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Dec. 1, 1970 P. FENSTER 3,545,002
WIDEBAND WAVE TRAPPING ANTENNA HAVING A TIME
LIMITED IMPULSE RESPONSE
Filed Feb. 4, 1969

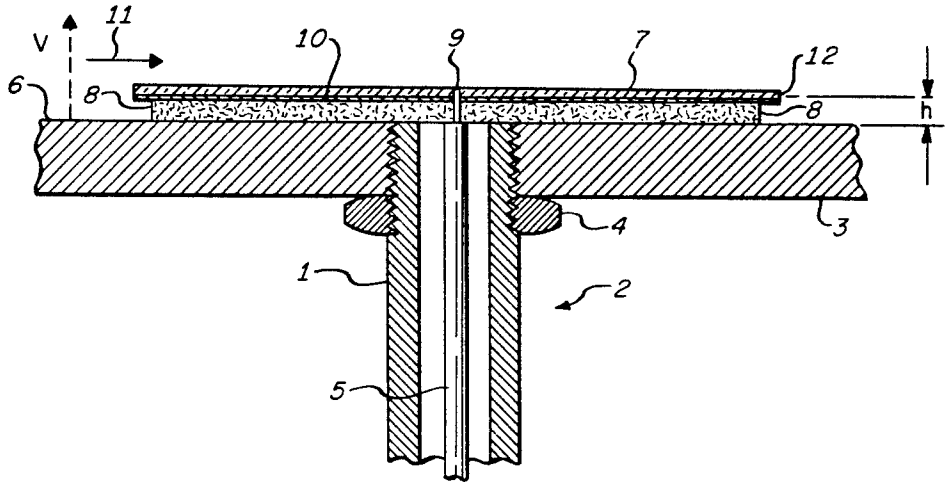


FIG. 1.

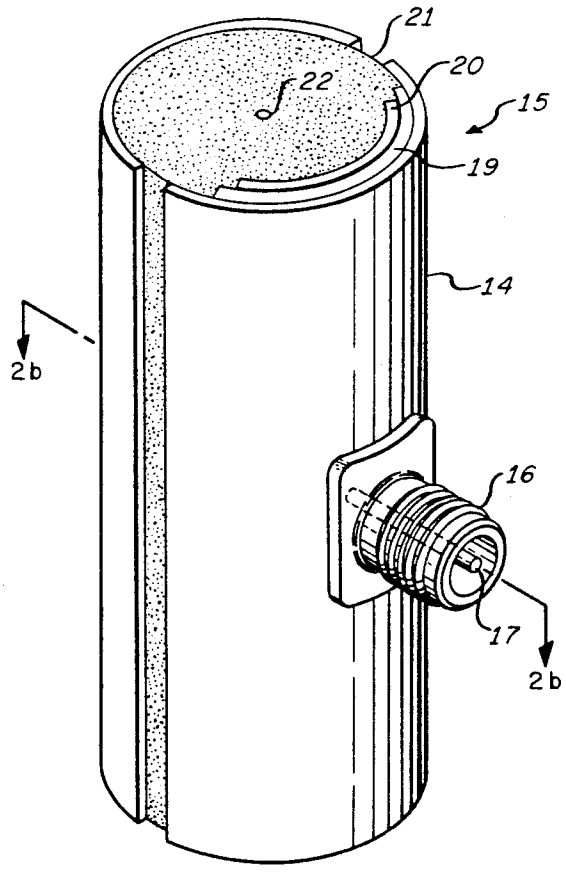


FIG. 2a.

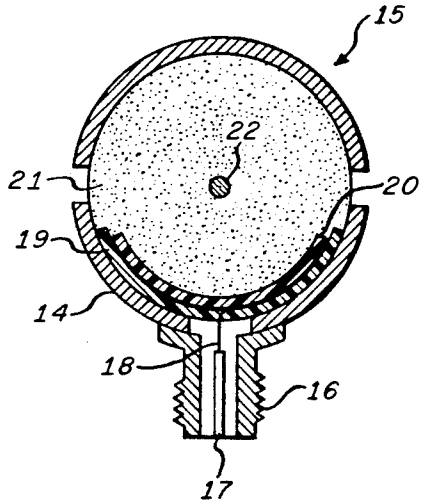


FIG. 2b.

