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# Ultra-Wide Band Microstrip Patch Antenna for C and X -Band Applications with Effect of Copper Thickness

**Komal Jaiswal, Shekhar Yadav, Nagendra Yadav, Ram Suchit Yadav**

***Abstract:** An ultrawide band partial ground miniaturized rectangular shape microstrip patch antenna is investigated in this paper. The size of the proposed antenna is 17×10×1.6 $mm^3$ and is excited by microstrip line feed which operates for C band and X-band. In this article we have compared the variation in the output by changing the thickness of copper of the proposed antenna from 35µm and 70µm. The design is simulated by Ansoft's HFSS13v which is based on finite element method then is fabricated using wet etching method and finally measured by copper mountain reflectometer R140 version. The performance of the rectangular shaped antenna is analyzed on various parameters like reflection coefficient, VSWR, group delay, gain, radiation pattern and radiation efficiency. The measured and simulated results reveal that proposed antenna resonates from 6.3-12GHz giving ultrawide band with bandwidth impedance of 62.9% with the gain of 3.94dBi and maximum radiation efficiency of 95% targeted for satellite communication, radars and radio navigation applications.*

***Keywords:** UWB, C-band, X-Band, Defected Ground Structure.*

## I. INTRODUCTION

Researcher in the field of academics and industries are interested to design compact communication devices that can work for various applications [1]. In radar and space communication applications microstrip patch antenna has gained attention as they are inexpensive, easy to fabricate, light in weight, low profile and integral with other devices. The major limitations with these antennas are that they have narrow bandwidth and low gain [2]. To overcome these drawbacks and to make an antenna that can be useful for many applications antennas are integrated into single chip which makes the device bulky.

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The motto of researchers from past decade is to design an antenna that can work for ultrawide band. To overcome multiple utilization of different service in a single device multiple band, wide band and ultrawide band are huge interest for the researchers and many such designs have been made to achieve the requirements. According to the Federal Communication Commission (FCC) approves, if the impedance bandwidth of an antenna is above 20%; it will be considered as UWB [3-4]. The aim of researchers is to design the UWB antenna for band rejection characteristics and eliminating interference from narrowband wireless applications. Ultrawide band have some meritorious features like high data rate, low cost, secure, low complexity, less interference and maximum radiating power [5]. To achieve UWB different techniques are used such as adding slots of different shapes in patch, feed and using defected ground structures (DGS).

Defected ground structure is one of the popular ways to reduce size and improve the performance of an antenna [6]. Different shapes and sized like square, circular, triangular, periodic and non-periodic defects are intentionally etched on the ground plane is used to increase the gain, impedance bandwidth and to suppress cross polarization and mutual coupling. The defect created on the ground plane disturbs the current distribution [14] which causes disturbance in the transmission line that helps in increasing capacitance and inductance [7-9].

The perusal of Table-I clearly reports that the proposed antenna is miniaturized in size than the other reported antennas. We have compared the proposed antenna by reference antennas parameters such as volume, peak gain, impedance bandwidth and resonating frequencies. From Table I, it is observed that peak gain of Ref. ([12], [13]) is more whereas impedance bandwidth of the proposed microstrip antenna is more than rest of the reported antenna. It is clearly established that Ref. ([10], [12], [13]) resonates at dual or multiple bands .It can be clearly reported that Ref. ([10],[11]) operates for S and C, Ref.[ [12] works in S ,C and X-band, whereas Ref. ([15] and proposed ) targets C and X-band .

