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HIGH FREQUENCY ATTENUATION CONTROL DEVICE

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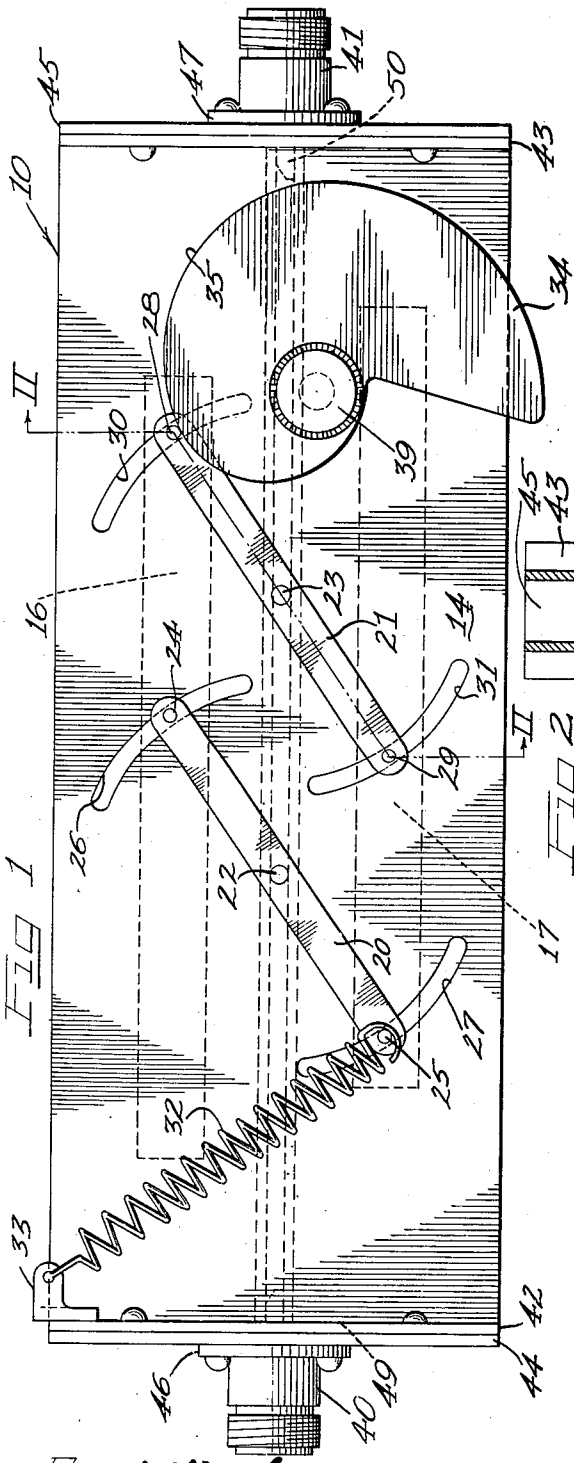


Fig 1

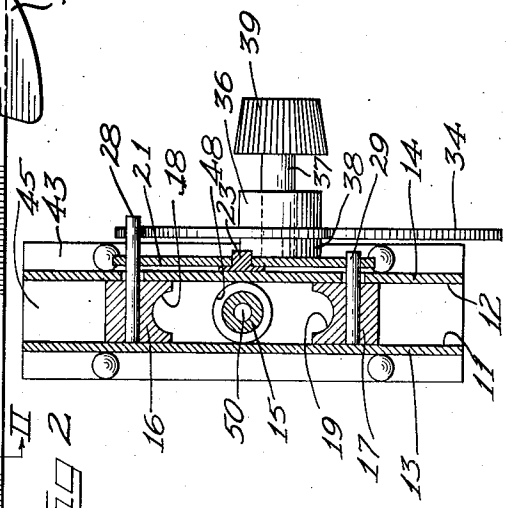


Fig 2

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HIGH FREQUENCY ATTENUATION CONTROL DEVICE

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1 Claim. (Cl. 333—81)

This invention relates to a device for operation at high frequencies and to means for varying the impedance thereof. The device most preferably takes the form of a transmission line section in which the resistance or degree of attenuation is varied without substantially varying characteristic impedance. It will be understood, however, that the broad aspects of the invention are not limited to such a form, and that the term variable impedance is used herein in a generic sense to include variable capacitance, variable inductance and variable characteristics impedance, as well as variable resistance or variable attenuation.

