Design of a Compact Hexagonal Monopole Antenna for Ultra-Wideband Applications

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***Abstract* – This paper presents two design compact hexagonal monopole antennas for ultra-wideband applications. The two antennas are fed by a single microstrip line . The Zeland IE3D version 12 is employed for analysis at the frequency band of 4 to 14 GHz which has approved as a commercial UWB band. The experimental and simulation results exhibit good agreement together for antenna 1. The proposed antenna1 is able to achieve an impedance bandwidth about 111%. The proposed antenna2 is able to achieve an impedance bandwidth about (31.58%) for lower frequency and (62.54%) for upper frequency bandwidth. A simulated frequency notched band ranging from 6.05 GHz to 7.33 GHz and a measured frequency notched band ranging from 6.22 GHz to 8.99 GHz are achieved and gives one narrow band of axial ratio (1.43%).**

***Keywords* – Ultra-wideband antenna, Circular polarization, Notch band.**

I. Introduction

Ultra Wideband (UWB) technology has become a major interest to researchers and scientists. The commercial usages of frequency band from 3.1 GHz to 10.6 GHz, was approved by Federal Communications Commission (FCC) in 2002 [1]. However, there is always an increasing demand for smaller size, and greater capacities and transmission speeds, which will certainly require more operating bandwidth in the near future. In the last few years, researchers have investigated several kinds of microstrip slot and printed antennas for UWB applications [2–12]. Ultra-wideband (UWB) communication systems are currently under investigation and have been widely adopted in commercial and military domains. In this paper, a compact planar monopole antennas for UWB applications are proposed, The proposed antennas not only occupy a small size but also preserve a very single structure which is easy to be fabricated. The input impedance matching over a wide frequency range is achieved (4 GHz–14 GHz) .

Two design compact hexagonal monopole antenna for ultra-wideband applications are:

Antenna 1: Hexagonal monopole antenna,

Antenna 2: Hexagonal monopole antenna with asymmetrical U-slot

The detailed design and experimental results are presented and discussed below.

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II. Antenna Geometry

The configuration and the photo of the proposed UWB antennas are illustrated in Figure 1 and Figure 2, respectively. The proposed antenna have a compact size of 30×30mm and it is printed on conventional RT5880 substrate with thickness of 1.57mm, and relative permittivity =2.2.The radiating element is a hexagonal patch and the ground is a rectangular. The radiator and the 50Ω feed line are printed on the same side of the substrate and the ground plane is located on the other side. An asymmetrical U-slot is used to obtain dual circular polarization for ultra wideband applications.

