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Pierrot

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[54] **MULTIFREQUENCY OPERATING RADOME**

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[52] **U.S. Cl.** **343/872,** 343/909

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

[58] **Field of Search** .... 343/705, 708, 872, 909, 343/911 R

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[57] **ABSTRACT**

A radome designed to transmit two electro-magnetic waves of different frequencies. The dielectric wall has a thickness such that it is transparent vis-a-vis the first wave of frequency F_1.

A network of continuous wires integral with the wall renders the latter transparent vis-a-vis the second wave of frequency F_2 lower than F_1.

Discontinuous metal elements integral likewise with the wall are arranged in accordance with a second network in order to eliminate the grating lobes due to the presence of the network of continuous wires.

12 Claims, 6 Drawing Figures

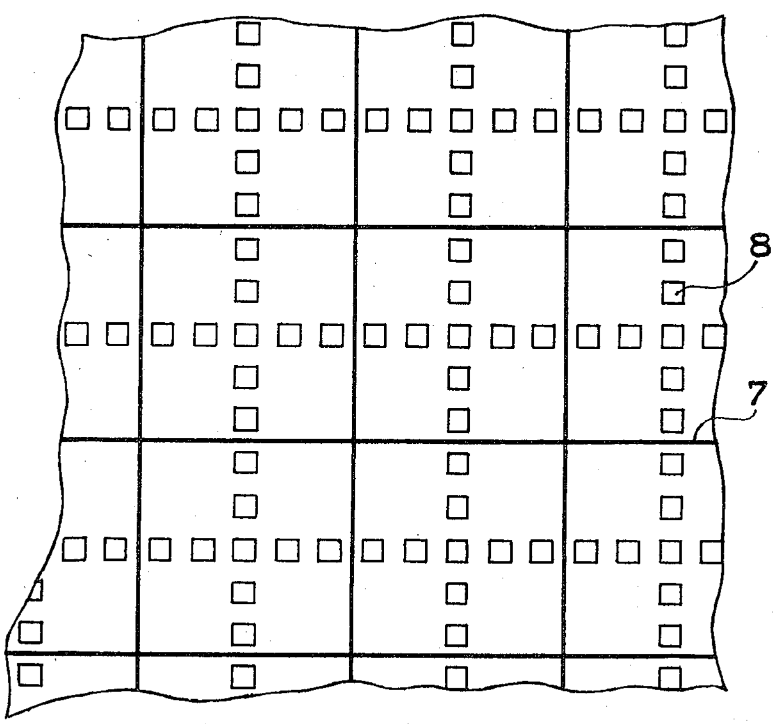


FIG. 1

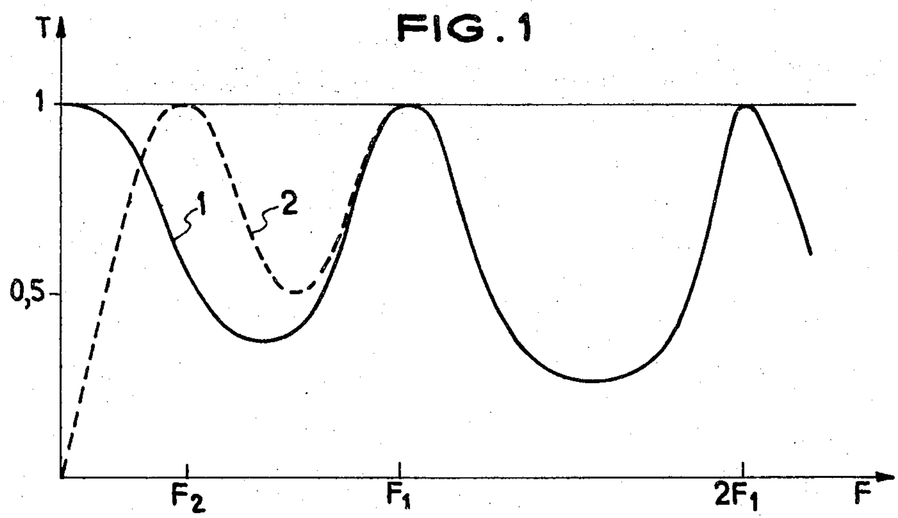


FIG. 2

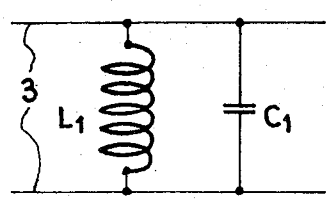


FIG. 3

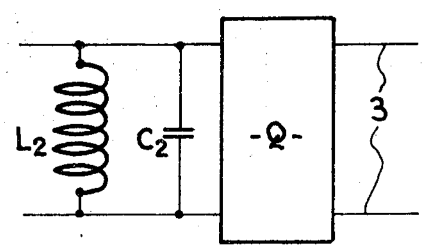


FIG. 4

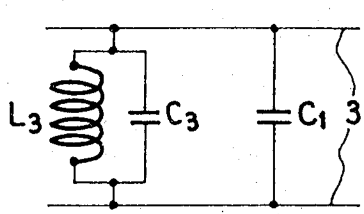


FIG. 5

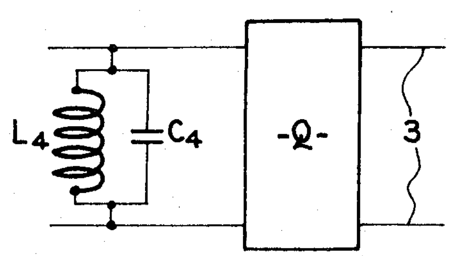
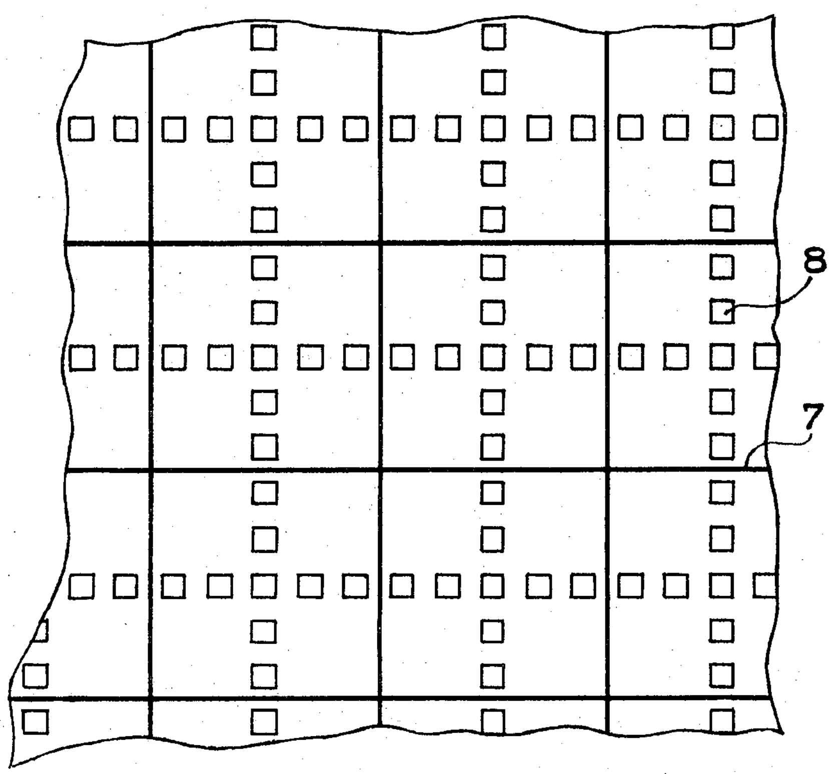


Fig. 6



MULTIFREQUENCY OPERATING RADOME

This invention relates to radomes used to protect radio equipment in supersonic aircraft.

The only location available in aircraft of this kind, for the housing of the equipment in a radome, is the nose, which due to the aerodynamic and mechanical stresses imposed upon it, has a conical or ogival form. These stresses also make it necessary to utilise a monolithic or homogeneous dielectric wall as for example a fibreglass weave impregnated with resin, or an epoxy glass. The electrical characteristics of the wall are determined by the wave passing through it. The wall, in all cases, has a minimum thickness corresponding to half a wavelength in the dielectric.

