# United States Patent [19]

**Bacher**

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[54] **MICROWAVE ATTENUATORS**


[75] Inventor: **Helmut Bacher,** Ann Arbor, Mich.

[73] Assignee: **Midwest Microwave Inc.,** Ann Arbor, Mich.



[22] Filed: **May 22, 1973**

[21] Appl. No.: **363,178**

**Related U.S. Application Data**

[63] Continuation of Ser. No. 208,093, Dec. 15, 1971.

[52] **U.S. Cl.** ..... **333/81 A,** 338/195, 338/309, 338/333

[51] **Int. Cl.** ..... **H01p 1/22**

[58] **Field of Search** ..... 333/81 R, 81 A; 338/195, 338/216, 306, 309, 333; 323/94



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*Primary Examiner*—Paul L. Gensler

*Attorney, Agent, or Firm*—Harness, Dickey & Pierce



[57] **ABSTRACT**

A microwave coaxial attenuator having a centrally disposed arcuate resistive layer with opposite axial ends thereof in electrical contact with a pair of center conductors and a pair of side ends in electrical contact with an outer ground conductor.


**45 Claims, 7 Drawing Figures**

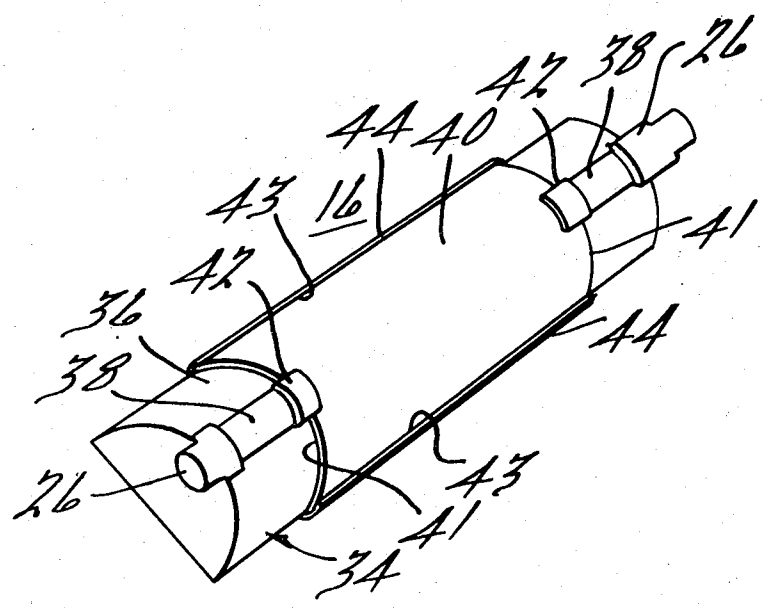
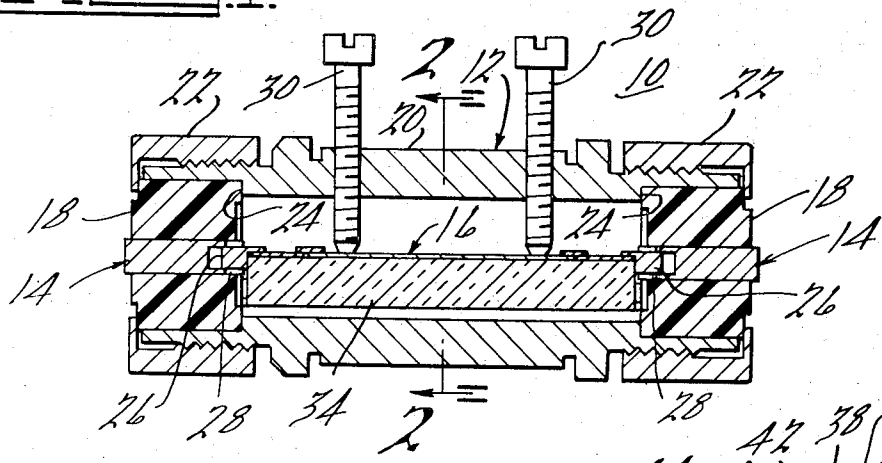


Fig. 1.



