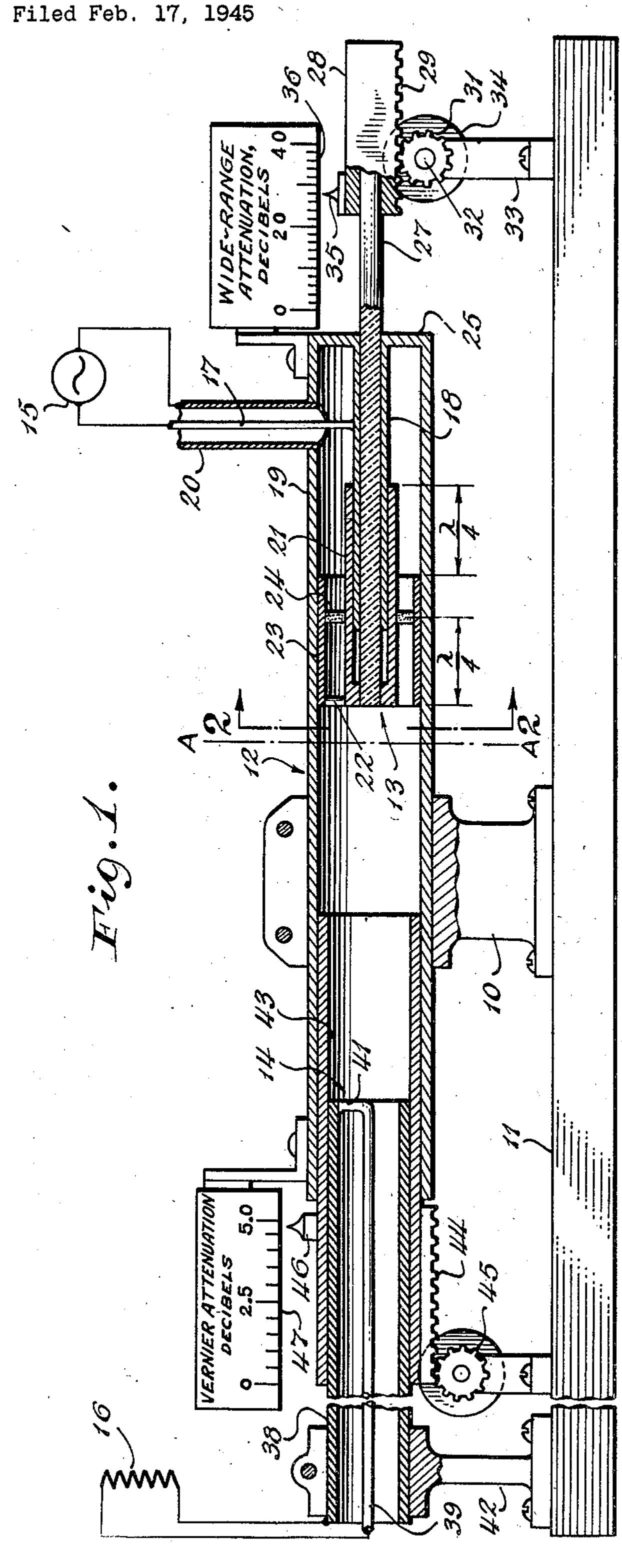
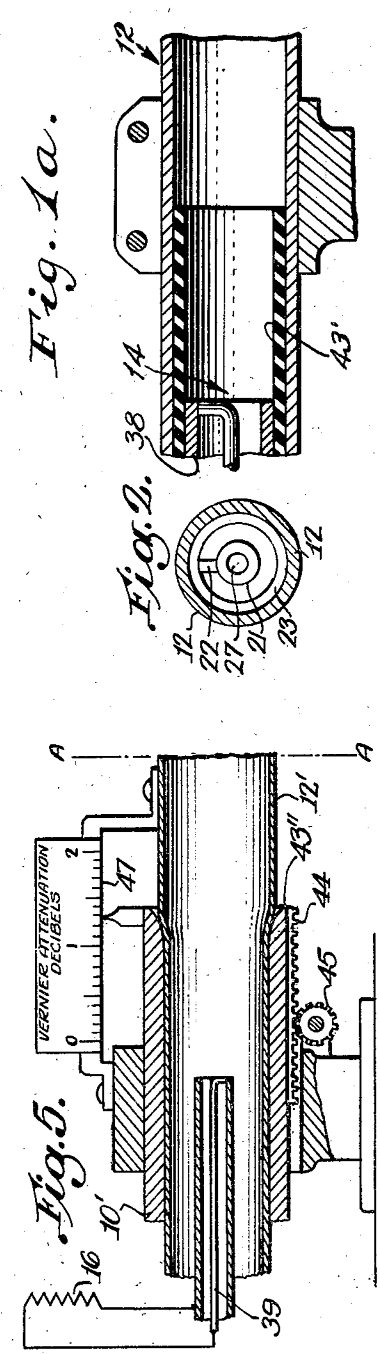
June 19, 1951 E. T. JAYNES 2,557,110