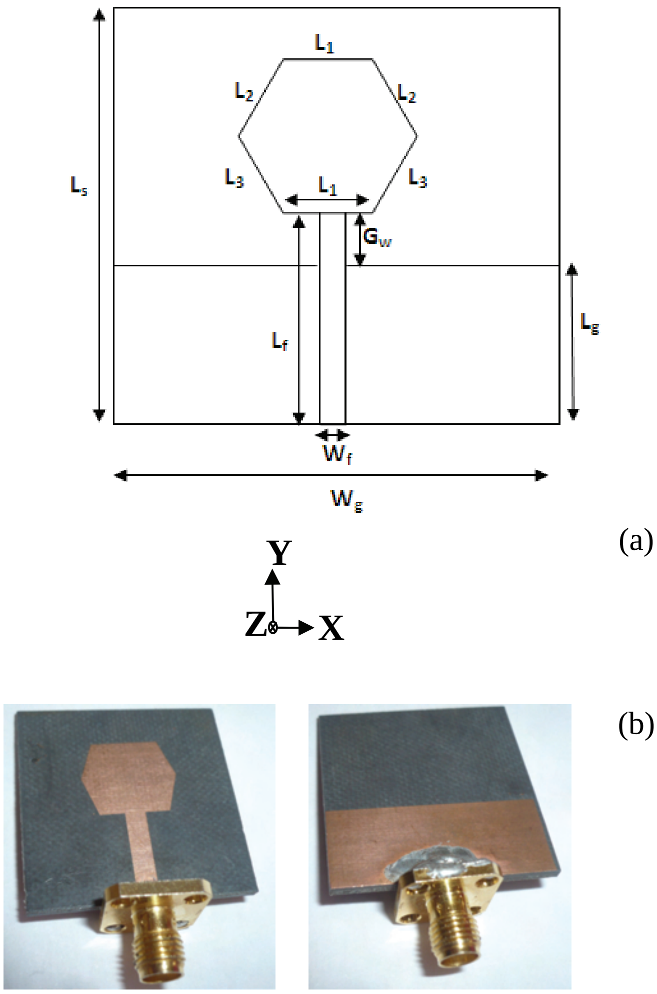
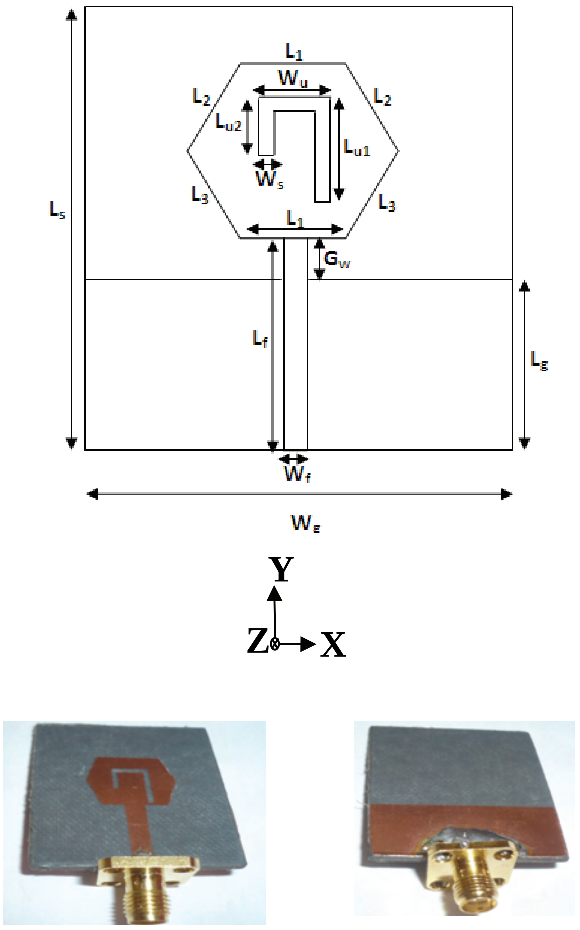


Fig. 1. Antenna 1: Hexagonal monopole antenna (a) Antenna geometry (b) Photograph



(a)

(b)

Fig. 2. Antenna 2: Hexagonal monopole antenna with asymmetrical U-slot (a) Antenna geometry (b) Photograph

The geometry and photograph of the proposed antenna1 with its parameters is depicted in Figure 1. The antenna is located in the xy plane and the normal direction is parallel to the z axis. The dimensions of the proposed antenna1 including the substrate L_s X W_g = 30mm x 30mm ,The radiation element is a hexagonal patch with dimensions L_1 = 10 mm, L_2 = 5.5 mm, L_3 = 6 mm, A 50Ω microstrip feed line with width of W_f =3 mm and the length of L_f = 13 mm, The gap G_w= 1 mm is the distance between the ground plane on the back side and the hexagonal patch on the front size. The ground plane size of L_g x W_g = 12 mm X 30 mm.The geometry of the proposed antenna 2 with its parameters is depicted in Figure 2. The dimensions of proposed antenna in figure 2 is similar to dimensions of the proposed antenna in figure 1 except the radiation element is a hexagonal patch with asymmetrical U-slot with dimensions L_1 = 10 mm, L_2 = 5.5 mm, L_3 = 6 mm ,L_{u1}= 8.5 mm, L_{u2}= 5mm, W_u = 6 mm, W_s = 1 mm.

III. MEASUREMENT AND SIMULATION RESULTS OF ANTENNA 1

The structures are simulated with IE3D which utilized the moment method for electromagnetic computation.

A. Return Loss

The measured and simulated return loss S_{11} of antenna 1 are shown in Figure 3. From the Figure, it is predicted that there is a good agreement between numerical and experimental results. The experimental and the simulated band frequencies from 3 GHz to 14 GHz are predicted, The slight frequency shift and discrepancy are achieved due to the probable deviation on the substrate permittivity at high frequency, Otherwise, a good agreement is achieved.