**Table- I: Comparative analysis of proposed antenna with other reported antenna in terms of antenna parameters.**

| Reference | Antenna size(mm) | Type of feed | No. of bands | Bandwidth % | Resonating frequencies (GHz) | Gain (dBi) |
|---|---|---|---|---|---|---|
| [10] | 30×50 ×1.6 | Microstrip line | 2 | 4,2.2 | 1.85-1.93,3.48-3.57 | 1, 2.4 |
| [11] | 46×46 ×1.6 | Coaxial feed | 1 | 22 | 4.4 to 5.5 | NA |
| [12] | 32×32 ×1.6 | Microstrip line | 7 | 6.4, 8.5, 7.6, 3.9, 5.7, 1.2, 2.2 | 3.1,4.7,6.4, 7.6, 8.9,10.4 and 11.84 | 4.54, 5.97, 3.46,2.41,6.51, 4.14, 6.51 |
| [13] | 24×37 ×1.6 | Inset feed | 7 | 5.8, 4.1, 6.3, 7.4, 5.6, 7.3, 6.7 | 4.3, 5.5, 6.4, 8.5, 9.5, 11.4, 12.5 | 4.4, 0.4, 0.37,3.36, 6.76,1.36, 2.91 |
| Proposed Antenna | 17×10 ×1.6 | Microstrip line | 1 | 62.29 | 7,10.6 | 3.94 |

In this article a miniaturized rectangular shaped microstrip patch antenna is proposed with a partial defect embedded on the ground plane. The antenna of dimension 17×10×1.6 mm$^3$ is designed on FR4 substrate with dielectric constant of 4.4 and is excited by microstrip line. The factor such return loss, radiation efficiency, gain, group delay, radiation pattern, polar plot, surface density, and current distribution are detected. It is observed that the antenna radiated from 6.3-12 GHz with the ultrawide band of 5.7 GHz and impedance bandwidth of 62.29% with the maximum radiating efficiency of 95% and gain of 3.9dBi.

## II. ANTENNA DESIGN

The miniaturized rectangular structured microstrip patch antenna is depicted in Fig.1 which is designed on FR4 with dielectric constant of 4.4, loss tangent of 0.2 and the total dimension of antenna is (10×17×1.6) mm$^3$.The size of the antenna is clearly shown in Table-II. The proposed structure is fed by microstrip line feed of 50Ω SMA connector and on the ground plane and etched with a partial defected ground structure. The ground is partially defected that has helped in the reduction of the size of antenna. The principle figure of the proposed antenna is shown in Fig. 1 where simulated and fabricated top view and the bottom view are well illustrated. The volume of the proposed antenna is 272 mm$^3$ and the overall volume of the radiating patch is 2.95mm$^3$ (8.45×10×0.035) mm$^3$. The comparative analysis of proposed antenna is done based on copper thickness i.e. 35µm and 70µm shown in Fig. 2.

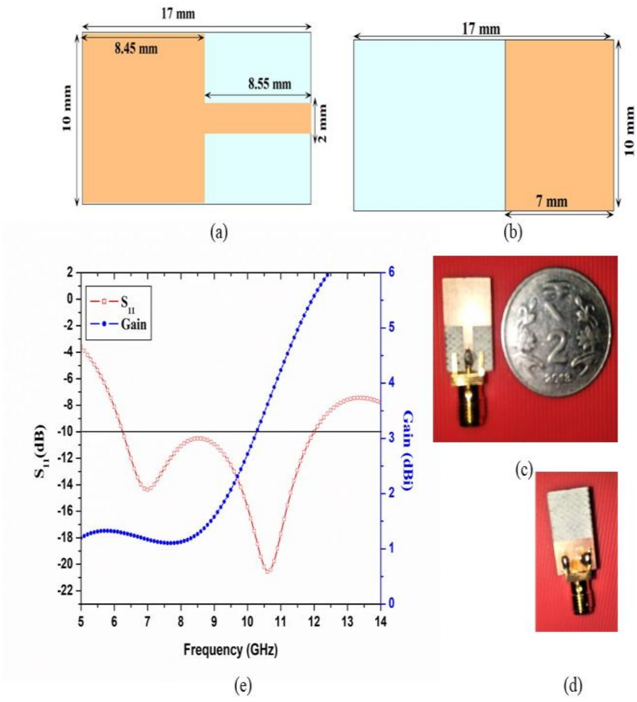


**Fig. 1. Principle figure of the proposed antenna (a) top view (b) bottom view (c) fabricated top view of the proposed antenna (d) bottom view (e) $S_{11}$ and gain as a function of frequency.**