WAVE GUIDE ATTENUATOR APPARATUS

Filed Feb. 17, 1945 2 Sheets-Sheet 1





INVENTOR
EDWIN T. JAYNES
BY Paul B. Hunter
ATTORNEY

June 19, 1951 E. T. JAYNES 2,557,110

WAVE GUIDE ATTENUATOR APPARATUS

Filed Feb. 17, 1945 2 Sheets-Sheet 2

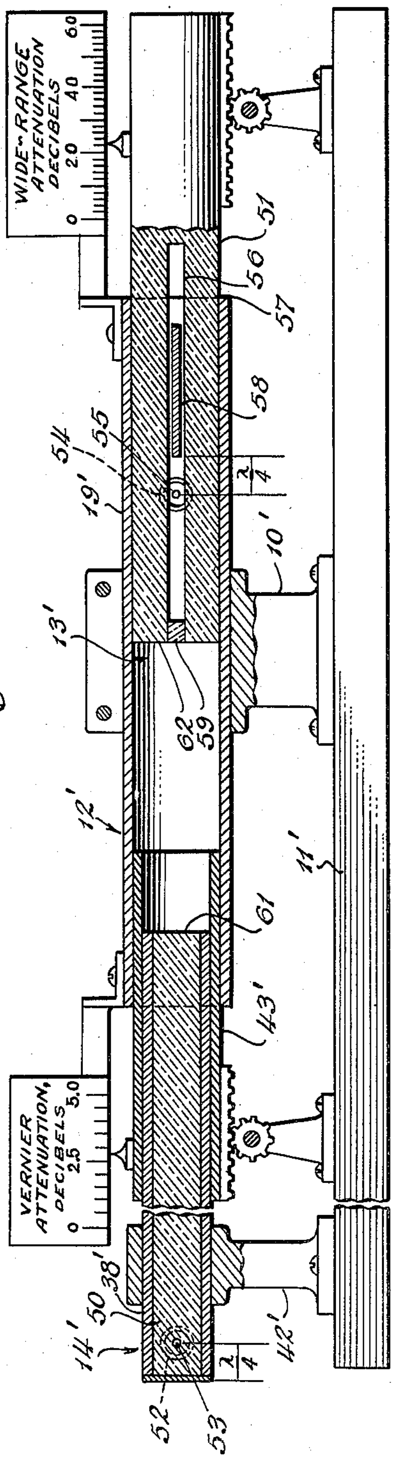


Fig. 3.

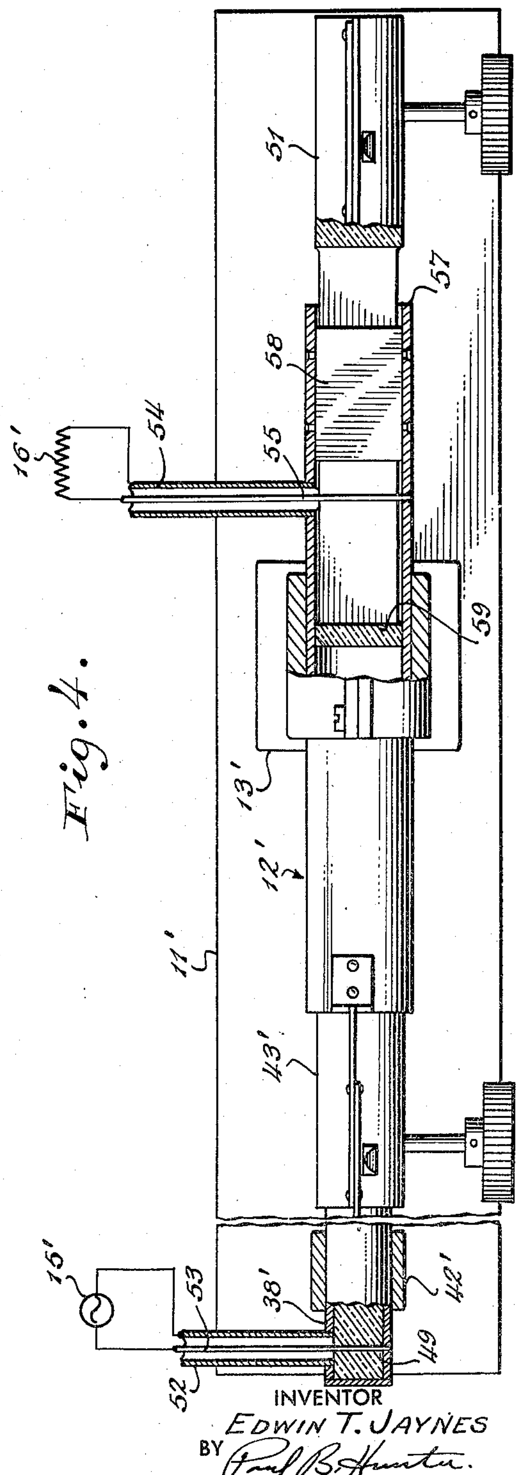


Fig. 4.

