United States Patent

[11] 3,599,215

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[31] 43/40172

[54] LEAKY WAVEGUIDE-ANTENNA COMBINATION

3 Claims, 4 Drawing Figs.

[52] U.S. Cl. ..... 343/767, 343/772, 343/781, 333/78 M

[51] Int. Cl. H01q 13/10, H01q 13/22

[50] Field of Search ..... 333/1, 98 M, 1.1; 343/775, 785, 767, 770, 771, 772, 781; 179/82

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Saxfield Chatmon, Jr.
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ABSTRACT: A leaky waveguide-antenna combination employing a leaky waveguide having a coextending ground plate attached thereto and an elongated antenna positioned in parallel over the leaky coaxial cable to receive waves therefrom. Metallic plates extend from both sides of the antenna in parallel to the ground plate and are provided with parallel grooves which extend longitudinally and have a depth of about one-fourth the cutoff wavelength of the antenna so that the input impedances for the modes propagating in space between the grooved plates and the ground plate is infinite thereby preventing stray interferences.

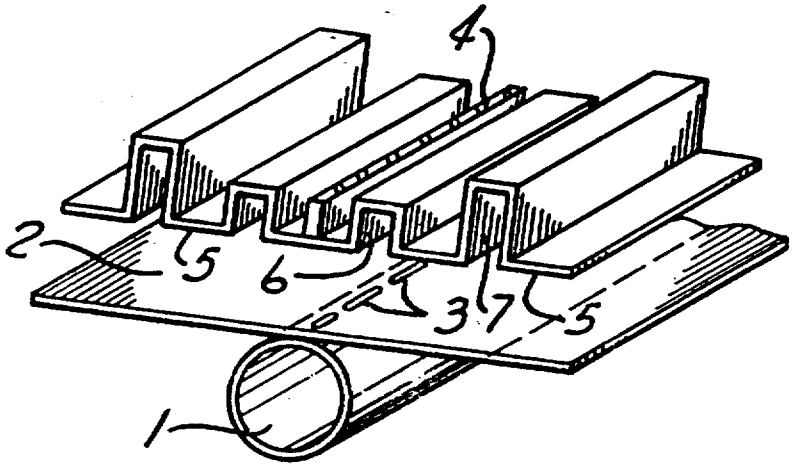


Fig. 1
PRIOR ART

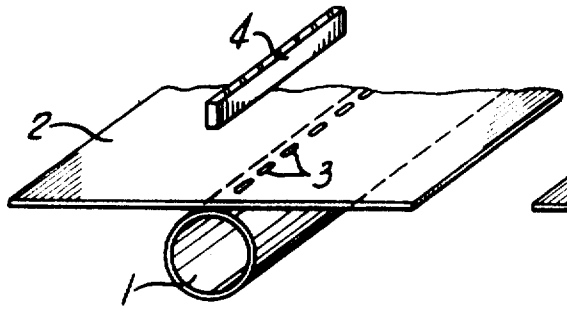


Fig. 2
PRIOR ART

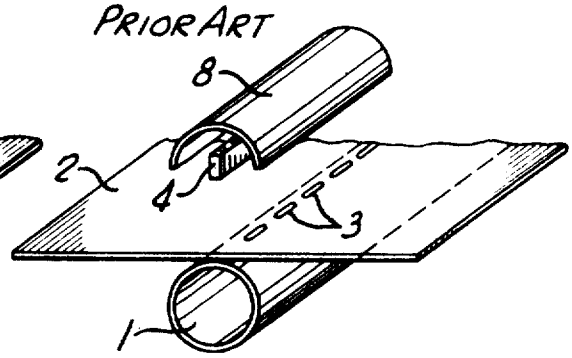


Fig. 3

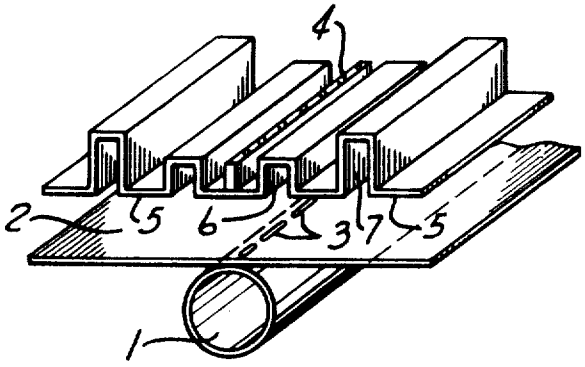
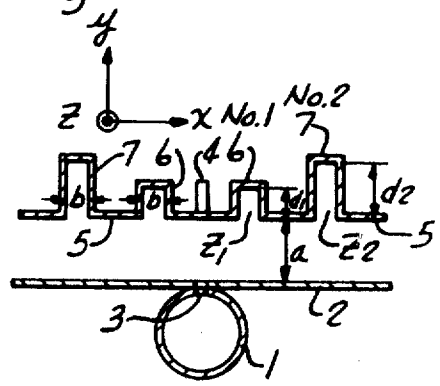