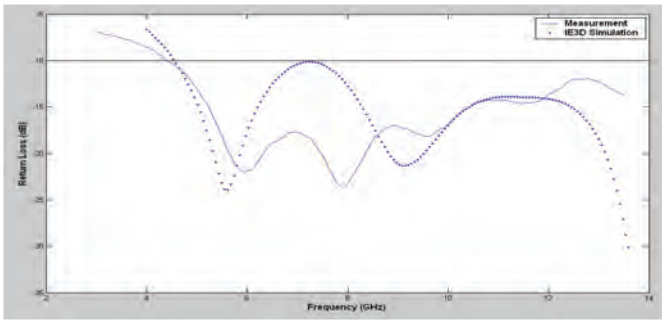


Fig. 3. Simulated and measurement return loss of Antenna 1

B. Gain

The Simulated maximum gain of the proposed antenna 1 is performed by using IE3D and presented in Figure 4. The antenna gain varies from 2.32 dB to 4.4 dB over the operating UWB frequency range. It can be concluded that the gain variation is not less than 1.25 dB over the entire operating frequency range from 4 to 14 GHz.

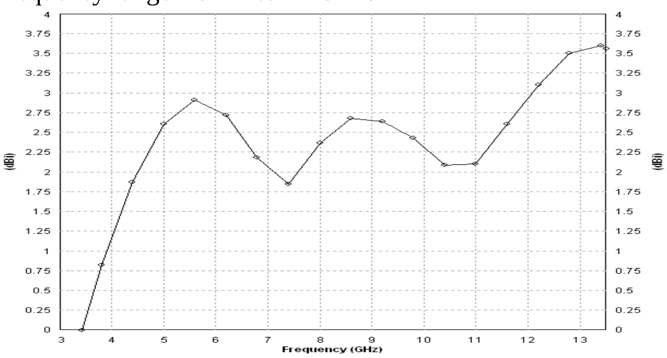


Fig. 4. Simulated maximum gain of Antenna 1

IV.MEASUREMENT AND SIMULATION RESULTS OF ANTENNA 2

A. Return Loss

The measurement and Simulated return loss S_{11} of antenna 2 are shown in Figure 5. The simulated impedance bandwidth for return loss (RL) less than -10dB ($|S11| \leq -10$ dB) is obtained. It is seen that the impedance bandwidth for return loss of less than -10 dB ranges from 4.4 GHz to 14 GHz, in which a simulated frequency notched band ranging from 6.05 GHz to 7.33 GHz is achieved, a measured frequency notched band ranging from 6.22 GHz to 8.99 GHz is achieved. Due to this notch frequency, there are two bandwidth of the UWB antenna. The Simulated Lower frequency bandwidth (BW1) is starting from 4.4 GHz to 6.05 GHz and the simulated upper frequency bandwidth (BW2) is starting from 7.33 GHz to 14 GHz. The measured Lower frequency bandwidth (BW1) is starting from 5.19 GHz to 6.22 GHz and the measured upper frequency bandwidth (BW2) is starting from 8.99 GHz to 14 GHz.

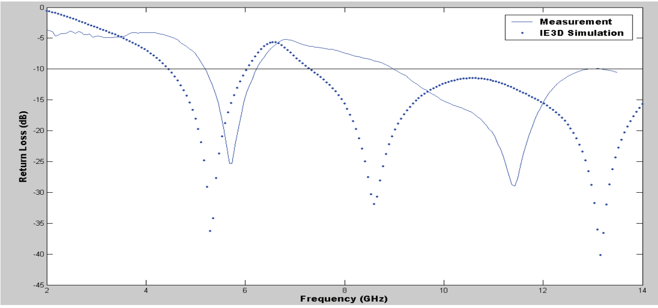


Fig. 5 Simulated and measurement return loss of Antenna

B. *Axial Ratio*

The simulated axial ratio (AR) of antenna 2 is shown in Figure 6. The simulated axial ratio bandwidth (AR) ≤ 3 dB provides single circular polarization. It is seen that the (AR) bandwidth have ranges (6.92 – 7.02) GHz , BW = (1.43%) .The circularly polarized (CP) antenna could have many different types and structures where the basic operation principle is to radiate two orthogonal field components with equal amplitude but in phase quadrature. The CP is generated by the unequal arms of the U-slot (Asymmetrical U-slot). Also Antenna 2 gives Left Hand Circular Polarization (LHCP) at one frequency 6.9 GHz which presented in Figure 7, [13, 14].