INVENTOR
EDWIN T. JAYNES
BY Paul B. Hunter
ATTORNEY

Patented June 19, 1951 2,557,110

UNITED STATES PATENT OFFICE

2,557,110

WAVE GUIDE ATTENUATOR APPARATUS

Edwin T. Jaynes, Anacostia, D. C., assignor to The Sperry Corporation, a corporation of Delaware

Application February 17, 1945, Serial No. 578,390

11 Claims. (Cl. 178—44)

1

The present invention relates to electromagnetic energy transmission devices, and more particularly to hollow pipe wave guide attenuating devices.

An object of the present invention is to provide an improved hollow pipe wave guide attenuator.

A further object is to provide a hollow pipe wave guide attenuator capable of accurate adjustment and of reliable attenuation variation characteristics.

It is well known that a hollow pipe wave guide, while a highly efficient conductor of electromagnetic energy of wavelengths shorter than a critical value often referred to as the "cut-off wavelength," determined by the internal dimensions of the guide, is an excellent attenuator of electromagnetic energy of a wavelength longer than the cut-off wavelength of the wave guide. For example, an air-filled hollow pipe of 3-inch inside diameter attenuates ultra high frequency energy of wavelengths shorter than 5 inches or 12.7 centimeters, in accordance with an attenuation constant far smaller than $\frac{1}{10}$ decibel per foot of length of the wave guide. On the other hand, such a 3-inch inside diameter hollow pipe attenuates electromagnetic energy of wavelengths appreciably greater than 5 inches by an attenuation constant in excess of 120 decibels per foot of length of the wave guide through which the electromagnetic energy is transmitted.

Variable attenuators have been devised to make use of the relatively high attenuation of wave guides operated at wavelengths in excess of the cut-off wavelength—the critical value of wavelength in the vicinity of which the attenuation per unit length of the wave guide rises steeply from an extremely low attenuation value to a substantially constant and quite appreciable value of approximately 32 decibels per unit length of the wave guide equal to the inside diameter thereof.

For variation of the attenuation provided in devices of this type, apparatus usually is provided for varying the distance in the wave guide through which is transmitted electromagnetic energy of wavelength greater than the cut-off of the wave guide. Ordinarily, such apparatus takes the form of a mechanical arrangement for varying the distance in the wave guide between an input coupling element and an output coupling element.

A disadvantage of an attenuator of the above type is that in cases where a compact attenuator structure is desirable as, for example, a structure employing a 1-inch inside diameter air-filled wave guide for attenuating wavelengths appreciably in excess of 2 inches (or appreciably in excess of 5 centimeters), the attenuation per inch of distance along the cut-off wave guide is approximately 32 decibels per diameter, i. e., approximately 32 decibels per inch of length therealong. Thus, it is seen that a variation of the distance between the energy input coupling member and the energy output coupling member of $\frac{1}{32}$ of an inch in a 1-inch wave guide results in a change of attenuation of 1 decibel. For many purposes, where high accuracy of both the attenuation adjustment and the attenuation readings is desirable, such a great change of attenuation relative to a small movement of the adjustable member is found unsatisfactory for accurate and reliable performance.

2

Accordingly, it is an object of the present invention to provide a cut-off wave guide attenuator having an attenuation adjustment arrangement wherein large movements of an adjustable member result in relatively small changes of attenuation.

If a wave guide is excited in only one excitation mode by energy of a wavelength in excess of the cut-off wavelength for that mode, the attenuation in decibels varies linearly with variation of the length of the energy transmission path therethrough. If the wave guide is excited in a plurality of modes, on the other hand, the attenuation in decibels varies non-linearly with variation of the length of the energy transmission path. Such attenuation non-linearity due to multiple-mode excitation ordinarily is slightly objectionable in a cut-off wave guide attenuator, but it becomes especially objectionable in an attenuator intended for very precise variation of attenuation and dependable indication of the attenuation variations effected therein.

Therefore, it is another object of the present invention to provide wave guide coupling members so arranged as to suppress the excitation of the wave guide in excitation modes other than a single predetermined mode.

For reliability, high accuracy, and convenience of installation, it is desirable that cut-off wave guide attenuators be so constructed and arranged as to provide stationary cable input and output connectors, so that the attenuator may be installed with rigid connections to other ultra high frequency devices independently of variation of the distance between the input coupling member and the output coupling member in the cut-off wave guide.

Accordingly, a further object of the present invention is to provide improved wave guide attenuator coupling members, permitting adjustment of the distance through which energy is transferred by the cut-off wave guide without any resultant change of the position of the input and output cable connectors or terminals of the attenuator.