According to this invention, a variable impedance device comprises a transmission line section including a first conductor having a plane surface and a second conductor in spaced relation to the plane surface with an energy transmission control member movable over the plane surface toward and away from the second conductor to vary the transmission of energy. With this arrangement a wide range of variation of impedance is possible and a comparatively low characteristic impedance of the transmission line section may be achieved without unduly close spacing between conductors. Also, movement of the member over the surface toward and away from the second conductor is readily controlled.

According to a more specific feature of the invention, the transmission line section may further include a third conductor having a surface in spaced facing relation to the surface of the first conductor with the aforesaid second conductor spaced between the facing surfaces and with the energy transmission control member movable between the surfaces toward and away from the second conductor. This feature produces the additional advantage in that there is very little radiation of energy from the transmission line section.

This variable impedance device may be employed to advantage in transmission line systems of the coaxial type and, for connection of the device in such systems, the transmission line section as above described is connected at opposite ends to coaxial line sections with the conductors forming the spaced facing surfaces being connected to the outer conductors of the coaxial line sections and with the intermediate conductor being connected to the inner conductors of the coaxial line sections. The conductors forming the spaced facing surfaces may, of course, be preferably defined by a pair of metallic plates.

In accordance with a still more specific feature of the invention, a pair of energy transmission control members may be disposed between the plates on opposite sides of the conductor between the plates. By this feature, a greater range of control of impedance is possible and also the members serve to block radiation of energy from between the plates.

In accordance with another specific feature of the invention, the energy transmission control members may have recesses shaped to receive the center conductor so that a maximum degree of control of impedance is possible.

A still further feature of the invention is in the provision of peculiarly advantageous means for supporting and moving the transmission control members. In accordance with this feature, a pair of arms are pivotal on spaced parallel pivot axes which are preferably normal to the facing surfaces of the plates and preferably extend through the center conductor. These arms are pivotally connected to the members so that the members may be conjointly moved toward and away from the center conductor. The arms are preferably located on the outer surface of one of the plates and connected to the transmission control members through pins extending through arcuate slots in said one plate. Spring means are provided to urge the arms in one direction with rotatable cam means for actuating the arms in the reverse direction, both the spring means and the cam being preferably mounted on the aforesaid one plate, for compactness as well as ease of manufacture and assembly.

The variable impedance device of this invention is preferably employed as a variable attenuator with the transmission control members composed of energy absorbing material. The construction is particularly desirable when used as such an attenuator since the members will more effectively block radiation of energy from between the plates when they are composed of such energy absorbing material. This construction is also particularly desirable when used as an attenuator since the amount of attenuation may be varied between a very low value and a very high value.

When the device is used as a variable attenuator, it is desirable that the characteristic impedance should be maintained constant so as to eliminate reflections that might be caused by a mismatch. According to a further important feature of the invention, the characteristics of the transmission control members are such that the characteristic impedance of the device is constant regardless of the amount of attenuation.

In particular, the characteristic impedance of a dielectric filled coaxial type transmission line is given by the expression:

$$Z_0{}^1 = \sqrt{\frac{\mu}{\epsilon}} Z_0$$

where:

$Z_0{}^1$=characteristic impedance of the dielectric filled line,
μ=relative permeability of the medium in the transmission line;
ϵ=dielectric constant of the medium in the transmission line; and
Z_0=characteristic impedance of the air filled transmission line.

