Effect of the Different End Shapes on the Gain Flatness of the Antipodal Vivaldi Antenna

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Abstract

In this study, effects of the different end shapes on the gain flatness of an Antipodal Vivaldi Antenna (APVA) operating over 3.1-10.6 GHz are investigated. The antenna having an ending with parallel wires is proposed for gain flatness in this study. Numerical studies are performed for four different APVAs having endings in different shapes of elliptical, circular and partially square forms and parallel wires. The best gain flatness is obtained for the antenna having the ending of the parallel wires.

1. Introduction

Bandwidth of 3.1-10.6 GHz was allocated for commercial UWB applications by Federal Communications Commission (FCC) in 2002. From this date, we see that studies including the antenna, filter, frequency selective surface (FSS), radar cross section reduction for communication and radar systems which operate within this frequency band have shown up rapidly in literature.

UWB antennas are foremost elements among the elements in these systems. Planar geometry, wide operating bandwidth, directive radiation pattern and high gain capability as well as small group delay and gain flatness are desired properties for UWB applications [1]-[2]. Vivaldi antennas are a prominent candidate for UWB applications. There are different versions of the Vivaldi Antenna [3]-[13]. Antipodal Vivaldi Antenna is one these versions with simple feeding mechanism [7], [13].

In this study we focused on investigating the effect of the end shape of the antipodal Vivaldi antenna (APVA) on the gain flatness. There different antenna having end shapes in elliptical (APVA-I), circular (APVA-II) and partially rectangular (APVA-III) forms are compared to our proposed antenna having an ending with parallel wires (APVA-IV). We will show that the proposed APVA-IV provides more antenna gain flatness compared to the other antennas.

2. Design

A basic APVA is composed of two metallic arms as shown in Fig. 1. One of the arms is printed on the front side of a low-loss dielectric substrate. The other arm having a small ground is printed on the back side of the substrate. Outermost parts of the arms are defined by outer, inner and end curves. Equations of the inner and outer curves are in the Gaussian form as follows:

$$a(z) = \begin{cases} 19.6 \exp(-4\pi \left(\frac{z}{117}\right)^2 & -80 \le z \le -2 \\ (inner\ curve) & \\ 48 \exp(-4\pi \left(\frac{z}{162}\right)^2 & -80 \le z \le -28.5 \\ (outer\ curve) & \end{cases} \quad (1)$$

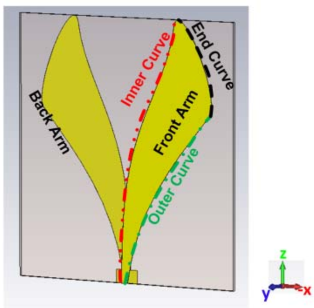

Fig. 1. Perspective view of the basic antipodal Vivaldi antenna

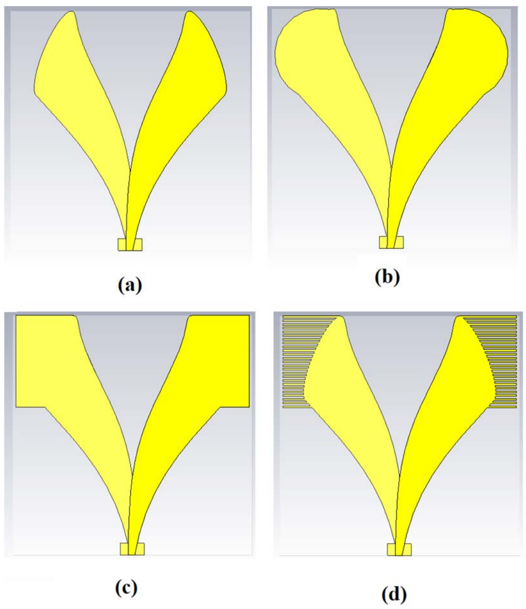

Fig. 2. Antennas with different end shaping: (a) APVA-I, (b) APVA-II, (c) APVA-III, (d) APVA-IV.

All antennas are designed using Arlon DiClad 880 square-shaped substrate of parameters side lengths L_s=80 mm, permittivity ε_r = 3, thickness d = 0.762 mm and loss tangent tanδ = 0.009. Metal inclusions are made of copper with conductivity σ= 5.8×10^7 S/m and thickness t = 0.035 mm.

