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Tricoles et al.

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[54] **RADIO FREQUENCY TRANSMITTING
APPARATUS HAVING SLOTTED METALLIC
RADIO FREQUENCY WINDOWS**

[75] Inventors: **Gus P. Tricoles**, San Diego; **Eugene L. Rope**, El Cajon, both of Calif.

[73] Assignee: **General Dynamics Corporation**, San Diego, Calif.

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[51] Int. Cl. **H01q 1/42**

[58] Field of Search..... **343/770, 771, 872 R,
343/872, 767**

[56] **References Cited**

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Primary Examiner—Eli Lieberman
Attorney—Martin Lu Kacher

[57] **ABSTRACT**

A slot antenna or radome having increased bandwidth capability may be made of a metallic sheet which is curved in the case of a radome, or flat in the case of the side of a waveguide, the sheet has a plurality of slots with edges which are beveled toward each other from the outer surface of the sheet, such that the metallic walls of the window are thin and approach the skin depth for the highest frequency of radio frequency waves which are to be transmitted. With longer wavelengths the electromagnetic field penetrates through the thin edge so that the window is effectively larger, thereby providing improved transmittance over a broad bandwidth.

11 Claims, 6 Drawing Figures



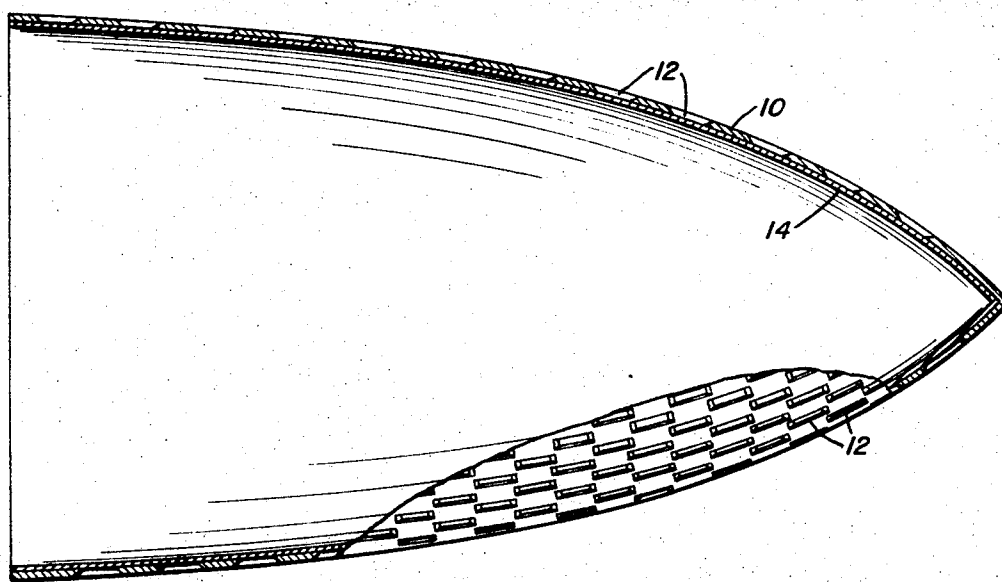


FIG. 1.

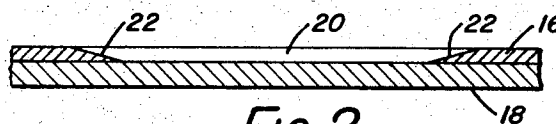


FIG. 2.



FIG. 3.

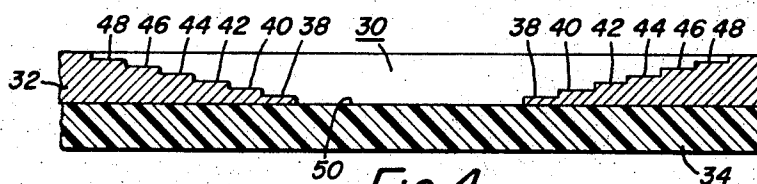


FIG. 4.

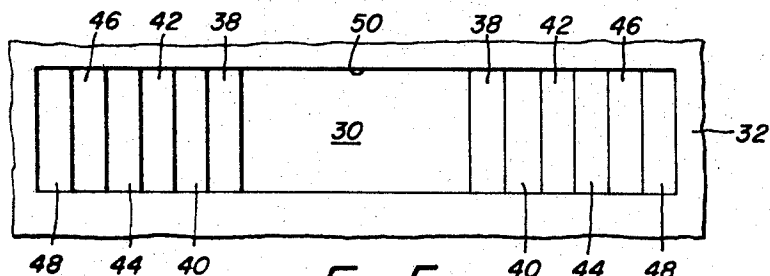


FIG. 5.

