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Design and Performance Analysis of Microstrip Antenna using different Ground Plane Techniques for WLAN Application

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Abstract

This paper is concentrated on comparison of rectangular patch antenna with different ground plane dimensions i.e. short edge, double ground, triple ground in terms of Bandwidth, Gain, Directivity, VSWR, Reflection coefficient and efficiency performance. The finite ground plane gives rise to diffraction of radiation from the edges of ground plane resulting in modifying of radiation conductance, radiation pattern, and resonant frequency. The substrate used is Flame Retardant-4epoxy having dielectric constant of 4.4 and dielectric tangent loss of 0.02. The patch antenna is provided by inset feed line. The design was optimized to obtain the most suitable configuration in terms of desired values of reflection coefficient, bandwidth and Voltage Standing Wave Ratio (VSWR) for antenna with and without modifying on ground plane. These antennas are suitable for WLAN Applications. In this observation, the paper calls for an attention that, the cachet is an amelioration of the 2.4 GHz Industrial, Scientific and Medical (ISM) Band patch antenna is simulated and analysed using HFSS 13.0 and fabricated by photo lithography. The proposed antenna is tested using VNA E5071C.As a result it can be also observed in being when the size of ground plane is increased, the ripples in the main pattern diminishes.

Index Terms: Microstrip Antenna, Rectangular Patch, Ground Plane, Inset Feed, Bandwidth Enhancement, Return loss, Gain, WLAN, HFSS.

1. Introduction

Microstrip patch antenna has become a vogue, as it makes it easy to analyze and fabricate a low profile, low cost, light weight, indolent to feed and has affinity to radiation characteristics [1]. This day of age the micro patch antenna has been widely used in reflector feeds, aerospace, radars, satellite communications and wireless communications. The *versatile* of bandwidth, radiation pattern polarization and resonant frequency of patch antenna makes it unprecedented antenna.
In enabling user mobility of wireless communication system, the Wireless Local Area Network (WLAN) is popularly recognized as cost effective, viable and high speed data connectivity Solution [2]. Despite of several advantages patch antenna has some limitations like narrow bandwidth is one of its kind [3]. As depicted the various techniques have been introduced and enhanced to overcome the limitation, such as using different thickness of dielectric substrate, slot on the patch and modified ground plane[4]-[11]. Disparate techniques are used to improve the bandwidth have been reported in[12],E-shaped with two parallel slots patch antenna is introduced to achieve a wide bandwidth antenna in [13] Ultra Wide Band (UWB) antenna using stepped feed, partial slotted ground , two level stair with notches in patch has been propounded. Some other design can be constructed using three different geometry shapes like E, U and H etc has been developed from a rectangular patch using dielectric substrate with higher dielectric constant shows bandwidth enhancement also reported[14]

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The purpose of this paper is to improve the performance characteristics like Band Width, VSWR, Reflection coefficient, Gain, Directivity, return loss and Efficiency of patch antenna by using different ground plane techniques for WLAN applications at 2.4 GHz. The patch was designed on substrate FR4 and inset feed line is used as feeding method due to its simplicity of realization [15][16] It has been assumed in the analysis and design of microstrip antenna that the size of ground plane is infinite. While in actual usage only a finite size ground plane can be implemented. The ultimate goal is to reduce the antenna size and the ground plane extension beyond the patch dimension to a minimum.

2. Design Consideration

2.1 Rectangular patch Antenna

In this paper the proposed rectangular patch antenna has been designed to operate at resonant frequency of 2.4 GHz with input impedance of 50Ω using FR4 substrate with ε_r = 4.4, lose tangent δ = 0.02 and thickness h = 1.6 mm. The patch antenna parameters are calculated from the following standard antenna design equation [17] at reference resonant frequency.