From this equation it is evident that an ordinary lossy dielectric material inserted in the transmission line will lower its characteristic impedance by the factor

$$\frac{1}{\sqrt{\epsilon}}$$

Such a device could be designed to have a specific characteristic impedance for any given amount of attenuation between the minimum and maximum attainable.

However, for other values of attenuation, the characteristic impedance would be different and a mismatch would result.

However, if a material is used which has a relative permeability approximately equal to the dielectric constant, then the characteristic impedance will remain the same regardless of the amount of attenuation. In other terms, the material has an intrinsic impedance substantially equal to free space.

An object of this invention, accordingly, is to provide an improved variable impedance device including a first conductor having a plane surface and a second conductor in spaced relation to said surface with an energy transmission control member movable over the surface toward and away from the second conductor.

Another object of this invention is to provide an improved variable impedance device including conductors defining spaced facing surfaces with a conductor disposed therebetween.

A more specific object of this invention is to provide an improved impedance control device utilizing a pair of energy transmission control members disposed on opposite sides of a conductor of a transmission line and conjointly movable toward and away from said conductor.

Still another object of this invention is to provide an improved variable impedance device which is simple, readily manufactured and assembled.

Yet another object of this invention is to provide an improved variable attenuator particularly adapted for coaxial line systems in which the degree of attenuation may be varied within wide limits.

A still further object of this invention is to provide a variable attenuator having improved manual control mechanism.

Still another object of this invention is to provide an improved variable attenuator device having a substantially constant characteristic impedance.

This invention contemplates other objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate a preferred embodiment and in which:

Figure 1 is a top plan view of a valuable impedance device constructed according to the principles of this invention; and

Figure 2 is a sectional view taken substantially along lines II—II of Figure 1.

In the drawings, reference numeral 10 generally designates a variable impedance device constructed according to this invention. The device 10 comprises means defining spaced facing surfaces 11 and 12 which means may, of course, take the form of metallic plates 13 and 14 as illustrated. A conductor 15 is supported between the facing surfaces 11 and 12 of the plates 13 and 14 so as to define therewith a transmission line section and at least one and preferably a pair of members 16 and 17 having energy transmission control characteristics are movable between the surfaces 11 and 12 toward and away from the conductor 15 to control the transmission of energy along the transmission line section.

The members 16 and 17 may be of a purely dielectric material, for example, so as to control the characteristic impedance of the transmission line section, but they are preferably of a lossy material arranged to absorb high frequency energy and dissipate the energy in the form of heat, so that the device may act as a continuously variable attenuator. It will be noted that the members 16 and 17 may be moved a considerable distance away from the center conductor 15 so that the minimum attenuation (insertion loss) is very low. Also, the members 16 and 17 may be moved into positions in which the entire field between the center conductor and the facing surfaces 11 and 12 of the plates 13 and 14 must pass through the members 16 and 17 so that maximum attenuation, or maximum change in impedance, may be achieved. For this purpose, the members 16 and 17 have recesses 18 and 19, respectively, in their facing surfaces which are shaped to receive the inner conductor 15. In the embodiment of the invention illustrated, the recesses 18 and 19 are of semicylindrical shape since the inner conductor 15 is cylindrical. However, the center conductor 15 might be of an entirely different shape, such as a flat plate, and in such a case, the shape of the recesses 18 and 19 would be changed.

It might further be noted that the members 16 and 17 are of elongated bar-like shape and extend for nearly the entire length of the plates 13 and 14. This is highly advantageous, particularly when the members 16 and 17 are of lossy material, since high frequency electromagnetic energy transmitted along the transmission line sections might tend to be radiated from the sides of the space between the facing surfaces 11 and 12 and the members 16 and 17 effectively block such radiation.