During the numerical trials four APVAs are designed as presented in Fig. 2. For these trials, while the other design parameters are kept constant, the shape of the end curve is only changed. For the first and second cases, the APVA-I and APVA-II have an end shape in the elliptical and circular forms as seen in Fig. 2 (a) and Fig. 2 (b), respectively. For the third case, the end curve of the antenna (called APVA-III) is turned into a shape partially wrapped around a rectangle as in Fig. 2 (c). As for the final case, the additional part which is added to the end of the APVA-I to form APVA-III is turned into the parallel wires. Design parameters of these ending parallel wires are width w = 0.65 mm, gap distance g = 0.65 mm.

Designed antennas are simulated by using the time domain solver of the commercial electromagnetic simulator CST Microwave Studio.

3. Numerical Results

Firstly, return loss, |S$_{11}$|, values of the antennas are given in Fig. 3 in dB. |S$_{11}$| curves show that all the antennas are matched to the 50 Ω source.

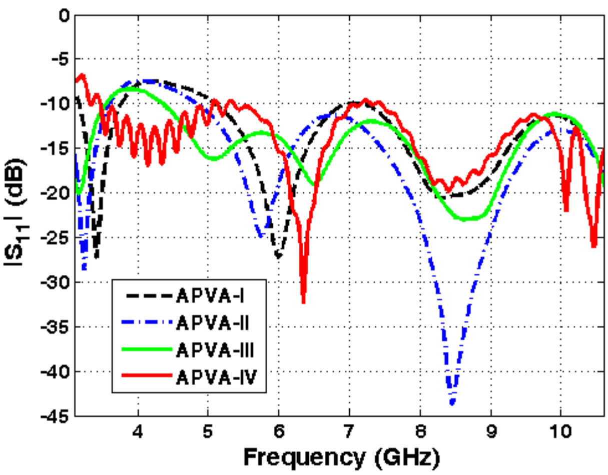

Fig. 3. |S$_{11}$| values of the designed antennas

Secondly, gain values of the antennas along the end-fire direction (i.e. along the z axis) over 3.1–10.6 GHz are presented in Fig. 4 in dB. The minimum and maximum gain values of the APVA-I are 2.41 dB and 11.23 dB, respectively. For APVA-II, the gain values are between 4.14 dB and 10.64 dB. As for the APVA-III the minimum and maximum gain values are 4.57 dB and 9.92 dB, respectively. For the final antenna, the APVA-IV, the highest and lowest values of the gain graph are 7.35 dB and 10.02 dB, respectively. The maximum gain deviation is 8.82 dB, 6.5 dB, 5.35 dB and 2.67 dB for APVA-I, APVA-II, APVA-III and APVA-IV, respectively. In summary, the best gain deviation is equal to 2.67 dB which is obtained for the proposed APVA-IV as seen in the Fig.4.

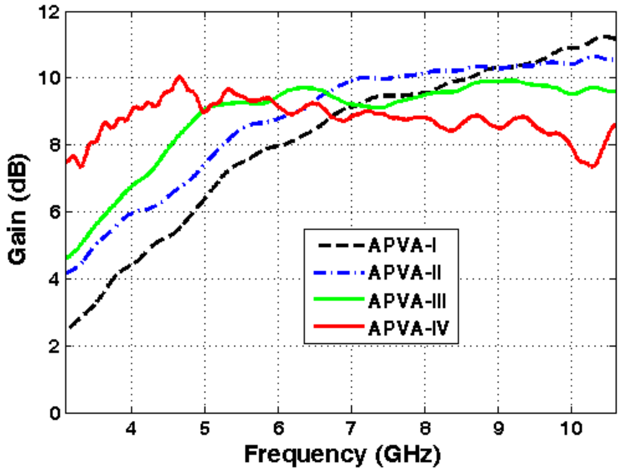

Fig. 4. Gain values of the designed antennas in dB.