Nomenclature

C Speed of light in vacuum/free-space/air
v_0 Phase-velocity of signal
f Frequency
h Substrate height
y_0 Inset feed depth
L Actual length of patch antenna
L_{eff} Effective length of patch antenna
W_f Feed width
g Notch gap
W Width of microstrip patch antenna
Z_0 Characteristic impedance
ε_r Dielectric constant of substrate
ε_{re} Effective dielectric constant
λ Wavelength of signal in free-space
λg Guided wavelength of signal

Step 1: Specifications:

Table 1. Design Specifications of an Antenna

Input Parameters	Specifications
Frequency operation	2.4GHz
Input impedance	50Ω
VSWR	< 2
Return loss	>=9.54dB
Reflection coefficient	<=-9.54dB
Directivity	6-8 dB
Gain	4-6 dB

Step 2: Substrate selection:

Substrate in patch antenna is principally needed for the mechanical support of antenna metallization. For providing this support a substrate with dielectric material is needed, which effects the electrical performance of the antenna. The characteristics of substrates i.e., dielectric constant, loss tangent and their variation with temperature and frequency are to be considered for the selection of substrate. Table 2. Provides characteristics of different substrates

Table 2. Characteristics of different substrates

Name	Relative premitivity (ε_r)	Dielectric tangent loss (δ)
ART-Duriod	2.2	0.0009
Teflon	2.09	0.001
Flame Retardant-4 (FR-4)	4.4	0.02
Gold	1	0
Plexi glass	3.4	0.001

Similarly, other physical properties like resistance to chemicals, tensile and structural strengths, flexibility are important for fabrication process. FR-4 was picked as the substrate material because of the low cost and easy to fabricate. The dimensions of the inset feed patch antenna are determined using equations in following steps by considering the FR-4 as substrate material with thickness of 1.6 mm. h=1.6mm, $\varepsilon_r = 4.4$

Step 3: Calculation of Width (W):

Width of the patch antenna is calculated by using

$$W = \frac{c}{2f_0\sqrt{(\varepsilon_r + \frac{1}{2})}} \quad (1)$$

Where $c = 3 * 10^8 m/s$

Step 4: Calculation of Actual Length (L):

The effective length of patch antenna depends on the resonant frequency (f_0).

$$\mathrm{L_{eff}} = \frac{\mathrm{c}}{2\mathrm{f_0}\sqrt{\varepsilon_{\mathrm{reff}}}} \quad (2a)$$

Where

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon_{\mathrm{r}}+1}{2} + \frac{\varepsilon_{\mathrm{r}}-1}{2}\left[1 + 12\frac{\mathrm{h}}{\mathrm{W}}\right]^{-\frac{1}{2}} \quad (2b)$$

The effective length of patch antenna is equal to the one half of a wave length within the dielectric medium. The E-fields at the edges of the patch undergo fringing effects. As a result of these effects, effective length of the patch antenna appears to be greater than its actual length. So, actual length of the patch antenna is usually considered as $L < \lambda/2$.

Actual length and effective length of a patch antenna can be related as

$$L = L_{eff} - 2\Delta L \quad (3)$$

Where ΔL is a function of effective dielectric constant ε_{reff} and the width to height ratio $\left(\frac{W}{h}\right)$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Step 5: Calculation of Inset feed Depth (y_0):

The edge of the patch antenna will have high input impedance. Impedance falls rapidly if the inset position is moved from edge of the patch towards the center. For providing impedance matching with a 50Ω connector, a curve fit formula for the inset feed depth y_0 is expressed as

$$y_0 = 10^{-4}\{0.016922\varepsilon_r^7 + 0.13761\varepsilon_r^6 - 6.1783\varepsilon_r^5 + 93.187\varepsilon_r^4 - 682.69\varepsilon_r^3 + 2.561.9\varepsilon_r^2 - 4043\varepsilon_r + 6697\}\frac{L}{2} \quad (5)$$

Step 6: Calculation of feed width (W_f):

To achieve 50Ω characteristic impedance, the required feed width to height ratio$\left(\frac{W_f}{h}\right)$ is computed as

$$\frac{W_f}{h} = \begin{cases} \frac{8e^A}{e^{2A}-2} & \frac{W_0}{h} \leq 2 \\ \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} & \frac{W_0}{h} \geq 2 \end{cases} \quad (6a)$$

Where

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r + 1}{\varepsilon_r - 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad (6b)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}} \quad (6c)$$

Step 8: Calculation of notch gap (g):

Resonant frequency of patch antenna depends on the notch gap (g).Expression which relates notch gap and resonant frequency is given by

$$g = \frac{v_0}{\sqrt{2*\varepsilon_{reff}}}\frac{4.65*10^{-12}}{f_0(in\ GHz)} \quad (7)$$

With the help of these formulae all the parameters that are required to design an antenna are obtained. With the help of design equations the dimensions of the single patch are calculated and shown in Table 3.

