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Characteristics of Vivaldi antenna located on a cylindrical surface

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Abstract. The paper analyzes the directional properties of antipodal of Vivaldi antenna, located on the faces of the wedge, coupled with the two cylinders at the top and bottom. Two antenna patterns are considered. The first pattern has one antenna, located symmetrically on the edge of each face of the wedge, the second pattern has two of them. The comparative analysis of these antennas is done. The influence of the angle at the apex of the wedge and its size on the parameters of antennas is studied. The frequency and directional characteristics of antennas depending on their structural dimensions and their location are examined.

1. Introduction

«Vivaldi» antennas, including the ones in the composition of the active video pulse scanning antenna arrays (AR), are most widely used in a variety of ultra-wideband radio systems, communications, radar, and navigation. The development of possible options of constructing emitters of ultra short electromagnetic field pulses with one dimensional or two-dimensional scanning and given polarization characteristics is an urgent task [1-4].

In some cases, the antennas must be able to emit the shortest possible pulses. Such antennas include the lamellar structure in the form Vivaldi emitter with a power unit in the form of two cylinders spaced by a certain distance from each other, passing from one side into two metal emitter plates with the gap extending further [5]. The coaxial cable is connected to the area of the gap on the diametrically opposite side of the plates. The antipodal Vivaldi antenna has the same properties [6].
The purpose of this work is to study models of antipodal Vivaldi emitters, located on a cylindrical surface formed by the wedge conjugated with the cylinders at the top and bottom.

2. Statement of the problem

Antipodal Vivaldi antennas, made on a high-frequency dielectric with double-sided metallization, are located on a cylindrical surface formed by cylinder-wedge-cylinder conjugation (figure 1). This design can be used as a model of an aircraft wing or its part. Two variants of the antennas are considered. Two single antennas are located on the faces of the wedge symmetrically relatively to the *yz* plane (figure 1a) – antenna A_1. The planar Vivaldi antenna (figure 2) is orthogonal to the metal screen size 20mm*48mm - antenna A_2.
The wedge is made of a perfectly conducting material with through-cuts for antennas. Thus, the space inside the structure under the material from which the antennas are made (at the interval *L* (figure 1,b)) is filled with the vacuum.

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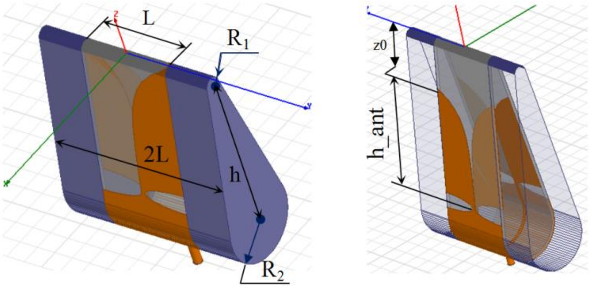


$a) z0 = 0$ b) $z0 \neq 0$

Figure 1. Vivaldi antennas A_1 on a cylindrical surface

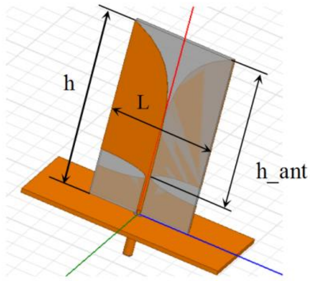


Figure 2. Vivaldi antennas A_2

It is necessary to study the directional properties of these antennas A_1 and A_2 depending on the geometry: length of the wedges' edges, cylinder radii, length h and width *L*.

3. Analysis of radiation characteristics of antenna

Numerical studies of antennas were carried out in HFSS software package [7]. Antenna designs were optimized for minimum VSWR and the maximum gain in the broadest possible operating frequency band. All antennas discussed below are made on a substrate Rogers RO4003(tm) with double-sided metallization 0.07 mm thick. The thickness of the substrate is 1mm. The width of the wedge in all antenna designs was taken twice as much as the width of the antennas, that is equal to 2L. For comparison, the planar Vivaldi antenna A_2 (figure 2) is made on the same substrate, and it is located perpendicularly to the metallic screen with dimensions 20mm*48mm. The dimensions of antenna A_2 are: width L, height from the main axis of the resonator h_ant, altitude to the screen h.

Let us study the influence of the surface's shape on the antenna's A_1 parameters with dimensions: L_1=24mm, h_ant=35mm, h=40mm from cylinders radii R_1 and R_2. The design parameter z0 (figure 1,b), determining the distance from the antenna aperture A_1 to plane z=0, is chosen equal to zero.
Figure 3 shows the dependence of VSWR from frequency for $R_1 = R_2 = 2$mm (curve ——), 4mm (curve – – –), 6mm (curve - - - -) and 8mm (curve ....). VSWR of A_1 is also shown here (curve — . . .).

