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A NOVEL COMPACT STAR SHAPED PLANAR ULTRA-WIDEBAND ANTENNA

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Abstract

This paper introduces a low profile planar antenna for ultra-wide band applications. The antenna consisting of star shaped conducting patch, dielectric substrate and a partial conducting ground plane. The patch is excited using a rectangular microstrip feed line. The antenna size is 32x21 mm. The impedance bandwidth of the antenna extended from 3 GHz to 14 GHz, thus meeting the requirements of a good UWB system. The gain of the antenna in enhanced significantly by implementing a reflector plane under the antenna.

Introduction

Microstrip antennas inherently have a narrow bandwidth and low gain; therefore, bandwidth and gain enhancements are usually demanded for practical applications especially for ultra-wideband radio systems. Due to their interesting geometrical features, microstrip patch antennas (MPA) are attractive candidates for use in developing ultra-wideband (UWB) antennas for short-range high-speed wireless communication networks [1]. Ultra-Wideband radio systems use a bandwidth extending from 3 to 10.5GHz to transfer data consistent with the Federal Communications Commission (FCC) regulations [2]. Good UWB antennas should have low return loss, suitable radiation pattern and high efficiency over their entire bandwidth [3]. In addition, radio systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile units. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas [4]. One of the challenges facing the development of UWB radios is developing antennas that meet bandwidth requirements. The most straightforward way to improve the MPA bandwidth is to increase the patch-ground plane separation by using a thicker substrate [5],[6]. However, thick substrates support surface waves that can increase mutual coupling in antenna arrays and possibly degrade the radiation pattern [7]. The bandwidth of an MPA can also be improved by combining several resonant structures into one antenna, such as increasing the metallization layers, increasing the number of patches or adding extra components [8]. Many antenna configurations have been used in UWB antenna designs, such as square, circular, elliptical, pentagonal and hexagonal shapes [9-12]. Many techniques such as meandered ground plane [13], slot-loading [14], stack shorted patch [4], feed modification [15]–[17] and chip loading [18] have been reported to reduce size and achieve wide bandwidth.

In this paper, a low profile star shaped patch antennas for ultra-wide band applications is presented. The patch is excited using a rectangular edge-fed microstrip line. A partial conducting ground plane is used for the impedance bandwidth enhancement of the antenna. A reflector was implemented for gain enhancement.

Antenna Design

The geometry of the proposed antenna is shown in Fig. 1. It is composed of a single radiating star shaped patch excited using a rectangular edge-feed microstrip feed line with a conducting partial ground plane. The partial ground and the antenna symmetrical shape have been used previously for bandwidth improvement [12]. The antenna was designed on a Rogers RT/Duroid 5880LZ substrate with dielectric constant of ε_r =1.96 and loss tangent of 0.0009.

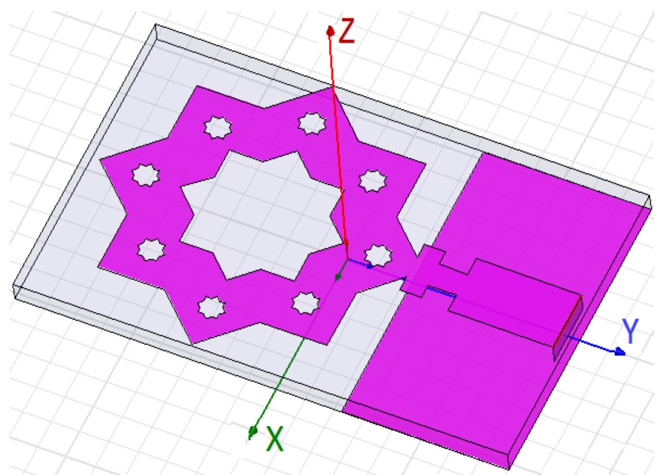

Fig. 1. Antenna Geometry

The substrate has a length of 32mm, a width of 21mm and a thickness of 1.27mm. The width of the partial conducting ground plane is 21mm (L1) and the length is 11.5mm (L3). The top view of the patch configuration is shown in Fig. 2. The dimensions of all parts listed in the caption of Fig. 2 are given in millimeters. The antenna was designed and simu-

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lated using the full-wave software packages ANSOFT's High Frequency Structure Simulator (HFSS) [19].