Table 3. Dimensions of the Patch Antenna

Description	Value (mm)
Width of the Patch(W)	38.036
Length of Patch(L)	29.443
Width of Microstrip feed(W_f)	3.059
Notch gap (g)	0.2
Inset feed depth(y_0)	9.044

Considering the ground plane dimensions i.e., Length and Width of substrate as 6h+L and 6h+W (short edge), along with the dimensions in Table 3. a patch antenna is drawn. It is simulated using HFSS 13.0and fabricated by photo lithography. Patch is tested using VNA E5071C.

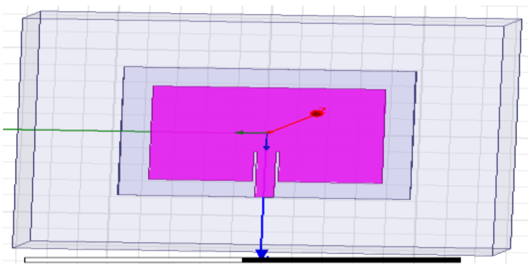

Fig.1.Top view of an inset fed short edge patchantenna

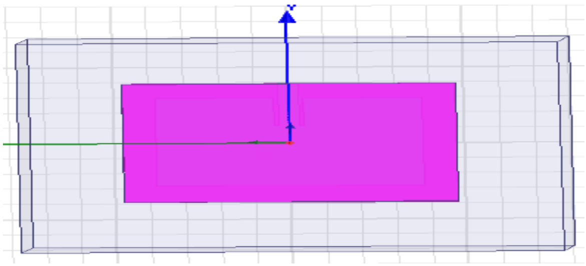

Fig.2.Bottom view of an inset fed short edge patch antenna

2.2 Bandwidth and Gain enhancement using ground plane techniques

To improve the gain and Bandwidth ground plane dimensions are varied as double ground (2L,2W) and triple ground (3L,3W). Fig. 10 and fig. 11 shows the fabricated patches with ground plane dimensions as double ground (2L,2W) and triple ground (3L,3W) respectively. Along with gain other parameters like Reflection coefficient, VSWR and directivity are observed.

3. Simulation Results and Discussion

In this section, simulated and fabricated frequency responses were presented in respect of reflection coefficient, Voltage Standing Wave Ratio (VSWR), directivity, gain and bandwidth of the proposed antenna with different ground plane techniques are presented. As the design is intended to operate at 2.4GHz resonant frequency, simulation is performed on fixed inset length or position. Simulated and analysed using HFSS 13.0 and fabricated by photo lithography. The proposed antenna is tested using VNA E5071C

3.1 Simulated results of antenna with short edge

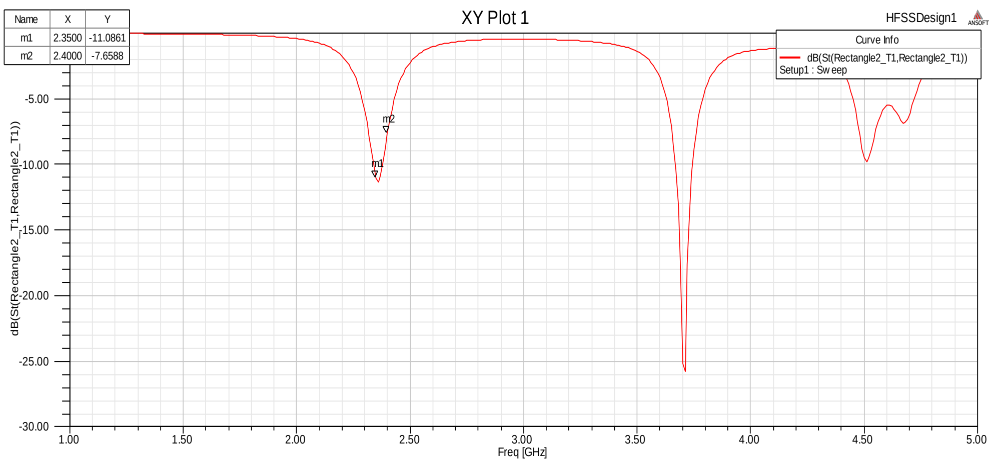

Fig.3.Reflection coefficient curve (s_{11}) $indB$ for inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+W.

