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DESIGN OF PLANAR PLATE MONOPOLE ANTENNA WITH VERTICAL RECTANGULAR CROSS-SECTIONAL PLATES FOR ULTRA-WIDEBAND COMMUNICATIONS

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Abstract. *In this paper, a novel design for planar plate monopole antennas is proposed with applications to ultra-wide band (UWB) communications. To verify the proposed antenna design, simulations are performed by means of CST and HFSS software tools, showing that the impedance bandwidth is significantly increased by vertical cross-sections. By adding a series of parameters to the vertical cross-sections, the antenna efficiency is effectively enhanced by achieving a return loss of 10 dB over the bandwidth range between 3.1 GHz and 10.6 GHz. In addition, our experimental results demonstrate that the fabricated antenna has a return loss performance similar to that obtained by the simulation results.*

Key words: *Monopole antenna with vertical cross plates, planar monopole antenna, ultra-wideband (UWB).*

1. INTRODUCTION

During the recent years, broadband antennas covering a wide range of the frequency spectrum have found increasing applications. These antennas are particularly applied to high data rate wireless communications [1-4] with high quality of service requirements, such as multimedia transmission [5-7], real time navigation and tracking systems, photography and radars. The planar monopole antennas are well suited to broadband applications due to their wide impedance bandwidth, omnidirectional pattern with linear polarization, low cost and noncomplex shape. The rectangularity of such antennas is more appealing because of its simple structure and easier construction in contrast to the circular or elliptical antenna structure. There are several approaches for increasing the impedance bandwidth of

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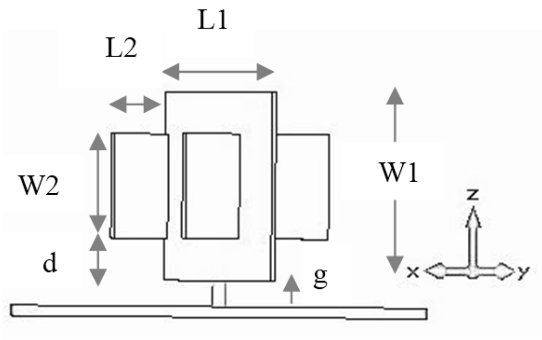
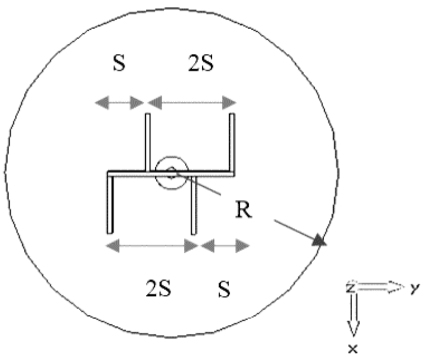
rectangular plate-shaped monopole antennas including beveling and shorting techniques [8-14]. In this work, a novel structure is proposed based on adding vertical cross-linked plates to a simple rectangular monopole antenna, which leads to a remarkable improvement in the impedance bandwidth. For different cross-sections, some new parameters such as length, width and height of the cross-sectional plate are considered to provide proper adaptation for the impedance bandwidth. All the parameters are optimized to maximize the attainable performance. Compared with a simple monopole antenna, the proposed antenna has smaller rectangular plates. This type of antennas exhibits wideband characteristics with a stable pattern over the entire operating bandwidth. A planar disc monopole antenna was developed and studied by Honda *et al.* in 1991 for the Japanese television band (90-770MHz) [6], where the antenna is mounted on a bounded circular ground plate. In this work, we use both CST and HFSS software tools to simulate the proposed antenna. The proposed antenna is suitable for indoor radar applications. The comparison between proposed structure and the rectangular monopole antenna, proposed structure provides higher impedance bandwidth but patterns of the rectangular plate monopole are more stable with frequency [8].



(a) Front view



(b) Top view

Fig. 1 A monopole antenna including vertical plates

2. Antenna Design

Fig. 1 illustrates the schematic of the proposed monopole antenna with cross-sectional vertical plates from the top and front views. The rectangular antenna (L1 × W1) with cross plates (L2 × W2) is placed on the top of the circular ground plane with the radius R and is fed by an SMA connector at a distance of g. In this figure, S is the gap between the cross-sections of the vertical plates. The central part of the bottom edge of the monopole antenna is connected to a pin, which is coming out of the ground plane through the hole. We consider this pin to facilitate connection with the feeding source. For the distance between the main monopole antenna and its side, the following formula is adopted in our design based on [8].

$$f_L(GHz) = \frac{61.9}{W1} \tag{1}$$

where *W1* and f_L are the side length in mm and the frequency corresponding to the lower edge of the bandwidth, respectively. In our work, the width of the monopole antenna is optimized in order to increase the impedance bandwidth. Then, the monopole antenna is augmented by mounting the proposed vertical cross-sectional plates on the substrate. These plates provide new degrees of freedom for a more flexible adjustment of the impedance bandwidth so as to achieve the optimum performance without any reduction in the target 10 dB return loss.

