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V-SHAPED MONOPOLE ANTENNA FOR BROADBAND APPLICATIONS

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Abstract—In this paper, design and analysis of a novel broadband V-shaped monopole antenna is presented. The proposed antenna has a simple configuration to fabricate with low cost. The antenna is composed of two elliptical conducting plates connected to the two edges of a small horizontal rectangular plate and placed over a small circular ground plane. The designed antenna has a very wide bandwidth range of 3–18 GHz, low cross polarization, relatively high gain and good far-field radiation characteristics in the entire operating bandwidth. To obtain the broad bandwidth, the antenna dimensions have been optimized. A comprehensive parametric study has been carried out to understand the effects of various parameters and to optimize the performance of the final design. The designed antenna is simulated with software packages CST microwave studio and Ansoft' HFSS in the operating frequency range. Simulation results for VSWR and far-field radiation patterns of the antenna over the frequency band 3–18 GHz are presented and discussed.

1. INTRODUCTION

Broadband monopole antennas have found extensive applications in many wireless communication systems such as airborne and ground-based communication systems. The numerous applications are made possible due to the particular characteristics of these antennas such as broadband frequency range, good radiation properties, low cost, light weight, simple structure and ease of fabrication [1–3].

In recent years, many researches have taken place on UWB and broadband monopole antennas and its applications. A microstrip square-ring slot antenna (MSRSA) for UWB applications was reported in [4]. By splitting the square-ring slot antenna (SRSA) and optimization of the feeding network, the required impedance bandwidth was achieved over the UWB frequency range, 3.1 to 10.6 GHz. In [5], a compact printed circuit board monopole antenna over 2.6–14.3 GHz was presented and its performance through a large amount of simulations and measurement was reported. Several monopole configurations, such as circular, square, elliptical and triangle-shaped, have been proposed for UWB applications [6–12]. Planar UWB monopoles have been realized by using either a microstrip-line [13] or CPW feeds [14, 15]. In [16] a novel butterfly-shaped monopole antenna over 2.6–9.6 GHz has been presented along with simulation and measurement results. In that paper, elliptical wings were chosen and they were kept vertical to the ground plane. The highest gain over the entire frequency was around 6 dB.

The conventional broadband antennas have relatively complex feeding network and non fixed phase center, as a result, serious distortion will occur when transmitting and receiving wideband signals [17–19]. These drawbacks limit practical applications of these broadband antennas.

In this paper a novel V-shaped monopole antenna, including a $50\,\Omega$ coaxial feed input is presented. The designed antenna is composed of two elliptical conducting plates, which are connected to the two edges of a horizontal rectangular plate and placed over a small circular ground plane. The proposed antenna has a relatively small size and is broadband, 3 to 18 GHz, which also covers the UWB (3.1–10.6 GHz) applications [20]. Compared to the butterfly-shaped monopole antenna in [16], the proposed V-shaped monopole antenna has a much higher bandwidth, higher gain and lower cross polarization. A comprehensive parametric study has been carried out to understand the effects of various parameters and to optimize the performance of the final design. By optimization process, an optimum operating bandwidth, good radiation patterns and low cross polarization over the whole band is achieved. The proposed V-shaped monopole antenna is simulated with commercially available packages such as Ansoft HFSS which is based on finite element method and CST microwave studio which is based on the finite integral technique. Simulation results of VSWR and far-field radiation patterns of the designed antenna over the frequency band are presented.

2. ANTENNA CONFIGURATION

Figure 1 shows the configuration of the proposed monopole broadband antenna. As shown in this figure the proposed antenna is composed of two conducting plates, which are connected to the two edges of