**Table- II: Design specification and dimensions of proposed antenna.**

| | |
|---|---|
| Substrate used | FR4 |
| Thickness of the substrate | 1.6 mm |
| Dimension of the substrate | 17×10 $mm^2$ |
| Dimension of the patch | 8.45×10 $mm^2$ |
| Dimension of defected ground | 7×10 $mm^2$ |
| Dimension of microstrip line | 8.55×2 $mm^2$ |

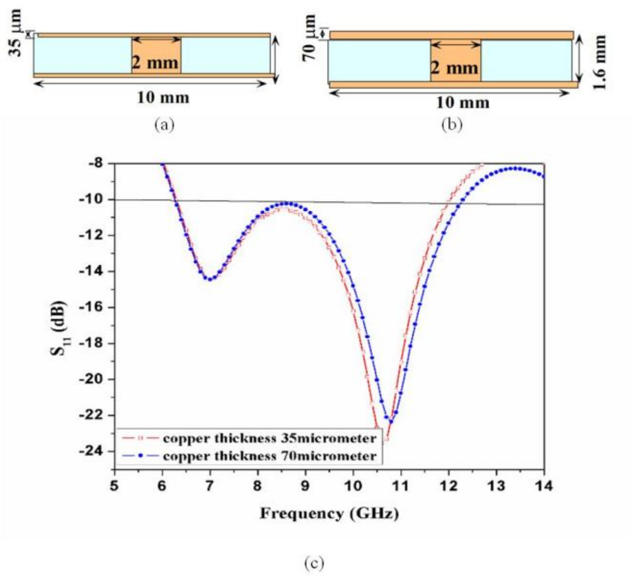


**Fig. 2. Comparative analysis of side view of proposed antenna (a) with copper thickness 35µm (b) copper thickness 70µm**

**Table-III: Comparative analysis of proposed antenna with the copper thickness of 35µm sand 70µm.**

| Copper thickness | 7 GHz | | 10.6 GHz | |
|---|---|---|---|---|
| | $S_{11}$(dB) | Gain(dBi) | $S_{11}$(dB) | Gain(dBi) |
| **35µm** | -14.447 | 1.23 | -23.52 | 3.94 |
| **70µm** | -14.448 | 1.08 | -21.22 (-22.35 at 10.8 GHz) | 3.69 (4.03 at 10.8 GHz) |
| Difference | 0.001 | 0.15 | 2.3 | 0.25 |

In Fig. 2 shows the side view of the proposed antenna with change in the copper thickness from 35µm (c.f. antenna (a)) to 70µm (c.f. antenna (b)) and the comparative analysis of these two antenna have been done in terms of reflection coefficient as a function of frequency and it is observed that the antenna (b) shows that the second resonance at 10.6 GHz has shifted to 10.8 GHz, it can be clearly seen from Table-III.

## III. EQUIVALENT CIRCUIT OF PROPOSED ANTENNA

Theoretical analysis of proposed rectangular shaped microstrip patch antenna with partially defected ground has been performed by RLC equivalent circuit (lumped element equivalent). There are LC, RLC equivalent circuit, Quasi-static equivalent circuit, π shaped equivalent circuit and Butterworth type [16]. The equivalent rectangular shaped microstrip patch antenna is the parallel combination of resistance R, inductance L and capacitance C can be calculated by length and width of an antenna [17].

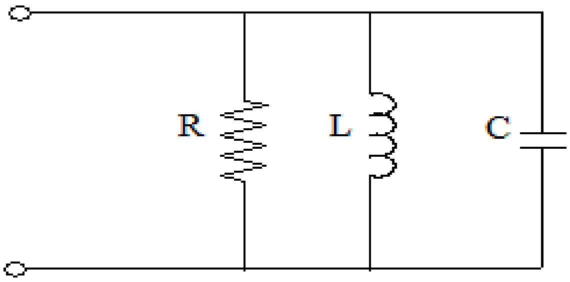


**Fig. 3. RLC equivalent circuit of rectangular microstrip patch antenna.**

$$C = \frac{LW\varepsilon_0\varepsilon_e}{2h}\cos^{-2}\left(\frac{\pi Y_0}{W}\right) \quad (1)$$

$$R = \frac{Q}{\omega_r C} \quad (2)$$

$$L = {}^{1}/_{C\omega_r^2} \quad (3)$$

$$f_r = \frac{c}{2Z\sqrt{\varepsilon_e}} \qquad \omega_r = 2\pi f_r, \quad (4)$$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{L}\right)^{-1/2} \quad (5)$$