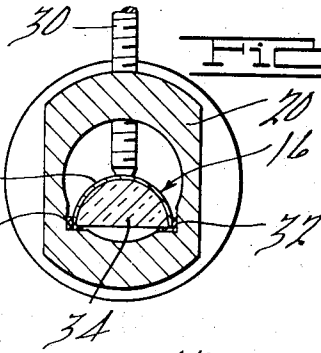




Fig. 2.

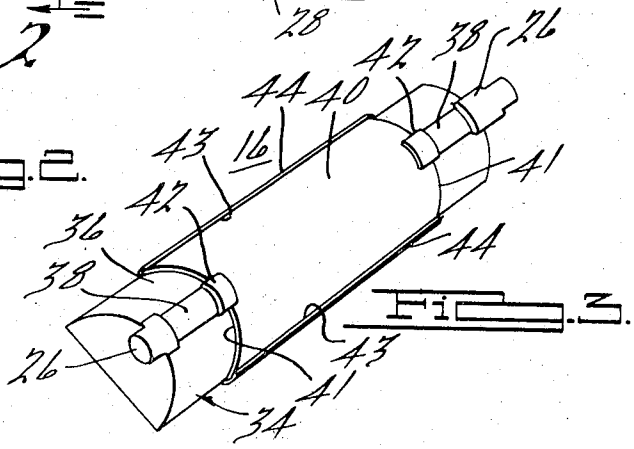



Fig. 3.

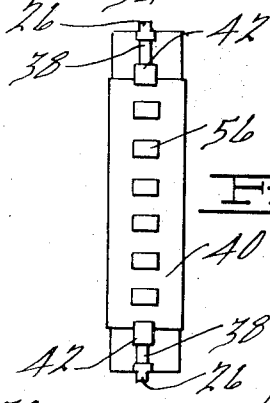



Fig. 6.

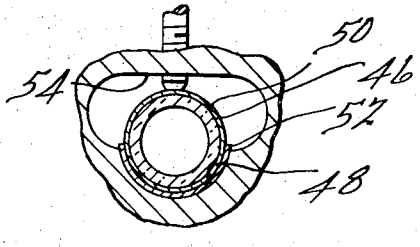



Fig. 5.

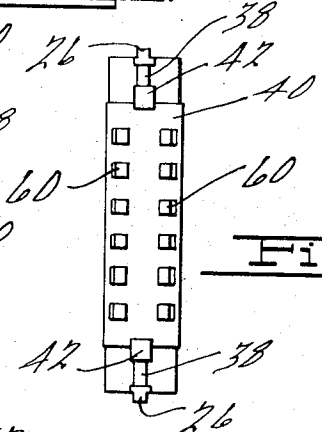



Fig. 7.

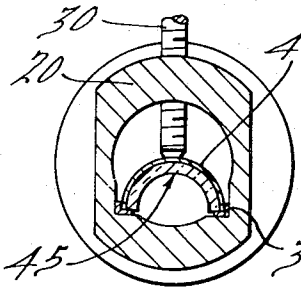



Fig. 4.

# MICROWAVE ATTENUATORS

This is a continuation, of application Ser. No. 208,093, filed Dec. 15, 1971, now abandoned.

## BACKGROUND AND SUMMARY OF THE INVENTION

Various microwave attenuators are known to the art which include a single resistive surface which forms both the series and shunt resistive paths of the attenuator. The resistive surfaces of these devices are ordinarily deposited on a rectangular "plane" surface of a ceramic member. It has been difficult to satisfactorily secure the ceramic members of the above type within an outer conductor of a microwave coaxial device. This difficulty is especially acute when the device is subjected to a harsh environment.

The present invention provides a microwave attenuator having an attenuator element which is satisfactorily secured for use in harsh environments, provides excellent heat dissipation from the resistive layer to the outer conductor, and additionally, which is readily interchangeable to permit replacement of attenuator elements. This is accomplished by providing a microwave attenuator element having a dielectric member which is configured to allow the device to efficiently and safely receive a compressive retention load.

