Dec. 3, 1946. H. R. MEAHL 2,412,055

ATTENUATOR FOR ULTRA HIGH FREQUENCY SYSTEMS

Filed Jan. 25, 1943

Fig. 1.

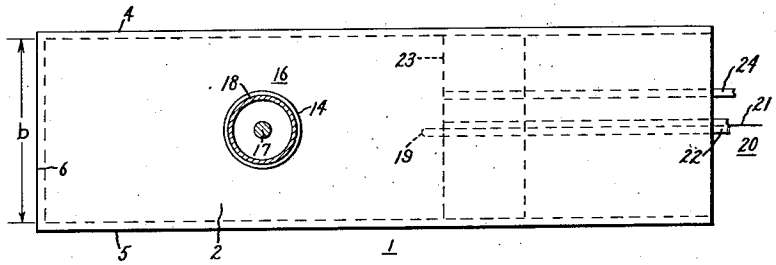
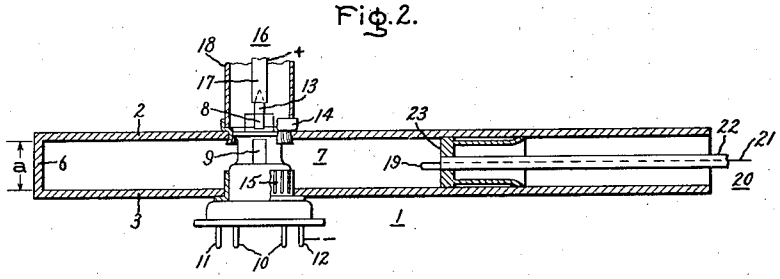


Fig. 2.



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Patented Dec. 3, 1946

2,412,055

UNITED STATES PATENT OFFICE

2,412,055

ATTENUATOR FOR ULTRA HIGH FREQUENCY SYSTEMS

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Application January 25, 1943, Serial No. 473,501

6 Claims. (Cl. 178—44)

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My invention relates to ultra high frequency systems and more particularly to an attenuator for utilization therein. It has been appreciated for some time that ultra high frequency electromagnetic waves, now referred to as microwaves, may be transmitted dielectrically through guides of the hollow-pipe type, that is through guides defined by conductive members. The types of electromagnetic waves which may be transmitted through guides of this nature have been generally classified as transverse electric, TE, and transverse magnetic, TM, depending upon the nature of the electric and magnetic fields constituting the electromagnetic waves.

In accordance with the teachings of my invention described hereinafter, I provide a new and improved attenuator for systems of this nature wherein accurately controllable and determinable voltages may be derived upon energization or excitation of the guide.

It is an object of my invention to provide a new and improved system for the utilization of ultra high frequency electromagnetic waves.

It is another object of my invention to provide a new and improved attenuator for ultra high frequency systems.

It is a further object of my invention to provide a new and improved attenuator for an ultra high frequency system which comprises a dielectric guide of the hollow-pipe type which is excited at a frequency below the critical or cut-off frequency, and in which means are provided for deriving therefrom voltages of predeterminable magnitude.

It is a still further object of my invention to provide a new and improved attenuator for a high frequency system which comprises a dielectric wave guide of the hollow-pipe type which is energized or excited at a frequency below the cut-off frequency and in which the exciting means for the guide is positioned with respect to a closed end thereof in order to minimize reflections therefrom, so that accurately determinable output voltages may be derived from the guide.

Briefly stated, in accordance with the illustrated embodiment of my invention, I provide in an ultra high frequency system a dielectric wave guide of the hollow-pipe type which is excited at a frequency below the critical or cut-off frequency in order to produce a predetermined attenuation of the excitation within the guide. The exciting means for the guide may comprise an electric discharge device, such as a diode, peculiarly adapted for the utilization of ultra high frequency energy, and the discharge device, in turn, is connected

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to a coaxial transmission line and is associated with oppositely disposed walls or sides of the guide in order to excite the guide in response to the energization of the concentric line. The electric discharge device comprising a part of the input or excitation means is displaced an appreciable distance from a closed end of the guide so that the attenuation characteristic of the guide is not affected appreciably by the reflections from the closed end, and an axially adjustable output electrode means which may be attached to an adjustable plunger is positioned at the other end of the guide and serves to derive from the guide accurately predetermined voltages dependent upon the distribution of the guide energization, and more particularly upon the attenuation characteristic of the guide.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims. Figs. 1 and 2, which are respectively a plan view and a cross-sectional vertical view, represent one embodiment of my invention as applied to an attenuator excited from a coaxial transmission line, and wherein an electric discharge device is employed for converting the energization of the transmission line into the desired energization of the attenuator.

