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# Design and Analysis of An Enhanced Microstrip Patch Antenna For Ultrawideband (UWB) Applications

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## Abstract

A microstrip patch antenna with enhanced features for ultra wide band (UWB) applications is presented in this paper. The antenna gain has been enhanced by inserting a slot and by adding a circular patch on the ground plane. Inserting the two notches on the circular patch has improved the impedance bandwidth. This antenna is designed with Roger RT/ Duroid 5880 with a permittivity of$\varepsilon r$=2.2. The proposed antenna has the dimensions of 30 x 40 x 1.6 mm3. The antenna is designed and simulated using the Ansoft HFSS software. The simulation results in this paper validate that the antenna has achieved a significant bandwidth improvement of 28.35 GHz ranging from 2.65 GHz to 30 GHz. A relatively high gain with a nearly omni directional radiation pattern is evident in the results. The antenna has obtained a VSWR of less than 1.75 over the entire band with the lowest achieved return loss of -30 dB. The results exhibit that the bandwidth of the proposed antenna is remarkably improved beyond the UWB frequency range defined by the Federal Communication Commission (FCC). Therefore it is recommended that the proposed antenna is not only suitable for the UWB applications but is also recommended for the applications operating between 10.6 GHz and 30 GHz.

**Keywords:** Microstrip patch antennaarray, Circular Patch, Gain enhancement, Improved return loss, Considerable Bandwidth enhancement, Directivity, Omnirectional Radiation Pattern, UWB band.

## Introduction

A wide-slot antenna fed by an equiangular spiral is reported in [1]that achieved a UWB bandwidth enhancement. The antenna with a circular slotted square ground and frequency independent feed line-equiangular spiral attained a wide band performance. In addition, a circular plane in connection with the slotted ground is positioned in the

centre which further enhanced the antenna bandwidth performance. It is concluded that by varying the radius of the circular plane, a wider impedance bandwidth can be achieved. The impedance bandwidth of a rectangular planar antenna reported in [2] can be enhanced by a truncated ground plane and by adding the extra patch on the other side of substrate. The return loss and the impedance bandwidth can be enhanced by using a partial ground plane rather than a full ground plane of a microstrip line [3, 4].
Notches on the circular patch of a microstrip antenna with a truncated ground plane can enhance antenna bandwidth and helps in improving impedance matching [5]. In [6], a printed Circular Disc Monopole antenna for the UWB wireless application with an impedance bandwidth from 3.0 to 11.4 GHz is reported. It is concluded that antenna impedance bandwidth can be controlled by the feed gap width and the radius of circular slot. A compact UWB Microstrip-Fed Printed Monopole antenna is presented in [7]. It is reported that the impedance bandwidth can be improved by modifying the circular patch by placing rectangular cuts at the corners.
This paper is organized as follows: Section II presents the proposed antenna geometry, whereas the antenna simulation results and discussion are presented in section III. In the end, Section IV concludes the paper.

## Antenna Design Geometry

In this section we present the geometry of the proposed circular patch microstrip antenna for ultra-wideband applications. The performance of the proposed antenna is enhanced by adding slots and notches at the patch and the ground plane. The designed UWB microstrip antenna has a radiation patch on the front side of dielectric substrate and ground plane on the back side of the substrate. The radiation patch is made of copper which is connected to a microstrip feeding line. The Roger 5880 as the substrate is used because it possesses enhanced features compared to Teflon.
The dimensions of the microstrip patch antenna design such as length, width and matching network parameters have been mathematically calculated. In order to obtain the desired results the antenna dimensions have been carefully optimized. To improve the antenna performance two slots, a circular slot a1 on the radiation element and a rectangular slot (rectangular slot W1×L1) have been extracted from the ground plane. The geometry of the proposed compact UWB microstrip patch antenna is shown in Figure1.
The antenna is designed on Roger RT/Duroid 5880 substrate with dielectric constant ($\varepsilon_r$) 2.2. The antenna has the overall dimensions of 30×40 $mm^2$ and substrate thickness (h) 1.6 mm. The designed antenna consists of two steps in the circular patch of size W3 × L3 and W4. A microstrip feed line has a width of 3 mm and a length of 12 mm. The proposed antenna utilizes the partial ground plane $W_g \times L_g$ with a rectangular slot of 3 x 2 $mm^2$.The optimized parameters of the enhanced antenna are given in Table 1.