In a coaxial microwave attenuator according to this invention, a resistive layer is placed upon a ceramic member having a surface which is arcuate in cross-section when viewed along the axis of the attenuator. Consequently, the end boundaries of the resistive layer engaging the center conductors of the device are arcuate whereas the side boundaries of the resistive layer are linear. The attenuator element may be used in combination with an outer conductor having an abutment shoulder which is forcibly engaged by the attenuator element due to a compressive retention force on the attenuator element. For example, one or more dielectric bolts or other clamping device may engage the arcuate surface on the axis thereof to provide a compressive retention force on the ceramic attenuator member which acts along a bisecting axis passing through the attenuator element to retain the attenuator element in position and to provide a contacting force between the side boundaries of the resistive layer and the abutment shoulder on the outer conductor. In the preferred exemplary embodiment, the ceramic member is in a form of a cylindrical tube and is located by an arcuate recess in the outer conductor so as to provide a large area of contact between the attenuator element and the outer conductor which provides exceptional heat dissipation from the attenuator element to the outer conductor.

The resistive layer may be provided with various means for changing the electric fields therein by establishing series and shunt resistance relationships to prevent burnouts and/or to establish center conductor separations to prevent capacitive interactions between the center conductors. For example, spaced areas of highly conducting material such as gold may be placed along the series path to reduce the resistance of the path for a given path length so that the spacing of the center conductors may be increased. Alternatively, spaced voids may be provided in the shunt resistive path, for example, by masking prior to deposition of the resistive layer or by sandblasting portions of the resistive layer after deposition, so as to increase the shunt resistance for a given path length. With the latter construction, a heavier layer of resistive material may be used to provide a lower unit resistively so that the spacing between the center conductors may be increased.



In view of the above explanation, it will be appreciated that a microwave attenuator is provided having attenuation elements which are securely held in position so as to be suitable for use in harsh environments and which may be readily inserted and removed without destruction of the device.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of an exemplary microwave coaxial attenuator according to this invention;

FIG. 2 is an end cross-sectional view of the attenuator of FIG. 1 taken generally along the line 2—2;

FIG. 3 is a perspective illustration of the attenuator element of the attenuator of FIG. 1;

FIG. 4 is an end cross-sectional view of a second exemplary embodiment of an attenuator according to the present invention;

FIG. 5 is an end cross-sectional view of a third exemplary embodiment of an attenuator according to the present invention;

FIG. 6 is an illustration of an exemplary attenuator element according to this invention which has been modified by the deposition of sequential portions of a highly conductive material along the series resistive path of the element; and

FIG. 7 is an illustration of yet another exemplary embodiment of an attenuator according to this invention which has been modifield by the provision of sequential spaced voids in the shunt resistive path.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, an exemplary microwave coaxial attenuator 10 as taught by this invention is illustrated. The attenuator 10 consists of an outer or ground conductor assembly 12, a pair of coaxial center conductors 14 and an attenuator element 16. The center conductors 14 are supported at each end with respect to the ground conductor assembly 12 by dielectric support beads 18. The ground conductor assembly 12 consists of a tubular main body member 20 which is externally threaded at each end so as to receive internally threaded end caps 22 which retain the dielectric support beads 18 and hold the support beads 18 in position against radial shoulders 24 on the outer conductor 20. The attenuator element 16 has a terminal 26 at each end which is engaged by radially inwardly extending prongs 28 on the center conductors 14. With reference now to FIG. 2, the main attenuator element 16 is retained in position within the barrel 12 by a pair of dielectric bolts 30 which may be of Nylon, Teflon or other suitable material which are threadedly engaged with the outer conductor 12 and bear downwardly on the attenuator element 16 to bring opposite side edges of the device into forced engagement with axially-extending abutment shoulders 32 formed on the outer conductor 12. The attenuator element 16 has a dielectric substrate 34 which may be ceramic material such as beryllium oxide or aluminum oxide. Beryllium oxide is preferred because of its excellent thermal conductivity which allows heat generated by the dissipated microwave power in

the attenuator element **16** to be efficiently transferred to the outer conductor **12.**