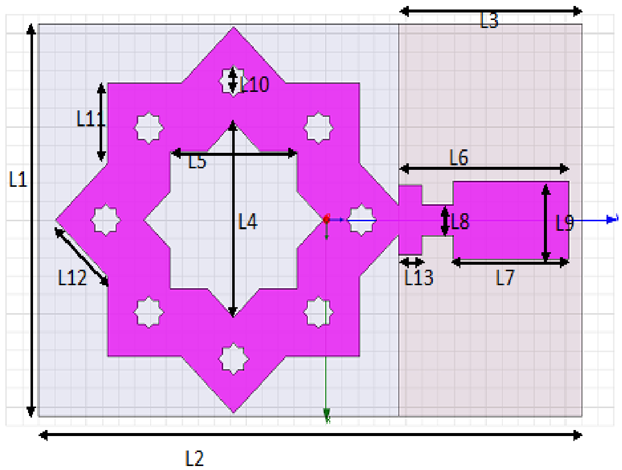

Fig. 2. Antenna's top view (L1=32, L2=21, L3=11.5, L4=10.45, L5=7.94, L6=10.69, L7=7.3, L8=1.7, L9=4.2, L10=1.55, L11=4.33, L12=4.45, L13=1.5).

The ground plane is an important part of the matching component for the proposed antenna; hence, changing its dimension and position will affect the resonance frequency and the gain. An intensive optimization study was conducted to gauge the effect of the ground plane size on the performance of the antenna. Fig. 3 shows the variation of the return loss with respect to the ground plane length, Lg. It is clear that changing the ground plane length will change the resonant frequency and the return loss of the antenna. From Fig. 3, it can be concluded that good |S11| is achieved when Lg is between 11mm and 13mm. HFSS optimization tool was employed to achieve an optimal Lg of 11.5mm.

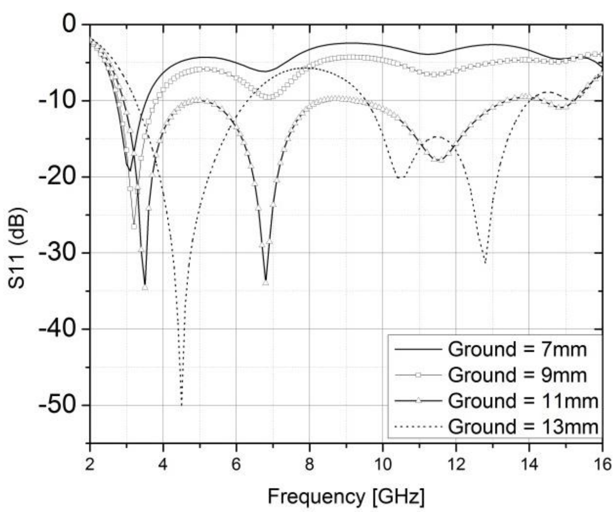

Fig. 3. Simulated return loss for different ground plane lengths.

Removing parts of the copper changes the current distribution on the patch and reduce losses as a result of the surface waves. Fig. 4 shows the variation of return loss with respect to the size of the copper removed, with Lg=11.5mm. In the figure, MPS refers to the side length of the two squares forming the middle star. Furthermore, the effects of copper removed on the maximum antenna gain in Phi=90^o plane is shown in Figs 5. In addition, the antenna dimensions were optimized for maximum gain using the HFSS optimization tool.

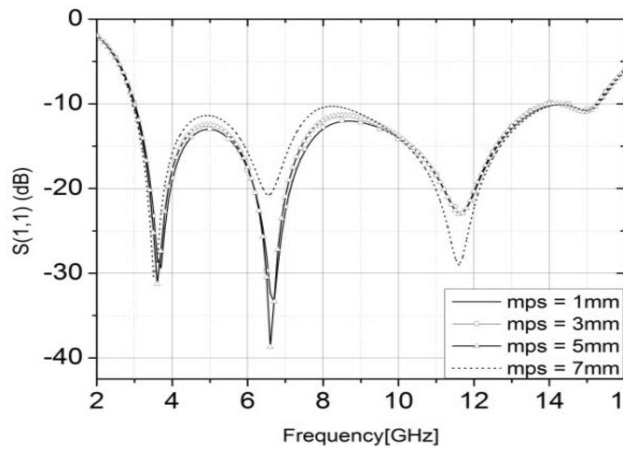

Figure 4:- Simulated return loss for the different middle squares lengths

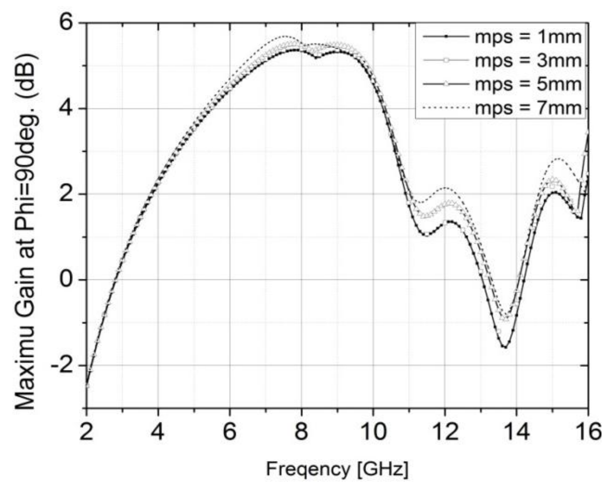

Figure 5:- Simulated maximum gain in theta plane at Phi=90^o for different middle squares lengths