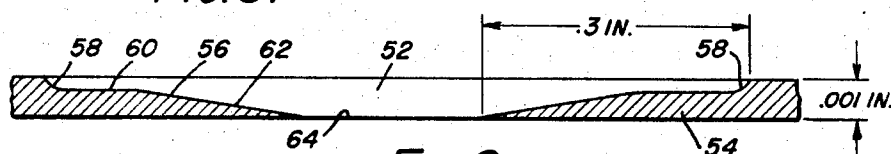


FIG. 6.

RADIO FREQUENCY TRANSMITTING APPARATUS HAVING SLOTTED METALLIC RADIO FREQUENCY WINDOWS

The present invention relates to apparatus for transmitting radio frequency waves and particularly to radio frequency apparatus having slotted metallic windows through which the waves are transmitted.

The invention is especially suited for use in slotted antennas and radomes and provides for improved transmittance characteristics over a broad band of radio frequencies.

Various types of microwave apparatus use windows through which microwave energy is transmitted. For example, slotted waveguides have been used as microwave antennas. It has also been suggested that radomes be made of metal and provided with slotted windows through which the radio frequency waves can be transmitted. Metallic radomes and antennas are especially desirable for use in aircraft since they provide a protection from lightning and discharge static electricity accumulated during flight. Metallic antennas and radomes are also helpful in reducing the radar cross section of the aircraft by causing divergent reflections from a streamlined surface, for example, of the radome. Such metallic radomes having windows have been described in an article by L. L. Oh, et al., entitled "Fenestrated Metal Radomes" which appeared in the Microwave Journal, Volume 7, page 62 (1964). Unfortunately, such radomes have performance drawbacks. They are particularly narrow-banded and have low transmittance.

It has been discovered, in accordance with the invention, that frequency dependence upon the size of the slotted window can be minimized by beveling the edges of the slots so that the skin depth or thickness is approached. For low frequencies the field penetrates into and through the beveled edges; for a wave at high frequencies, the skin effect provides a slot of proper dimensions to support transmission of such waves, thus providing a slotted window which is virtually or effectively larger for radio frequency waves of lower frequency.

Accordingly, it is an object of the invention to provide improved apparatus for transmitting radio frequency waves.

It is a further object of the invention to provide improved apparatus having increased bandwidth for microwave radiation through slotted windows.

It is a still further object of the present invention to provide radiating windows in the form of slots having increased effective slot size with wavelength of the incidence wave.

It is a still further object of the present invention to provide improved metallic, slotted antennas and radomes.

It is a still further object of the present invention to provide an improved radome having a slotted metallic surface which is transparent to radio frequency waves and can be used in place of conventional dielectric radomes.

The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will become more readily apparent from a reading of the following description, taken with the accompanying drawings, in which:

FIG. 1 is a side view of a radome embodying the invention; the view being broken away to illustrate the wall of the radome in cross section;

FIG. 2 is a fragmentary sectional view of a slotted window in accordance with an embodiment of the invention;

FIG. 3 is a sectional view of a slotted metallic window which is constructed in accordance with another embodiment of the invention;

FIG. 4 is a sectional view of a slotted window constructed in accordance with still another embodiment of the invention;

FIG. 5 is a plan view of the slotted window shown in FIG. 4; and

FIG. 6 is a sectional view of a slotted metallic window constructed in accordance with still another embodiment of the invention.

FIG. 1 illustrates a fenestrated radome of streamlined shape which is constructed from a sheet of metallic material, 10; the sheet suitably being aluminum, copper or stainless steel. The sheet, 10, has an array of slots 12 distributed uniformly in spaced relation over its entire surface. In juxtaposition with the metallic sheet 10 is a thin sheet 14 of dielectric material, such as fiberglass cloth which is laminated with epoxy resin. The metallic sheet 10 and the dielectric sheet 14 are juxtaposed in side by side relationship. Preferably, the dielectric sheet is of a thickness much smaller than a wavelength of the radio frequency (microwave) waves to be transmitted through the radome.

The slots 14 are rectangular in shape, say 1.5 centimeter long by 0.5 centimeter wide for radio frequency waves of the order of 8.2 GHz. Opposite edges along the narrow sides of the rectangular are beveled from the 1.5 centimeter dimension which is measured on the inner surface (interior of the radome), outwardly a distance of approximately 0.3 inch. It has been found that the radio frequency waves of lower frequency, say from 7 GHz to 8.2 GHz, penetrate into and through the beveled edges for greater thicknesses than the higher frequency waves, thus the slots are larger for the longer wavelengths and the transmittance bandwidth of the radome is wider than for slots without the beveled edges. It may be desirable to bevel the longer (1.5 centimeter) edges of the rectangular slots in order to increase the transmittance of the radome, particularly for larger scan angles. Thus the radome would then be more transmissive for more incidence angles of radiation, such angles being measured with respect to the axis of the radome.