A highly important feature of the present invention resides in the means for supporting and moving the transmission control members 16 and 17. According to this feature, a pair of arms 20 and 21 are supported on the plate 14 by pins 22 and 23, respectively, for movement about axes normal to the plates 13 and 14 and preferably extending through the outer conductor 15. The opposite ends of the arm 20 are pivotally connected to the bars 16 and 17 by means of pins 24 and 25 which extend through slots 26 and 27, respectively, in the plate 14. The opposite ends of the arm 21 are similarly pivotally connected to the members 16 and 17 through pins 28 and 29 which extend through slots 30 and 31, respectively.

The slots 26, 27, 30 and 31 are all arcuate and thereby of minimum width so that they will have negligible effect on transmission of energy.

The arms 20 and 21 are urged in a clockwise direction (Figure 1) to move the bars 16 and 17 toward the inner conductor 17 by means of a coiled tension spring 32 acting between the pin 25 and a lug 33 attached to the plate 14.

To control movement of the bars 16 and 17 toward and away from the center conductor 15, a cam plate 34 is mounted for movement about an axis normal to the plate 14 and has a curved peripheral edge 35 of varying radius engageable with the pin 28 to move the arms 20 and 21 counterclockwise and to move the members 16 and 17 away from the center conductor 15 on counterclockwise rotation of the cam plate 34 with the arms 20 and 21 being rotated clockwise and the members 16 and 17 being moved toward the center conductor 15 under the influence of the spring 32 on rotation of the cam plate 34 clockwise.

The cam plate 34 has an integral hub portion 36 affixed to a shaft 37 which is supported for rotation in an annular bushing 38 affixed to the plate 14 with a knob 39 being affixed to the shaft 37 for manual actuation of the cam plate 34.

It will be noted that this actuating mechanism is very effective and yet is simply constructed from a minimum number of parts and is compactly mounted on the one face of the plate 14.

The cam plate 34 may, of course, be made of any desired shape so as to achieve any desired relation between the control of impedance or attenuation and angular movement of the cam.

The impedance control device 10 is particularly adapted for connection in transmission line systems of the coaxial type. For connection of the device 10 in such systems, a pair of coaxial line sections 40 and 41 may be connected at the opposite ends of the transmission line section defined by the plates 13 and 14 and the center conductor 15.

For connection of the plates 13 and 14 to the coaxial line sections 40 and 41 and to rigidly connect the plates 13 and 14, the plate 14 may have up-turned end flanges 42 and 43 riveted or otherwise secured to rectangular plates 44 and 45, respectively, the plate 13 having similar down-turned end flanges also secured to the plates 44 and 45. The outer conductors of the coaxial line sections 40 and 41 have integral plate-like flange portions 46 and 47, respectively, secured to the plates 44 and 45. The outer conductors of these coaxial line sections 40 and 41 may, as illustrated, be threaded for connection in a coaxial line system. The plates 44 and 45 may have openings having a diameter substantially equal to the inner diameter

of the coaxial line sections **40** and **41**, an opening **48** in the plate **45** being illustrated in Figure 2.

The coaxial line sections **40** and **41** have inner conductors **49** and **50** fixedly supported therewithin which may preferably be utilized to support the center conductor **15**. For this purpose, the center conductor **15** may be of hollow shape to receive the inner extremities of the inner conductors **49** and **50**.

In the embodiment of the invention illustrated, the plates **13** and **14** are substantially equally spaced from the center conductor **15** which is desirable in many applications. However, it may oftentimes be desirable to have unequal spacing as, for example, where it is desirable to have a large spacing between the plates for disposition of the impedance control members but still desirable to have a low characteristic impedance. In some cases, it may be desirable to have the plates adjustably movable toward and away from the center conductor.

The device **10** may, of course, be used as an impedance matching device with the members **16** and **17** of dielectric material and movable toward and away from the center conductor **15** to vary the characteristic of the transmission line defined by the center conductor **15** and the facing surfaces **11** and **12**. In such cases, there is no critical relation between the characteristic impedance of the coaxial line sections **40** and **41** and that of the transmission line section defined by the center conductor **15** and the plates **13** and **14**.

