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ELECTROMAGNETIC WAVE ATTENUATOR

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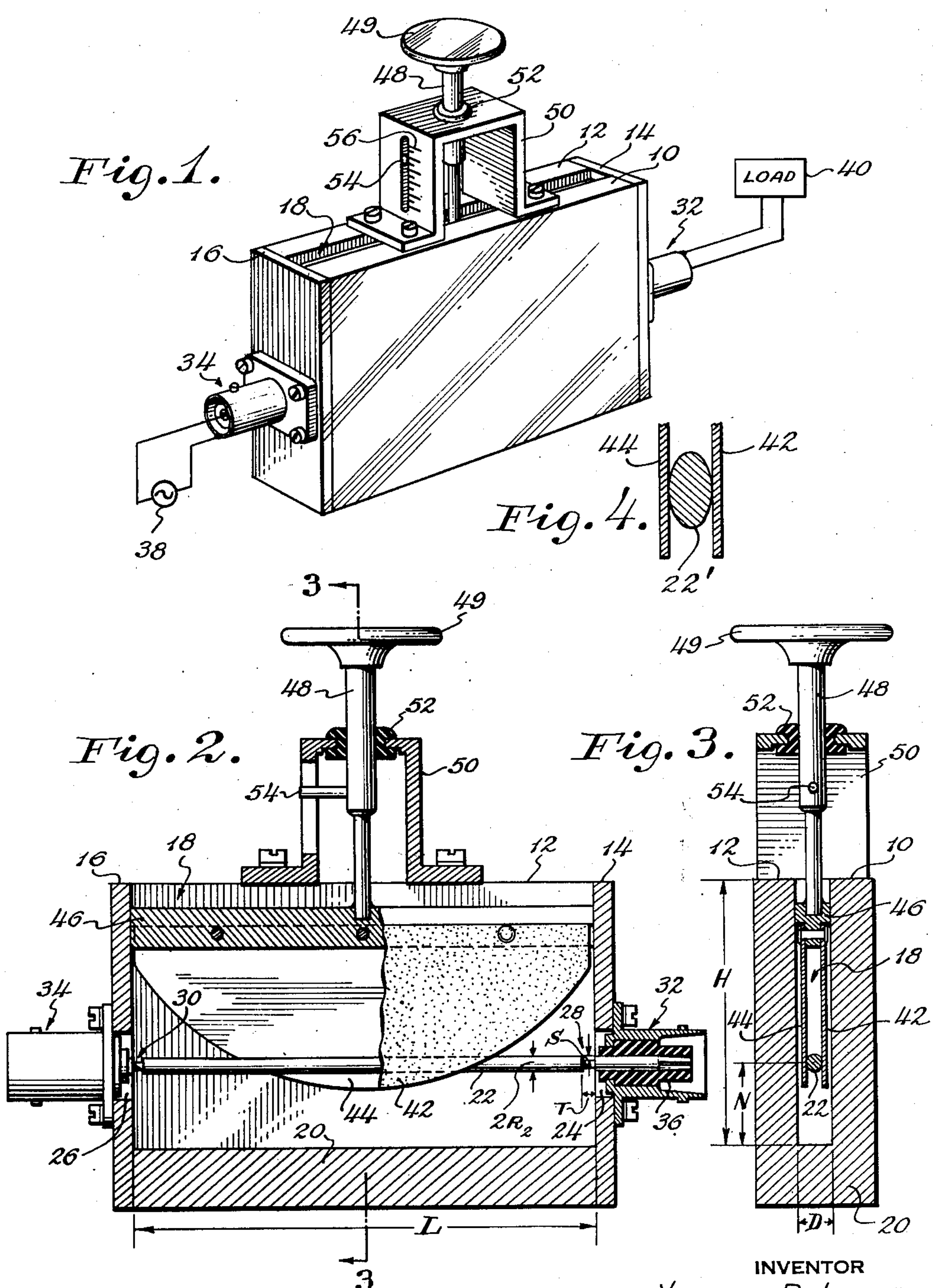

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ELECTROMAGNETIC WAVE ATTENUATOR

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3 Claims. (Cl. 333—81)

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This invention relates to adjustable attenuator apparatus and particularly to adjustable attenuators for use in coaxial transmission lines.

Conventional adjustable attenuators for coaxial transmission lines generally employ rounded cards of resistive material inserted into a slot in the coaxial line. However, such attenuators serve to produce a very limited amount of attenuation since the resistive material can be inserted only a limited distance due to the presence of the inner conductor of the coaxial line. Also, the insertion loss inherent in such attenuators is large, thereby introducing an undesired fixed loss in the transmission line.

Copending application Ser. No. 672,751, filed May 28, 1946, issued as Pat. No. 2,515,228, July 18, 1950, by Joseph V. Hupcey discloses variable attenuator apparatus for coaxial lines which provides comparatively large attenuation. The Hupcey device employs a resistive card which is inserted through a slot in the outer conductor of the coaxial line and either alongside the inner conductor or through a slot in the inner conductor. The Hupcey device has an appreciable insertion loss and is rather expensive to manufacture since the slots and the card-inserting mechanism must be constructed within narrow tolerances in order to obtain accurately determined attenuation.