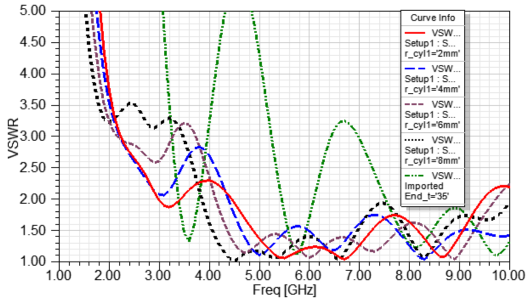


Figure 3. Dependence of VSWR on frequency of antenna A_1

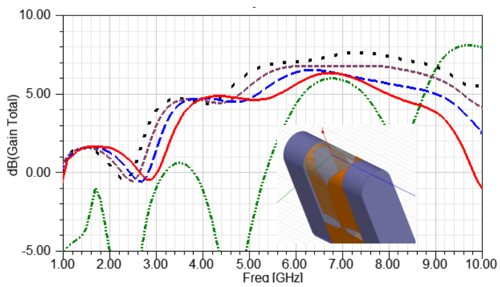
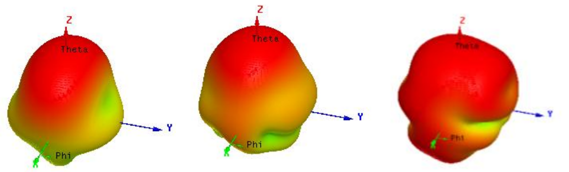


Figure 4. The dependence of the gain of antenna A_1 on frequency

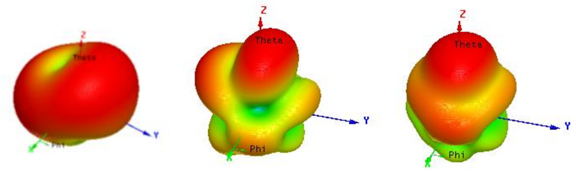
Figure 4 shows the dependence of the gain of antenna A_1.

Type of antenna structure for $R_1 = R_2 = 8$mm is shown in the inset of figure 4. i.e. with increase of R_1 antenna design increasingly shields the aperture, which negatively affects the parameters of antenna (increases VSWR, decreases gain).
As it is seen from the analysis of figures the antenna with $R_1 = R_2 = 4$mm (see curves – – –) has the best parameters, in terms of the minimum VSWR in the broadest possible bandwidth and maximum gain.



3.5GHz 7GHz 10GHz

Figure 5. 3D radiation pattern of antenna A_1



3.5GHz 7GHz 10GHz

Figure 6. 3D radiation pattern of antenna A_2

Figures 5 and 6 show 3D nonnormalized radiation patterns of antennas A_1 (figure 5) (with $R_1 = R_2 =$ 4mm) and A_2 (figure 6) on frequencies 3.5 GHz, 7 GHz and 10 GHz.

As can be seen, antenna A_1 in all considered parameters surpasses planar version of the same antenna (A_2).

Figures 7, 8 show the results of the analysis of influence of the radius $R_1 = 5$mm (curve ——), 10mm (curve – – –), 15mm (curve - - - -) and 20mm (curve ....), for R_2=2mm (diverging upward faces of the wedge (like that of a horn, see in the inset of figure 7)) on directional properties of A_1 antenna. Thus, to avoid obscuring the aperture, the distance z0 is chosen equal to radius R_1.

Figure 7 shows dependence of VSWR on frequency. As it is seen, the change in surface shape, in comparing with the previous case (figure 3), did not increase antenna's frequency band.

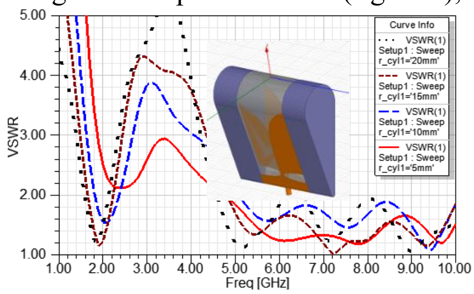


Figure 7. Dependence of VSWR on frequency of A_1 antenna for various $R_1 = 5mm; 10mm; 15mm$ and $20mm$

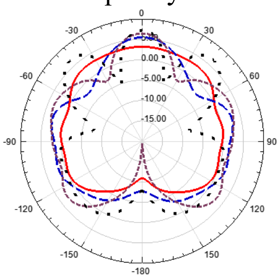


Figure 8. Radiation pattern of the antenna A_1 on frequency 10GHz for different R: $R_1 = 5mm; 10mm; 15mm$ and $20mm$

Moreover, the divergence of the wedge's edges (inset in figure 7 shows that the antenna design with the parameters $R_1 = 10$mm; R_2=2mm) leads to deterioration of antenna matching at frequencies 2.5GHz - 4.5GHz (VSWR increases with the increase of R_1).

