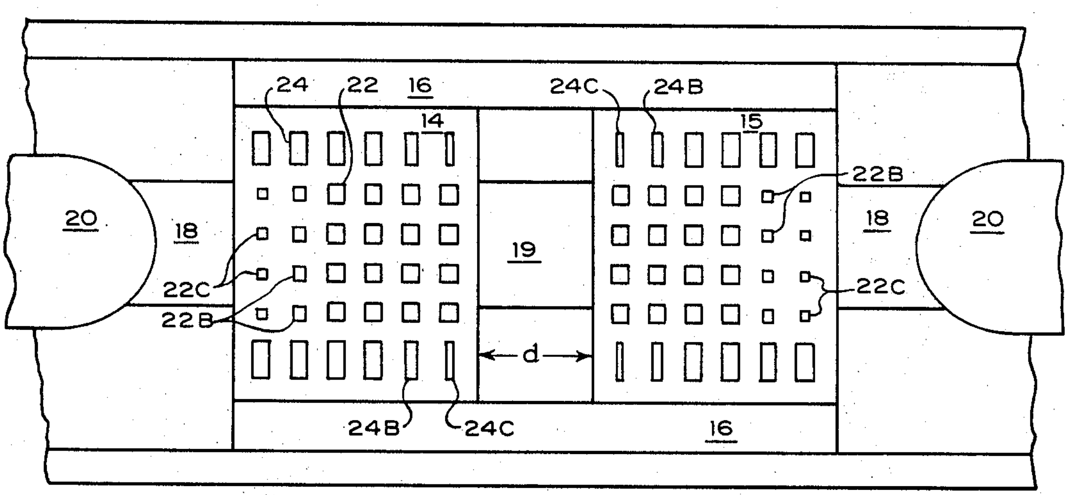

Figure 3

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COAXIAL ATTENUATOR HAVING AT LEAST TWO REGIONS OF RESISTIVE MATERIAL

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ABSTRACT OF THE DISCLOSURE

A distributed network resistive film attenuator having a substantially constant attenuation over a broad frequency range is provided with two aligned rectangular areas of resistive film disposed a selected distance apart on a substrate supported within an outer coaxial conductor, each area having small aligned rectangular apertures therein to provide selected values of resistivity per unit area within selected portions of the film. The resistive film areas are connected by a connecting electrode of a selected length which is less than one-half of the wavelengths of the electromagnetic wave energy being attenuated. A first pair of electrodes provides electrical contacts between the outer conductor and opposite edges of both rectangular areas of resistive film, and the second pair of electrodes provides electrical contacts between sections of a coaxial inner conductor and the resistive film areas, thereby interconnecting both areas between the coaxial inner conductor sections.

BACKGROUND OF THE INVENTION

Distributed network resistive film attenuators are described in U.S. Pat. No. 3,227,975 issued to W. R. Hewlett, et al., Jan. 4, 1966, and entitled Fixed Coaxial Line Attenuator with Dielectric Mounted Resistive film. These attenuators have a substantially constant attenuation over a wide range of frequencies, for example, from direct current to 18 kilomegacycles per second (DC–18 gc.).

Resistive film attenuators of this type suffer from several known limitations. First, in order to achieve a desired attenuation or a desired impedance throughout the operating frequency range of the attenuator, a resistive film is required which has different values of resistivity in selected locations within the film. However, if the resistivity, for example, is too low then the resistive film may have to be made long in order to maintain a desired attenuation and impedance and this may affect attenuation characteristics at higher frequencies. To provide desired resistance properties along selected portions of the substrate, resistive film attenuators are often constructed with two or more layers of resistive material, each deposited on a single substrate in a selected pattern and each deposited to a selected thickness. This method requires two or more deposition steps to provide specific resistances of different values.

Second, the power handling capabilities of the resistive film attenuator often limit signal power to values which can be handled in the immediate vicinity of the high voltage electrode. This is due to the fact that most of the power is dissipated in the area of the resistive film that is close to the high voltage electrode (i.e., the electrode nearer the source). Consider, for example, the case of a 10 db attenuator where nine-tenths of the signal power supplied to the attenuator is dissipated in the attenuator, and most of this power is dissipated in the area close to the transition between the input electrode and the resistive film. This causes the resistance film to burn out close to the junction of the high voltage electrode if the very thin resistance film in this region, together with the supporting substrate, cannot safely dissipate the heat.

A third limitation of resistive film attenuators of this type is that the attenuation varies with frequency when operated at frequencies from about 12.4 gHz. to about 18 gHz. A resistive film attenuator that provides a uniform attenuation below this range usually introduces reactive components into the circuit at these higher frequencies, and such reactive components cause the attenuation to deviate from the desired value. For example, the current paths through the resistive film produce small inductive or capacitive reactances which change the attenuation value as the operating frequency changes.

