Ultra-Wideband Differential Fed Antenna with Improved Radiation Pattern

Shukla Aditi and Medhane Dipak

Abstract The main objective of this work is to design compact size Ultra-wideband antenna with improved radiation pattern. In this project, the effect of change in antenna dimension has been studied also technique like Beveling, DGS, and Differential feed has been implemented and the radiation pattern is enhanced. The antenna has simulated and evaluated in Finite Element Method based ANSOFT-HFSS v11.0 simulation software using FR4_epoxy substrate with dielectric constant of 4.4, loss tangent of 0.02. The Proposed antenna shows return loss of S11 < −10 dB (3.1–10.6 GHz), 85–90 % radiation efficiency within operating frequency band and 10–15 dB cross polarization has been reduced. The differential feeding technique shows an improved radiation pattern.

Keywords Radiation pattern · Microstrip Antenna (MSA) · Ultra-wideband antenna · Defected Ground Structure (DGS)

1 Introduction

Ultra-wideband (UWB) systems due to their advantages like high data rate, wide bandwidth, and short-range characteristic are paid more attention since the Federal Commercial Commission (FCC) issued the frequency band 3.1–10.6 GHz for commercial UWB systems. A vital component of Ultra-wideband system, UWB antenna is required to have features such as compact, easy integration with the radio-frequency front end circuits, low-cost, stable radiation pattern, and constant gain in the required direction [1, 2].

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Various types of antenna such as the circular monopole antennas [3], rectangular aperture antenna [4], fractal bow tie antenna [5], open slot antenna [6], multimode slot line antenna [7, 8], and self-complementary antenna [9] has been introduced. But then, the radiation pattern of these antennas was not stable across the whole frequency band, especially above 9 GHz.

To reduce this problem and improve the radiation pattern of the UWB antenna several techniques have been proposed. In [10], the (EBG) mushroom-like electromagnetic band-gap structures are implemented for intensification of the gains of the antenna at high frequencies. To stabilize the radiation pattern across the whole operating frequency band in [11, 12] the strip-loaded wide slot antenna (SWSA) is used. However, though at the high frequency radiation pattern is improved to some extent, the cross polarization of the antennas is at a high level, thus the polarization purity still needs to be improved.

In order to reduce the cross polarization, which is caused by higher order mode, especially higher-odd-mode, can be suppressed when the antenna is symmetrically driven using differential feeding systems [13, 14]. Therefore, in this study, a compact differential-fed microstrip antenna is presented and analyzed for UWB applications. The proposed antenna exhibits S11 < 10 dB, stable omnidirectional radiation patterns in H-plane, with bidirectional radiation patterns in E-plane. By implementing differential feeding systems, the cross-polarization level is kept low across the whole operating frequencies, which results in high polarization purity of the antenna.

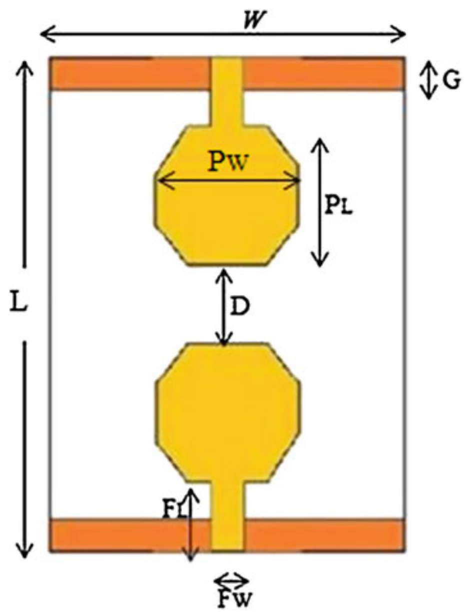

Fig. 1 Geometries of proposed antenna (L = 40 mm, W = 26 mm, G = 3.7 mm, Pw = 16 mm, PL = 12.25 mm, D = 5.75 mm, FL = 4.87 mm, FW = 2.55 mm)

2 Antenna Fabrication

The differential-fed antenna with compact size is designed. It has improved the radiation pattern with maintaining high polarization purity. Also, radiation efficiency has enhanced by the unique structure shown below.

Figure 1 shows the configuration of the proposed antenna. Here, an FR4_epoxy substrate is used, that has a thickness of 1.6 mm, relative dielectric constant of 4.4, and loss tangent of 0.02. The octagon patch along with the differential microstrip feeding lines is etched on the top of the substrate. The width of the microstrip feeding lines is chosen as 2.55 mm to achieve the characteristic impedance of 50 Ω. The partial ground plane is on the bottom side of the substrate. The proposed differential-fed antenna has a compact size of 26 mm × 40 mm.