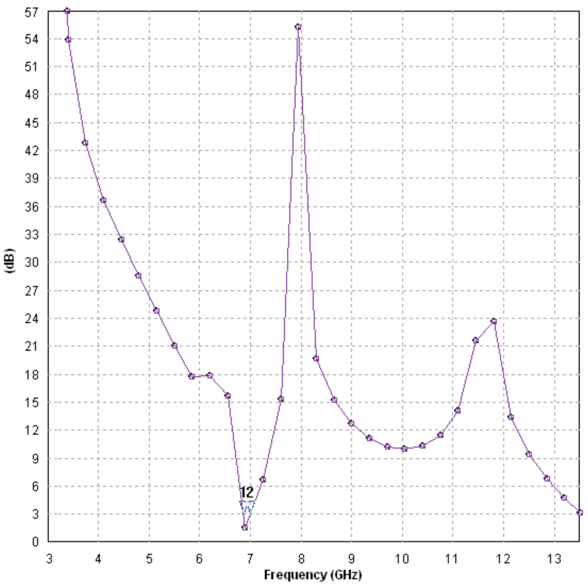


Fig. 6. Simulated AR vs. Frequency of Antenna 2

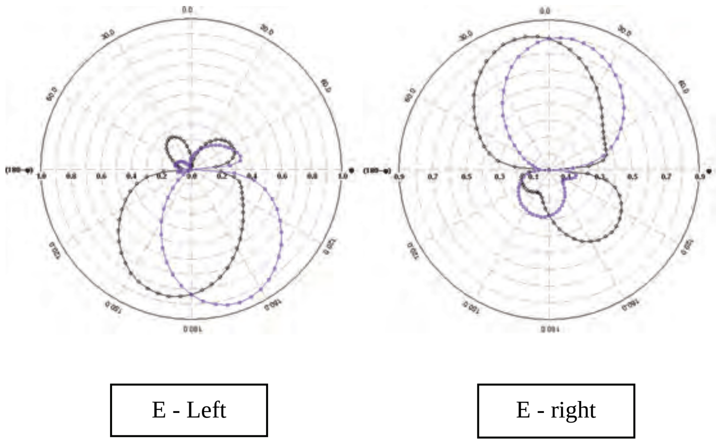


Fig. 7. Radiation Pattern at 6.9 GHz of Antenna 2

C .*Gain*

The Simulated maximum gain of the proposed antenna 2 is performed by using IE3D and presented in Figure 8. The antenna gain varies from 2.2 dB to 3.6 dB over the operating UWB frequency range. It can be concluded that the gain variation is not less than 1.38 dB over the entire operating frequency range from 4 to 14 GHz.

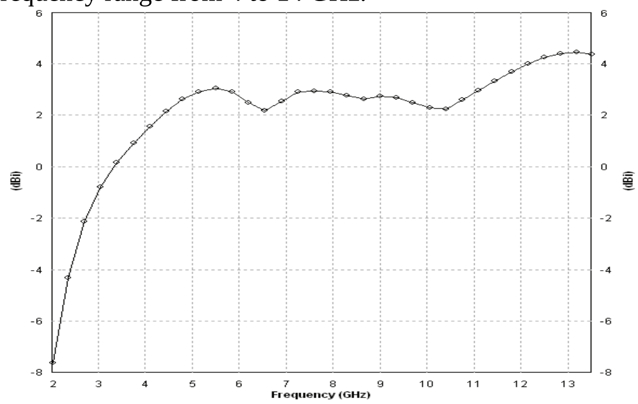


Fig. 8. Simulated maximum gain of Antenna 2

CONCLUSION

This paper presented two design of a compact hexagonal monopole antenna for ultra-wideband applications. Antenna 1 (Hexagonal monopole antenna) gives an return loss bandwidth about 111% with acceptable gain over the entire frequency band of operation. Antenna 2 (Hexagonal monopole antenna with asymmetrical U-slot) gives the lower frequency bandwidth (BW1) is starting from 4.4 GHz to 6.05 GHz (31.58%), the upper frequency bandwidth (BW2) is starting from 7.33 GHz to 14 GHz (62.54%) and the frequency notched band ranging from 6.05 GHz to 7.33 GHz. Antenna 2 gives single axial ratio (AR) band have ranges (6.92 – 7.02) GHz, BW = (1.43%). Antenna 2 gives Left Hand Circular Polarization (LHCP) at one frequency 6.9 GHz. Also, the gain of this antenna is presented. It is noticed that the gain is accepted for the band of operation.

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