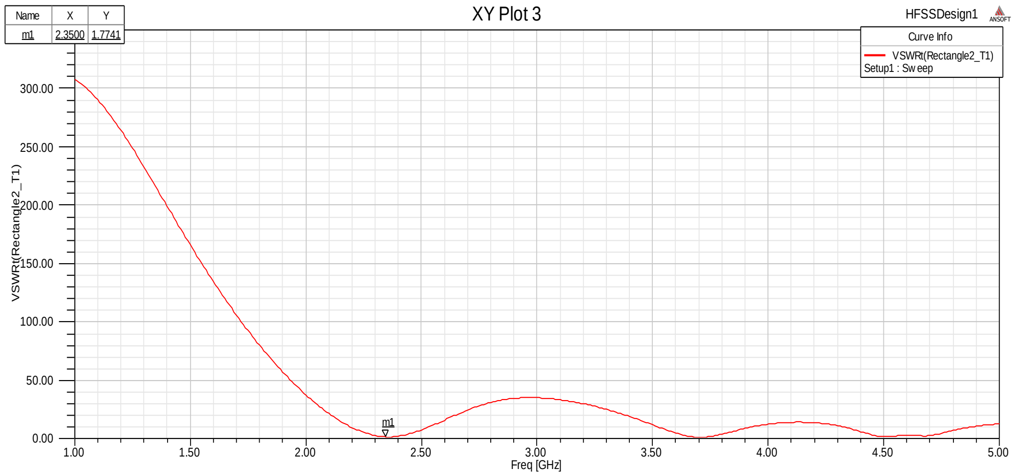

Fig.4.VSWR Curve for inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+W

Fig.5.Fabricated inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+w

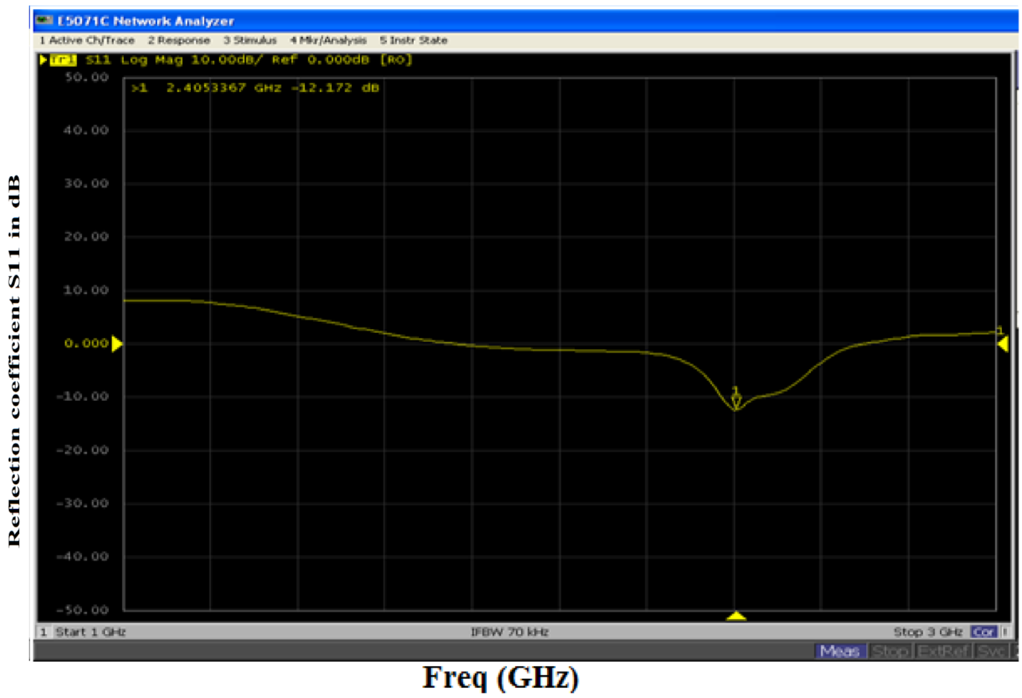

Fig.6.Reflection coefficientcurve (s_{11}) $indB$of the fabricated inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+W