The utilisation on board such aircraft, of several electromagnetic systems operating at widely different frequencies, is generally out of the question. The electrical characteristics of the wall being matched to a first wave, are generally not so in respect of another since, the coefficient of reflection of the wall relative to such other wave, is then too high. For a second wave of frequency lower for example than that of the first, the dielectric wall thus appears as either too thin in relation to the half wavelength or too thick to be considered as a negligible skin.

DESCRIPTION OF THE PRIOR ART

It is known, in this context, to incorporate into the dielectric wall networks of wires which are inductive when the polarisation is parallel to them. The overall assembly then behaves as a band-pass filter whose elements are designed so that they present either a very wide pass-band or responses at two different frequencies.

These networks of conductor wires in effect constitute a kind of grid through which the electromagnetic waves have to pass. Each free space between the conductors constitutes a radiating aperture. Phase distribution in the radiating apertures is not uniform since the radome is not flat and the result is accordingly a distortion in the radiation patterns of the antennas located inside the radome. This distortion is translated by the appearance of secondary lobes or grating lobes.

The object of the present invention, is precisely that of providing a radome which does not produce such distortion.

SUMMARY OF THE INVENTION

In accordance with the invention, the radome comprises a monolithic dielectric wall whose thickness is such that it is transparent for at least a first wave of frequency F1, a first network of continuous wires integral with the wall, designed in such a fashion that it acts in concert with said wall as an assembly resonating at a second frequency F2 lower than the frequency F1, and an assembly of discontinuous metal elements, likewise integral with the wall and distributed in accordance with the lines of a second network interleaved with said first network.

The invention and its application will be better understood from a reading of the following description and by reference to the figures in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a graph showing the transmission factor as a function of frequency, for a wall with or without metal elements;

FIGS. 2 and 3 illustrate equivalent impedance networks for a radome comprising a network of continuous wires, at two frequencies F1 and F2 respectively;

FIGS. 4 and 5 represent the equivalent impedance networks of a radome comprising networks of continuous wires and discontinuous elements, for two respective frequencies F2 and F1;

FIG. 6 illustrates metal networks printed on a dielectric substrate.

FIG. 1 illustrates a graph showing the value of the transmission factor T of the wall of a radome as a function of the frequency F of a wave passing through it, and also for a given wall thickness, a given dielectric constant and a given angle of incidence.

The graph 1 illustrates the case of a radome which does not incorporate any metal elements. At the low frequencies, the thickness appears small compared with the wavelength, and the radome behaves as a very thin skin whose attenuative effect is negligible. The transmission factor is then equal to 1. As the frequency rises, the thickness becomes progressively greater in relation to the wavelength and the transmission factor reduces. However, the factor returns to a value close to 1 whenever the thickness of the dielectric is equal to a multiple of the half wavelength in the dielectric, that is to say to a given thickness *e*, at the frequencies F1, 2F1, 3F1.. where F1 is the frequency at which the wavelength in the dielectric is equal to twice the thickness *e* of the wall. It should be pointed out, too, that the pass-band at the frequencies 2F1, 3F1, . . . , becomes progressively narrower.

The graph 2 illustrates the case of a radome comprising at least one network of wires. For frequencies other than those which are multiples of F1, the dielectric wall constitutes a capacitive or inductive barrier. Each wire network, integral with the wall, acts as barriers, of inductive or capacitive kind. The combination of the wall and the wire networks, constitutes therefore an assembly which resonates at a selected frequency F2 at which frequency, furthermore, the transmission factor of the wall becomes close to unity. The radome is thus transparent to at least two waves, of frequencies F1 and F2. By contrast, it becomes opaque to low frequencies, the metal barriers constituting a Faraday cage. At higher frequencies, the two graphs 1 and 2 merge together.

FIG. 2 illustrates an equivalent impedance network corresponding to the frequency F2, for a radome equipped with a network of continuous wires. The dielectric wall and the wires are equivalent from the radio point of view, respectively to a capacitance C1 and and inductance L1 in parallel with a transmission line 3 loaded at one end by the electromagnetic device operating at frequency F2, and at the other end by the space outside the radome. By satisfying the condition $L1C1\omega 2^2$ at the frequency $F2 = \omega 2/2\pi$, and neglecting ohmic losses, the overcall impedance placed in parallel with the transmission line 3, is rendered infinite and the wave transmitted is unaffected. The transmission factor, in reality, is practically equal to 1, the wall matching condition being achieved at the frequency F2.