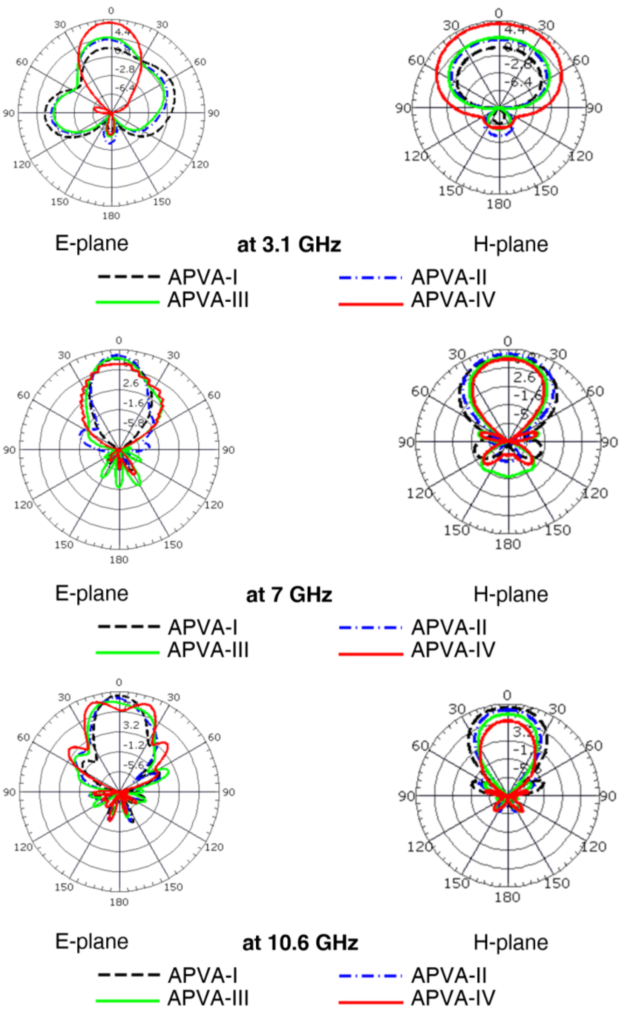

Fig. 5. Co-pol components of the gain patterns (dB) of the antennas.

Co-pol and cross-pol components of the gain patterns (dB) of the antennas are shown in Fig. 5 and Fig. 6, respectively. All the antennas have main beam directions along the end fire directions as in Fig. 5. Higher Cross-pol levels are observed in the H plane (i.e. yz plane) patterns of all the antennas compared to their E (i.e. xz plane) plane patterns.

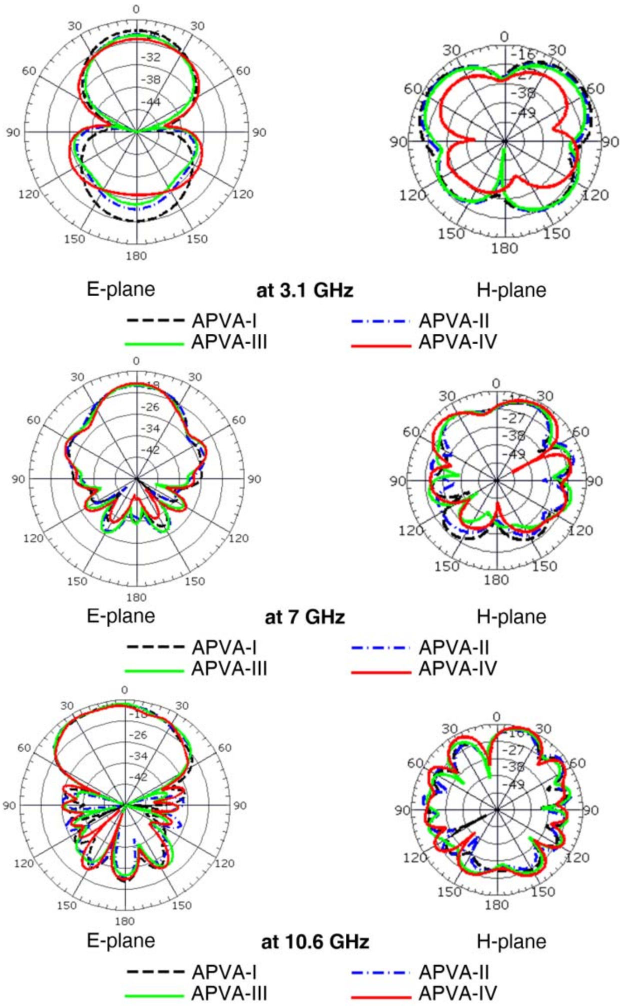

Fig. 6. Cross-pol components of the gain patterns (dB) of the antennas.

6. Conclusions

In this study we proposed a modified antipodal Vivaldi antenna having an ending with parallel wires to enhance the gain flatness of the antipodal Vivaldi antennas. Antenna gain characteristics of the different three antennas having end shapes in elliptical, circular and partially rectangular forms are compared to the proposed antenna. Numerical studies showed that the proposed APVA-IV provides more antenna gain flatness compared to the other antennas.

7. Acknowledgement

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8. References

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