SUMMARY OF THE INVENTION

In accordance with the illustrated embodiment of the invention these limitations commonly associated with fixed resistive film attenuators are overcome by using a plurality of spaced, resistive films supported on a dielectric substrate within a cylindrical outer conductor between sections of a coaxial inner conductor. The resistive films are selectively disposed on the dielectric substrate to form at least two aligned rectangular areas of predetermined width and length a selected distance apart, each area having small aligned rectangular apertures therein. The shape and location of the apertures within the resistive film determines resistivity per unit area of the film. By providing aligned equally-spaced rectangular apertures of different length and width dimensions, the resistivity per unit area can be varied along a selected direction in the plane of the film. Other patterns of apertures may be used to provide logarithmic or exponential or other desired variations with length in the resistivity per unit area of the resistive film.

The two rectangular sheets of resistive film are positioned on the substrate between first and second pairs of electrodes. The first pair of electrodes provides electrical contacts between the outer conductor and the lengthwise or longitudinal sides of the rectangular sheets along the full length of the sheets. The second pair of electrodes provides electrical contacts between the sections of the coaxial inner conductor and a central portion of a lateral side of each rectangular sheet. Between the two separated sheets of resistive film there is provided a connecting electrode of a selected length which electrically interconnects the remaining sides of the sheets to provide an electrical path between the second pair of electrodes through each resistive sheet and the connecting electrode. Signal delay along the length of the connecting electrode between the two, otherwise isolated, resistive sheets is used to improve the linearity with frequency of the attenuation at frequencies from about 12.4 gHz. to about 18 gHz.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cutaway perspective view of the preferred embodiment of the invention;

FIG. 2 is an equivalent circuit diagram of the preferred embodiment of the invention; and

FIG. 3 is a detailed drawing of the rectangular resistive films in the preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a fixed coaxial attenuator including a cylindrical outer conductor **10** and a dielectric substrate **12** supported therein. Dielectric substrate **12** is sufficiently wide so that the lengthwise edges thereof are contiguous with substantially diametrically opposed portions of outer conductor **10**. Dielectric substrate **12**, which may be sapphire, has a flat surface which is aligned with the central axis **17** of the sections of coaxial inner conductor **20**. Rectangular resistive films **14** and **15** are deposited on the surface of substrate **12** in spaced relationship along axis **17** with a selected distance *d* between adjacent lateral edges of the films. The longitudinal edges of the rectangular resistive films **14** and **15** are disposed in electrical contact with the pair of conductive electrodes **16** that connect to the outer conductor **10**. A second pair of conductive electrodes **18** and a connecting electrode **19** are disposed on the surface of dielectric **12** in electrical connection with the lateral edges of the resistive films **14** and **15** for forming a continuous conductive path between inner conductor sections **20**. Electrodes **18** and **19** are disposed along axis **17** and have a width *a*. Electrode **19** has a length dimension *d* indicative of the distance between resistive films **14** and **15**. The length *d* of the connecting electrode **19** is selected for greatest linearity of attenuation with frequency over a broad frequency range from D.C. to about 18 gHz. Specifically, the connecting electrode **19** is not longer than one-half of a wavelength at the highest operating frequency of the attenuator.

Rectangular resistive films **14** and **15** may be formed of a metal such as tantalum nitride on the surface of dielectric substrate **12** using known thin film techniques. Films **14** and **15** may be selectively deposited on substrate **12** in a pattern having an array of apertures therein. Alternatively, the apertures may be etched into a continuous deposited film. In the illustrated embodiment, the apertures are rectangular holes **24** and square holes **22** disposed in a grid pattern on substrate **12** but, in general, these apertures may have any shape or be arranged in any suitable pattern which provides the required resistivity per square over the area of the films. Electrodes **16** are disposed between the outer conductor **10** and the edges of rectangular resistive films **14** and **15** along the full width thereof to provide a good electrical signal connection between the edges of rectangular resistive films **14** and **15** and outer conductor **10**. End electrodes **18** of width *a* are disposed between the sections of coaxial inner conductor **20** and central portions of the lateral edges of the resistive films **14** and **15** to provide good electrical signal connections between these portions and the sections of the coaxial inner conductor **20**. Connecting electrode **19**, also of width *a*, is disposed between rectangular resistive films **14** and **15** to provide a good electrical signal connection therebetween. Electrodes **16**, **18** and **19** may be formed by deposition of a thin layer of a conductive metal such as gold on the dielectric substrate **12** prior to deposition in contact therewith of the metal which forms the resistive films **14** and **15**.