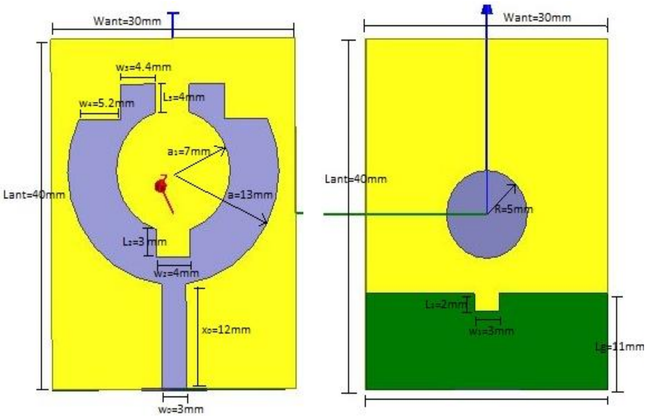


**Figure1:** Geometry of the proposed antenna

**Table 1:** Optimised Parameters of The Proposed Antenna

| Parameter | Dimension | Parameter | Dimension |
|---|---|---|---|
| $W_{ant}$ | 30 mm | R | 5 mm |
| $L_{ant}$ | 40 mm | $w_1$ | 3 mm |
| $w_0$ | 3 mm | $L_1$ | 2 mm |
| $x_0$ | 12 mm | $w_2$ | 4 mm |
| $W_g$ | 30 mm | $L_2$ | 3 mm |
| $L_g$ | 11 mm | $w_3$ | 4.4 mm |
| a | 13 mm | $L_3$ | 4 mm |
| $a_1$ | 7 mm | $w_4$ | 5.2 mm |

## Simulation Results and Analysis

The proposed antenna is simulated at 3.5 GHz. The proposed antenna is designed and simulated in the commercially available Ansoft High-frequency Structure Simulator (HFSS) software.

The bandwidth performance of the proposed antenna has been analysed with different substrate thicknesses. Figure 2 shows the bandwidth performance when the substrate thickness of 0.7mm is used. It can be observed the frequency range from 17.5 GHz to 30 GHz is achieved. A wider bandwidth from 2.6 GHz to 30 GHz has been obtained with an increase in the substrate thickness of 1.6 mm and this is evident in Figure 3. This concludes that the higher the substrate thickness the higher the bandwidth performance. However, the increase in antenna size with a thick substrate is not desirable in portable wireless devices or electronic gadgets. Alternatively a substrate with a smaller thickness and high dielectric constant can be used but it may provide a narrower bandwidth.

It is worth to mention here that the width of a microstrip antenna affects the gain and the directivity. By increasing the width of an antenna the gain and the directivity could further be improved. Figure 4 shows the gain and the directivity results of the proposed antenna achieved with an antenna width of 40 mm, and Figure 5 shows the results with an antenna width of 30 mm.