With particular reference now to FIGS. **2** and **3,** the dielectric member **34** is uniform in cross-section and is seen to have a semi-cylindrical or arcuate upper surface **36** defined by arcuate end boundaries and linear side boundaries. The upper surface **36** carries the electrodes **26** at its arcuate ends. The electrodes **26** are connected to input resistive layers **38** which are deposited on a central portion of the surface **36** so as to be generally coaxial with the outer conductor **12.** The resistive layers **38** each have a thickness and a width so that approximately 50 percent of the input energy into the attenuator **10** is dissipated in the input layer **38** which first receives the input microwave energy. A transition is made from the input layers **38** to a main attenuator layer **40** through intermediate electrodes **42,** each of which may be a deposited layer of a highly conductive metal such as gold.

The input attenuators **38** dissipate sufficient input energy to prevent steep field gradient at the entry to the main resistive layer **40.** Steep field gradients are further minimized by the intermediate electrodes **42** which distribute the input energy over a predetermined area of the resistive surface **40.** By minimizing steep field gradients using the input attenuators **38** and the intermediate electrodes **42,** local heating near the input electrodes which often causes attenuator burnout is avoided. It will be appreciated that the intermediate electrodes **42** and input attenuators **38** are identical in design and function in the same manner so that each one of the input electrodes **38** may first receive the input microwave energy with the same results.

As is well known in the card attenuator art, the main resistive layer **40** may generally be defined as having a series resistance portion and a shunt resistance portion with the former connected between the center conductors and the outer conductor. Accordingly, the layer **40** is deposited on a portion of the upper surface **36** and has a pair of curvilinear, e.g., arcuate, end boundaries **41** which are centrally connected to the intermediate electrodes **42** and a pair of linear side boundaries **43** which preferably have a deposited axially extending layer **44** of highly conductive material such as gold providing good conduction between the layer **40** and the outer conductor member **20.** The layer may be of uniform thickness, graduated thickness, or a steeped layer design to provide shunt and series resistance relationships which are well known to those skilled in this art.

The arcuate configuration of the ceramic member **34** provides a substantial increase in strength or resistance to failure under compressive loading in the direction of the bolts **30,** i.e., in the direction of curvature of the surface **36** generally, or more specifically, in a direction which is perpendicular to a plane which is tangential to the upper surface **36** of the dielectric member **34.** Consequently, clamping devices such as the screws **30** may be effectively used to exert a downward force on the element **16** to securely retain the element **16** in position and to provide good electrical contact with the outer conductor **12** along the side edges **32** of the resistive layer **40.**

If it is desired to minimize the field within the dielectric material of the device **10,** the upper and lower surface of the dielectric member may be semi-cylindrical, with the lower surface preferably being of a smaller diameter so as to provide an arch-like structure as illustrated at **45** in FIG. **4.** Additionally, a tube-like ceramic element **46** as illustrated in FIG. **5** may be utilized to minimize the field which is within the dielectric material of the attenuator device. In the embodiment of FIG. **5,** the preferred embodiment of this invention, the outer conductor **12** is provided with an arcuate recess **48** which conforms to and closely receives a major circumferential portion of the cylindrical element **46,** e.g., nearly 180° thereof. The cylindrical element **46** has a resistive layer **50** which may extend about the full circumference thereof or, if desired, generally to the outer conductor **12** at each side so as to be placed in electrical continuity therewith. Preferably, the axial ends of the resistive layer **50** joins with intermediate electrodes **42,** input resistive layers **38,** and input electrodes **26** respectively, essentially as illustrated with respect to the embodiment of FIG. **3.** To provide good electrical continuity between the resistive layer **50** and the outer conductor **12,** a layer **52** of highly conducting material such as gold may be deposited on the resistive layer **50** adjacent the outer conductor **12.** The layer **52** may extend about the entire circumferential portion within the recess **48.** In the embodiment of FIG. **5,** the cavity of the ground conductor **20** is shaped to reduce the microwave attenuation at very high frequencies so as to compensate for an increase in attenuation which occurs at very high frequencies due to an increase in dielectric loss and the increase in skin effect which effectively reduces the cross-sectional area of the conducting portion of the resistive layer **40.** More specifically, the attenuator cavity is provided with a generally flat surface **54** which is in cross proximity to the mid-portion of the resistive surface **50** along the axis thereof so as to electrically cooperate therewith to provide higher axially flowing current densities near the mid-portion of the surface **50** for increasing frequencies. The spacing of the flat surface **54** with respect to the resistive surface **50** is established to provide a substantially flat response, i.e. substantially uniform attenuation regardless of the frequency of the microwave energy transmitted through the attenuator.