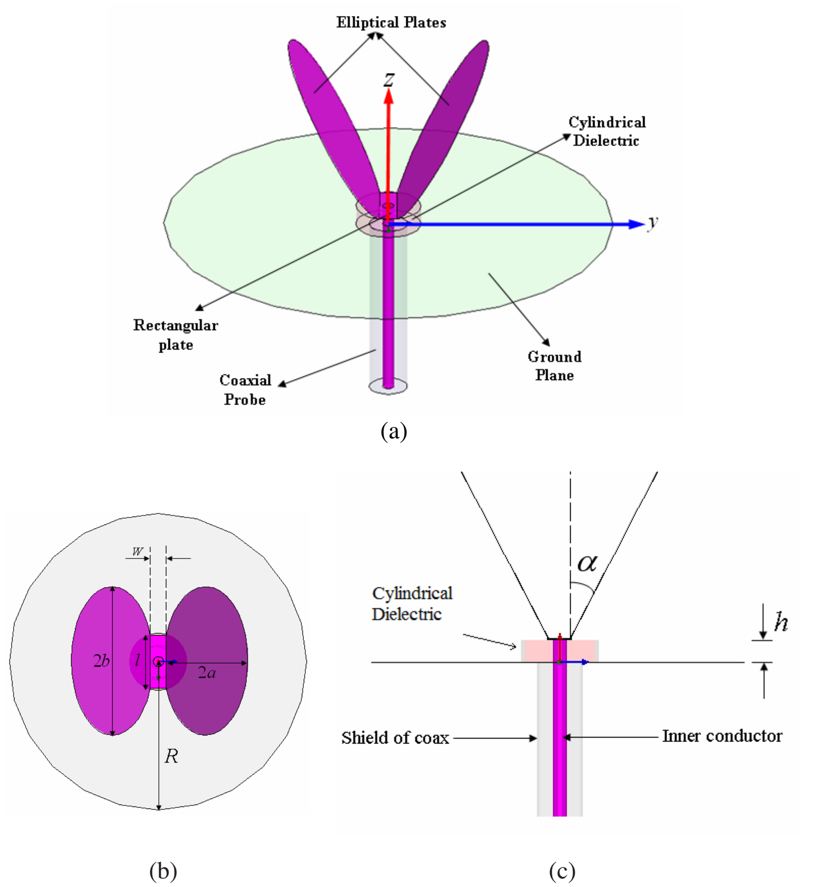

Figure 1. (a) Configuration of the proposed antenna (b) top view, (c) side view.

a small horizontal rectangular plate and placed over a small circular ground plane. In general, the two conducting plates can be elliptical, circular, square, or other shapes. These two plates can be placed vertical, parallel or at an angle to the ground. The angle between the two plates and the z-axis is adjustable for good impedance matching and desired radiation patterns. Here, the proposed monopole antenna employs elliptical conducting plates and the angle between the two plates and the z-axis is set at 45 degree. This combination can be shown to provide the broadest impedance bandwidth along with good radiation characteristics. Through extensive simulation via HFSS and optimization the following dimensions are obtained and used in the proposed antenna: $2a = 19.5\,\mathrm{mm}$, $2b = 31.4\,\mathrm{mm}$, $l = 7.1\,\mathrm{mm}$, $W = 2\,\mathrm{mm}$, $R = 46\,\mathrm{mm}$ and $\alpha = 45°$.

In order to achieve a wide impedance bandwidth a cylindrical dielectric ($\varepsilon_r = 2.2$) between the rectangular conducting plates and the ground plane is used, Figure 1. Cylindrical dielectric affects the high frequency performance of the proposed antenna most effectively but the low frequency performance of the antenna is approximately independent of it. The height and radius of the cylindrical dielectric are $h = 2.3\,\mathrm{mm}$ and $r = 2.6\,\mathrm{mm}$, respectively. The antenna is fed at its small rectangular plate by a $50\,\Omega$ coaxial probe. As shown in Figure 1, the shield of the coaxial probe is connected to the ground plane and its inner conductor is connected to the rectangular conducting plate by passing it through a tunnel in the cylindrical dielectric.

3. RESULTS OF SIMULATION

In this section simulation results of the V-shaped monopole broadband antenna are presented. To emphasis on the accuracy of the simulated results, two commercially available software packages, the HFSS and CST have been used. Both show a very close results confirming that the simulated results are obtained with reasonable accuracy.