Referring now to Figs. 1 and 2 jointly, my invention is there illustrated as applied to an ultra high frequency system for controlling the transmission of energy through a dielectric wave guide of the hollow-pipe type which comprises a conductive or metallic guide 1 which may have a rectangular cross section. For example, the top and the bottom of the guide may be defined by conductive or metallic plates 2 and 3 and the side walls by plates 4 and 5. One end of the guide is closed by means of a metallic end plate 6.

In order to excite the guide, I provide an electric discharge device 7 comprising a plurality of enclosed electrodes such as an anode 8 and a cathode 9 arranged in relatively close proximity in order to utilize effectively ultra high frequency currents. A cathode heating element (not shown) lies within the cylindrical cathode 9 and heating current is supplied thereto by means of lead-in conductors and terminal posts 10. Terminals 11 and 12 may be employed for connecting the cathode to an external source of uni-directional current for energizing the discharge device. The electrodes of the discharge device are enclosed within a vacuum-tight envelope, and the anode 8 is provided with an extension 13 to serve as an

adaptor for connection to the central conductor of a concentric transmission line to be described presently.

In order to facilitate the insertion of the discharge device 7 into operative relationship with respect to the guide and to maintain the discharge device firmly in position after insertion, I employ a pair of metallic adaptors 14 and 15 designed to afford appreciable resilience for engaging parts of the discharge device.

Discharge device 7, and particularly the electric discharge path between anode 8 and cathode 9, is controlled in response to the potential provided by a concentric transmission line 16 comprising an internal conductor 17, which is connected to the anode adaptor 13, and a tubular outer conductor 18 which is inserted into adaptor 14 and which is electrically connected to one side of the wave guide such as plate 2.

In accordance with my invention, the wave guide is designed to attenuate the excitation introduced into the guide by the concentric transmission line 16 and electric discharge device 7. More particularly, the height a and the width b of the guide are chosen with respect to the frequency of excitation so that the electromagnetic energization is not propagated in wave form along the longitudinal axis of the guide but is rapidly attenuated.

Each type of electromagnetic wave, that is each type of transverse electric or transverse magnetic wave in a given dielectric wave guide can be propagated at a frequency only above the critical or cut-off frequency. Considering a rectangular-type wave guide, the propagation constant γ may be expressed as follows:

$$\gamma=\left[-\omega^2\epsilon\mu+\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2\right]^{\frac{1}{2}} \quad (1)$$

where ω is the angular velocity of the wave under consideration, ϵ is the dielectric constant of the medium through which the wave is propagated, μ is the permeability, m is the mode of propagation of the wave, and n is the order of the wave, a is the height of the guide, and b is the width of the guide.

For frequencies below the critical frequency, the first term of Equation 1 is smaller than the sum of the other two terms, and γ is real. Consequently, under this condition of operation the electromagnetic wave is attenuated. For frequencies greater than the critical frequency, the first term is greater than the sum of the other two terms; consequently, γ is imaginary, thereby resulting in a real propagated wave.

The critical or cut-off frequency f_0 for a rectangular wave guide may be expressed as:

$$f_0=\frac{1}{2\sqrt{\mu\epsilon}}\left[\left(\frac{n}{a}\right)^2+\left(\frac{m}{b}\right)^2\right]^{\frac{1}{2}} \quad (2)$$

In order to simplify still further the presentation of the subject matter, it will be assumed that the dielectric is air and that the system is arranged for the transmission of an H_{01} type wave where the electric component of the field is perpendicular to the base b, in which case the critical frequency may be expressed as:

$$f_0=\frac{c}{2b} \quad (3)$$

where c is the velocity of light. Of course, in any practical wave guide operated at a frequency above the cut-off frequency, electromagnetic waves are propagated with attenuation, the magnitude of the latter being determined by the conductivity of the conductive material defining the guide. Stated in other words, the waves are propagated with a predetermined attenuation.

In accordance with the present invention, the wave guide is excited at a frequency below the critical frequency defined by Equation 3 above, so that the electromagnetic waves are rapidly attenuated along the longitudinal axis of a guide; that is, the propagation constant γ contains no imaginary component.

Furthermore, in accordance with my invention, the excitation means for the guide including the electric discharge device 7 and the concentric transmission line 16 are positioned with respect to the end wall 6 so that there is little or no reflection therefrom, in this way increasing the accuracy of the attenuated energization proceeding from the electric discharge device toward the right of the guide. I have found that prevention of undesirable reflections from the closed end wall 6 of the wave guide may be obtained by positioning the electric discharge device 7 from the end wall 6 at a distance which causes an attenuation therebetween of at least 10 decibels so that the reflected excitation from the closed end 6 will be attenuated at least 20 decibels when it arrives at the electric discharge device 7.