INVENTOR
PAUL FENSTER
BY Joseph M. Rachl
ATTORNEY

United States Patent Office 3,545,002 Patented Dec. 1, 1970

3,545,002

WIDEBAND WAVE TRAPPING ANTENNA HAVING A TIME LIMITED IMPULSE RESPONSE

Paul Fenster, Highland Park, N.J., assignor to Sperry Rand Corporation, a corporation of Delaware

Filed Feb. 4, 1969, Ser. No. 796,347
Int. Cl. H01q 1/48, 15/00
U.S. Cl. 343—830 9 Claims

ABSTRACT OF THE DISCLOSURE

A wave trapping type antenna comprising an apertured ground plane conductive member through which the center conductor of a coaxial line extends to form a monopole antenna, the outer conductor of the coaxial line being connected to the member. The center conductor is terminated with a disk of conductive material having a thickness and an angle relative to the member so as to equalize the amplitudes of the waves propagating on opposite sides of the disk. The energy propagating media on opposite sides of the disk provide substantially the same velocities of propagation to travelling waves. A coaxial line coupler embodiment of the antenna is also disclosed.

BACKGROUND OF THE INVENTION

Increasing attention is being directed to microwave communication and radar systems utilizing pulses of extremely fast rise times. Microwave components for use in such systems, including antenna and other energy coupling components, should be characterized by a time limited impulse response, i.e., where the response of the component to excitation is fully terminated and reduced to negligible distortion residues within a limited time period. For example, where the excitation is step-modulated radio frequency energy, the limited time period should be short with respect to the R.F. period. Where the excitation is an impulse, the limited time period should be shorter than the width of the impulse.

The need for microwave components suitable for use with fast rise-time video pulses has been recognized for some time. R. C. Fletcher, for instance, in the Review of Scientific Instruments, vol. 20, page 861 (1949) introduced several types of voltage pick-offs for use in coaxial systems. These devices, however, were difficult to construct. Furthermore, their rise-time was limited and their fidelity was poor because of overshoot and because they generated time residues.

McDonald et al., in the Review of Scientific Instruments, vol. 36, page 504 (1965) described a simple capacitance voltage pick-off. However, this pick-off also generated time residues.

It is a principal object of the present invention to provide energy coupling devices that will respond to ultra fast rise-time pulses with fidelity and without the generation of spurious time residues.

SUMMARY OF THE INVENTION

According to the present invention, a wave trapping type antenna is provided having an apertured conductive member through which the center conductor of a coaxial line extends to form a monopole antenna terminated by a disk of conductive material. Time limited impulse response is achieved when the waves propagating on either side of the disk are given substantially the same amplitude and phase as they reach the far edge of the disk in the direction of wave propagation. The amplitudes of the waves are equalized by providing a submicron thickness of conductive disk material and/or by setting the disk at an approximate angle relative to the conductive member. The submicron thickness of the conductive disk

permits the exchange of energy between the two electromagnetic waves travelling on opposite sides of the disk. The angle of the disk determines the initial energy split between the two waves and the energy balance at the trailing edge of the disk.

The energy of the wave travelling between the disk and the conductive member is reduced in part due to scattering losses as the wave encounters the monopole and in part due to energy coupled out via the coaxial line. The energy of the wave travelling on the other side of the disk is not so reduced. In the absence of means for energy equalization between the two waves travelling on the opposite sides of the disk, objectionable reflections would occur when the two waves reach the far edge of the disk in the direction of wave travel. However, the provision of a submicron thickness of conductive material for the disk permits energy "leak through" from the higher level energy of the upper wave to the lower level energy of the lower wave which travels between the disk and the ground plane. With sufficient "leak through" coupling of energy between the waves, the two waves equalize to substantially the same amplitude before reaching the far edge of the disk in the direction of wave travel. The two waves retain the same phase by virtue of the substantially identical velocities of propagation of the media on the opposite sides of the disk. The two waves then reunite without reflection at the far edge of the disk and permit the response of the antenna to the impulse excitation to be terminated quickly.