In order to effect simple resolution of the delicate problem of the orientation of the wires in relation to the polarisation, the inductive element is constituted by two networks of wires at right-angles to one another, this rendering it isotropic and making it possible to install it in the radome without any problem associated with orientation of the wires.

FIG. 3 illustrates the equivalent of the same radome, at the frequency F1. The value of the inductance L2 placed in parallel by the metal network, is much higher than it is at the frequency F2. Its effect is small and can be compensated by a slight increase in the thickness of the dielectric wall whose equivalent impedance is then that of a small capacitance C2 shunted across the input terminals of the four-terminal device Q representing the wall which is matched at frequency F1 only. By satisfying the condition $L2C2\omega 1^2 = 1$ at the frequency $F1 = \omega 1/2\pi$, the wall matching condition is achieved.

DESCRIPTION OF THE PREFERED EMBODIMENTS

Instead of simply utilising a network of continuous wires, the radome in accordance with the invention comprises a network of continuous wires and a network of discontinuous metal elements (networks 7 and 8 shown in FIG. 6). This variant embodiment has the advantage over the network of continuous wires, that it does not introduce any secondary lobes or so-called grating lobes, at the frequency F1, into the radiation pattern of the antenna protected by the radome.

The discontinuous metal elements can take various forms. They are arranged in lines to produce a network of parallel lines or rather two mutually perpendicular networks like the network or networks of continuous wires. The aligned sets of discontinuous elements are interposed between the continuous wires. The pitch of the network of the discontinuous elements can be the same as that of the continuous wires (FIG. 6) or may be larger or smaller, depending upon the desired effect. The metal elements are constituted either by segments of wire, or by segments of metal tape of given width and thickness. In the case shown in FIG. 6, the network 8 is constituted by metal squares whose sides have a length of around $\lambda/8$ for the highest frequency, the pitch of the network being equal to $\lambda/2$. In this case, the radome comprises continuous wires and rows of discontinuous elements, in alternation.

FIG. 4 illustrates the equivalent impedance network of the network and wall assembly, at the frequency F2. The networks are equivalent to an inductance L3 and a capacitance C3 in parallel with a capacitance C1 representing the wall. The matching conditons $L3(C1 + C3)\omega 2^2 = 1$ is achieved with an inductance L3 smaller than the inductance L1 in the case of a network of continuous wires only. The inductance L3 is made smaller by reducing the pitch interval of the network of wires. It is possible in this fashion to reduce the pitch sufficiently to prevent the development of grating lobes at the frequency F1.

FIG. 5 illustrates the equivalent impedance networks the frequency F1. The network is again equivalent to an inductance L4 of high value and to a capacitance C4 of low value, shunted across the terminals of the matched fourterminal device Q representing the wall. By satisfying the condition $L4C4\omega 1^2 = 1$, the assembly is transmission matched.

The utilisation of discontinuous metal elements, introduces a capacitive impedance at the wall. One advantage of the invention resides in the fact that the dielectric wall can be transmission matched, even in the case where the wall appears as an inductive barrier at the frequency F2. It is then necessary for the network of discontinuous elements to be capable of presenting an adequate capacitive impedance.

The design of a radome in accordance with the invention can be effected in various ways. The networks of continuous and discontinuous metal elements are first of all etched, printed, stuck or deposited by vaporisation, on a dielectric substrate (for example a substrate of polyethyleneterephthalate) which will subsequently form an integral part of the wall of the radome.

The wall itself is made of ceramic or of some refractory material or again of resin-impregnated fibreglass.

In the case of fibreglass, the radome is manufactured by arranging on a mould a tissue of fibreglass which is stiched and then impregnated with resin. Another method consists in weaving or winding the glass fibres directly on to the mould, this avoiding the need for stiching. Generally, several layers of impregnated tissue or weave are required in order to achieve the desired thickness.

The introduction of the metallised substrate is effected prior to or during the building of the wall. The substrate is then placed on the mould before the winding on or before the introduction of the glass tissue or weave. It can then be arranged between two layers of said tissue.