3 Performance Improvement Stages

3.1 *Beveling Technique*

The rectangular monopole antenna (RMA) is chosen as a basic structure and it is optimized to the octagonal-patch-shaped antenna. Beveling the edges of rectangular radiator has been demonstrated and it is found that any reshaping of radiating area, strongly affects the current path. Here the angle of beveling is 45°.

The simulated results before and after beveling are depicted in Fig. 2. It shows that, before the beveling, the current flowing at the corner will cause the main beam tilting away and increase in cross polarization. Also, it affects return loss, depicted in Fig. 3.

With the decrease in return loss and VSWR, the bandwidth and directivity increases. The return loss has been reduced as depicted in Fig. 3 with octagon radiator. The E-plane shown in Fig. 4 is unidirectional and it has become more

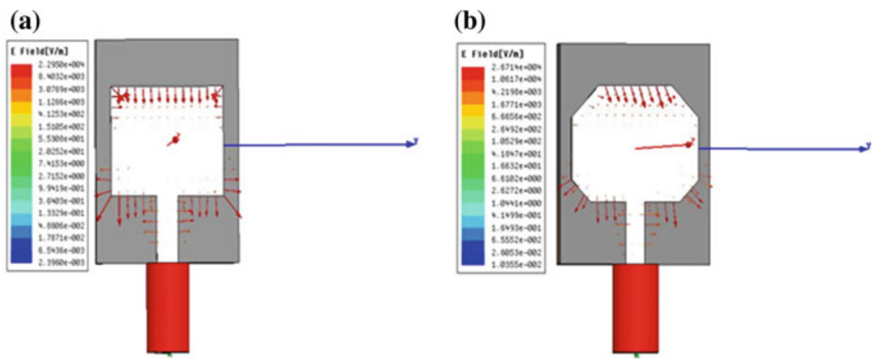

Fig. 2 Current distribution of **a** Rectangular MSA and **b** Octagonal MSA

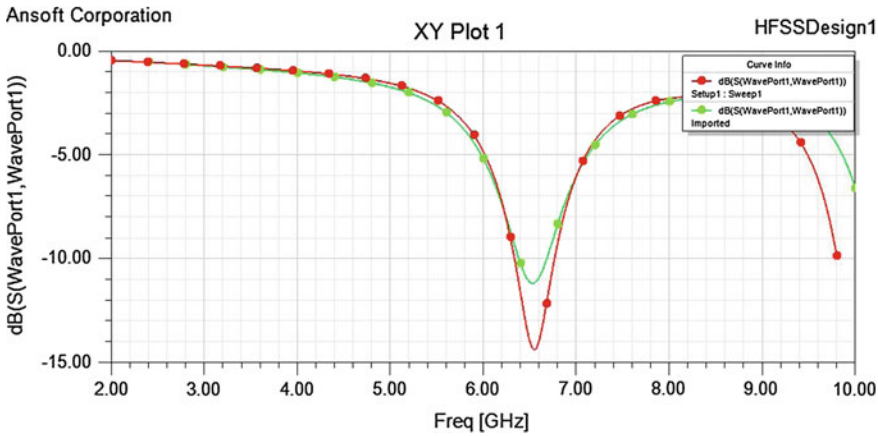

Fig. 3 Return loss verses Frequency curve: Rectangle patch (*green*), Octagon patch (*Red*)

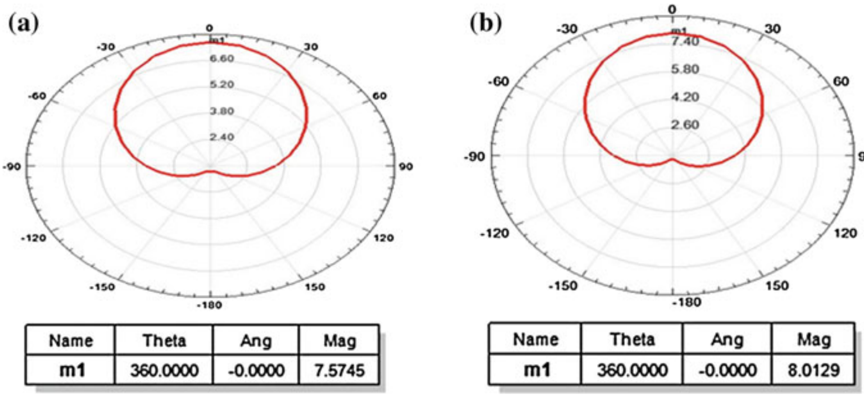

Fig. 4 Radiation pattern of **a** Rectangular MSA, **b** Octagon MSA

directive with octagon patch antenna. At frequency 6.5 GHz, magnitude of RMSA is 7.6 and magnitude of OMSA is 8.2. Figure 5 shows three-dimensional radiation patterns of rectangular microstrip as well as octagon microstrip antenna. Thus octagon patch radiator has improved the radiation efficiency.