A similar result is achieved by using a conductive disk of sufficient thickness to isolate the two waves travelling on opposite sides of the disk and tilting the disk relative to the apertured conductive member at an angle to cause an appropriate initial energy split and final energy balance between the two waves to offset the energy loss experienced by the lower wave.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified cross-sectional sketch of a typical antenna embodiment of the present invention; and

FIGS. 2*a* and 2*b* are perspective and cross-sectional views, respectively, of a voltage divider (coupler) embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the outer conductor **1** of coaxial line **2** conductively engages apertured ground plane conductive member **3**. As presently preferred, conductor **1** and member **3** are threadably engaged and secured by lock nut **4**. The inner conductor **5** and outer conductor **1** of coaxial line **2** are cut flush with the top surface **6** of ground plane **3**. A conductively clad glass disk **7** is supported above ground plane **6** by dielectric foam spacers **8** which have a dielectric constant closely matching that of air. The conductive film **10** on disk **7** is of the order of several hundred angstroms in thickness, and is electrically connected to the center conductor **5** of coaxial line **2** by thin wire **9**.

Let it be assumed that a TEM wave with electric field indicated by a vector V propagates across the antenna of FIG. 1 in the direction of arrow **11**. The electric field of the wave is perpendicular to ground plane **3** whereby equipotential planes exist which are parallel to ground plane **3**. The presence of disk **7** with its thin conductive film **10** along one of the equipotential planes does not disturb the incoming wave other than to split it into two portions, one being above and the other being below film **10**. The two portions of the wave travel along with substantially the same phase inasmuch as the velocities of propagation in the media on opposite sides of film **10** are substantially the same. Since a relatively small amount

of upper wave energy propagates within disk **7** and since the dielectric constant of the spacers is approximately equal to that of air, negligible velocity effects are introduced. If the amplitudes of the two portions of the wave also remain equal as the wave propagates across the antenna, the two waves may recombine without reflection at the far edge **12** of disk **7**. However, the lower wave, i.e., the "trapped" wave propagating between disk **7** and ground plane **3**, encounters thin wire **9** which scatters some of the energy and couples additional energy out coaxial line **2**. Thus, the amplitude of the energy of the lower wave is reduced relative to the amplitude of the energy in the upper wave portion.

A time limited impulse requires that the energy coupled out via coaxial line **2** terminates with no significant residual distortion transients in a time which is short compared to the radio frequency period of the input impulse excitation. Unless special provision is made for the equalization of the amplitudes of the energies in the two waves propagating on opposite sides of disk **7**, the resulting reflections created when the two waves recombine at the edge **12** of disk **7** would couple out via coaxial line **2** at times greatly in excess of the desired time limited inpulse response.

The present invention provides for the equalization of the amplitudes of the energies in the two waves propagating on opposite sides of disk **7** by setting the angle between disk **7** and ground plane **6** to an appropriate value whereby the energy of the incident wave travelling in the direction of arrow **11** is split in a manner to offset energy coupled out of the lower wave by coaxial line **2**. Alternatively, the energies in the two waves propagating on opposite sides of disk **7** are substantially equalized through the use of a submicron thickness of conductive film **10** which allows energy from the higher amplitude upper wave to "leak through" the thin resistive film to replenish the energy lost in the lower wave. In either manner, the upper and the lower waves become equal in amplitude before the two waves reach the far edge **12** of disk **7** in the direction of wave propagation.

It should be noted that both techniques can be employed simultaneously although in general, in embodiments employing a conductive film, the angle of the disk **7** is adjusted so that the disk is parallel to the top surface **6** of the ground plane **3**.

It will be recognized by those skilled in the art that the amount of "leak through" energy penetrating through thin film **10** depends upon the resistivity of the film, the thickness of the film and the wave length of the impinging electromagnetic wave. Energy penetrates the conductive film when the thickness thereof is less than several skin depths at the frequency of the impinging wave.