In accordance with the present invention, a movable member, which may take the form of a relatively thin-walled metal tube, for example, may be inserted telescopically between the inner surface of a stationary cut-off wave guide and the outer surface of a tubular coupling member associated therewith. Such a thin-walled metal tube may be moved in a direction parallel to the axis of the cut-off wave guide, so as to vary the projection of the thin-walled metal tube into the cut-off wave guide beyond the end of the tubular coupling member. The portion of the thin-walled metal tube thus extending within the cut-off wave guide beyond the coupling member operates substantially as a movable cut-off wave guide portion having a slightly smaller diameter than the stationary cut-off wave guide and, accordingly, having a slightly greater attenuation constant per unit length thereof.

By movement of the thin-walled tube farther into the cut-off wave guide, the attenuation provided between the above-mentioned tubular coupling member and a further coupling member positioned at the opposite end of the stationary cut-off wave guide at a fixed distance from the tubular coupling member is gradually increased by virtue of a reduction of the distance through which the wave energy is propagated through the exposed portion of the stationary cut-off wave guide and an equal increase of the distance in the slightly higher attenuation thin-walled metal tube through which the energy must travel.

In accordance with one feature of the present invention, a vernier calibration scale and a vernier drive member may be associated with such a thin-walled metal tube, while a wide-range attenuation calibration scale and a rough adjustment mechanism may be associated with one of the above-mentioned energy coupling members, for variation of the total distance between the coupling members through which the energy must be transmitted through the successive cut-off wave guide portions.

With the high accuracy obtainable with a vernier attenuation adjustment and indicating arrangement as generally discussed above, any non-uniformity of attenuation per unit length along a uniform-diameter section of cut-off wave guide becomes particularly objectionable. As a further feature of the present invention, therefore, the tubular coupling member discussed above may comprise a section of conductive tubing filled with solid dielectric material having such a dielectric constant in relation to its diameter as to provide efficient transmission therethrough in a predetermined excitation mode of the electromagnetic energy supplied to the cut-off wave guide. The dimensions and the properties of the dielectric material employed in this coupling member are so chosen that energy of only the desired mode of excitation of the cut-off wave guide is efficiently transmitted therethrough; while for energy of modes of excitation which, if transmitted efficiently through the coupling member, would excite the cut-off wave guide in other than the desired excitation mode, the coupling member is a cut-off wave guide. Thus, the solid dielectric

filled wave guide input coupling member serves as a filter, passing only energy of a desired excitation mode for the cut-off wave guide, and preventing excitation of the cut-off wave guide with appreciable energy in any other mode.

The above objects and general description of the present invention will be clarified, and further objects will become apparent, by reference to the following detailed description of the present invention, taken in conjunction with the drawings, wherein:

Fig. 1 is a side elevation, partly in section, of one embodiment of the present invention;

Fig. 1A is a fragmentary cross-sectional view illustrative of a modified form of the invention;

Fig. 2 is a cross-sectional view taken along the line 2—2 in Fig. 1;

Fig. 3 is a side elevation, partly in section, and Fig. 4 is a plan view, partly in section, of a further embodiment of the present invention.

Fig. 5 is a side elevation, partly in section, of a further embodiment of the present invtntion. The structure to the right of line A—A is arranged as shown in Fig. 1.

In Figs. 1 and 2 is shown an attenuator comprising a base 11 supporting the fixed portions and the control elements of a cut-off wave guide attenuator constructed in accordance with the present invention. A hollow pipe wave guide 12 having a circular cross-section, for example, is secured to the base 11 by a supporting bracket 10. The hollow pipe wave guide 12 is provided with an input coupling member 13 and an output coupling member 14 arranged for connection to a high frequency energy source 15 and a load 16, respectively.

Energy from source 15 may be conducted through a coaxial transmission line having an outer conductor 20 and an inner conductor 17 into a further coaxial transmission line formed by a reentrant tubular conductor 18 operating in conjunction with an extension 19 of the hollow pipe wave guide 12. A conductive sleeve 21, telescopically slidable along the reentrant tubular conductor 18, is connected through a radially extending conductor 22 to a tubular conductor 23 arranged in slidable relation with the tubular extension 19 of the hollow pipe wave guide 12. A dissipator disc 24 may be provided at a distance of one-fourth of the wavelength of the energy derived from source 15 from the radially extending conductor 22 for providing a load connected between sleeve 21 and conductor 23 in addition to the load presented by the radially extending conductor 22, such that standing waves are minimized in the coaxial transmission lines 18, 19 and 21, 23. For this purpose, also, the conductive sleeve 21 may be arranged to extend axially beyond the tubular conductor 23 by a distance equal to one-fourth of the wavelength of the energy derived from source 15. The movable structure 21, 22, 23, 24 cooperating with conductor 18 and tubular extension 19 serves as the input coupling member 13 for introducing or feeding energy into the cut-off wave guide 12.

The coaxial transmission line 20, 17 is preferably joined to the line 18, 19 at a distance of substantially one-fourth of the wavelength of the energy derived from source 15 from the end of the line 18, 19, and a conductive disc 25 preferably is connected between the tubular conductor 18 and the extension 19 of the hollow pipe wave guide to prevent radiation of ultra high frequency energy from the end of the line

18, 19 and to afford suitable mechanical support of the reentrant tubular conductor 18.