3.2 Defected Ground Structure Technique

DGS technique is incorporated to improve the bandwidth of the octagon microstrip antenna. DGS can be integrated onto the ground plane of MSA without requiring any additional circuit for implementation. Introduction of DGS will etch the ground

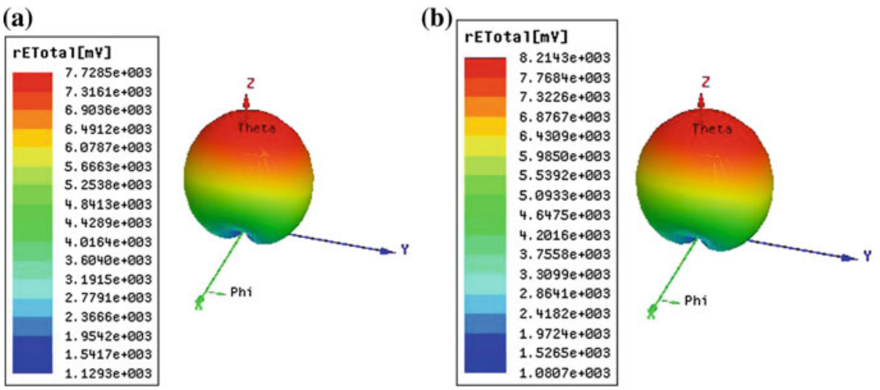

Fig. 5 Three-dimensional radiation pattern of **a** Rectangular MSA **b** Octagon MSA

plane and will thus disturb the shielded current distribution depending on shape and dimension of the defect. The excitation and electromagnetic propagation through the substrate layer can also be controlled by DGS.

DGS influences the radiation parameter. Figure 6a depicts the return loss versus frequency. The octagonal patch with rectangular DGS has the lowest return loss. By implementing DGS, the bandwidth has been greatly enhanced. However, bandwidth and directivity are inversely proportional to each other and hence with increase in bandwidth the directivity has decreased. Here we can observe this effect in Fig. 6b. Also, we have achieved the bidirectional radiation pattern, as the slot of rectangular shape is made in the ground plane, the E- and H-plane with cross polarization are shown in Fig. 7.

3.3 Differential Feed Technique

The bandwidth is improved with DGS technique, but the directivity has decreased as noted Sect. 3.1. And now to improve the directivity and polarization purity, differential-fed antenna is being introduced.

Differential-fed microstrip antenna is differentially excited by two probes to suppress the unwanted radiation, with the signals of the two probes being equal in magnitude but 180° out of phase. The differential feed antenna depicted in Fig. 1, has small size of $40 \times 26\ \text{mm}^2$.

Figure 8 illustrates the simulated result DFA, $|S_{11}| < -10$ dB (3.1–10.6 GHz). Isolation and Cross polarization radiation are the important electrical parameters. Antenna to antenna mutual coupling describes energy absorbed by one antenna receiver when another nearby antenna is operating. That is, mutual coupling is typically undesirable because energy that should be radiated away is absorbed by a