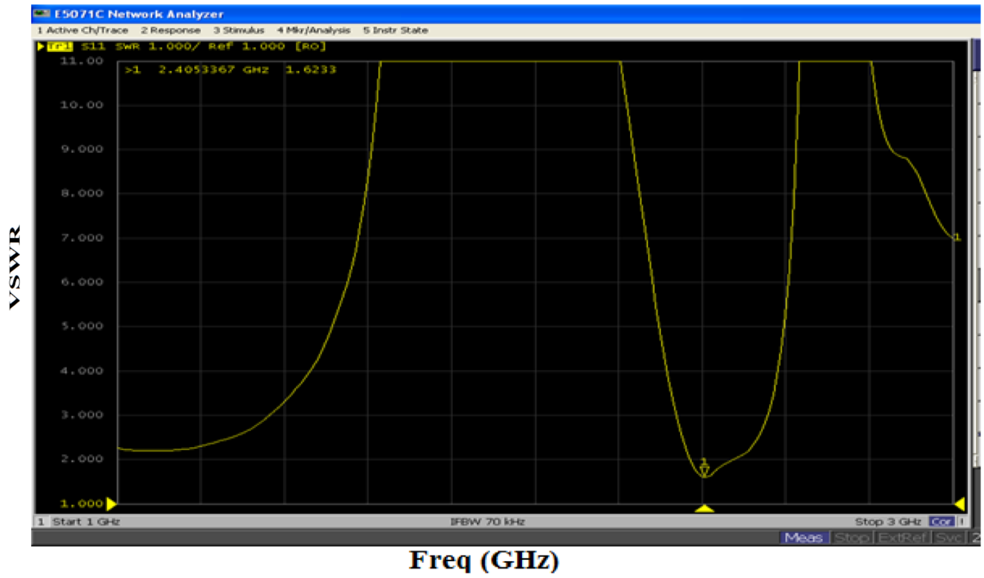

Fig.7.VSWR curve of the fabricated inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+W Gain and directivity of an inset fed short edge patch antenna is shown in Figure 8 and Figure 9. respectively.

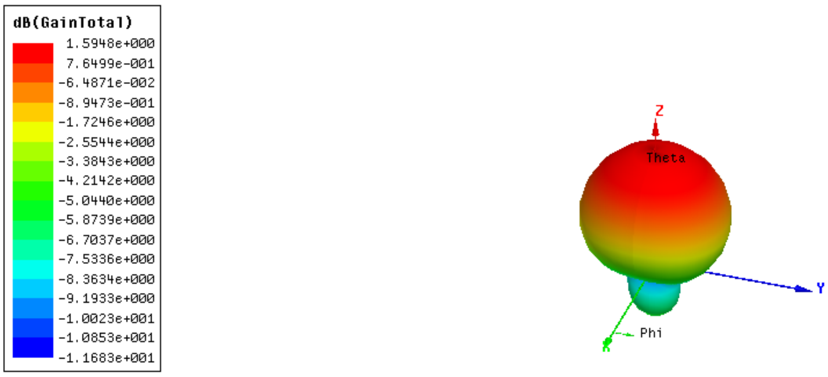

Fig.8.Gain plot of the inset fed short edge patch antenna with ground plane dimensions 6h+L and 6h+W

Fig.9.Directivity plot of the short edge inset fed rectangular antenna with ground plane dimensions 6h+L and 6h+W

From Fig. 8 and Fig. 9. The gain and directivity of the patch are noticed to be only 1.5948dB and 4.8815dB at 2.4 GHz respectively.

From the above simulation and practical results for the proposed patch antenna with short edge (6h+L, 6h+w) ground plane dimension is given in table 4.

Table 4. Parameters of Short Edge Dimensions.