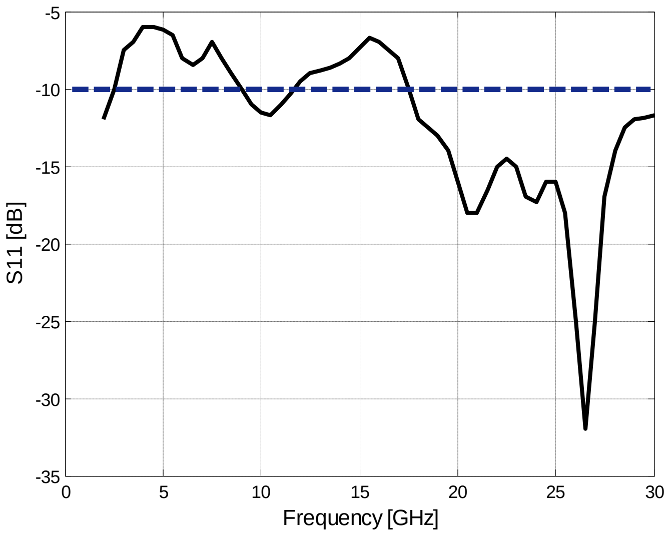


**Figure2:** Bandwidth performance of the proposed antenna with substrate thickness 0.7 mm

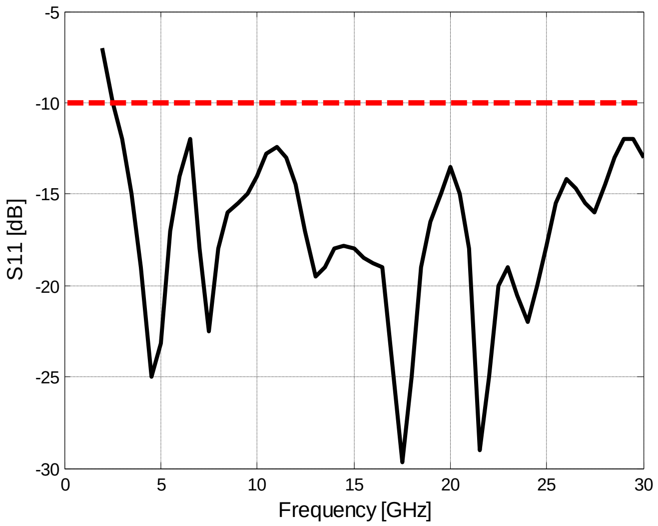


**Figure3:** Return loss of the proposed antenna for substrate thickness 1.6 mm

Another important part of the antenna which affects the performance is the ground plane. The ground plane is used as a reflector to reflect back the electric field radiations within the cavity. Ideally the larger the ground plane the better the radiation but as mentioned earlier the antenna size shall be compact and small and hence the small ground planes are preferable.

Finally, the feeding technique has a great impact on the overall performance of an antenna and it is important on how well the transmission line is matched with the circuit impedance of an antenna. Using a microstrip feed line technique; the current supplied to the antenna is matched to a feed of 50Ω resistance.

The performance of a microstrip antenna is mainly interpreted by simulation results such as return loss, impedance bandwidth, gain, VSWR, and radiation pattern. The simulation results of the proposed antenna have been obtained by using Ansoft HFSS.

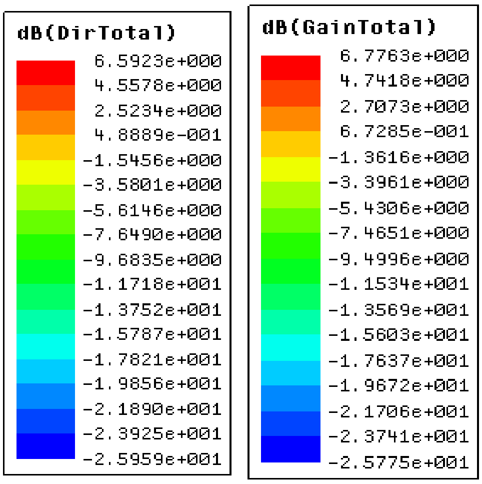


**Figure 4:**Gain and directivity performance of the proposed antenna for antenna width of 40 mm

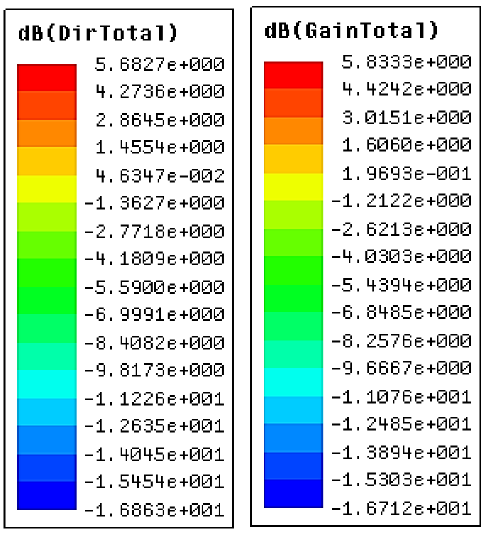


**Figure 5:**Gain and directivity of the proposed antenna for antenna width of 30 mm

Return loss is one of the important parameters when demonstrating the performance of an antenna. It is a representation of the relationship between the supplied power to an antenna to the reflected power. It is also an indication of how well an antenna is correctly matched with the transmission line. If an antenna is not correctly matched with the transmission line, a portion of the supplied power is reflected back which significantly decreases the efficiency of an antenna. Figure 6 shows the simulated return loss (S11) of the proposed antenna; and from this result, a very wide bandwidth of 27.35 GHz ranging from 2.65 to 30 GHz is evident. The minimum return loss -30 dB is obtained at a resonant frequency of 17.5 GHz. Therefore, the simulation results achieve a wide operating impedance bandwidth and a low return loss which meet the requirements for the UWB applications. This improved bandwidth is sufficient for WLAN, WIFI and other UWB applications.