Result and Discussin

Selecting the optimum ground plane length and the optimum antenna dimensions insures that the antenna is operating at UWB frequency band with maximum gain performance. The simulated results of the return loss (|S11|) of the antenna for the frequency range 2GHz-16GHz is shown in

Fig. 6. It is shown in the figure that the antenna impedance bandwidth with |S11|< −10 dB is about 11 GHz, from 3.0GHz-14GHz, which exceeds the FCC UBW requirement. In fact, the antenna is matched across the frequency range and a balun is not needed to reduce the return loss. Also, for the impulse system, the SWR level of the antenna is a critical parameter to avoid ringing effect. In order to avoid undesired ringing in the impulse system, the antenna input and the RF generator impedance should be matched over the wide frequency band. Therefore, the antenna is very useful for impulse systems due to its low-level SWR over its entire frequency bandwidth.

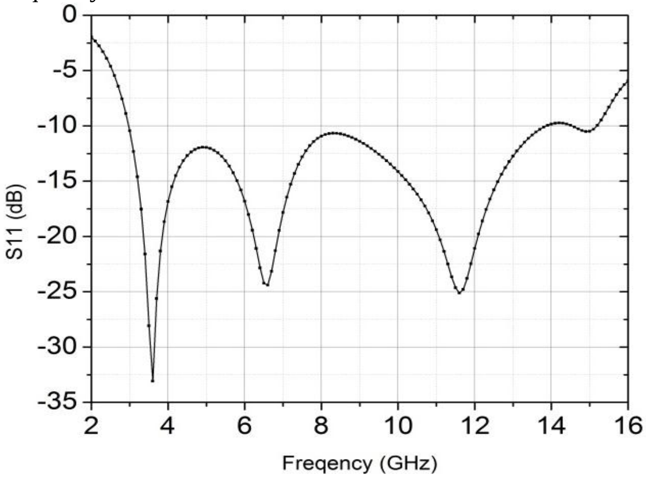

Fig. 6. The return loss

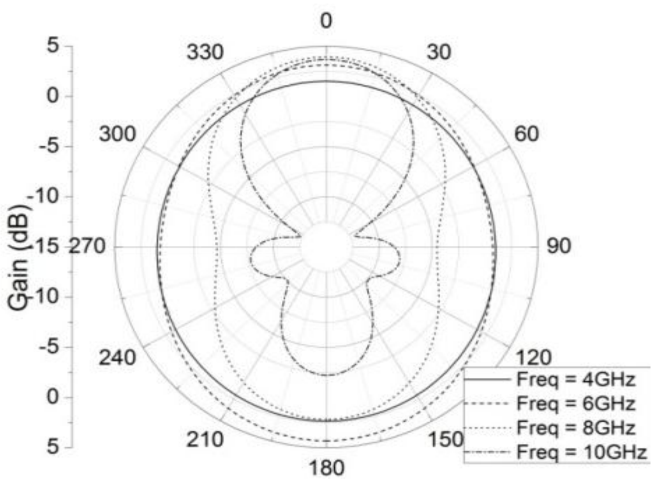

Fig. 7. 2-D polar radiation pattern at 4, 6, 8 and 10 GHz, Phi=0°

The antenna 2D radiation patterns at 4, 6, 8, and 10GHz in both E-plane and H-plane are shown in Figs. 7 and 8, respectively. Furthermore, the simulated maximum gain over the frequency range from 2GHz-16GHz is given in Fig. 9 which shows that the antenna has acceptable gain across the entire bandwidth. From Fig. 10, it can be seen that the group delay variation is less than 0.25 ns over most of the frequencies; however, it increases to about 2ns over a narrow segment of the bandwidth in the lower frequency region.