3. Simulation and Results

The return loss of the antenna is simulated by the CST software tool. To this end, the antenna is excited via the waveguide port. The thickness of the monopole plate antenna is 0.5 mm filled with bronze and a thin layer of tin. The main dimensions of the antenna are set to L1 = 15 mm, W1 = 18 mm and four vertical cross-sections are considered to increase the impedance bandwidth of the main antenna. The 50 mm radius circular-shaped ground plate is also fed into the antenna above an SMA connector. The pin is a wire with a diameter of 1.3 mm and a length of 2 mm. The gap between the antenna and the ground is considered to be 1.5 mm. This value is obtained through the analysis of the return loss by taking into account the effect of the dimensions of the rectangular plate monopole antenna and its distance from the ground plane on the impedance bandwidth.

Fig. 2 shows the return loss of a simple rectangular monopole antenna with different values for L1 and W1 and with a constant ground radius of 50 mm. It can be observed that the impedance bandwidth is bounded between 3.1 to 6.5 GHz. In the following, by fixing the main dimensions of the antenna at L1=15 mm and W1=18 mm, the design of the dimensions of the vertical cross-sectional rectangular plates is discussed using Fig. 3. As shown in Fig. 3 for different lengths and widths of the cross-vertical plates, the return loss is optimized to acquire the best impedance bandwidth. Likewise, as shown in Fig. 4, the antenna distance from the ground plane is optimized to minimize the return loss.

The effect of choosing different values for the ground radius on the return loss is investigated in Fig. 5. The results suggest that the optimum value aiming to achieve the wide bandwidth is around 50 mm. In this work, we choose the value of *d* to be equal to 5 mm, so that the vertical cross-sections are centered on the antenna width, see Fig. 1.

In Fig. 6, the current distribution is shown for both a simple monopole antenna and the one designed using the CST software tool. It can be seen that the current concentration for the simple monopole antenna is focused on the side near the edges of the antenna. Therefore, the use of the vertical cross-sectional plates to some extent offloads the current near the edges toward the vertical plates, thus increasing the impedance bandwidth. The maximum achievable gain over the considered frequency range is computed by using the HFSS software tool and the results are shown in Fig. 7. The simulated and measured radiation pattern for a monopole antenna with vertical rectangular plates are shown in Figs. 8 and 9. The omnidirectional pattern is shown in Fig. 8(c).

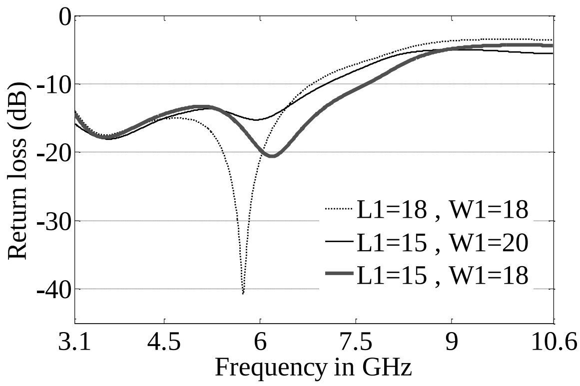


Fig. 2 Return loss of a simple monopole antenna with a length of L1 and different W2 width with a radius of 50 mm

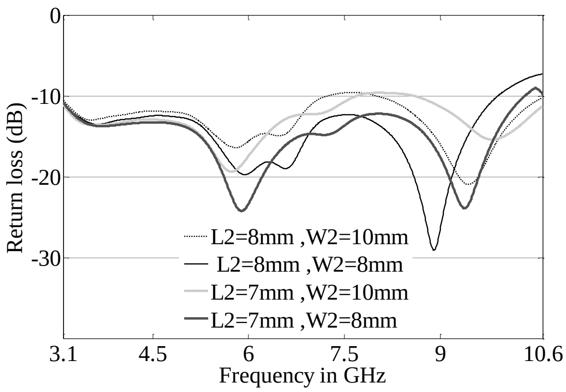


Fig. 3 Antenna return loss for different L2 and W2 with L1 = 15mm, W1 = 18mm, g = 1.5mm, S = 5mm, d = 5mm and R = 50mm