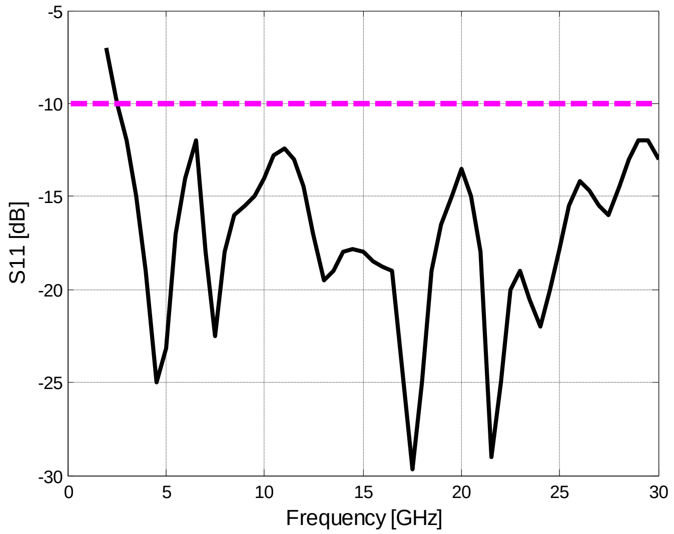


**Figure6:** Simulated return loss of the proposed antenna

The gain is another important parameter that indicates the efficiency of the antenna. It can be defined as the measurement of the amount of power transmitted in a certain direction.In other words, it describes how well the antenna converts input power into radio wave transmitted in a specific direction. From the gain measurements, the efficiency and the directivity of the antenna can be obtained as well. The efficiency shows the ratio between the amount of power transmitted to the antenna and the amount of the radiated power. And the directivity shows the ability of the antenna to radiate power in a certain direction.

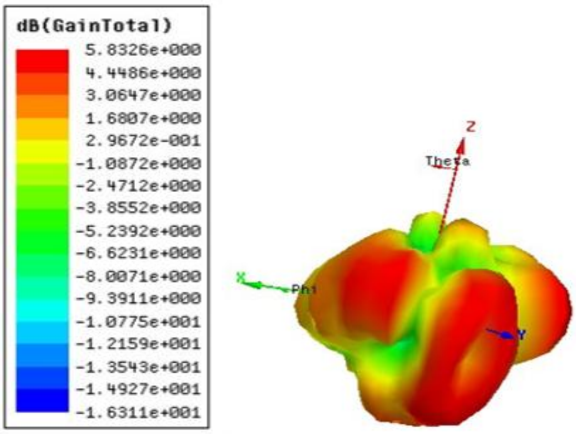


**Figure 7:** Simulated Gain of The Proposed Microstrip Antenna

Figure 7 shows the simulated gain of the proposed antenna. The simulated gain of the antenna is 5.83dB. The gain is improved by 46% compared to the antenna design in [6] and by 24% compared to design proposed by [7].
Figure 8 shows the directivity of the proposed antenna. The directivity of the antenna is 5.68 dB. The proposed antenna was designed to be omni directional, in order to radiate radio waves uniformly in all directions. As it can be seen in the figure, the antenna exhibits a directional radiation pattern of between 60$^o$ and -60$^o$ in clockwise.