It also can be seen that a relatively large area of contact exists between the conducting film **52** and the arcuate recess **48** which provides excellent heat dissipation from the attenuator element to the outer conductor. Consequently, the power handling capability of the attenuator of FIG. **5** is enhanced.

In FIG. **6,** an exemplary method is shown for increasing the distance between center electrodes for a given low value of attenuation which utilizes a plurality of sequentially disposed, spaced gold films **56** deposited on the series portion of the resistive layer **40** along an axial line between the center electrodes **26.** It will be appreciated that the gold layers **56** reduce the overall resistance of the series path between the electrodes **26** with respect to the resistance of the shunt paths. Accordingly, the central electrodes **26** may be spaced to a greater extent for given attenuation with the use of the gold film portions **56** while maintaining a theoretically desirable shunt resistance to series resistance ratio. Alternatively, as shown in FIG. **7,** a resistive layer **40** may be provided having a plurality of spaced portions **60** which are devoid of resistive material and are axially aligned in the shunt resistive layer portion, i.e., along an axis which in parallel but displaced from the central axis of the attenuator **10.** With the construction of FIG.

7, the resistance of the series path is reduced with respect to the shunt path, and accordingly, the distance between the center electrodes **26** may be increased. In essence, the same effect as that described with respect to FIG. **6** is achieved. It will be appreciated that an increase in the distance between center electrodes reduces capacitance effects between center conductors which would decrease the attenuation valve at very high frequencies. This result had formerly been accomplished by providing a second layer of resistive material along the series path so as to decrease the unit resistivity of the series path. In this regard, it will be appreciated that resistive layers are difficult to apply and normally require a significant period of manufacture time. On the other hand, the gold conducting portion **56** may be rapidly and easily applied, for example, by a masking process. Moreover, the areas **60** which are devoid of resistive material also may be readily provided by masking and sandblasting the resistive layer through the mask. It will be understood that the methods described with respect to FIGS. **6** and **7** are equally applicable to attenuators having plane, i.e., flat resistive layers as well as arcuate resistive layers.

In view of the above description, it can be seen that the present invention provides a microwave attenuator which features exceptional ease of manufacture, durability in service, and stable electrical characteristics. The construction of the present attenuator is well suited to the cartridge-type of unit with respect to which easy replacement of attenuator elements is desired.

While it will be apparent that the teachings herein are well calculated to teach one skilled in the art the method of making preferred embodiments in this invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope of meaning of the subjoined claims.

What is claimed is:

**1.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of each of said linear side boundaries.

**2.** A microwave attenuator according to claim **1** wherein said curvilinear surface portion has an arcuate cross-section.

**3.** A microwave attenuator according to claim **1** wherein said ground conductor means has a wall opposing and spaced from said curvilinear surface portion and wherein a portion of said wall is more closely spaced from said surface portion than the remainder of said wall.

**4.** A microwave attenuator according to claim **3** wherein said wall portion is parallel to an axis intersecting said curvilinear end boundaries.

**5.** A microwave attenuator according to claim **3** wherein said wall portion is parallel to an axis connecting said first conductors.

**6.** A microwave attenuator according to claim **5** wherein said wall is a flat wall and the spacing of said wall from said surface portion which provides said wall portion is established by said curvature of said curvilinear surface.

**7.** A microwave attenuator according to claim **6** wherein said ground conductor means has a recess and wherein said dielectric member partly resides in said recess.

**8.** A microwave attenuator according to claim **7** wherein said dielectric member is a cylindrical member and wherein said two opposite linear side boundaries are connected along their full length to said ground conductor means at said recess in said ground conductor means.