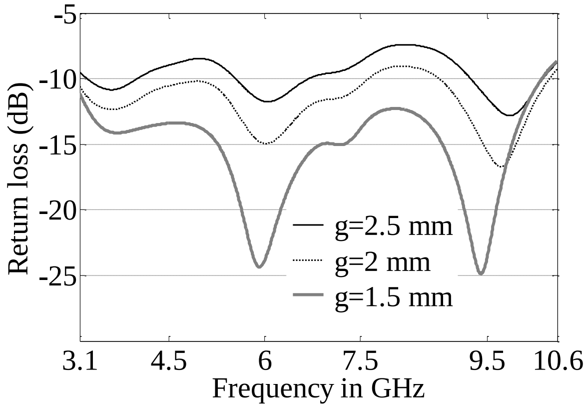


Fig. 4 Antenna return loss for different heights g with L1=15mm, W1 = 18mm, L2 = 7mm, W2 = 8mm, S = 5mm, d=5mm and R = 50mm.

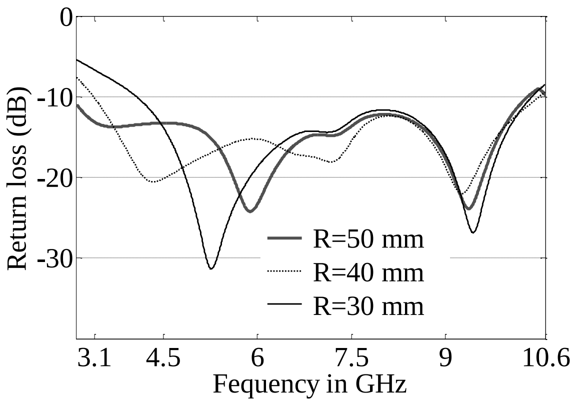


Fig. 5 Antenna return loss for different radius R of circular ground plane with L1 = 15mm, W1 = 18mm, L2 = 7mm, W2 = 8mm, S = 5mm, d = 5mm and g = 1.5mm

4. Experimental Results

Our antenna sample is implemented based on mentioned parameters in Fig. 6.

Monopole antenna with rectangular cross-section plates with L1 = 15mm, W1 = 18mm, L2 = 7mm, W2 = 8mm, S = 5mm, d = 5mm and R = 50mm

Simple monopole antenna with length L1 = 15mm and width W1 = 18mm with a radius of 50mm