DGS is mostly represented as parallel RLC connected to the transmission lines on both the side as it is most efficient way [19]. The radiation, conductor, and dielectric constant directly correspond to the resistance of the RLC circuit of the defected ground.

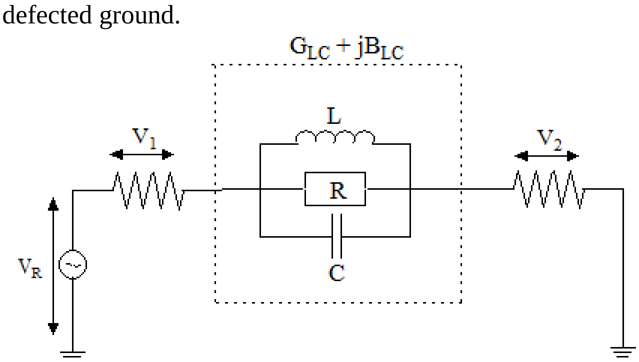


**Fig. 4. Equivalent circuit of the defected ground structure**

$$C = \frac{\omega_c}{2Z\left(\omega_0^2 - \omega_c^2\right)} \quad (6)$$

$$L = 1/4\pi^2 f_0^2 C \quad (7)$$

$$R(\omega) = \frac{2Z_o}{\sqrt{\frac{1}{|S_{11}(\omega)|} - \left(2Z_0\left(\omega C - \frac{1}{\omega L}\right)\right)^2 - 1}} \quad (8)$$

$$E_{in} = A\,sech\left[\frac{T}{T_o}\right] exp\left[\left(\frac{z}{2L_D}\right) - i\omega_o t\right] \quad (9)$$

## IV. RESULTS AND DISCUSSION

The proposed compact sized, UWB microstrip patch antenna is fabricated and tested. The design is simulated using Ansoft's High Frequency Structure Simulator version 13 EM solver. Fig. 1(e) represent the $S_{11}$ (dB) and gain (dBi) as a function of frequency it is clearly observed that the proposed antenna has two resonating frequencies at 7GHz with the gain of 1.23 dBi and 10.6 GHz with the gain of 3.94 dBi and operates from 6.3 -12 GHz with the impedance bandwidth of 62.9% and gain of 5.78dBi at 12GHz.

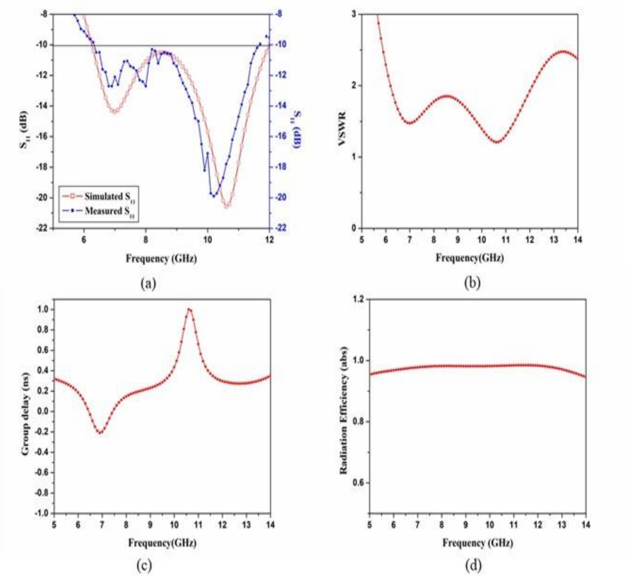


**Fig. 5. (a) Simulated and Measured $|S_{11}|$ (dB) versus frequency (GHz) (b) Simulated VSWR as a function of frequency (c) group delay as a function of frequency (d) radiation efficiency as a function of frequency**.