**9.** A microwave attenuator according to claim **8** further including means bearing on said element so as to exert a force along an axis passing through said surface generally in the direction of curvature of said curvilinear surface.

**10.** A microwave attenuator according to claim **9** wherein said cylindrical dielectric member is a tubular member.

**11.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween;

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductors means along the full length of each of said linear side boundaries; and

means bearing on said element so as to exert a force along an axis passing through said surface generally in the direction of curvature of said curvilinear surface.

**12.** A microwave attenuator according to claim **2** wherein said curvilinear surface portion has an arcuate cross-section.

**13.** A microwave attenuator according to claim **1** wherein said axis along which said force is exerted lies generally in the direction of said curvature of said curvilinear surface.

**14.** A microwave attenuator according to claim **13** wherein said curvilinear surface portion has an arcuate cross-section.

15. A microwave attenuator according to claim 14 wherein said dielectric member has a flat surface portion joining said arcuate curvilinear surface portion at each of said linear side boundaries.

16. A microwave attenuator according to claim 14 wherein said arcuate curvilinear surface portion comprises one side of said dielectric member and said dielectric member has an opposite side which comprises a surface having an arcuate cross-section.

17. Attenuator for operation of microwave frequencies comprising:

a pair of first conductors disposed on an axis, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature with a layer of resistive material on said surface portion, said layer having a pair of opposite curvilinear end boundaries which are electrically connected intermediate said first conductors and a pair of opposite linear side boundaries which are electrically connected along the full length thereof to said ground conductor means, said attenuator element further including a plurality of spaced portions of highly conducting material disposed on said layer along said axis between said first conductors.

18. Attenuator for operation of microwave frequencies comprising:

a pair of first conductors disposed on an axis, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature with a layer of resistive material on said surface portion, said layer having a pair of opposite curvilinear end boundaries which are electrically connected intermediate said first conductors and a pair of opposite linear side boundaries which are electrically connected along the full length thereof to said ground conductor means, said resistive layer having a plurality of spaced voids therein disposed along an axis which is displaced from but substantially parallel to said axis between said first conductors.

19. Attenuator for operation of microwave frequencies comprising:

a pair of first conductors disposed on an axis, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor:

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a surface portion with a layer of resistive material on said surface portion, said layer having a pair of opposite end boundaries which are electrically connected intermediate said first conductors and a pair of opposite side boundaries which are electrically connected along the full length thereof to said ground conductor means, said attenuator element further including a pair of intermediate electrodes and a pair of input attenuation means with one of said intermediate electrodes being connected to one of said pair of end boundaries and the other of said intermediate electrodes being connected to the other of said pair of end boundaries, and with one of said input attenuation means being connected between the one of said intermediate electrodes and one of said first conductors and the other of said input attenuation means being connected between the other of said intermediate electrodes and the other of said first conductors.

20. A microwave attenuator according to claim 19 wherein each of said input attenuation means is a resistive layer on said attenuator element.

21. A microwave attenuator according to claim 20 wherein said input attenuation means and intermediate electrodes are each coaxially disposed with respect to said first conductors.

22. Attenuator for operation of microwave frequencies comprising:

a pair of first conductors, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature and having a uniform cross section defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of each of said linear side boundaries.

23. A microwave attenuator according to claim 22, wherein said curvilinear surface portion has an arcuate cross-section.

24. Attenuator for operation of microwave frequencies comprising:

a pair of first conductors disposed on an axis, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature and being symmetrical with respect to said axis defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said

surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of each of said linear side boundaries.

**25.** A microwave attenuator according to claim **24** wherein said curvilinear surface portion has an arcuate cross-section.

**26.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors which are substantially aligned with an axis of said microwave attenuator, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors including a tubular conducting member which is coaxially disposed with respect to said axis for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of each of said linear side boundaries.

**27.** A microwave attenuator according to claim **26** wherein said dielectric member is a tubular member and said arcuate curvilinear surface portion is a radially outward surface of said tubular dielectric member.