In some cases, and particularly where the device is utilized as a variable attenuator, it is desirable that the characteristic impedance of the transmission line section defined by the plates **13** and **14** and the center conductor **15** should be equal to the characteristic impedance of the coaxial line sections **40** and **41** so as to minimize reflection of the high frequency electromagnetic energy.

With air as the dielectric, the characteristic impedance of the section is given by the following equation:

$$Z_0{}^1 = 138\sqrt{\frac{\mu^1}{\epsilon}} \log \frac{4h}{\pi d}$$

where:

h=separation of plates **13** and **14**, and
d=diameter of center conductor **15**.

The characteristic impedance of a dielectric filled coaxial line is given by the expression:

$$Z_0 = 138\sqrt{\frac{\mu}{\epsilon}} \log \frac{b}{a}$$

where:

$Z_0{}^1$=characteristic impedance of the dielectric filled line;
μ=relative permeability of the medium in the transmission line;
ϵ=dielectric constant of the medium in the transmission line; and
Z_0=characteristic impedance of the air filled transmission line.

From this equation it is evident that an ordinary lossy dielectric material inserted in the transmission line will lower its characteristic impedance by the factor

$$\frac{1}{\sqrt{\epsilon}}$$

Such a device could be designed to have a specific characteristic impedance for any given amount of attenuation between the minimum and maximum attainable. However for other values of attenuation, the characteristic impedance would be different and a mismatch would result.

However, if a material is used which has a relative permeability approximately equal to the dielectric constant, then the characteristic impedance will remain the same regardless of the amount of attenuation. In other terms, the material has an intrinsic impedance substantially equal to free space.

According to this invention a material is used which has such characteristics. One such material is a ferrite material known under the General Ceramics and Steatite Corporation trade name Ferranics H, but any other material which possesses similar properties may be used.

Further, it may be noted although a material having the above noted characteristics is preferred, ferrite materials are generally satisfactory at high frequencies for the purposes of this invention.

These materials are available commercially under the trade names Croloy, Ferrocube and Ferramic. They may have the chemical composition $Me^{2+}Me^{3+}O_4$, where Me^{2+} is a symbol for a divalent metal, and may be considered cubic ferrites with the same crystal structure as $Fe^{3+}O_4$, which is also the structure of the mineral spinel ($MgAl_2O_4$) and is therefore called the spinel structure. They may be imagined as being derived from $Fe^{3+}O_4$ by replacing the divalent ferrous ions by one or more divalent ions e. g. Mn, Co, Ni, Cu, Mg, Zn or Cd.

It will thus be apparent that this invention provides a variable impedance device which is continuously variable, has negligible radiation therefrom, is very compact, durable and efficient in operation and is readily and economically manufacturable from a minimum number of component parts.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

I claim as my invention:

In an attenuation control device for high frequency electromagnetic energy, a transmission line section including a pair of conductors having planar surfaces in spaced facing relation and a third conductor disposed between said pair of conductors, a pair of energy transmission control members of lossy material on opposite sides of said third conductor movable toward and away therefrom, each of said members having opposite surfaces in closely spaced facing relation to said planar surfaces of said pair of conductors and having a third surface facing said third conductor, means supporting said control members for conjoint movement toward and away from said third conductor, said members having recesses in said third surfaces shaped to receive said third conductor to substantially surround said third conductor when said members are moved together.

References Cited in the file of this patent

UNITED STATES PATENTS

2,436,427	Ginzton	Feb. 24, 1948
2,480,189	Irving	Aug. 30, 1949
2,605,413	Alvarez	July 29, 1952
2,610,250	Wheeler	Sept. 9, 1952
2,670,461	Learned	Feb. 23, 1954
2,719,273	Rambo et al.	Sept. 27, 1955
2,725,535	Grieg et al.	Nov. 29, 1955