New Diamond Antenna for Ultra Wideband Applications

Ziani Kerarti Djalal [1], Meriah Sidi Mouhamed [2]

**[1] Department of Electrical and Electronics Engineering,Univ. Abou-BekrBelkaid
Tlemcen, 1300/Bp.320, Algeria**

Abstract

There has been a flourishing prospect of UWB technology in recent years in both communication and other purposes like microwave imaging and radar applications. Recent studies of UWB antenna structures are specially concentrated on microstrip [1], slot and planar monopole antennas [2]. In this work, a small monopole antenna with diamond shape of the patch (30 x 26 mm²) printed microstrip fed monopole antenna has been designed, some parameters like return loss (S_{11}), Voltage Standing Wave Ratio (VSWR), radiation pattern has been performed to test the validity of simulation and verify eligibility of the antenna for the wireless communications purpose.

The proposed antenna is simulated in CST Microwave Studio and has surpassed the bandwidth of UWB requirement, which is from 3.1 GHz to 10.6 GHz, and exhibits good UWB characteristics. The 10 dB return loss bandwidth of this antenna element is from 3.39 GHz to more than 14 GHz.

Keywords: *Planar Monopole Antenna, Diamond Antennas, Ultra Wideband, Return Loss, Impedance Bandwidth, Voltage Standing Wave Ratio (VSWR), CST Microwave Studio.*

1. Introduction

Ultra Wideband (UWB) utilizes narrow pulses (on the order of a few nanoseconds or less) for sensing and communication. The Federal Communications Commission (FCC) in the U.S.A allocated the UWB frequency spectrum from 3.1 GHz to 10.6 GHz below the transmitter noise threshold of –41.3 dBm/MHz [2], [3]. Antennas are in high demand for various UWB applications such as wireless communications, medical imaging, radar and indoor positioning [4]. This is due to its ability to enable high data transmission rate and low power consumption.

Microstrip patch antenna is frequently used in UWB antenna designs due to its advantages such as lightweight, ease of integration, small size and compact [5]. Many UWB microstrip patch antennas have been discussed in the literature to achieve the requirement for different applications, one of which to increase the bandwidth. Since microstrip patch antennas inherently have narrow bandwidth characteristic, there have been numerous techniques developed for bandwidth enhancement in order to achieve the UWB characteristics [6]. These antennas have been discussed in the literature, for instance, Square-ring slot antenna, dual-band slotted antenna, and dual-band notched antenna. Other techniques employed to increase the bandwidth of antennas include meandered ground plane, slot loading and fractal antenna.

In this paper, the antenna is printed on microstrip substrate with a diamond shape of the patch, which operates in the range of 3.39 - 14 GHz, thus achieving the UWB bandwidth enhancement. Section II describes the basic configuration of the antenna design, whereas Section III discusses a simulated result of the antenna performances. Lastly, the findings of the simulated results are summarized in the conclusion.

2. Antenna Geometry

Fig.1 shows the geometry of the proposed planar antenna whose parameters have been obtained using commercially available simulations software CST Microwave Studio [7] and compared to IE3D software [8]. This antenna is printed on FR4 Rogers substrate $\varepsilon_r = 4.5$ with thickness 1.6 mm and size 30 x 26 mm² and the antenna feeding structure is 50 Ω microstrip line.

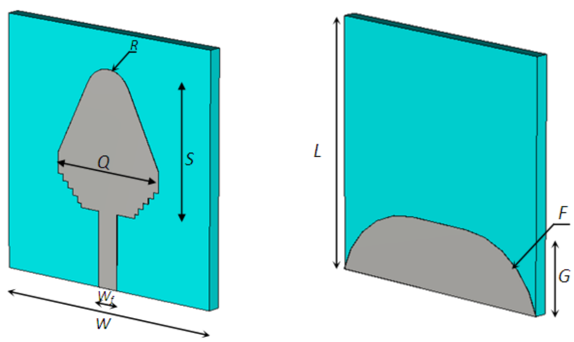
Several techniques have been adopted to acquire large impedance bandwidth including a diamond like triangular radiating patch with five steps of various sizes and a partial ground plane. The feed line is denoted by W_f.

The patch antenna structure is printed on one side of the FR4 substrate with the ground on the other side. The ground plane is denoted by G and rounded corner with rayon F as shown in Figure 1.The physical structure of five steps with various dimensions have been adopted to increase the effective electrical length at the lower frequency band (3-4 GHz).

The design parameters such as the patch shape, steps, the feed line width and shape of partial ground plane are optimized to obtain the best return loss, S_{11} and impedance bandwidth before determining the best dimensions for the proposed antenna. The dimensions of the antenna structure are as shown in Table 1.