**28.** A microwave attenuator according to claim **27** wherein said tubular dielectric member is a cylindrical member.

**29.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a curvilinear surface portion of substantial curvature defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of at least one of said linear side boundaries.

**30.** A microwave attenuator according to claim **29** wherein said curvilinear surface portion has an arcuate cross-section.

**31.** A microwave attenuator according to claim **30** wherein said dielectric member is a tubular member and said arcuate curvilinear surface portion is a radially outward surface of said tubular dielectric member.

**32.** A microwave attenuator according to claim **31** wherein said tubular dielectric member is a cylindrical member.

**33.** A microwave attenuator according to claim **29** further including means bearing on said element so as to exert a force along an axis passing through said surface generally in the direction of curvature of said curvilinear surface.

**34.** A microwave attenuator according to claim **33** wherein said curvilinear surface portion has an arcuate cross-section.

**35.** A microwave attenuator according to claim **29** wherein said ground conductor means has a wall oposing and spaced from said curvilinear surface portion and wherein a portion of said wall is more closely spaced from said surface portion than the remainder of said wall.

**36.** A microwave attenuator according to claim **35** wherein said wall portion is parallel to an axis intersecting said curvilinear end boundaries.

**37.** A microwave attenuator according to claim **35** wherein said wall portion is parallel to an axis connecting said first conductors.

**38.** A microwave attenuator according to claim **37** wherein said wall is a flat wall and the spacing of said wall from said surface portion which provides said wall portion is established by said curvature of said curvilinear surface.

**39.** A microwave attenuator according to claim **38** wherein said ground conductor means has a recess and wherein said dielectric member partly resides in said recess.

**40.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor;

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween, said ground conductor means having a recess and a cylindrical planar wall including a portion which is parallel to an axis connecting said first conductors; and

an attenuator element including a member of dielectric material partly residing in said recess of said ground conductor means having a curvilinear surface portion of substantial curvature defined by two opposite linear side boundaries and two opposite curvilinear end boundaries and a layer of resistive material on said surface portion, said surface portion being more closely spaced to said wall portion than the remainder of said wall due to the curvature of said surface portion, said resistive layer being electrically connected intermediate said first conductors at said curvilinear end boundaries and being electrically connected to said ground conductor means along the full length of said linear side boundaries at said recess in said ground conductor means.

**41.** A microwave attenuator according to claim **40** further including means bearing on said element so as to exert a force along an axis passing through said sur-

face generally in the direction of curvature of said curvilinear surface.

**42.** A microwave attenuator according to claim **41** wherein said cylindrical dielectric member is a tubular member.

**43.** Attenuator for operation of microwave frequencies comprising:

a pair of first conductors disposed on an axis, one being adapted to receive microwave energy and another adapted for transmitting an attenuated portion of said microwave energy which is received at said one conductor:

ground conductor means associated with said first conductors for establishing a microwave transmission path therebetween; and

an attenuator element including a member of dielectric material having a surface portion with a layer of resistive material on said surface portion, said layer having a pair of opposite end boundaries which are electrically connected intermediate said first conductors and a pair of opposite side boundaries, at least one of said side boundaries being electrically connected along the full length thereof to said ground conductor means, said attenuator element further including a pair of intermediate electrodes and a pair of input attenuation means with one of said intermediate electrodes being connected to one of said pair of end boundaries and the other of said intermediate electrodes being connected to the other of said pair of end boundaries, and with one of said input attenuation means being connected between the one of said intermediate electrodes and one of said first conductors and the other of said input attenuation means being connected between the other of said intermediate electrodes and the other of said first conductors.

**44.** A microwave attenuator according to claim **43** wherein each of said input attenuation means is a resistive layer on said attenuator element.

**45.** A microwave attenuator according to claim **44** wherein said input attenuation means and intermediate electrodes are each coaxially disposed with respect to said first conductors.

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# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,824,506 Dated July 16, 1974

Inventor(s) Helmut Bacher

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 47, "steeped" should be --stepped--; Column 4, line 67, "in" should be --is--; Column 6, line 51, "conductors" should be --conductor--.

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

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