The portion of the input coupling member comprising the conductive sleeve 21, the tubular conductor 23, the radially extending conductor 22 and the dissipator disc 24 may be moved axially along the wave guide 12, effectively lengthening or shortening the distance between coupling members 13 and 14, through a range of movement determined by the length of the sleeve 21. For this purpose, a rod 27 which may be made of conductive or non-conductive material, as desired, may be inserted slidably through the reentrant tubular conductor 18 and may be connected mechanically to the conductive sleeve 21 at the end thereof adjacent the radially extending conductor 22. If desired, a bushing 28 may be rigidly fastened to the end of the rod 27 extending beyond the transmission line 18, 19 and the bushing 28 may be provided with a rack 29 for cooperation with the pinion 31 to afford fine mechanical adjustment of the movable coupling member described above. Pinion 31 may be arranged on a shaft 32 supported in a suitable bearing by a bracket 33 extending upward frome base 11, and the shaft 32 may be provided with a manual adjustment knob 34.

If desired, a pointer 35 may be fastened to the bushing 28 and arranged for cooperation with a calibrated wide-range stationary attenuation scale 36 for indicating the variation of attenuation resulting from the adjustment of the movable coupling member 13.

The output coupling member 14 for extracting energy from cut-off wave guide 12 may comprise a section of coaxial transmission line having an outer tubular conductor 38 and an inner conductor 39. The conductor 39 may be bent at one end and connected as shown at 34 to the tubular outer conductor 38, to form a radially extending conductor portion coupled to the wave guide 12. The output coupling member 14 may be supported by a bracket 42 positioned near one end of the base 11.

In accordance with a major feature of the present invention, a movable member is provided for effecting a predetermined shift in the attenuation per unit length along a variable length portion of the cut-off wave guide 12 between the input coupling member 13 and the output coupling member 14. For example, a conductive sleeve 43, such as a thin-walled metal tube, may be provided in telescopic relation with the hollow pipe wave guide 12 and the tubular coupling member 14, for providing along the portion of conductive sleeve 43 extending beyond the tubular coupling member 14 an attenuation per unit length, which is greater by a predetermined margin than the attenuation per unit length along the portion of cut-off wave guide 12 between the end of sleeve 43 and the coupling member 13. For example, a conductive sleeve 43 having an inside diameter of fifteen-sixteenths of an inch would provide an attenuation constant of approximately 34 decibels per inch along the length thereof, while the portion of the wave guide 12 extending between the end of the conductive sleeve 43 and the coupling member 13, if of one-inch inside diameter, provides an attenuation of the order of 32 decibels per inch. Thus, if the coupling members 13 and 14 are separated by a given distance, and the conductive sleeve 43 is moved toward the coupling member 13, the attenuation inserted between the source 15 and the load 16 would be increased by approximately 2 decibels per inch of movement of the conductive sleeve 43.

As shown in Fig. 1, a portion of the conductive sleeve 43 extending outside the hollow pipe wave guide 12 may be provided with a rack 44 for cooperation with a pinion 45, and also with a pointer 46 for cooperation with a calibration scale 47. By rotation of pinion 45, the attenuation of the energy supplied to the load 16 may be gradually varied over a narrow vernier range, as indicated by the pointer 46 and scale 47.

If desired, large changes of attenuation may be effected by the rotation of pinion 31, providing relatively large movements of the input coupling member 13. Then, after the member 13 is positioned for a desired approximate attenuation value, the pinion 45 may be rotated to drive the sleeve 43 to a desired position for more accurate control of the attenuation of energy supplied from source 15 to load 16. It will be seen that rotation of pinion 31 varies the distance between the coupling member 13 and the coupling member 14, while the rotation of pinion 45 leaves the total distance between the coupling members fixed while varying differentially the lengths of two successive or cascade portions along cut-off wave guide 12 characterized by two slightly different attenuation constants.

If desired, and as shown in Fig. 1A, sleeve 43' may be made of a solid dielectric material, rather than a conductive material, with a resultant increase of the cut-off wavelength along the portion of the hollow pipe wave guide 12 occupied by the sleeve 43', and thus with a resultant decrease, rather than increase, of the attenuation per unit length in the portion of the wave guide 12 occupied by the sleeve 43' as compared to the attenuation per unit length within the portion of the wave guide 12 between the end of sleeve 43' and the input coupling member 13.

With the sleeve 43' composed of a dielectric material, energy loss due to ultra high frequency potential difference between the outside of the tubular conductor 38 and the inside of the hollow pipe wave guide 12 may be prevented from producing appreciable radiation or energy leakage by making the length of the coupling member 14 extending within the hollow pipe wave guide 12 appreciable, and thus providing an axially extensive energy attenuating path between the wave guide 12 and the output coupling member 14.