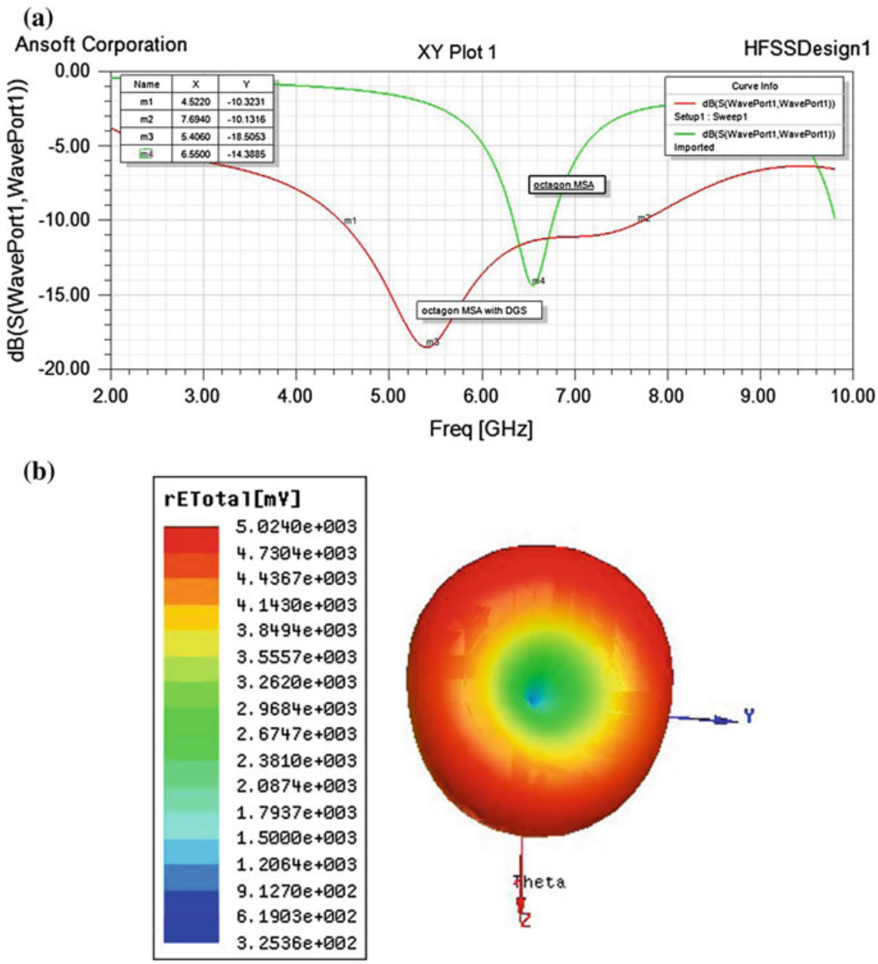

Fig. 6 **a** |S11| showing the effect of DGS, **b** Three-dimensional radiation pattern

nearby antenna; more than 85–90 % radiation efficiency is achieved within the operating frequency band with 9 DB gain.

In comparison to the radiation pattern in Fig. 7, the radiation pattern in Fig. 9 has 10–15 dB reduced cross-polarization level. Thus, using differential feed system, we have improved the radiation pattern of UWB antenna and made antenna suitable for various wireless applications.

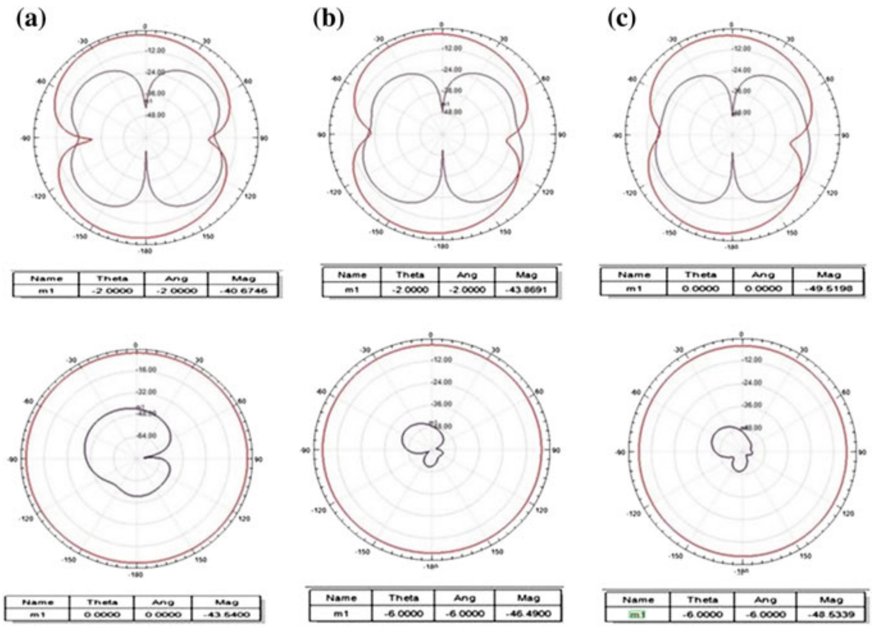

Fig. 7 Cross polarization of Octagon MSA with Rectangular DGS for E-plane and H-plane **a** at 5 MHz **b** at 6 MHz **c** at 7 MHz