Figure 8 shows the radiation pattern of antenna on H-vector plane at frequency of 10GHz for $R_1 =$ 5mm (curve ——), 10мм (curve – – –), 15мм (curve - - - -) and 20мм (curve ....) and for R_2=2mm.

Figures show that increase of radius R_1 does not lead to a simple narrowing of radiation pattern, as it is in a conventional horn antenna. In this case, the divergence of the wedge's edges at a distance greater than the wavelength λ (for $R_1 = 20$mm the distance between the apertures of Vivaldi antenna 40mm, $= 30$mm) leads to the appearance of diffraction lobes.

The calculations showed that the expansion of wedge's edges upward (like a horn) leads to a slight increase of gain.

Figures 9-12 show characteristics of antenna A_1 depending on value of radius $R_2 = 5$mm (curve——), 10mm (curve – – –), 15mm (curve - - - -) and 20мм (curve ....) for $R_1 = 2$mm (converging upward face of the wedge). The design of antenna with parameters $R_1 = 2$mm; R_2=10mm is shown on the inset of figure 9.

As it is seen (figures 9-11), if VSWR of this model of A_1 is not worse than VSWR of the previous one (figure 7), then efficiency and gain are slightly lower at almost all frequencies (gain on 1-2dB).

Figure 12 shows non-normalized radiation pattern of the antenna in the plane of **H-**vector at frequency of 10GHz for $R_2 = 5$mm (curve——), 10mm (curve – – –), 15mm (curve - - - -) and 20mm (curve ....), R_1=2mm.

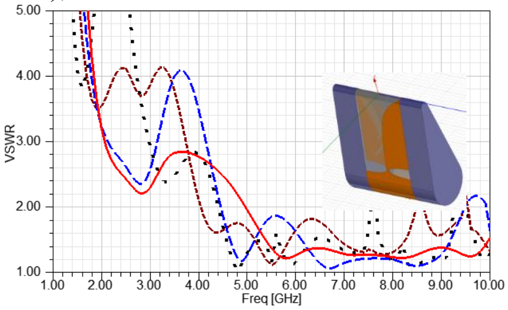


Figure 9. Dependence of VSWR on frequency of A_1 antenna for various $R_1 = 5mm; 10mm; 15mm$ and $20mm$

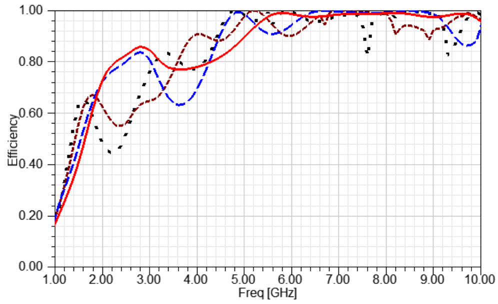


Figure 10. The dependence of the efficiency of the antenna A_1 on frequency for different $R_1 = 5mm; 10mm; 15mm$ and $20mm$

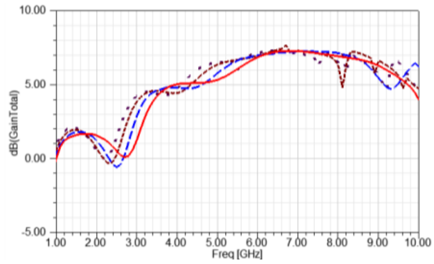


Figure 11. The dependence of the gain of antenna A_1 on frequency

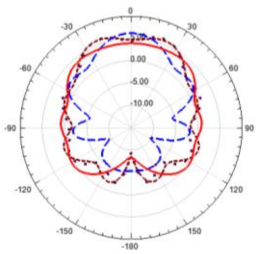


Figure 12. Radiation pattern of A_1 antenna at 10GHz

Therefore, the directional properties of the latter structure of the antenna (see inset on figure 9) are more preferable to previous, especially in wideband scanning antenna arrays.

Conclusion

The studies have shown that, changing the number of antennas and the size of the structure surface where the antennas are placed, it is possible to achieve an optimal balance between VSWR and the gain in a wide range of frequencies. Such antennas can be used as the flush-mounted ones on many types of objects with the components of constructive elements in the form of the wedge-cylinder conjunction.

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