The comparative analysis between the simulated and measured value of the proposed antenna is done in terms $S_{11}$ (dB) as a function of frequency and it is observed that the nature of the curve in Fig. 5(a) validates bandwidth and resonating frequency. It is observed that the dip of 10.6 GHz has shifted to 10.3GHz this behavioral difference occurs due to antenna fabrication losses, material of the substrate and atmospheric losses whereas HFSS works on ideal mathematical assumption considering ideal conditions of atmosphere, material of the substrate etc.

Fig. 5. (b) illustrates the variation of voltage standing wave ratio with respect to frequency, it is characterizing the matching property of antennas, here theoretical possible values of VSWR (dimensionless) lies from 1(perfectly matched) to ∞ (unmatched) and practically lies between 1 to 2. VSWR measures how much power is delivered to a device as opposed to amount of power that is reflected from the load, Fig. 6(a) shows the value of VSWR for 7GHz and 10.6 GHz are 1.45 and 1.20 respectively which clearly indicate that, the source and the load impedance are matched at these particular frequencies.

We knew that the linear distortion happens in any linear systems and system magnitude of frequency response is not constant and the phase of frequency is non-linear. Group delay is measuring for phase distortion. The group delay of antenna can be constructed as a measurement of how distance signal to traverse a network (transit time) Fig. 5 (c) shows the group delay versus frequency plot. At resonance frequencies 7GHz and 10.6GHz corresponding values of group delay are -0.2ns and 0.93ns.

The efficiency of an antenna is the most important parameter. It is the ratio of the power delivered to the antenna relative to the power radiated from the antenna or potential power received from all possible angles to an antenna or efficiently radiation of the input power to free space wave. High efficiency antenna shows that power present at the antenna's input radiated away and lower efficiency means impedance mismatch (most of the power absorbed as losses). Antenna efficiency lies between 0 to1 because we say that it is the ratio of the radiated power to the input power of the antenna and if an antenna radiation efficiency value is more than 60%. In Fig. 5(d) portray the radiation efficiency versus frequency curve it is observed that for resonance frequency at 7GHz and 10.6 GHz the values are 0.97 and 0.98 respectively which indicates that the antenna efficiency is good.

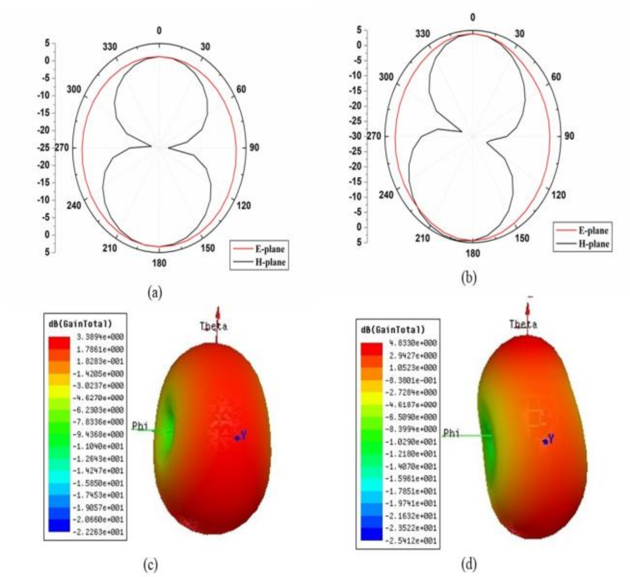


**Fig. 6.(a) Far field radiation pattern of the proposed antenna in terms of E-Plane and H-plane at 7 GHz (b) Far field radiation pattern of the proposed antenna in terms of E-Plane and H-plane at 10.6 GHz (c) 3D gain distribution for 7 GHz (d) 3D gain distribution for 10.6 GHz.**