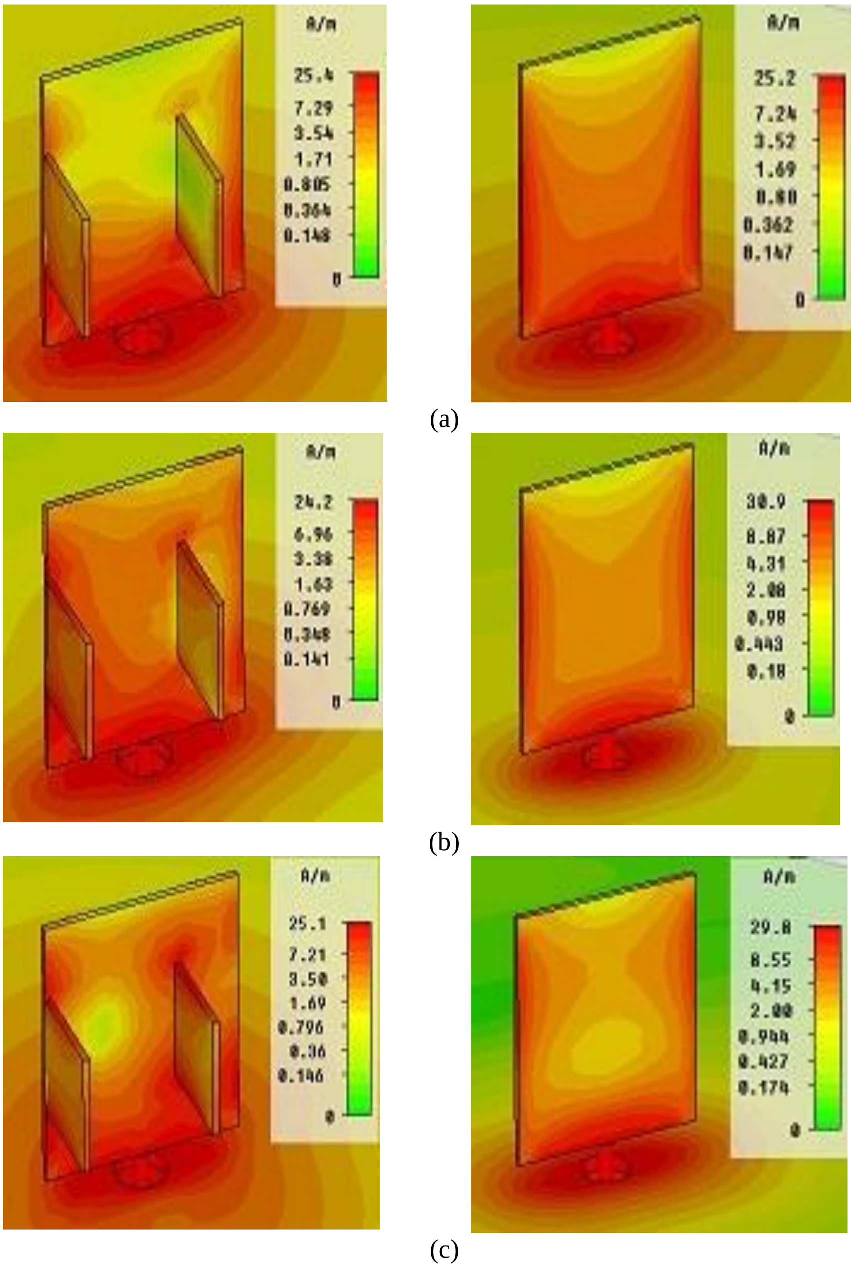


Fig. 6 Comparison of current distribution (*A*/*m*) for three frequencies. (a) 4 GHz, (b) 7 GHz, and (c) 9.5 GHz

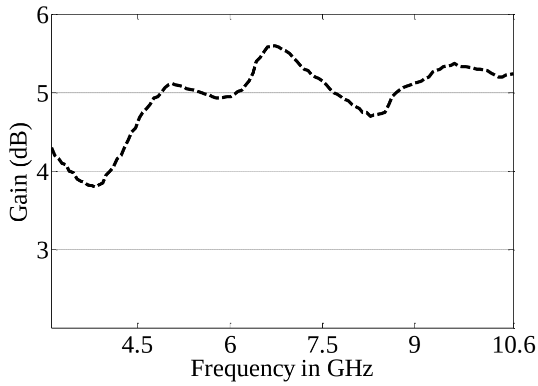


Fig. 7 The vertical cross-sections monopole antenna gain with L1 = 15mm, W1 = 18mm, L2=7mm, W2 = 8mm, S = 5mm, d = 5mm, g = 1. 5mm and R = 50mm

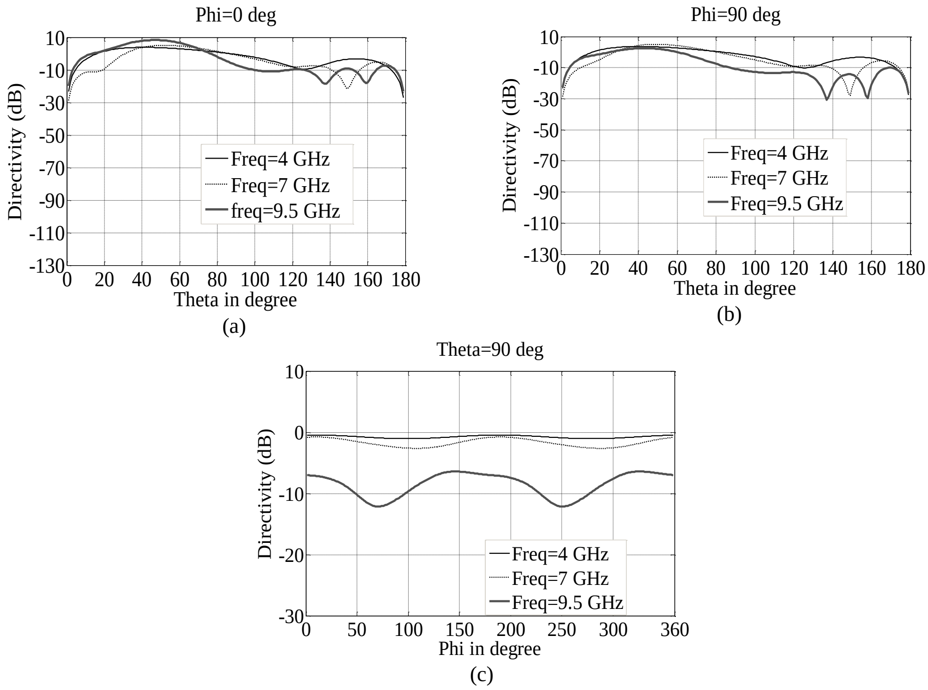
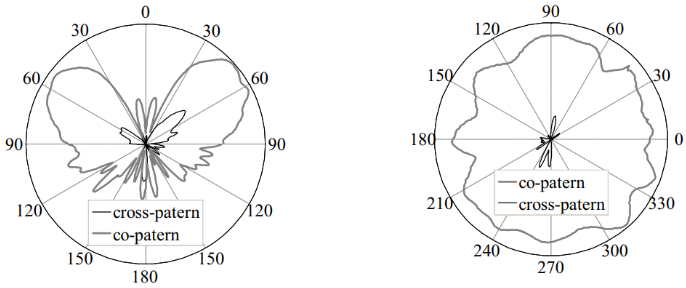