Accordingly, it is an object of this invention to provide a simple adjustable attenuator apparatus which has a wide range of attenuation and a low insertion loss.

Another object is to provide attenuator apparatus for high frequency energy in coaxial lines in which the reflected energy is minimized, while large amounts of attenuation are provided.

A further object is to provide attenuator apparatus for high frequency energy in coaxial lines that produces very small variations in the energy reflected with changes in the attenuation or in the frequency of the energy.

Other objects and advantages of the invention will be apparent from the following description, the appended claims and the drawings, in which:

Fig. 1 is an oblique view of the attenuator apparatus;

Fig. 2 is a longitudinal sectional view, partially broken away, of the apparatus shown in Fig. 1;

Fig. 3 is a sectional view of the apparatus taken along line 3—3 of Fig. 2, and

Fig. 4 is a partial sectional view of the apparatus showing the use of a center conductor of elliptical cross-section.

Copending application Ser. No. 84,457, filed

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March 30, 1949, issued as Pat. No. 2,534,437 on December 19, 1950, by Edward L. Ginzton, discloses and claims the parallel plate high frequency transmission line section employed in the attenuator of the present invention.

As disclosed in the Ginzton application, by the conformal transformation

$$Z = R_0 \tan \frac{\pi W}{2D}$$

from a Z-plane to a W-plane, the electric and magnetic field patterns in an ordinary coaxial line can be converted to the electric and magnetic field patterns between a conductor of elliptical cross-section and two infinite planes equidistant from and parallel to the major axis of the elliptical conductor. R_0 is the inner radius of the outer conductor of the coaxial line in the Z-plane, Z represents the radius vector in the Z-plane, W represents the radius vector in the W-plane, and D is the distance between the two infinite planes.

If the characteristic impedance of the combination of the elliptical conductor and the infinite planes is to have the same characteristic impedance as the coaxial line,

$$R_1 = R_0 \tan \frac{\pi W}{2D}$$

where R_1 is the radius vector of the inner conductor of the coaxial line in the Z-plane.

It has been found that a conductor of circular cross-section can be substituted for the conductor of elliptical cross-section without materially affecting the electric and magnetic fields between the conductor and the infinite planes. The conductor of circular cross-section has a diameter slightly larger than the calculated diameter of the minor axis of a conductor of elliptical cross-section, and it is determined from the relation:

$$R_2 = \frac{2D}{\pi} \text{ arc tan } \frac{R_1}{R_0}$$

where R_2 is the radius of the conductor of circular cross-section.

The electric and magnetic fields between the cylindrical conductor and the two planes decrease rapidly along the two planes away from the cylindrical conductor, and, in practice, the "infinite" planes can be terminated a short distance away from the cylindrical conductor. It has been found that planes having a width approximately equal to twice the spacing between the planes give satisfactory results. Very little power is radiated with such an arrangement, and hand effects are negligible.

Thus, the combination of two planes and a cylindrical conductor positioned between and spaced equidistant from the two planes may be inserted in a coaxial line without affecting the characteristic impedance of the line or the speed of propagation of electromagnetic energy along the line.

This affords a convenient and practical means for inserting an attenuator element in the transmission line since very little energy is radiated and consequently the insertion loss is small.

The transitions from the coaxial line sections to the flat plate transmission line comprising the two planes and the cylindrical conductor cause fringing electric and magnetic fields at each end of the flat plate line, since the field configurations are different, and this causes a small amount of energy to be reflected along the line. Gradual tapering of one line into the other is a possible method of transforming one line into the other so as to eliminate reflections. However, this is mechanically awkward, and increases the unsupported length of the inner conductor.

A more satisfactory junction is obtained by joining the outer conductors of the two coaxial lines directly to end plates connecting the parallel planes and placing a circumferential groove in the inner conductor of each coaxial line at the junction between each inner conductor of the coaxial lines and the cylindrical conductor of the flat plate line. The purpose of these grooves is to introduce a small inductive discontinuity at each junction, and these inductive discontinuities serve to balance out the reflections caused by the changes in field configuration at each end of the flat plate line.

By suitable choice of the dimensions of the grooves, the characteristic impedance of the combined effect of each groove and the discontinuity associated therewith can be made equal to the characteristic impedance of the coaxial line sections and the effect of the discontinuities substantially eliminated.

The proper dimensions for the groove are determined experimentally. The depth is not critical and is a function of the diameter of the cylindrical conductor of the flat plate line.

Referring now to the drawings, two spaced plates **10** and **12** having adjacent surfaces which are plane and parallel are connected at each end by end plates **14** and **16** to enclose a rectangular space **18** having a length L sufficient to accommodate suitable attenuator cards of resistive material.

In order to increase the mechanical strength of the apparatus, side plates **10** and **12** are preferably joined at the bottom by a base plate **20** which may be an integral part of plates **10** and **12**, if desired.