The simulated return loss of the designed antenna is presented in Figure 2. It can be seen that the proposed antenna has a very wide bandwidth ranging from 3 to 18 GHz for $S_{11} < -10\,\mathrm{dB}$ that is suitable

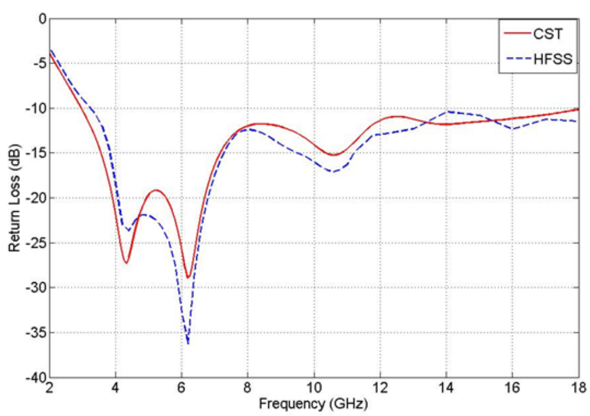

Figure 2. Simulated return loss of the proposed antenna. $2a = 19.5\,\mathrm{mm}$, $2b = 31.4\,\mathrm{mm}$, $l = 7.1\,\mathrm{mm}$, $W = 2\,\mathrm{mm}$, $R = 46\,\mathrm{mm}$, $h = 2.3\,\mathrm{mm}$, $r = 2.6\,\mathrm{mm}$ and $\alpha = 45°$.