Fig. 8 Radiation Pattern of monopole antenna with vertical crossed plates for three different frequencies for three sections with L1=15mm, W1 = 18mm, L2 = 7mm, W2 = 8mm, S = 5mm, d=5mm, g = 1.5mm and R = 50mm. (a) Phi = 0 °, (b) Phi = 90 °, and (c) Theta = 90 °



(a) (b)

Fig. 9 Measurement of co and cross-radiation patterns of proposed structure at 4 GHz (a) E-plane (xz-plane) and (b) H-plane (xy-plane. L1=15mm, W1 = 18mm, L2 = 7mm, W2 = 8mm, S = 5mm, d=5mm, g = 1.5mm and R = 50mm.)

The prototype of the antenna fabricated in this work is shown in Fig. 10. It is controlled by the SMA connector on top of the ground. This monopole antenna is made of tin-plated bronze with a thickness of 0.5 mm. The length of the SMA pin connector is 2 mm and the ground plane thickness is 0.5mm.

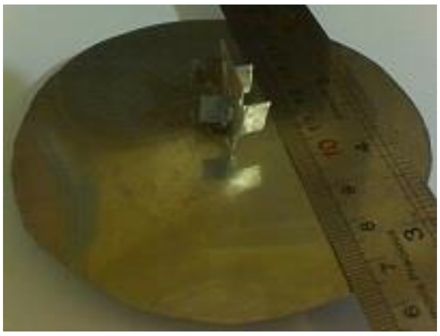


Fig. 10 The proposed antenna prototype

For comparison, the results of the return loss simulated by the CST software and those measured by the network analyzer are shown in Fig. 11. The discrepancy between the results are primarily because there is no loss in simulations, whereas in practice there are inevitable errors due to the non-ideal fabrication process and laboratory environment.

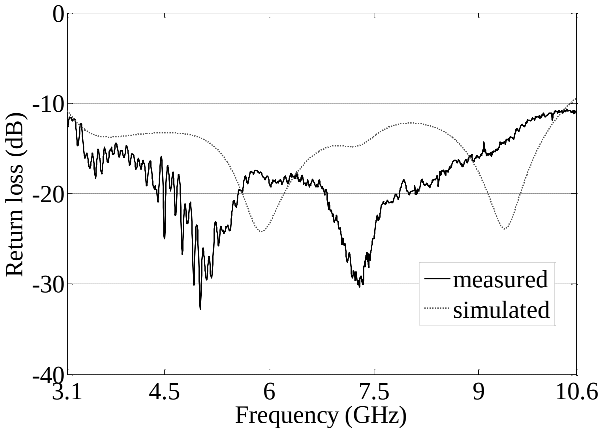


Fig. 11 Comparison between the measured and simulated results of return loss for proposed monopole antenna with vertical rectangular plates

5. Conclusion

In this paper, a novel method is presented based on designing vertical rectangular cross-sections for a monopole antenna. It is further shown in [2] that the new design structure reaches the same property while reducing 2 protruding plates. The results of the return loss performance show that by adding a series of parameters introduced by the rectangular vertical cross-sections, a return loss of 10 dB can be achieved over an ultra-wide bandwidth. The main outcome of this research constitutes substantial enhancement of the bandwidth for the input impedance of the monopole antenna.

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