GROUND PLANE DIMENSIONS		
Short Edge (6h+L, 6h+w)		
Resonant Frequency in GHz	Simulated	2.4
	Measured	2.4053
Reflection coefficient (S11) in dB	Simulated	-13.151
	Measured	-12.172
VSWR	Simulated	1.5642
	Measured	1.6233
Gain in dB	Simulated	1.5948
Directivity in dB	Simulated	4.8816
Band Width in MHz	Simulated	61.7
Efficiency (%)	Simulated	32.6

To improve the gain, ground plane dimensions are varied as double ground (2L, 2W) and triple ground (3L, 3W). Fig. 10 and fig. 11 shows the fabricated patches with ground plane dimensions as double ground (2L, 2W) and triple ground (3L, 3W) respectively. Along with gain other parameters Reflection coefficient, VSWR and directivity are observed. The simulated results using HFSS 13.0 and the measured values using VNA E5071C are given in Table 4.

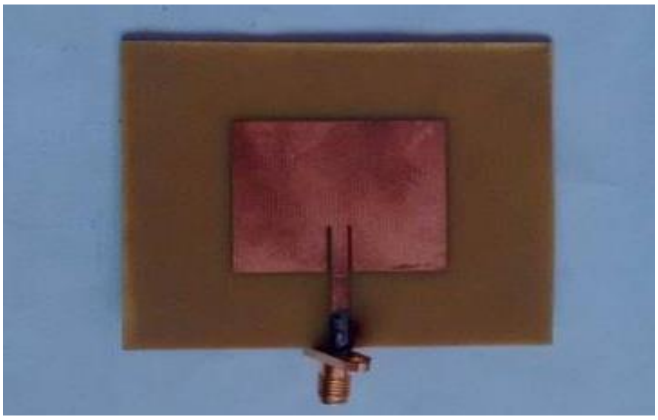

Fig.10.Fabricated inset fed patch antenna with double ground plane.

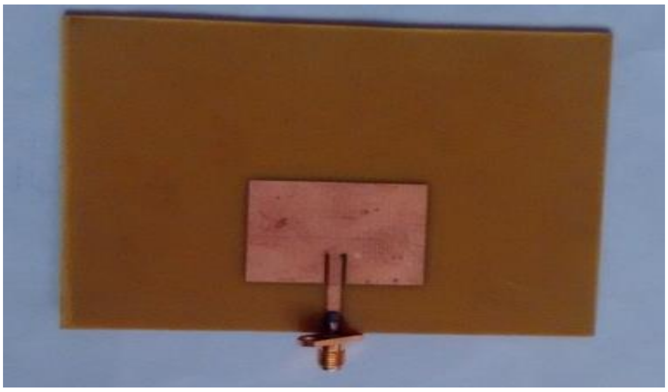

Fig.11.Fabricated inset fed patch antenna with triple ground plane.

From the above simulation and practical results for the proposed patch antenna with Double Ground (2L, 2W) plane dimension is given in table 5.

Table 5. Parameters of Double Ground Dimensions.

GROUND PLANE DIMENSIONS		
Double Ground (2L,2W)		
Resonant Frequency in GHz	Simulated	2.4
	Measured	2.4078
Reflection coefficient (S11) in dB	Simulated	-18.531
	Measured	-19.75
VSWR	Simulated	1.21162
	Measured	1.2344
Gain in dB	Simulated	2.6495
Directivity in dB	Simulated	5.7486
Band Width in MHz	Simulated	109.2
Efficiency (%)	Simulated	46.08

From the above simulation and practical results for the proposed patch antenna with Triple Ground (3L, 3W) plane dimension is given in table 6.

Table 6.Parameters of Triple Ground Dimensions.

GROUND PLANE DIMENSIONS		
Triple Ground (3L,3W)		
Resonant Frequency in GHz	Simulated	2.4
	Measured	2.4078
Reflection coefficient (S11) in dB	Simulated	-20.215
	Measured	-25.705
VSWR	Simulated	1.2687
	Measured	1.0797
Gain in dB	Simulated	3.0524
Directivity in dB	Simulated	6.648
Band Width in MHz	Simulated	120.4
Efficiency (%)	Simulated	45.91

From the above simulation and practical results for the proposed patch antenna with short edge (6h+L, 6h+w), Double Ground (2L, 2W) ,Triple Ground (3L, 3W) plane dimensions are compared and are given in table 7.

Table 7. Comparison of Parameters in Patch Antenna for Ground Plane Variations.