If desired, the input and output coupling members associated with the cut-off hollow pipe wave guide may be formed as wave guide elements filled with solid dielectric material of a high dielectric constant. An embodiment of this invention having such wave guide coupling members is illustrated in Figs. 3 and 4. As shown in these figures, a base 11' supports a hollow pipe wave guide 12' through a bracket 10'. A first coupling member 14', comprising a tubular conductor 38' filled by a solid dielectric body 50, is fixedly supported from base 11' by bracket 42'. A second wave guide coupling member is formed by a tubular extention 19' of the hollow pipe wave guide 12' substantially filled by a dielectric rod 51, which may be slidably supported in the tubular extension 19' for variation of the effective position of the coupling member 13', and thus of the effective distance between the coupling members 13' and 14'.

Coaxial transmission line connectors 52, 53 and

54, 55 may be provided for conduction of ultra high frequency energy from a source 15′ to the variable attenuator system and from the attenuator system to a load 16′. The outer conductor 52 of the first coaxial line, shown connected to source 15′, may be connected to the tubular conductor 38′ forming the conductive outer sheath of the wave guide coupling member 14′, while the inner conductor 53 of the first coaxial line is extended through the tubular conductor 38′ through a suitable passage in the dielectric body 50 along the diameter thereof and connected to the conductor 38′ at a point 49 opposite the junction of tubular conductor 38′ with the outer conductor 52 of the first coaxial line.

Similarly, the second coaxial line connector 54, 55, shown connected to load 16′, includes a junction of the outer conductor 54 with the extension 19′ of hollow pipe wave guide 12′, which serves as the tubular conductor cooperating with dielectric rod 51 to form an efficient wave guide for conduction of energy of the wavelength of source 15′. The inner conductor 55 of the second coaxial line extends through the extension 19′ of hollow pipe wave guide 12′ along the diameter thereof parallel to conductor 53 within tubular conductor 38′.

To permit the movement of the dielectric rod 51 along the axis of the wave guide 12′, a slit 56 is provided in rod 51 for passage therethrough of the inner conductor 55 of the second coaxial connector. Also, in order to prevent the transmission of ultra high frequency energy from the conductor 55 along dielectric rod 51 through the open end 57 of the tubular extension 19′, a conductive septum 58 may be fitted into the tubular extension 19′ of the hollow pipe wave guide 12′. This septum 58 is preferably arranged in the diametral plane including the conductors 53 and 55, spaced one-fourth of the wavelength of source 15′ from the conductor 55, and extending an appreciable distance toward the open end 57 of the extension 19′. In the above-described position, the edge of septum 58 adjacent conductor 55 forms a short-circuiting reflector for cooperation therewith, to arrest energy flow toward open end 57. Furthermore, the septum 58 divides the portion of the wave guide coupling member 19′, 51′ occupied thereby into two parallel wave guide portions, one positioned above the other and each having a semicircular cross-section, each of these wave guides being cut-off at the wavelength of source 15′.

If desired, a block of dielectric material 59 may be cemented into place in the end of the dielectric rod 51, filling the slit at the end of the rod and affording mechanical reinforcement thereto.

By virtue of the high dielectric constants of the bodies 50 and 51, the first wave guide coupling member extending between conductor 53 and the end 61 of the coupling member 14′, and the second wave guide coupling member extending between the end 62 of body 51 and the conductor 55, are rendered efficient wave guide conductors for ultra high frequency energy of the wavelength of source 15′.

A feature of the attenuator structure shown in Figs. 3 and 4 is the pre-attenuation provided by the first coupling member 14′, employed as shown in Figs. 3 and 4 as the input coupling member, of excitation energy components in modes other than the desired mode of excitation of the cut-off wave guide 12′. For this purpose, the dimensions of the coupling member 14′ and the characteristics of the dielectric material 50 are chosen

for efficient transmission of the energy from source 15′ only in the longest-wavelength mode permitted in a cylindrical wave guide, a mode sometimes referred to as the $TE_{1,1}$ mode.

Thus, even though ultra high frequency current produced in the conductor 53 by source 15′ may excite the solid dielectric filled wave guide in a plurality of modes in addition to the $TE_{1,1}$ mode for which the wave guide is designed, the attenuation along the solid dielectric filled wave guide of the $TE_{1,1}$ mode energy is almost negligible, whereas other modes of excitation are greatly attenuated along the coupling member 14′, so that their amplitude in the vicinity of the end 61 is negligible. Thus, only the desired excitation mode is provided at the end 61 of member 14′ for introduction of energy into the cut-off wave guide 12′.

The structure shown in Figs. 3 and 4 may be operated with the energy source connected to the coaxial connector 54, 55 and the load connected to the coaxial connector 52, 53. The pre-attenuation of excitation modes other than the desired $TE_{1,1}$ mode is then effected in the dielectric-filled wave guide portion of tubular extension 19′ extending between the conductor 55 and the end 62 of rod 51, in a manner similar to that described with respect to the coupling member 14′ when source 15′ is connected thereto.