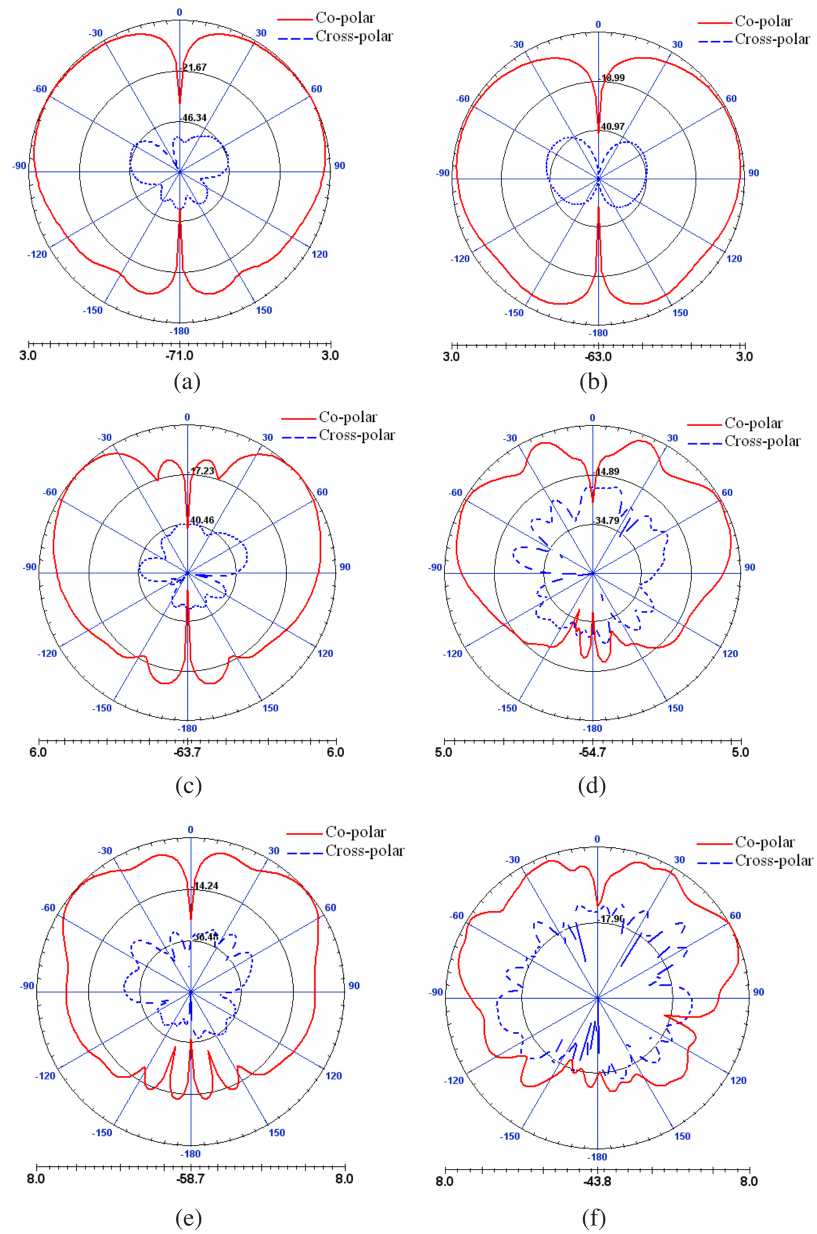

Figure 3. Simulated radiation patterns at: 3 GHz in (a) x-z plane, (b) y-z plane, 10 GHz in (c) x-z plane (d) y-z plane, 18 GHz in (e) x-z plane, (f) y-z plane. $2a = 19.5$ mm, $2b = 31.4$ mm, $l = 7.1$ mm, $W = 2$ mm, $R = 46$ mm, $h = 2.3$ mm, $r = 2.6$ mm and $\alpha = 45°$.

for broadband communication systems.

Figure 3 shows simulated co- and cross polar far-field radiation patterns for y-z and x-z plane at various frequencies 3, 10 and 18 GHz. From this figure it is seen that the designed antenna exhibits low cross polarization, low side lobe level, high gain, around 8 dB, and good far-field radiation characteristics over the entire operating bandwidth. Although V-shaped monopole broadband antenna provides wide operating bandwidth but generally its operating bandwidth is limited due to the degradation of the radiation patterns at the upper edge of the bandwidth.

The total gain of the proposed antenna versus frequency is shown in Figure 4. It can be seen that the gain of the antenna increases as frequency increases. Maximum value of gain occurs at the end of operating frequency band 18 GHz. To conclude, this antenna is capable of providing high gain and less distorted transmitted pulses for broadband wireless communication applications.

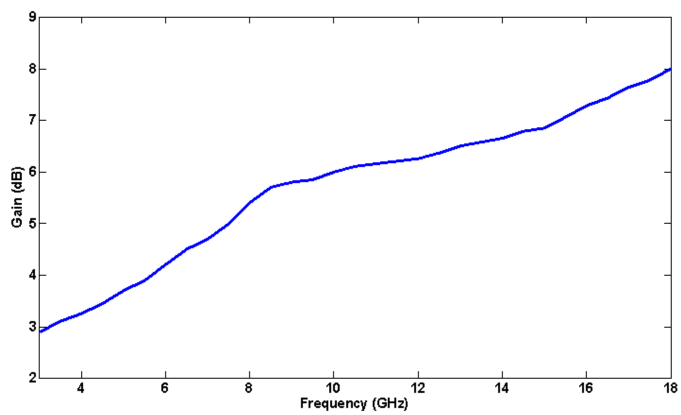

Figure 4. Gain versus frequency for the proposed antenna. $2a = 19.5\,\mathrm{mm}$, $2b = 31.4\,\mathrm{mm}$, $l = 7.1\,\mathrm{mm}$, $W = 2\,\mathrm{mm}$, $R = 46\,\mathrm{mm}$, $h = 2.3\,\mathrm{mm}$, $r = 2.6\,\mathrm{mm}$ and $\alpha = 45°$.

4. PARAMETRIC STUDIES AND DISCUSSION

It is found through the simulation that the operating bandwidth of the proposed monopole antenna is critically dependent on the angle between the conducting plate and the z-axis, α, and the radius of the ground plane R. These parameters are optimized for maximum bandwidth. More over the cylindrical dielectric extremely affects the

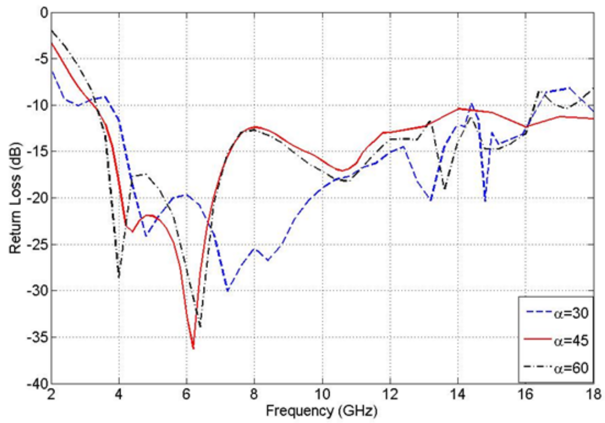

Figure 5. Simulated return loss of the antenna for various angles α. $2a = 19.5\,\text{mm}$, $2b = 31.4\,\text{mm}$, $l = 7.1\,\text{mm}$, $W = 2\,\text{mm}$, $R = 46\,\text{mm}$, $h = 2.3\,\text{mm}$ and $r = 2.6\,\text{mm}$.