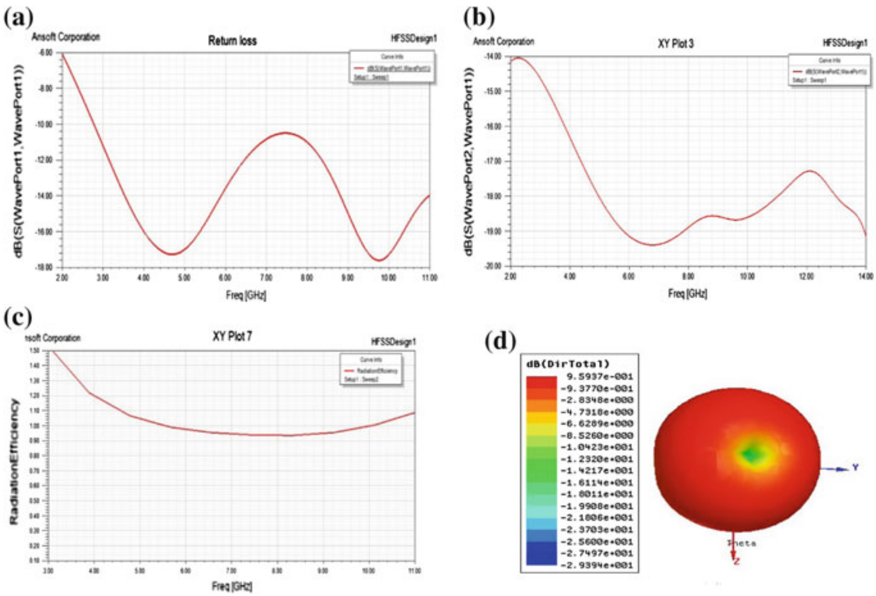

Fig. 8 **a** Return loss |S11|, **b** Mutual coupling |S21|, **c** Radiation efficiency versus frequency, **d** three-dimensional gain

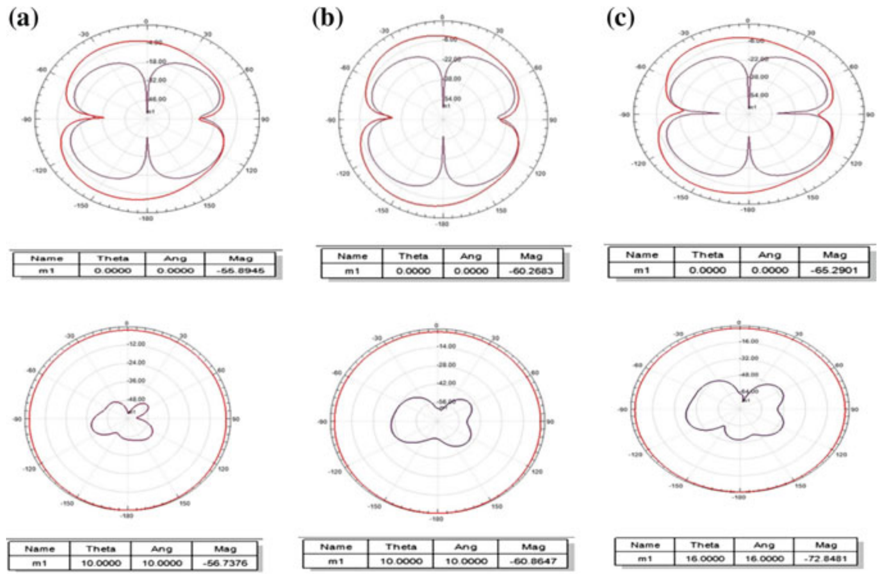

Fig. 9 Cross polarization of optimized differential feed antenna for E-plane and H-plane **a** at 5 MHz **b** at 6 MHz **c** at 7 MHz

4 Conclusion

An attempt is made to improve the radiation pattern of UWB. The work has presented different techniques for the improvement of the radiation pattern of Ultra-wideband antenna. Beveling technique has upgraded the antenna efficiency; Implementing DGS has improved the bandwidth; Directivity and antennas polarization purity has been enhanced by the differential feed technique. A compact differential-fed antenna with partial ground has been designed for improvement of radiation pattern of UWB. It achieves wide bandwidth of 93 %, radiation efficiency of 90 %, and 10–15 dB reduction in cross polarization. The compact size, simple structure, and improved radiation property make the proposed antenna a good candidate for various UWB utilization.

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