If the energy source is to be coupled to the connector 54, 55, the dielectric body 51 should be so arranged that, at the maximum attenuation adjustment thereof, an appreciable length of the dielectric body 51 extends between the end 62 and the conductor 55.

Although the illustrative embodiments of the present invention show a movable tubular sleeve of dielectric or conductive material as a vernier adjusting element, it will readily be seen that the principle of the invention could be applied in a variety of other forms. For example, the cut-off wave guide may be of rectangular or elliptical cross-section, and a movable member for vernier attenuation adjustment may comprise a bar or rod of material movable within the cut-off wave guide but of carefully chosen characteristics, such that the portion of the cut-off wave guide occupied by the bar or rod is not converted to an efficient energy conductor at the wavelength of the energy source. Furthermore, the internal cross-sectional shape of the cut-off wave guide might be altered from a normal shape to a predeterminedly altered shape along a variable length thereof for carrying out the principles taught in the foregoing objects and description. In Fig. 5 the shape of cut-off waveguide 12′ is altered by movable member 10′ over a portion of its length 43′′′.

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. Attenuating apparatus for electromagnetic energy of at least a predetermined wavelength, comprising a hollow pipe wave guide for conducting electromagnetic energy of at least said predetermined wavelength, said wave guide being so dimensioned as to provide substantially constant attenuation per unit length therealong of electromagnetic energy of longer wavelength than

said predetermined wavelength, a movable sleeve telescopically fitted within one end of said hollow pipe wave guide, first coupling means in said movable sleeve in energy-interchanging relation with said hollow pipe wave guide, and second coupling means engaging said hollow pipe wave guide in energy-interchanging relation therewith, whereby said hollow pipe wave guide conducts energy between said first and second coupling means; said first coupling means comprising a solid dielectric filled wave guide extending within said movable sleeve; and said second coupling means comprising a cable having a first conductor connected to said hollow pipe wave guide at a first point thereon and a second conductor extending through said hollow pipe wave guide adjacent said first point and connected thereto at a second point opposite said first point, and a dielectric rod slidably supported within said hollow pipe wave guide, said rod having a longitudinal slit therewithin through which said second conductor extends, whereby said rod may be moved along said hollow pipe wave guide for varying the length of said rod extending between said second conductor and said first coupling means.

2. Ultra high frequency apparatus comprising: a hollow pipe wave guide; a reentrant tubular conductor connected to said hollow pipe wave guide and extending through a predetermined distance therewithin; a movable member having an outer tubular portion slidably supported in contact with the inner surface of said hollow pipe wave guide, an inner tubular portion slidably supported in contact with said reentrant tubular conductor, and a radially extending conductor connecting said inner tubular portion to said outer tubular portion; and a rod coupled to said movable member and extending through and beyond said reentrant tubular conductor whereby the position of said movable member within said hollow pipe wave guide may be varied by movement of said rod.

3. In combination, a hollow pipe wave guide, a conductive sleeve telescopically fitted within said wave guide and arranged for movement therewithin, and a solid dielectric filled wave guide telescopically fitted within said movable sleeve, said movable sleeve being arranged for movement with respect to both said hollow pipe wave guide and said solid dielectric filled wave guide.

4. Ultra high frequency energy transmission apparatus comprising a hollow pipe wave guide, means coupled to said wave guide in energy-interchanging relation therewith, a transmission line having a first conductor connected to said hollow pipe wave guide at a first point thereon and a second conductor extending through said hollow pipe wave guide adjacent said first point and connected thereto at a side opposite said first point, and a dielectric rod slidably supported within said hollow pipe wave guide, said rod having a longitudinal slit therein through which said second conductor extends, whereby said rod may be moved along said hollow pipe wave guide for varying the length of the portion of said rod extending between said second conductor and said energy-interchanging means.

5. Attenuating apparatus for electromagnetic energy of at least a predetermined wavelength, comprising a hollow pipe wave guide for conducting electromagnetic energy of at least said predetermined wavelength, said wave guide being so dimensioned as to provide substantially constant attenuation per unit length for electromagnetic energy of wavelength longer than said predetermined wavelength, a movable sleeve telescopically fitted within one end of said hollow pipe wave guide, first coupling means in said movable sleeve in energy-interchanging relation with said hollow pipe wave guide, and second coupling means engaging said hollow pipe wave guide in energy-interchanging relation therewith, said second coupling means comprising a reentrant tubular conductor connected to said hollow pipe wave guide and extending therethrough toward said movable sleeve, a movable member having an outer tubular portion slidably supported in contact with said hollow pipe wave guide and an inner tubular portion slidably supported in contact with said reentrant tubular conductor and connected to said outer tubular portion through a radially extending conductor, and a rod coupled to said movable member and extending beyond said hollow pipe wave guide through said reentrant tubular conductor, whereby the position of said movable member within said hollow pipe wave guide may be varied by movement of a portion of said rod extending externally of said hollow pipe wave guide.