Another method consists in producing a metallised substrate which simply carries the networks of discontinuous metal elements. Independently the network of continuous wires is incorporated in the radome wall during the building up of same. Then the metallised substrate and the radome are joined. In the case of a radome which already contains a network of continuous wires, a substrate metallised with a network of discontinuous elements and produced in the same mould as that used for the radome, is stuck to the interior of the latter.

In all the cases, the introduction of the substrate can be effected after the building of the wall. The metallised substrate is stuck to the interior of the radome. Its assembly is a relatively simple matter if the ogival shape is not too different from that of a cone, and this is generally the case.

What is claimed is:

1. A multifrequency operating radome comprising:
   a monolithic dielectric wall for transmitting a first wave of a first frequency and its harmonics;
   a first network of continuous wires, said network being integral with said wall, for constituting with said wall an assembly tuned for a second wave to a second frequency lower than the first frequency, said network being the origin of grating lobes at the first frequency, and,
   a second network of discontinuous metal elements, said second network being likewise integral with said wall, for compensating for said grating lobes; and
   wherein the network of continuous wires and the network of discontinuous elements are printed on a dielectric substrate, said substrate subsequently being stuck to the internal face of the dielectric wall.

2. A radome as claimed in claim 1, wherein each of the discontinuous metal elements is constituted by a

segment of wire of short length, compared with the shortest operating wavelength.

3. A radome as claimed in claim 1, wherein the network of discontinuous elements and the network of continuous wires have the same pitch.

4. A multifrequency operating radome comprising:

a monolithic dielectric wall for transmitting a first wave of a first frequency and its harmonics;

a first network of continuous wires, said network being integral with said wall, for constituting with said wall an assembly tuned for a second wave to a second frequency lower than the first frequency, said network being the origin of grating lobes at the first frequency, and,

a second network of discontinuous metal elements, said second network being likewise integral with said wall, for compensating for said grating lobes; and

wherein the network of continuous wires and the network of discontinuous elements, are printed on a dielectric substrate, said substrate subsequently being incorporated into the thickness of the dielectric wall.

5. A multifrequency operating radome comprising:

a monolithic dielectric wall for transmitting a first wave of a first frequency and its harmonics;

a first network of continuous wires, said network being integral with said wall, for constituting with said wall an assembly tuned for a second wave to a second frequency lower than the first frequency, said network being the origin of grating lobes at the first frequency, and,

a second network of discontinuous metal elements, said second network being likewise integral with said wall, for compensating for said grating lobes; and

wherein said dielectric wall comprises at least one tissue of glass fibres, the network of continuous wires being incorporated into the tissue during the weaving stage, and the network of discontinuous metal elements being printed on a dielectric substrate which is subsequently stuck to the internal face of the dielectric wall.

6. A multifrequency operating radome comprising:

a monolithic dielectric wall for transmitting a first wave of a first frequency and its harmonics;

a first network of continuous wires, said network being integral with said wall, for constituting with said wall an assembly tuned for a second wave to a second frequency lower than the first frequency, said network being the origin of grating lobes at the first frequency, and,

a second network of discontinuous metal elements, said second network being likewise integral with said wall, for compensating for said grating lobes; and

wherein said dielectric wall comprises at least one tissue of glass fibres, the network of continuous wires being incorporated into the tissue during the weaving of the same, and the network of discontinuous metal elements being printed on a dielectric substrate which is subsequently incorporated into the thickness of the dielectric wall.

7. A radome as claimed in claim 4, wherein each of the discontinuous metal elements is constituted by a segment of wire of short length, compared with the shortest operating wavelength.

8. A radome as claimed in claim 4, wherein the network of discontinuous elements and the network of continuous wires have the same pitch.

9. A radome as claimed in claim 5, wherein each of the discontinuous metal elements is constituted by a segment of wire of short length, compared with the shortest operating wavelength.

10. A radome as claimed in claim 5, wherein the network of discontinuous elements and the network of continuous wires have the same pitch.

11. A radome as claimed in claim 6, wherein each of the discontinuous metal elements is constituted by a segment of wire of short length, compared with the shortest operating wavelength.

12. A radome as claimed in claim 6, wherein the network of discontinuous elements and the network of continuous wires have the same pitch.

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