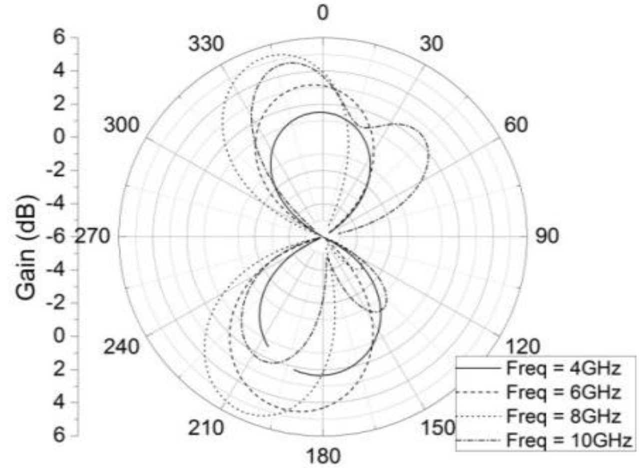

Fig. 8. 2-D polar radiation pattern at 4, 6, 8 and 10 GHz, Phi=90°

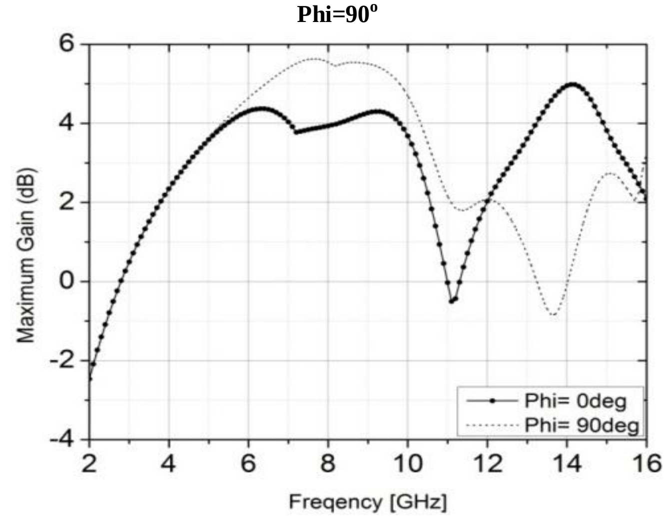

Fig. 9. Calculated maximum gain at Phi=0°, and Phi=90° antenna gain

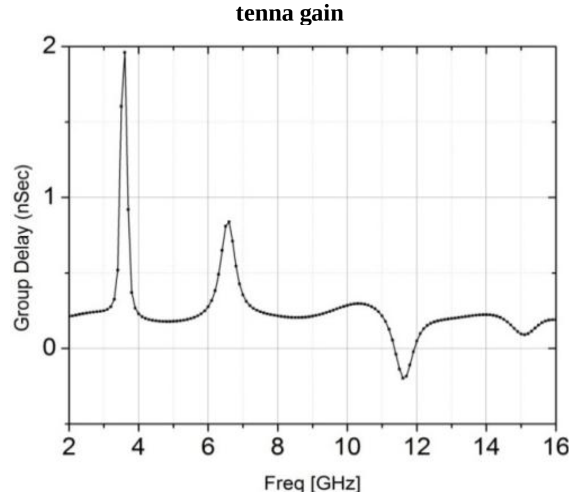

Fig. 10. Group delay

Enhancing Antenna Gain

Adding a reflector under the presented antenna was found to enhance the gain of the antenna. The dimension and the location of the reflector are critical for obtaining the maximum radiation of the antenna. The proposed antenna is integrated with the reflector as shown in Fig. 11. The reflector dimension is the same as the substrate dimensions. It is located a distance Lr under the antenna. The reflector consists of a copper layer printed over epoxy glass substrate of dielectric constant ε_r =3.4. Fig. 12 illustrates the return loss for a range of reflector gaps (5mm ≤ Lr ≤ 25mm). The return loss is observed to be inversely proportional to Lr. When Lr is more than 20mm, the antenna shows less mismatch for the targeted |S11| of less than -10dB.