Considering now the attenuation of the electromagnetic excitation in a dielectric wave guide operated below the cut-off frequency, it may be stated generally that the energy of the excitation is attenuated in accordance with the exponential $\epsilon^{-2\alpha z}$, where α represents the attenuation constant of the guide and z represents the axial or longitudinal distance along the guide. This relationship will be appreciated when it is considered that the energy of the excitation which may pass along the guide is a function of the cross product of the electric field intensity and the magnetic field intensity, and inasmuch as both the electric field intensity and magnetic field intensity are each attenuated in accordance with $\epsilon^{-\alpha z}$, the energy follows the squared law. Furthermore, from the above it will be appreciated that the magnitude of the electric field of the energization within the guide is a function of $\epsilon^{-\alpha z}$.

I provide within the guide output electrode means which is adjustable along the longitudinal axis of the guide in order to derive therefrom voltage of predeterminable magnitude in accordance with the attenuation characteristic of the guide. For example, the output electrode means may take the form of a loop of wire 19 constituting an extension of an inner conductor 21 of a concentric transmission line 20 which comprises the inner conductor 21 and an outer tubular conductor 22. As a means for positioning the loop 19, the concentric transmission line 20 and consequently the loop 19 may be supported by an axially or longitudinally positionable plunger 23 adapted to engage closely the top, bottom and side walls of the guide. The plunger 23 may be actuated by means of a suitable mechanical expedient such as a rod 24.

If it be considered that the guide is energized at a substantially constant excitation by means of the concentric transmission line 16, there will be established within the guide an excitation of constant value, the electric discharge device serving to periodically control the potential difference between plates 2 and 3 of the guide to establish this excitation. The attenuation of the excitation within the guide is determined in accordance with the above described principles so that by the positioning of the loop 19 with re-

spect thereto, I provide a system for obtaining accurately and precisely determinable ultra-high frequency voltages. The magnitude of the voltage supplied to the concentric transmission line 20 is, of course, determined by the position of the loop 19. As the loop 19 is moved toward the electric discharge device 7, the magnitude of the voltage obtained is increased; and the relationship of this voltage with respect to the longitudinal dimension of the guide follows the exponential relationship ϵ^{-az}, where z is measured from discharge device 7.

While I have shown and described my invention as applied to a dielectric wave guide of particular configuration and as employing various elements diagrammatically illustrated, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A dielectric wave guide system of the hollow-pipe type comprising a conductive member having a closed end, means for exciting said member below the critical cut-off frequency and positioned a distance from said closed end to prevent the reflection of appreciable energy therefrom, and output electrode means opposite the excitation means for deriving energy from said guide.

2. In an attenuator, the combination comprising a hollow conductive member having a closed end, means for exciting said member at a frequency below the critical cut-off frequency and positioned a distance from said closed end to minimize the reflection therefrom, and axially positionable means at the other end of said member and including output electrode means.

3. In an attenuator for a dielectric wave guide system, the combination comprising a hollow

conductive wave guide having a closed end, excitation means displaced from said closed end for exciting said guide at a frequency below the critical cut-off frequency, and means displaced from said excitation means for deriving predeterminable amounts of energy from said guide determined by the position thereof with respect to said excitation means.

4. In an attenuator, the combination comprising a hollow conductive member having a closed end, excitation means connected to said guide and displaced from said closed end for effecting excitation of said member at a frequency below the cut-off frequency thereby imparting to the electro-magnetic energization of said member a predeterminable attenuation characteristic, and adjustable means comprising a plunger having output electrode means for deriving predeterminable voltages from said member.

5. In an attenuator, the combination comprising a hollow conductive member having a closed end, means for exciting said member at a frequency below the critical cut-off frequency comprising an electric discharge device including a plurality of enclosed electrodes, said discharge device being positioned from said closed end at a distance to minimize the reflection therefrom, and axially adjustable output electrode means at the other end of said member for deriving from said member a voltage of predetermined magnitude determined by the excitation and the attenuation characteristic of said member.

6. In an attenuator, the combination comprising a hollow conductive member having a closed end, means for exciting said attenuator at a frequency below the critical cut-off frequency and positioned from said closed end at a distance to prevent appreciable reflection therefrom, and axially positionable means comprising an adjustable plunger supporting output electrode means at the other end of said member.

HARRY R. MEAHL.