The basic principles exploited in the antenna embodiment of FIG. 1 are readily applicable to the coupler embodiment of FIGS. 2*a* and 2*b*. Referring to FIGS. 2*a* and 2*b*, the outer conductor **14** of coaxial line **15** is split to permit the connection of output coaxial line **16** thereto. The center conductor **17** of coaxial line **16** is connected to a thin wire **18** which penetrates through dielectric layer **19** to contact conductive film **20**. In a typical application, coaxial line **15** is filled with a dielectric material **21** such as "Teflon." Dielectric layer **19** preferably is of the same type of material whereby the velocity of propagation of waves travelling between the center conductor **22** of coaxial line **15** and thin film **20** is substantially the same as the velocity of waves travelling between thin film **20** and outer conductor **14**. In the case where "Teflon" dielectric material fills coaxial line **15**, it is convenient to use "Teflon" tape for dielectric layer **19** and to employ aluminized "Mylar" or "Teflon" tape to provide the thin film **20** of conductive material on dielectric layer **19**.

In the coaxial line coupler embodiment of FIGS. 2*a* and 2*b*, thin film **20** of conductive material is parallel to outer conductor **14** of coaxial line **15**. The resistivity of thin film **20** is selected preferably within the range from about 1 ohm per square to about 50 ohms per square, although other resistivities are useful to permit an appropriate amount of energy "leak through" from the upper wave (travelling between the center conductor **22** of coaxial line **15** and thin film **20**) to the lower wave (travelling between film **20** and the outer conductor **14** of coaxial line **15**) whereby the amplitudes of the energies in the two waves become substantially equal before the waves reach the far edge of thin film **20** in the direction of wave propagation. Typically, film **20** is 0.001" thick or slightly thicker. A desired portion of the energy in the total wave travelling within coaxial line **15** is coupled out via coaxial line **16** in the same manner as described with respect to coaxial line **2** with respect to the antenna embodiment of FIG. 1. It will be observed that the phase of the upper wave remains the same as the phase of the lower wave in the coaxial line coupler of FIGS. 2*a* and 2*b* because both waves propagate through respective media providing the same velocity of propagation.

It has been observed in tests made with an antenna configuration of the present invention utilizing a 0.030 inch thickness and 8 inch diameter glass plate for disk **7** and approximately 200 angstroms of chromium for thin conductive film **10** that the desired imulse resonse is achieved only when the thin conductive film **10** faces ground plane **6**. Satisfactory time limited impulse response is not obtained when the glass plate faces ground plane **6**, i.e., when disk **7** is inverted. In the inverted case, a substantial amount of the lower wave is confined within the glass with the result that the velocity of propagation of the lower wave becomes significantly different from the velocity of the upper wave which travels in air. However, when conductive film **10** faces ground plane **6** both the upper and the lower waves propagate through substantially the same air media inasmuch as a relatively small amount of the upper wave energy propagates within the glass plate and a relatively small amount of lower wave energy propagates within the dielectric spacers **8**. It also has been observed that optimum time limited impulse response is achieved when the height of disk **7** above ground plane **6** is in the range from about 0.010 to about 0.375 inch.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. An energy coupling device comprising:
an apertured first conductive member,
a second conductive member,
said first and second members forming a first microwave transmission line, and
a second microwave transmission line coupled to said first microwave transmission line through an aperture in said first member,
the microwave energy propagating media on opposite sides of said second member providing substantially the same velocity of propagation,
said second member having a thickness and angular relationship with respect to said first member so as to equalize the amplitudes of microwave energies propagating on opposite sides of said second member in said media.

2. The device defined in claim **1** wherein said second microwave transmission line is a coaxial line whose center conductor extends through said aperture in said first member to contact said second member.

3. The device defined in claim **2** wherein said second conductive member is a disk.

4. The device defined in claim 3 wherein the thickness of said disk is a fraction of a micron.

5. The device defined in claim 4 wherein said disk is separated from said first conductive member by a distance in the range from about 0.010 inch to about 0.375 inch.

6. The device defined in claim 5 wherein the resistivity of said disk is in the range from about 1 ohm per square to about 50 ohms per square.

7. The device defined in claim 1 and further including a second coaxial line, said first member conforming to the outer conductor of said second coaxial line.

8. The device defined in claim 7 wherein said second coaxial line is filled with a dielectric material to provide the same velocity of propagation to microwave energy travelling on opposite sides of said second member.

9. The device defined in claim 1 wherein said second member comprises:

a substrate of dielectric material and a submicron film of resistive material deposited on said substrate, said film facing said first member.

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ELI LIEBERMAN, Primary Examiner

M. NUSSBAUM, Assistant Examiner

U.S. Cl. X.R.

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