Referring now to FIG. 2, there is shown an equivalent circuit diagram of the present attenuator having two rectangular resistive films. The equivalent circuit elements R_1, R_2 and R_3 of each attenuating film are shown connected in a T pad configuration between terminals AA′ and BB′ and between terminals CC′ and DD′. As the frequency of an input signal **30** is increased, capacitive and inductive reactances of the first resistive film between terminals AA′ and BB′ become significant and greatly affect the linearity of attenuation with frequency. The present invention includes the connecting electrode **19** of length *d* in the transmission line following the first resistive film and thus provides a compensating reactance which partially cancels out the effects of the reactance introduced by the first resistive film.

The length of this transmission line is less than one-half of a wavelength λ, at the highest operating frequency of the attenuator, and thus provides a reactive component within the transmission line which approximately cancels out the effect of the reactive components introduced into the high frequency circuit by the resistive film. The resistive film thus creates specific reactive components at various operating frequencies which are cancelled out in part by the reactive effects of the section of connecting electrode **19**.

Referring now to FIG. 3, there is shown a detailed view of resistive films **14** and **15** on substrate **12**. The portions of the resistive films having square apertures **22** provide in effect a series resistance between inner conductor sections **20**, while the portions of the resistive films having rectangular apertures **24** therein provide in effect a shunt resistance between the central portion of the resistive films and outer conductor **10**. The desired values of resistivity per unit square in these portions of the resistive films may thus be obtained by selectively varying the size, shape and spacing of the apertures.

Therefore, desired attenuator characteristics can be created by using a single layer of resistive film and by selecting the size, shape and pattern of the apertures within the resistive film. Also, the two electrodes **18** can be spaced sufficiently far apart that there will be little or no capacitive interaction between them simply by including smaller apertures **22** in the effective series circuit between the two electrodes. This capacitive interaction which varies with frequency and which disturbs the linearity of the attenuation with frequency can thus be selectively controlled by proper choice of aperture configuration. Also, the possibility of burn-out of the resistive film **14** or **15** in the regions about the center conductors **20** is greatly reduced by using smaller rectangular apertures **22*a*** and **22*b*** near the inner conductor sections **20** to decrease the resistivity per unit area of the resistive film in these regions. This reduction in the size of the apertures increases the power handling capabilities of the attenuator but has little or no effect on the attenuation provided by the resistive films. In addition, both the length of the resistive film (for reduced by-passing capacitance) and the power handling capabilities thereof can be increased by increasing the resistivity per unit area of the shunting resistance portions of the resistive films. This may be accomplished simply by increasing the rectangular apertures **24**. Specifically an exponential decrease in resistivity can be provided along the length of the resistive film toward the lateral edges near the middle of the substrate by decreasing the size of the apertures.

I claim:

1. In an electromagnetic wave energy transmission path for operation over a range of frequencies and including an outer conductor and sections of an inner conductor, an attenuator comprising:

a dielectric substrate disposed within said outer conductor and having at least one substantially flat surface, said surface having a lineal axis;

at least two regions of resistive material disposed in spaced relationship on said surface along said lineal axis of said surface with adjacent lateral boundaries thereof separated by a selected distance not more than one half the wavelength of an electromagnetic wave at the highest frequency of the operating range;

a first pair of electrodes spaced apart on said dielectric substrate and connecting opposite longitudinal boundaries of each of said resistive regions to the outer conductor;

a connecting electrode disposed on the surface of said substrate in a direction along said lineal axis between said regions of resistive material and electrically connecing together said regions along central portions of the adjacent lateral boundaries of said regions intermediate the longitudinal boundaries thereof; and

a second pair of electrodes spaced apart on the surface of said substrate in a direction along said lineal axis and connecting the sections of the inner conductor to said resistive regions along central portions of the remaining remote lateral boundaries of said regions intermediate the longitudinal boundaries thereof.

2. An electromagnetic wave energy attenuator as in claim **1** wherein:

each of said regions of resistive material includes an array of apertures therein which provide selected values of resistivity per unit area over portions of said regions and which provide a lattice-like array of cross-connected signal conduction paths about said apertures having signal reactances; and

said selected distance introduces signal reactance which substantially cancels the effect of the signal reactances of said signal conduction paths to provide overall electromagnetic wave transmission characteristic through the attenuator which is substantially constant with frequency over the operating range of frequencies.

3. An electromagnetic wave energy attenuator as in claim **2** wherein the size and location of said apertures provides resistivity per unit area which decreases with length in a direction along at least one axis of at least one of said resistive regions.

4. An attenuator as in claim **3** wherein the resistivity per unit area varies exponentially with length in said direction within a portion of at least said one of the resistive region having plural apertures therein.

5. An attenuator as in claim **3** wherein at least said one resistivity region including plural apertures has a first value of resistivity per unit area in the longitudinal direction within the plane of said material and a second, different value of resistivity per unit in the lateral direction within the plane of said material.

References Cited

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PAUL L. GENSLER, Primary Examiner

U.S. Cl. X.R.

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