A cylindrical conductor **22** extends the length of space **18** and is spaced midway between plates **10** and **12**. If desired, a conductor of elliptical cross-section may be employed as indicated by the conductor 22′ of Fig. 4. The ends of conductor **22** are passed through circular holes **24** and **26** in end plates **14** and **16**, respectively and connected through undercut sections **28** and **30** to the inner conductors of connectors **32** and **34**. The outer conductors of connectors **32** and **34** are attached to end plates **14** and **16**, respectively. Each of the connectors **32** and **34** is provided with a dielectric member **36** to support its inner conductor.

Coaxial lines may be coupled to connectors **32** and **34** so as to connect the attenuator apparatus between a suitable source **38** of high frequency energy and a suitable load or utilization device **40**.

One or more cards such as a pair of cards **42** and **44** of resistive material are rigidly secured to a longitudinal support **46** which fits snugly into the rectangular space **18**. Support **46** may be moved up and down by means of a shaft **48** having a handle **49** attached to its upper end. A bracket **50** is rigidly secured to the top edges of plates **10** and **12** and is provided with a bushing **52** for guiding the movement of the shaft **48**. A pointer **54** is rigidly secured to shaft **48** and in conjunction with a scale **56** on bracket **50** it serves to indicate the transverse position of the attenuator cards in space **18**.

Resistive cards **42** and **44** are cards of insulating material having a coating of resistive material on one surface of each card. The surfaces containing the resistive material face outward so as to be adjacent to side plates **10** and **12**. The inner surfaces which are composed of insulating material are spaced apart a distance equal to the diameter of the conductor **22** so that the cards **42** and **44** are in slidable contact with the inner conductor **22**, thereby causing cards **42** and **44** to be maintained substantially parallel to one another and to plates **10** and **12** and permitting an accurate determination of the attenuation introduced.

The cards **42** and **44** are preferably rounded so as to minimize the energy reflected thereby. In a preferred embodiment which is disclosed in Fig. 2 the edges of the cards are formed as arcs of a circle.

Suitable dimensions for the embodiment of the invention disclosed herein for use in a coaxial line having an impedance of 53.5 ohms are as follows:

$D=.181$ inch
$H=1.625$ inches
$L=2.817$ inches
$N=.500$ inch
$R_2=.450$ inch
$S=.012$ inch
$T=.080$ inch

Cards **42** and **44** are 180 ohms per square.

It will be apparent that various modifications may be made in the apparatus disclosed herein. For example, cards of resistive material of different types may be employed and the cards may be spaced from the inner conductor **22** if desired. The insertion loss of the attenuator may be reduced to a negligible amount by providing means for removing the resistive cards **42** and **44** from the electromagnetic fields in the immediate vicinity of conductor **22**. This may be accomplished by enlarging the distance between conductor **22** and the top of plates **10** and **12** and providing a longer shaft **48** and a longer slot to accommodate the point **54**, for example.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An attenuator for insertion between two coaxial line sections comprising a metallic member defining a pair of spaced parallel inner sur-

faces, a pair of end plates closing off opposite ends of said metallic member, the coaxial line sections having their outer conductors terminating at said end plates, an inner conducting member extending between and connecting the inner conductors of said coaxial line sections, said inner conducting member extending longitudinally in the space between said parallel inner surfaces, a longitudinal support member adjustably positioned between the parallel surfaces parallel to said inner conducting member, a pair of spaced parallel cards of resistive material secured to the support member and positioned on either side of the inner conducting member, and means carried by the metallic member for adjustably positioning the support member.

2. An attenuator as defined in claim 1 wherein said support member is made of conductive material and slidably engages said parallel inner surfaces and said end plates, whereby the support member is secured against lateral movement, and the interior space is substantially entirely bounded by conductive surfaces.

3. In combination, two coaxial line sections having inner and outer conductors, a metallic channel-shaped member defining a pair of spaced parallel inner surfaces, a pair of end plates secured to and closing off the ends of the channel-shaped member, the end plates having holes therethrough opening into the space between the parallel surfaces of the channel-shaped member, one of said coaxial line sections being secured to each of the end plates, the inner conductors of said coaxial line sections being aligned with said holes, a conductive rod extending longitudinally between said parallel surfaces and connecting the inner conductors of said coaxial line sections, the diameter of said rod and spacing between the parallel surfaces of the channel-shaped member being so proportioned as to provide the same characteristic impedance as the coaxial line sections, a support member adjustably positioned between the parallel surfaces of the channel-shaped member in parallel relation to the rod, a pair of cards of insulating material having their longitudinal edges secured to the support member and extending the length of the channel-shaped member, the cards being positioned on either side of the rod in parallel relationship to said inner surfaces of the channel-shaped member, the adjacent inner surfaces of said cards being in sliding contact with said conductive rod whereby the rod maintains the cards parallel, the opposite outer surfaces of said cards being coated with resistive material, and mounting means between the support and channel-shaped members for adjustably positioning the support member to provide movement toward or away from the rod.

VINCENT R. LEARNED.

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