Fig. 4



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LEAKY WAVEGUIDE-ANTENNA COMBINATION

BRIEF EXPLANATION OF THE DRAWING

FIG. 1 and FIG. 2 are diagrammatic perspective views of a transmitting and receiving device using a leaky waveguide. FIG. 3 is a diagrammatic perspective view of a transmitting and receiving device using a waveguide according to the present invention. FIG. 4 is a diagrammatic front sectional view of the device.

DETAILED EXPLANATION OF THE INVENTION

This invention relates to a leaky waveguide device in which unwanted radiation is suppressed.

When employing electromagnetic waves radiated from a leaky waveguide and received by an antenna aboard a vehicle in its vicinity, it has already been suggested to place an exposed antenna 4 facing the leaky waveguide 1 on the ground as shown in FIG. 1, or to use an antenna 4 provided with an arciform focusing reflector plate 8 as shown in FIG. 2. In the case of the device shown in FIG. 1, it is not effective for suppressing unwanted radiation because the antenna is exposed, so that unwanted electromagnetic waves are radiated into free space, interfering with other communication systems and incurring interference from other systems. This type electromagnetic interference is strictly controlled by Government Wave Regulations. In the case of the device shown in FIG. 2, electromagnetic waves from leaky wave apertures in an antenna 4 are focused toward the apertures 3 of leaky waveguide 1 by means of a focusing reflector plate 8 placed over the antenna 4, so that, as compared with the device shown in FIG. 1, this device has a suppression effect on unwanted radiation to some degree. However, this suppression can by no means be said to be satisfactory.

According to the present invention, metal plates having grooves are placed on both sides of an antenna in parallel to a ground metal plate of a leaky waveguide for the purpose of obtaining a leaky waveguide device free from the aforesaid drawbacks, i.e. a device which suppresses unwanted radiation. The depths of the grooves in the metal plates are made such that the input impedance becomes infinitely great for mode waves transmissible in the transverse direction of the antenna.

This will be explained in a concrete form with reference to the attached drawings. FIG. 3 shows a perspective of a leaky waveguide of the present invention. In FIG. 3, 1 denotes a leaky waveguide of ground potential, 2 denotes a flat metal plate attached to said leaky waveguide 1, 3 denotes leaky wave apertures provided in said leaky waveguide 1 and through plate 2, 4 and antenna located in parallel to the leaky waveguide 1, 5 metal plates attached to the antenna and having grooves which are attached to said antenna 4, 6 and 7 grooves provided on said metal plates 5 in parallel to said antenna. Each groove has a width "b" and is placed apart from an adjacent groove or the antenna by a distance which is determined by structural condition. FIG. 4 is a cross section of what is shown in FIG. 3. A metallic plate 2 has ground potential, the metallic plates 5 are provided on both sides of the antenna 4, the distance between metal plates 2, 5 is "a." The depths of the grooves 6, 7 are respectively d_1, d_2, and the impedances of the first, the second, grooves are Z_1, Z_2, respectively.

An electromagnetic wave propagating in a space determined by some boundary can be expressed with phase constants as follows:

$$exp[-j\beta x X - j\beta y Y - j\beta z Z] \quad (1)$$

$$\beta x^2+\beta y^2+\beta z^2=k^2=\omega^2\epsilon^2\mu \quad (2)$$

where, βx, βy, βz are phase constants in the x—, y—, z—directions, respectively, and ω is an angular frequency.

If any one of βx, βy and βz is an imaginary number, the wave becomes evanescent in the corresponding direction. For example, when βx is an imaginary number $-j\bar{\beta}x$ (where $\bar{\beta}x$ is a real number), $exp(-j\beta x X)$ becomes $exp(-\bar{\beta}x X)$ and the wave exponentially attenuates in the x-direction.