FIGS. 2 through 6 illustrate tapered metallic windows which are fabricated in different ways. In each case the thickness will vary from a few ten thousandths to a few thousandths of an inch. Materials of the metallic sheet in which the windows are fabricated may be copper, aluminum or stainless steel. Steel is preferred where extremely thin edges are desired.

In FIG. 2 a metal sheet 16 is backed by a sheet 18 of dielectric material, such as fiberglass cloth or ceramic material, the ceramic silicon dioxide which is sold under the trade name "Pryroceran" by the Corning Glass Company, of Corning, N.Y., is suitable. The slot 20 has beveled edges 22 which are formed by machining. It will be appreciated, of course, that the slot can be an aperture of any suitable geometric shape, for example, rectangular, oblong or circular and beveled on one or more, or all, sides.

In FIG. 3, the metallic sheet 24 is backed by a thin layer of ceramic material 26. The beveled edges 28 are provided by applying metallic paint, such as a paint made by an emulsion of metal particles in an epoxy resin. The paint may be applied with a brush so as to form the linearly tapered sides 28 of the slot.

FIGS. 4 and 5 illustrate a slot 30 in a metallic sheet 32 which is backed by a sheet 34 of dielectric material. The beveled edges 36 of the slot 30 is produced by photo chemical etching through several exposures and etchings. The material of the sheet 32 may be copper, having a thickness of 0.007 centimeters. The six steps along the tapered edges 36 may be of the following thicknesses: step 38, 0.0022 cm; step 40, 0.0030 cm; step 42, 0.0038 cm; step 44, 0.0046 cm; step 46, 0.0054 cm; and step 48, 0.0062 cm. The area of each of the steps, 38 to 48, is the same. The central opening, 50, may be 1.5 cm long by 0.5 cm wide.

FIG. 6 illustrates a slot 52 in a stainless steel sheet 54. The profile of the beveled edges 56 of the slot, which extends through the thickness of the sheet, illustrated as being one thousandth of an inch, has a curved section 58, a section 60 of constant thickness, and a linearly tapered section 62 which extends to the opening 64 in the sheet 54. The curved section 58 is of a thickness approximately 0.005 inch or one-half of the thickness of the sheet 54. This 0.005 thickness extends for approximately one tenth of an inch. Then the linearly tapered section 62 has a length of approximately two-tenths of an inch. The overall length of the taper being approximately three-tenths of an inch. The profile as illustrated in FIG. 6 is especially suitable for stainless steel sheets which provide a broadbanded operation at microwave frequencies of the order of 8 GHz.

From the foregoing description it will be apparent that there has been provided improved apparatus for transmitting radio frequency waves through the use of slotted metallic windows. Such windows may find application in radomes, slotted antennas and other microwave apparatus. The variations and modifications in the herein described system will become apparent to those skilled in the art. Accordingly, the foregoing description should be taken as illustrative and not in any limiting sense.

What is claimed is:

1. An apparatus for transmitting radio frequency waves through a metallic member, a window through

said member having a beveled edge which tapers at least to a thickness approaching the skin depth for the highest frequency of said waves.

2. The invention as set forth in claim 1 wherein said member is a metallic sheet having a continuous, solid sheet of dielectric material in side by side relationship therewith.

3. The invention as set forth in claim 1 wherein said member is a sheet, and said window is a rectangular opening in said sheet, opposite edges of said rectangular opening are beveled to diverge in opposite directions whereby said window is narrower on one surface of said sheet than on the opposite surface thereof.

4. The invention as set forth in claim 3 wherein said beveled edges extend to lines at the intersection of said beveled edges and the inner side of said sheet.

5. The invention as set forth in claim 3 wherein said beveled edges each have a plurality of steps, the steps at the narrowest dimension of said window having said thickness approaching said skin depth for said highest frequency of said waves.

6. The invention as set forth in claim 3 wherein said beveled edges each have a profile including a curved section extending from the thickest portion of said edge a distance approximately one-half the thickness of said sheet, followed by a section of constant thickness which is followed by a linear reduction in thickness to a point at the apex of said edge.

7. The invention as set forth in claim 3 wherein said beveled edges each are provided by a separate section of low-conductivity metallic material.

8. A radome which comprises a sheet of metallic material, a plurality of windows which extend through said sheet, each window being formed by a slot having a beveled edge the bevel of which extends between the opposite surfaces of said sheet.

9. The invention as set forth in claim 8 wherein said slots are beveled on at least two opposite edges.

10. The invention as set forth in claim 9 wherein said edges are beveled inwardly toward each other in a direction away from the outer surface of said radome.

11. The invention as set forth in claim 8 including a continuous sheet of dielectric material in juxtaposition with the surface of said metallic sheet which faces the interior of said radome.

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