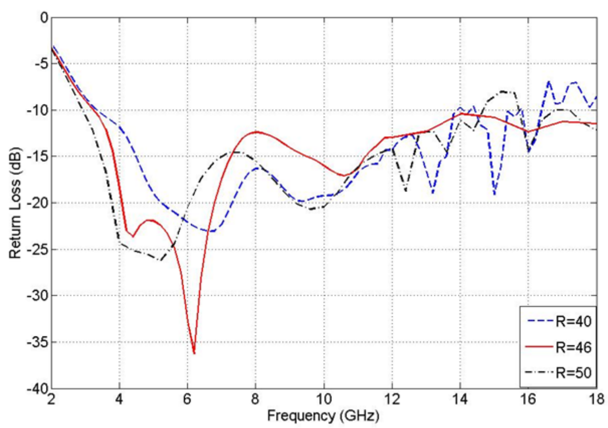

Figure 6. Simulated return loss of the antenna for various R. $2a = 19.5\,\text{mm}$, $2b = 31.4\,\text{mm}$, $l = 7.1\,\text{mm}$, $W = 2\,\text{mm}$, $h = 2.3\,\text{mm}$, $r = 2.6\,\text{mm}$ and $\alpha = 45°$.

high frequency performance of the proposed antenna. The effect of each parameter is investigated and results are provided here.

The angle α affects the performance of the proposed antenna most effectively. Figure 5 shows the simulated return loss curves for different angles between the conducting plate and the z-axis while the other parameters of the antenna are kept fixed. As shown in this figure the return loss deteriorates within the whole band as α changes. The best value for α in the designed antenna is 45 degree.

Figure 6 shows the simulated return loss of the proposed antenna for various radius of the ground plane, 40 mm, 46 mm and 50 mm. It can be seen that the frequency corresponding to the lower edge and the upper edge of the bandwidth are strongly dependent on the radius of the ground plane R. The optimum value of R is 46 mm.

The simulated return loss of the proposed antenna with and without the cylindrical dielectric are shown in Figure 7. As shown in this figure the dielectric can affect the high frequency performance but the low frequency performance of the proposed antenna is clearly independent of the dielectric.

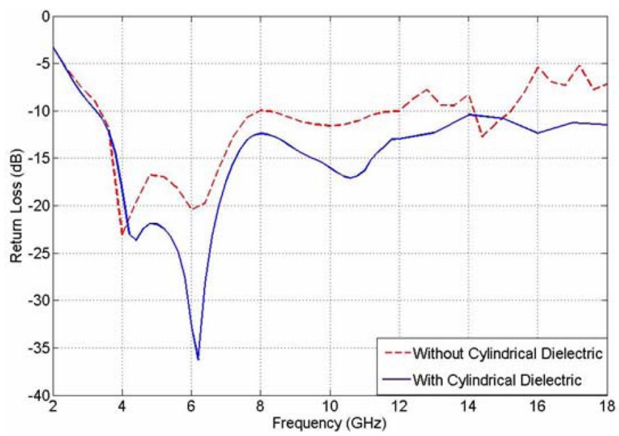

Figure 7. Simulated return loss of the proposed antenna with and without dielectric. $2a = 19.5$ mm, $2b = 31.4$ mm, $l = 7.1$ mm, $W = 2$ mm, $R = 46$ mm, $h = 2.3$ mm, $r = 2.6$ mm and $\alpha = 45°$.

5. CONCLUSION

This paper has presented a novel V-shaped monopole broadband antenna. The designed antenna has a very wide bandwidth ($S_{11} \leq -10$ dB) of 3–18 GHz. More over the antenna exhibits extremely low cross polarization, relatively high gain and good far-field radiation characteristics in the entire operating bandwidth. A comprehensive parametric study has been carried out to understand the effects of various parameters and to optimize the performance of the final design. Based on these characteristics, the proposed antenna can be useful for broadband communication applications.

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