In the present case, βz can be determined by the propagation constant in the waveguide of the antenna, and therefore βz is then $\sqrt{k^2-(2\pi/\lambda c)^2}$ where, λ_c is a cutoff wavelength of the waveguide for an antenna 4. On the other hand, β_y can be determined by the spacing a and its value can be given by $n\pi/a$ wherein n represents an integral number. These values for βy and βz give βx by using eg. (2) as follows:

$$\beta x^{(n)}=\sqrt{\omega^2\epsilon\mu-\beta x^2-\left(\frac{n\pi}{a}\right)^2}=\sqrt{\left(\frac{2\pi}{\lambda c}\right)^2-\left(\frac{n\pi}{a}\right)^2}$$

where λ_c is the cutoff wavelength when the antenna is regarded as a waveguide.

In consequence, the group of modes which satisfy the condition

$$\frac{n\pi}{a}>\frac{2\pi}{\lambda c}$$

namely $n>2a/\lambda c$ attenuate in the x-direction transverse to the direction of the leaky waveguide as, $\beta_x^{(n)}$ becomes imaginary. That is to say, if the metallic plates 5 and 2 are extended for some length larger than $\lambda_c/2$ in the transverse direction, whether the metallic plate 5 has grooves or not, the amount of unwanted radiation of the group of modes of $n>2a/\lambda c$ becomes very small. On the other hand, the group of modes which has the condition $n\leq 2a/\lambda c$ does not attenuate in the transverse direction in the space bounded by metallic plates 5 and 2, and unwanted radiation is not suppressed by no matter how long the metallic plates 5 and 2 are extended in the x-direction. In this case, it is necessary to provide grooves 6 and 7, etc. as shown in FIGS. 3 and 4 on said metallic plate 5. The phase constants in the groove can be determined in such a manner that βz is $\sqrt{k^2-(2\pi/\lambda c)^2}$

as per the above discussion, βx is expressed by $m\pi/b$ with an integral number m, and then

$$\beta y=\sqrt{(2\pi/\lambda c)^2-(m\pi/b)^2}.$$

If the width of the groove b is smaller than $\lambda c/2$, only one mode ($m=0$) can propagate in the y-direction in the groove. Then, the input impedance becomes infinite under the assumption that the top end of the groove is short circuited, when the depth d is $\lambda c/4+\Delta n$.

The correction term, Δn is related to the propagation mode number n in the spacing between the metal plates 2 and 5 as above mentioned, and is necessary for compensating the fringing effect to each mode and the spacing distance between adjacent grooves is not restricted by electromagnetic conditions, but is determined rather by structural conditions. The unwanted radiation of the group of the modes wherein n $2a/\lambda c$ is choked by these grooves. This prevents useless energy propagation in the transverse direction.

In other words, the total impedance between the grooved metallic plate and the ground plate for energy propagated in the transverse direction, is the impedance of the grooves plus the impedance between the two opposed plates. As the impedance of the groove or grooves is infinite, so therefore, is the sum of these two impedances. If there are n mode waves according to the condition of $n\leq 2a/\lambda c$, then n grooves should be provided on either side metal plate of the antenna and the depths of the grooves are so determined such that the input impedances Z_1, Z_2, ... for the modes corresponding to them respectively becomes infinitely great.

In the foregoing explanation, the depths of the grooves 6, 7 ... in the metallic plate 5 were shown as d_1, d_2, however, the present invention is merely not restricted by this. It is sufficient to say that grooves are provided for the transmissible modes and arranged to make their input impedance infinitely great.

As the invention places metallic plates having grooves on both sides of an antenna and makes the depths of the grooves such that the input impedance is infinitely great for their corresponding modes, it suppresses the radiation in the transverse directions on both sides of the antenna and can remarkably improve the coupling between the antenna and the leaky waveguide.

We claim:

1. A leaky waveguide-antenna combination comprising a leaky waveguide having a coextending ground plate extending laterally therefrom on both sides and attached thereto with leaky wave apertures of said leaky waveguide extending through said plate, an elongated antenna positioned in parallel with said leaky waveguide and in receiving proximity thereto to receive waves leaking from said apertures, a metallic plate extending laterally from both sides of said antenna and having parallel grooves extending in the longitudinal direction with their valleys extending away from said ground plate, said

grooves having depths of about $\lambda c/4$ so that the input impedances for the modes propagating in space between said grooved metallic plate and said ground plate is infinite.

2. The leaky waveguide-antenna combination of claim 2 characterized by a plurality of said grooves on each side of said antenna.

3. The leaky waveguide-antenna combination of claim 3 characterized in that said antenna is tubular with apertures facing said waveguide.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,599,215 Dated August 10, 1971

Inventor(s) Kenichi Yoshida and Hiroshi Kitani

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

Column 4, Claim 2, line 4, "claim 2" should read --claim 1--;
Claim 3, line 7, "claim 3" should read --claim 2--.

Signed and sealed this 25th day of January 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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