Table 1: Critical antenna dimensions

Parameters		***Dimensions* (mm)**
PATCH ANTENNA	W	30
	L	26
	W_f	2.5
	R	4,5
	S	14
	Q	15
Ground plan	F	10
	G	9.5



(a) (b)

Fig. 1 (a) - geometry of patch antenna (b) - ground plan

3. Results and Discussions

To verify the design and optimize antenna dimensions, numerical simulations have been used. Two numerical models of the antenna based on different computational methods have been built in order to cross-verify the results. The first model is based on the finite integrate technique (*FIT*) within the commercially available solver CST Microwave Studio. The results have been compared to the second model, which is based on mixed-potential form of the IE formulation in frequency domain. The metal parts as well as the dielectric substrates are modeled using surface integrals. The integral equations of the model are solved using Method of Moment (*MoM*) by the commercially available solver IE3D.

3.1 Return Loss, S11

Figure 2 illustrates the simulated return loss against frequency of the antenna. The results given by CST and *IE3D* agree with each other only with small deviations.
The -10dB bandwidth given by CST is from 3.38 GHz up to 14 GHz while that given by IE3D is from 3.13 GHz to 14 GHz. The observed deviation is due to the different numerical modeling and meshing techniques. Nevertheless, the variations are within tolerance, so we could say both CST model and IE3D model gave us good estimation of the antenna performance.
The plots of the return loss (Fig. 2) of the antenna show that simulated impedance bandwidth is 10.62GHz (from 3.38 GHz to 14 GHz), which is equivalent to 122% (CST) and 10.87 GHz equivalent to 126% (IE3D),both band width are calculated by using relation (1).

$$BP\%=2\times\frac{f_h-f_l}{f_h+f_l}\times 100 \quad (1)$$

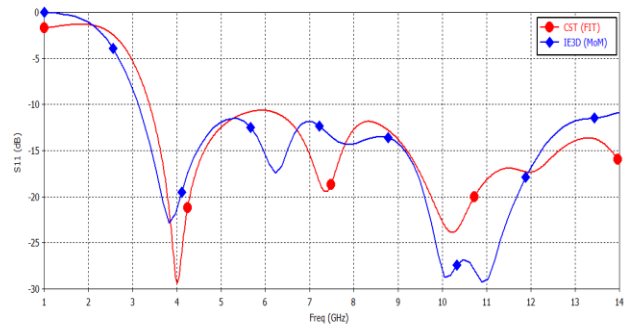


Fig. 2 Comparison of the return loss simulated by IE3D and CST

Overall, this antenna exhibits good UWB characteristics in terms of impedance bandwidth and return.

3.2 Voltage Standing Wave Ratio (VSWR).

Figure 3 illustrates the simulated voltage standing wave ratio (VSWR) against frequency of the antenna. Based on the simulated result, the VSWR value ranges from 1 to 2 throughout the frequency range. Both results are validated because the same frequency regions do fall in S_{11} above –10 dB as is shown in Figure 2.

3.3 Radiation Pattern

Figures 4 and 5 show two and three dimensional radiation patterns of the proposed antenna at different frequencies (3, 5,7and 10 GHz) which depict antenna's omnidirectional pattern over wide range of frequency.

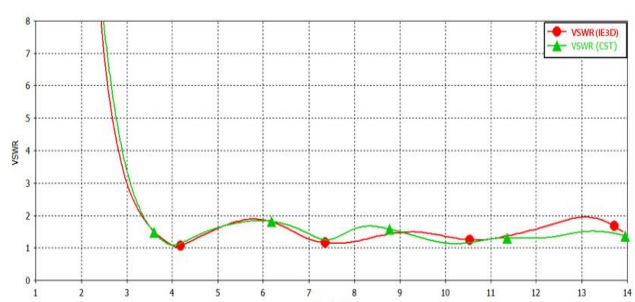


Fig. 3 simulated results of voltage standing wave ratio (VSWR) against frequency by ie3d and CST (GHz).