The radiation pattern in term of Electric field E-plane i.e. ($\phi$= 0°) and magnetic field H-plane ($\phi$=90°) is shown in Fig. 6(a), (b) at 7 GHz and 10.6 GHz and validates the broadside directive radiation pattern of the proposed antenna. The behaviors of the radiation pattern of E-plane for both the frequencies are Omni-directional whereas the radiation patterns of H-plane for both the frequencies are bi-directional. The three-dimensional gain plot of the radiating patch of the proposed antenna for two resonating frequencies as depicted in Fig. 6 (c), (d). It can be perceived that the maximum radiated power is along with the direction perpendicular to the surface of the patch and ground plane and it shows that antenna work in Omni direction with the peak gain at 7 GHz and 10.6 GHz is 1.23 dBi and 3.94 dBi respectively.

The surface current density of the radiating patch and impact of partial ground is described in Fig. 7(a), (b) for the lower frequency i.e. 7GHz and higher resonating frequency i.e. at 10.6 GHz of the proposed antenna. The current density on the surface of the antenna portrays that the maximum surface current density is close to the feed point and close to the partial ground structure with least at the top of the proposed antenna. From the Fig. 7 (c), (d) illustrate the current distribution in antenna, it is observed that the maximum current flows close to the feed point and the near the coupling of patch and partial ground structure at 7 GHz and 10.6 GHz. The flow of current is maximum at the lower part of the patch.

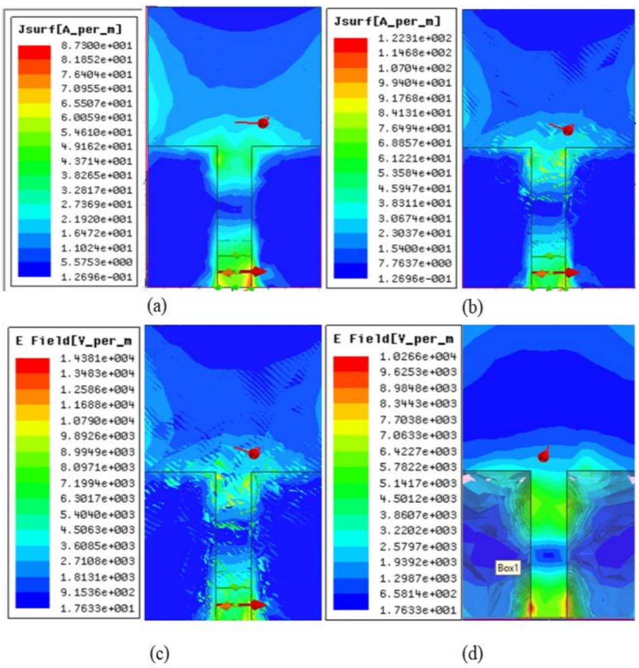


**Fig. 7. Surface current density of the proposed antenna at (a) 7 GHz, and (b) 10.6 GHz and Current distribution of the proposed antenna at (c) 7 GHz and (d) 10.6 GHz.**

## V. CONCLUSION

This paper presents a miniaturized square shaped micro strip patch antenna with defected ground structure. The proposed antenna is observed by using two different copper thickness of 35 µm and 70 µm. It has been analyzed that by using 70µm copper thickness of microstrip patch resonance frequency shifts from 10.6GHz to 10.8 GHz with operating frequency range of 6.3 to 12.3 GHz. Proposed antenna(c.f. Table-III) with copper thickness of 35 µm microstrip provides ultrawide band frequency range from 6.3 to 12 GHz with dual resonating frequencies at 7 GHz and 10.6 GHz. The merits of antenna are that it is compact sized with overall volume of 272mm$^3$, simple design, easy to fabricate and provide ultrawide band for C and X-band. The radiation efficiency is 97% with the gain of 3.94 dBi and impedance bandwidth of 62.9%. The proposed antenna well suited for all the application of partial of C and X-band like radar operation, satellite communication and military operations.

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