6. Attenuating apparatus for electromagnetic energy of at least a predetermined wavelength, comprising a hollow pipe wave guide for conducting electromagnetic energy of at least said predetermined wavelength, said wave guide being so dimensioned as to provide substantially constant attenuation per unit length for electromagnetic energy of wavelength longer than said predetermined wavelength, a movable sleeve telescopically fitted within one end of said hollow pipe wave guide, first coupling means in said movable sleeve in energy-interchanging relation with said hollow pipe wave guide, said first coupling means comprising a section of coaxial transmission line having an outer conductor and an inner conductor extending along said movable sleeve, said inner conductor being connected to said outer conductor at the end thereof adjacent said hollow pipe wave guide, and second coupling means engaging said hollow pipe wave guide in energy-interchanging relation therewith, said second coupling means comprising a reentrant tubular conductor connected to said hollow pipe wave guide and extending therethrough toward said movable sleeve, a movable member having an outer tubular portion slidably supported in contact with said hollow pipe wave guide and an inner tubular portion slidably supported in contact with said reentrant tubular conductor and connected to said outer tubular portion through a radially extending conductor, and a rod coupled to said movable member and extending through and beyond said reentrant tubular conductor, whereby the position of said movable member within said hollow pipe wave guide may be varied by movement of a portion of said rod extending externally of said hollow pipe wave guide.

7. Attenuating apparatus for electromagnetic energy of at least a predetermined wavelength, comprising a hollow pipe wave guide for conducting electromagnetic energy of at least said predetermined wavelength, said wave guide being so dimensioned as to provide substantially constant attenuation per unit length for electromagnetic energy of wavelength longer than said predetermined wavelength, a movable sleeve telescopically fitted within one end of said hollow pipe wave guide, first coupling means in said movable sleeve in energy-interchanging relation

with said hollow pipe wave guide, and second coupling means engaging said hollow pipe wave guide in energy-interchanging relation therewith, said second coupling means comprising a transmission line having a first conductor connected to said hollow pipe wave guide at a point thereon and a second conductor extending through said hollow pipe wave guide adjacent said point and connected thereto at a second point thereon opposite said first point, and a dielectric rod slidably supported within said hollow pipe wave guide, said rod having a longitudinal slit therein through which said second conductor extends, whereby said rod may be moved along said hollow pipe wave guide for varying the length of said rod extending between said second conductor and said first coupling means.

8. Attenuating apparatus for electromagnetic energy of at least a predetermined wavelength, comprising a hollow pipe wave guide for conducting electromagnetic energy of at least said predetermined wavelength, said wave guide being so dimensioned as to provide substantially constant attenuation per unit length for electromagnetic energy of wave length longer than said predetermined wavelength, a movable sleeve telescopically fitted within one end of said hollow pipe wave guide, first coupling means in said movable sleeve in energy-interchanging relation with said hollow pipe wave guide, and second coupling means engaging said hollow pipe wave guide in energy-interchanging relation therewith, said second coupling means comprising a conductive metal septum extending across said hollow pipe wave guide, a transmission line having a first conductor connected to said hollow pipe wave guide at a first point thereon and a second conductor extending through said hollow pipe wave guide adjacent said first point and connected thereto at a point thereon, said second conductor lying within the plane of said septum between said septum and said first coupling means, and a dielectric rod slidably supported within said hollow pipe wave guide, said rod having a longitudinal slit therein through which said septum and said second conductor extend, whereby said rod may be moved along said hollow pipe wave guide for varying the length of said rod extending between said second conductor and said first coupling means.

9. Ultra-high-frequency apparatus comprising a hollow pipe wave guide; a tubular conductor within said hollow pipe wave guide and extending through a predetermined distance therewithin; a movable member having an outer tubular portion slidably supported in contact with the inner surface of said hollow pipe wave guide, an inner tubular portion slidably supported in contact with said tubular conductor, and a radially extending conductor connecting said inner tubular portion and said outer tubular portion; and means connected to said movable member and extending through and beyond said tubular conductor for varying the position of said movable member.

10. High frequency apparatus comprising a hollow pipe wave guide section adapted to propagate energy therealong at a predetermined operating frequency, an energy-coupling means connected to said wave guide section at a point intermediate its ends, means dividing the portion of said wave guide between said energy-coupling means and one of said ends into at least two laterally adjacent below-cutoff wave guide portions, whereby propagation of energy to said one end is substantially reduced.

11. The apparatus defined in claim 10 wherein said portion of wave guide is substantially filled with a solid dielectric rod having a longitudinal slit and said last-named means comprises a conductive septum extending through said slit and across said wave guide section.

EDWIN T. JAYNES.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,197,123	King	Apr. 16, 1940
2,232,179	King	Feb. 18, 1941
2,376,785	Krasik	May 22, 1945
2,407,267	Ginzton	Sept. 10, 1946
2,411,553	Ramo	Nov. 26, 1946
2,423,396	Linder	July 1, 1947
2,427,098	Keizer	Sept. 9, 1947