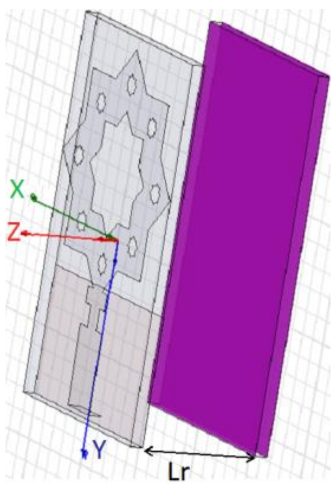

Fig. 11. Perspective view of the proposed antenna with the reflector

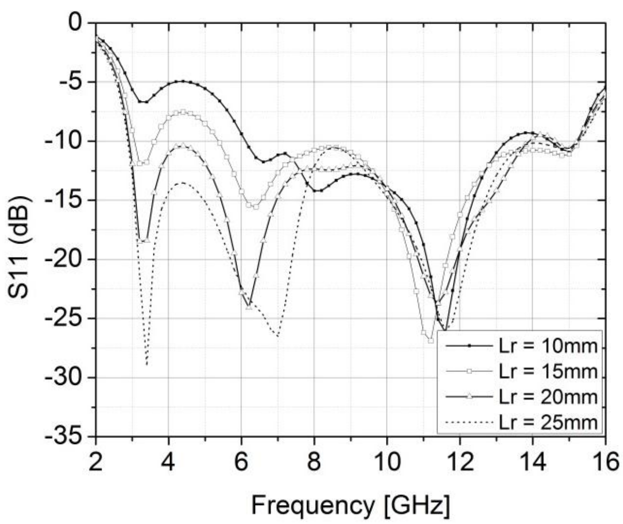

Fig. 12. The return Loss for different reflector distances Lr.

Comparison study for maximum gain for Phi=0^o and Phi=90^o with and without the reflector is shown in Fig.13 and 14, respectively. The maximum gain is obtained for Lr=20mm, 22mm, 24mm and 26mm.

The implementation of the reflector has increased the gain of the star antenna significantly at the lower frequency band. Fig. 13 shows an increase of 3.4dB in the gain at 4GHz for Lr=20mm in comparison to that of the antenna without the reflector. However, only a maximum increase of 1.8dB at 9GHz frequency was obtained with Lr=26mm.

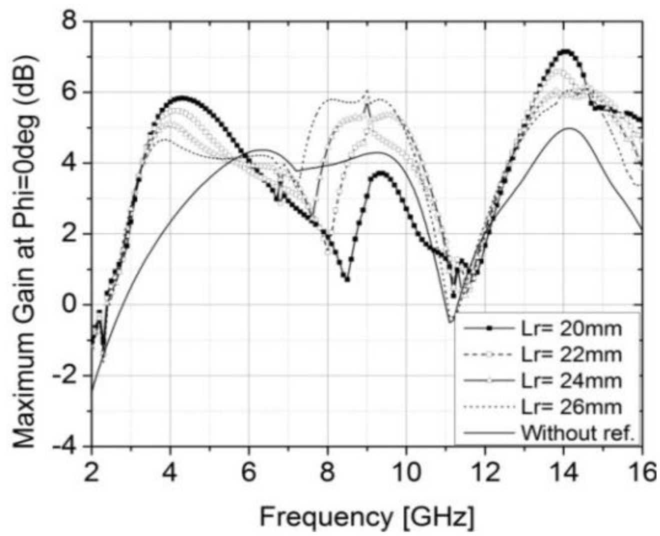

Fig. 13. Calculated maximum antenna gain at Phi=0^o.

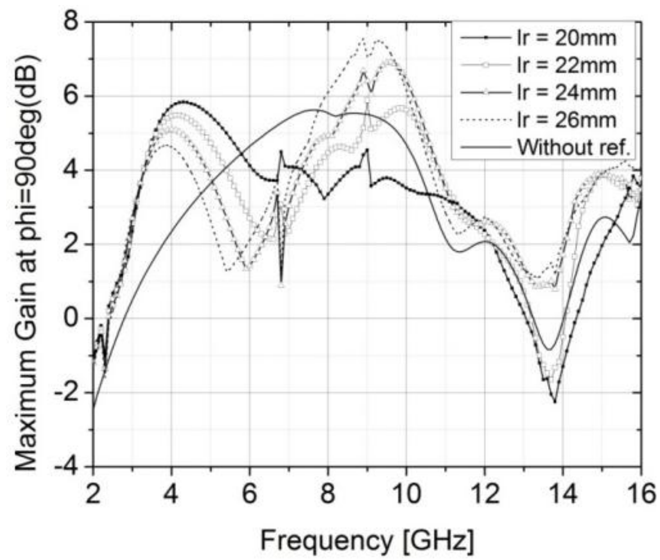

Fig. 14. Calculated maximum antenna gain at Phi=90o.

Conclusion

A compact, 31mm x 21mm low profile planar ultra-wide band patch antenna was introduced. The antenna was excited using a rectangular edge-feed microstrip feed line. A partial conducting ground plane was used to enhance the bandwidth of the antenna. All design and simulated results were performed using HFSS software. The effect of the ground plane length was studied and a suitable length was selected for the antenna. The ground dimension affects the resonance frequency and return loss of the antenna, thus can be used for tuning the antenna. The impedance bandwidth of the antenna is about 11 GHz (3.0-14GHz), which exceeds the FCC UBW requirement. The antenna has a stable radiation pattern and high gain over its bandwidth. Furthermore, the implementation of the reflector has significantly improved the gain of the antenna in the lower frequency band.

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