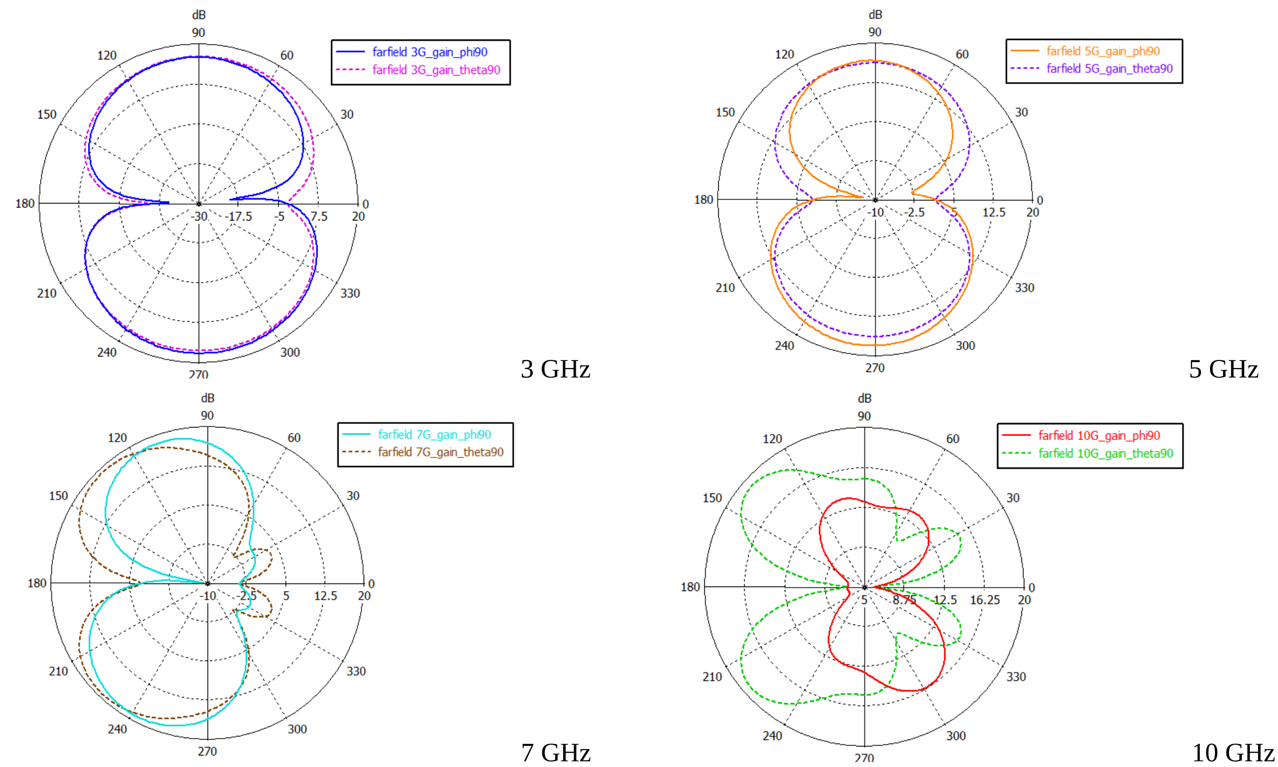


Fig. 3 simulated two dimensional radiation patterns

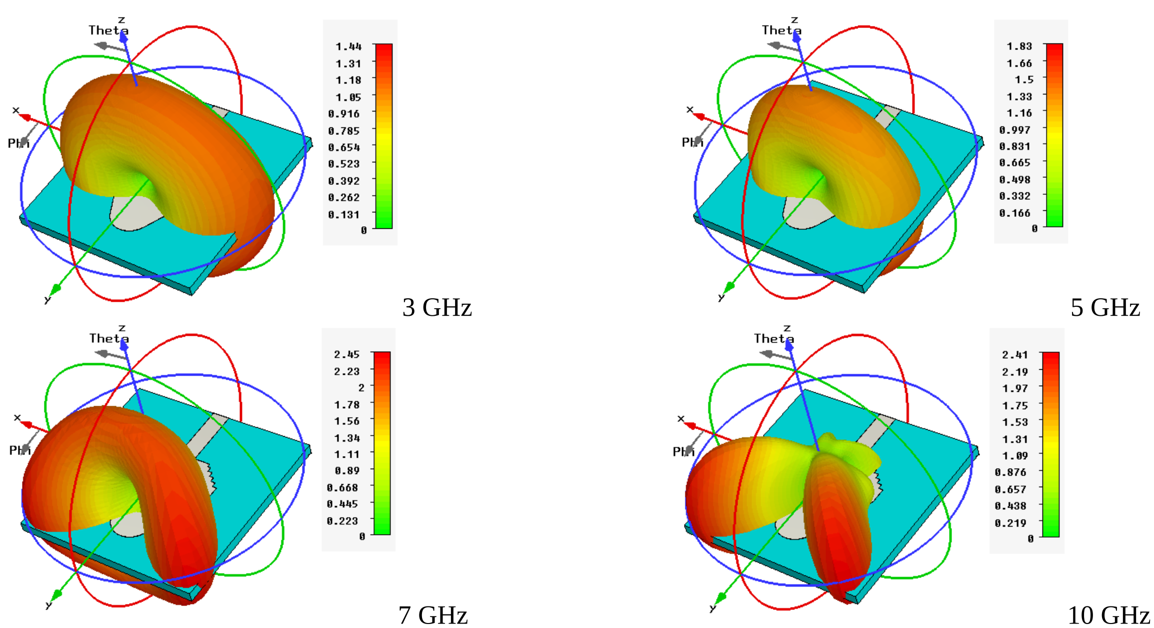


Fig. 4 simulated three dimensional radiation patterns

4. Conclusions

The proposed antenna exhibits good UWB characteristics, with its simulated result operating from 3.38 GHz to 14 GHz, having fractional bandwidth of more than 122% simulated with two different solvers. The antenna has successfully achieved enhanced UWB bandwidth, in which UWB frequency spectrum covers the range from 3.1 GHz to 10.6 GHz. Besides, it complies with the VSWR range from 1 to 2 throughout the impedance bandwidth, whereas the radiation patterns with stable radiation characteristics. The proposed antenna, with good UWB characteristics and geometrically small nature, is suitable for wireless communication systems.

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