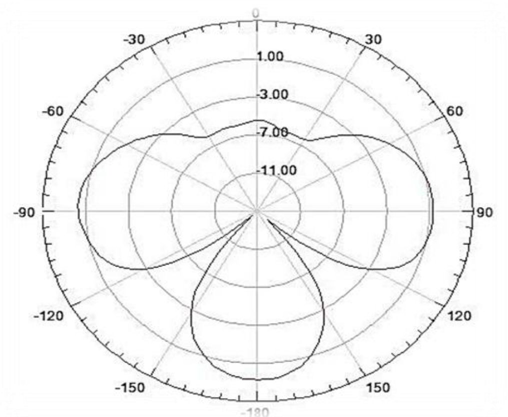


**Figure 8:** Simulated gain of the microstrip antenna

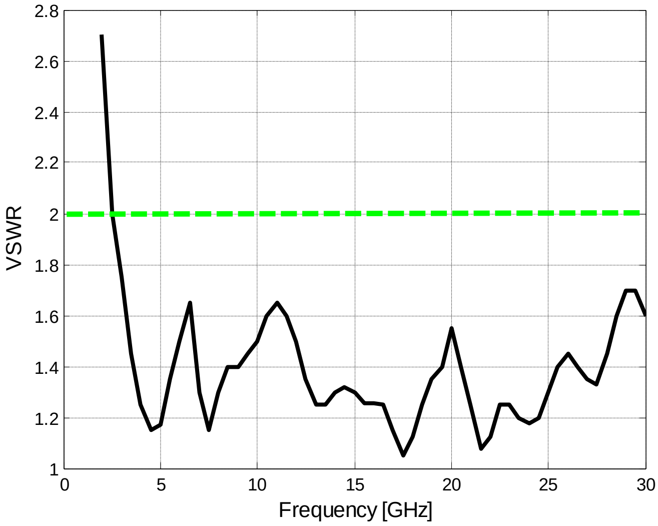


**Figure 9:** Simulated VSWR of the proposed antenna

The Voltage Standing Wave Ratio (VSWR) measures how well the impedance is matched to the transmission line. It describes how much power is reflected from the antenna. Ideally, the VSWR must be equal to unity, which means all the power is transmitted. However, it is not possible in practice, and practically it should be near unity. Figure 9 shows the simulated results of the VSWR of the proposed antenna. It can be seen in the figure that the VSWR is less than 1.75 over the entire range from 2.65 GHz to 30 GHz. The VSWR is less than 1.75 at 3.3 GHz, 1.05 and 1.06 at 17.5 GHz and 21.5 GHz respectively. The simulated results of the VSWR over the entire bandwidth are within the acceptable range, which validates that the antenna is correctly matched.
Table 2 compares the performance of the proposed antenna with two existing designs in the literature. The results show that the proposed antenna performs better than the existing designs published in [6] and [7].

**Table 2:** Summary of Performance Comparison of Proposed Antenna With The Existing Designs

| No | Comparison Parameters | **This Work** | Design in [6] | Design in [7] | **% Improvement of Proposed design** | |
|---|---|---|---|---|---|---|
| | | | | | **[6]** | **[7]** |
| 1 | Resonant frequency | **3.3 GHz** | 3.3 GHz | 10 GHz | **-** | **-** |
| 2 | Antenna dimensions (mm) | **30 x 40** | 41 x 50 | 30 x 40 | **41.5** | **0** |
| 3 | Bandwidth (GHz) | **2.65-30** | 3 -11.4 | 2-28 | **225.5** | **5.19** |
| 4 | VSWR | **≤ 1.75** | ≤ 2 | ≤ 2 | | |
| 5 | Max gain | **7.9 dB** | 5.2 dB | 6 dB | **51.9** | **31.6** |
| 6 | Min return loss | **-30 dB** | -22 dB | -28 dB | **36** | **7.1** |

## Conclusion

In this paper, a 2×1 enhanced circular microstrip patch antenna array at 5.8 GHz ISM band. The proposed antenna is reduced in size and exhibits an almost omni directional radiation pattern. The gain and the directivity of the antenna is more than 3 dB over the entire bandwidth. The antenna has achieved a minimum return loss of -30 dB and the VSWR less than 1.75 over the range between 2.65 GHZ and 30 GHz. The antenna has achieved a significant bandwidth improvement of 28.35 GHz ranges from 2.65 GHz to 30 GHz. The results exhibit that the bandwidth of the proposed antenna is remarkably improved beyond the UWB frequency range defined by the Federal Communication Commission (FCC). Hence, the proposed antenna is not only suitable for UWB applications but also for applications operating between 10.6 Hz and 30 GHz.

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