GROUND PLANE DIMENSIONS				
Antenna Parameters		**Short Edge (6h+L, 6h+w)**	**Double Ground (2L,2W)**	**Triple Ground (3L,3W)**
Resonant Frequency in GHz	Simulated	2.4	2.4	2.4
	Measured	2.4053	2.4078	2.4078
Reflection Coefficient (S11) in dB	Simulated	-13.1508	-18.5306	-20.2146
	Measured	-12.172	-19.75	-25.705
VSWR	Simulated	1.5642	1.21162	1.2687
	Measured	1.6233	1.2344	1.0797
Gain in dB	Simulated	1.5948	2.6495	3.0524
Directivity in dB	Simulated	4.8816	5.7486	6.648
Band Width in MHz	Simulated	61.7	109.2	120.4
Efficiency (%)	Simulated	32.6	46.08	45.91

From Table 7 by varying ground plane dimensions from short edge (6h+L, 6h+w) to triple ground (3L, 3W) there is an improvement in Return Loss from -13.15 dB to -20.2146 dB at 2.4 GHz and also a gain improvement from 1.5948dB to 3.0524dB is observed. It is observed that bandwidth increases from 61.7MHz to 120.4MHz along with that it is noticed that efficiency is also improved. For further improvement of gain and directivity, number of radiating elements should be increased. Hence an antenna array is designed.

4. Conclusions

The single band microstrip patch antenna operating at 2.4GHz with different ground plane techniques has been designed. The proposed antenna design with Triple ground was found to have better operating band width 120.4MHz and considerable reduction in reflection coefficient which is -20.2146 dB which indicates better impedance matching. Gain has been enhanced from 1.59 to 3.05 and directivity improved from 4.88 to 6.64. Patch antenna is simulated and analyzed using HFSS 13.0 and fabricated by photo lithography. The proposed antenna is well suitable for WLAN applications and this is a new technique, very limited data is available in the literature as if now.

This confirms that the design of ground plane with suitable dimensions along with the patch design is important for optimization of parameters. Yet this gain is not sufficient in long distance communications. To overcome this problem, patch arrays and different patch shapes with different feed networks will be considered.

References

[1] D. M. Pozar, Microwave Engineering, 2nd Edition, John Wiley and Sons,New York, USA, 1998.

[2] A. B. Mutiara, R. Refianti, Rachmansyah, “Design of Microstrip Antenna for Wireless Communication at 2.4 GHz,” Journal of Theoretical and Applied Information Technology, Vol. 33, No.2,30th November 2011

[3] Kin-Lu Wong, Compact and Broadband Microstrip Antennas,Copyrightc 2002 John Wiley & Sons, inc.

[4] Ali A. Dheyab Al Sajee and Karim A. Hamad, “Improving Bandwidth Rectangular Patch Antenna Using Different Thickness of Dielectric Substrate,” ARPN Journal of Engineering and Applied Sciences, Vol. 6, No. 4, April 2011

[5] Hatem H. Abbas and Jabar S. Aziz, “Bandwidth Enhancement of Micro-Strip Patch Antenna,” Journal of Mobile Communication 4 (3):pp.54-59, 2010

[6] E. Sivakumar, Srinivasa Rao O, A. V. M. Manikandan, Bandwidth enhancement of rectangular microstrip patch antenna using slots,”IQSR Journal of Electronics and Communication Engineering (IQSRJECE),Volume 6, Issue 1 PP 07-10, (May.-Jun.2013),

[7] Mimi Aminah, Nurfaridah Saman, and Hany AbdEl-Raouf, “Simulationand Design of Wide-Band Patch Antenna for Wireless Technology,” Proc. EuCAP 2006, Nice, France, ESA SP-626, October 2006

[8] Panchatapa Bhattacharjee, Vivek Hanumante, Sahadev Roy, “Design of U-Slot Rectangular Patch Antenna for Wireless LAN at 2.45 GHz,” 9th International Conference on Microwaves, Antenna, Propagation and Remote Sensing, ICMARS - 2013, 11th -14th December, 2013.

[9] Ms. Priyankan Doesarkar, Prod. Mrs. S.A. Shirsat, “Bandwidth Enhancement of Microstrip Antenna Using Partial Ground,” International Journal of Scientific & Engineering Research, Volume 4, Issue 11, November-2013

[10] Abishek Viswanathan, Rajasi Desai, “Applying Partial-Ground Technique to Enhance Bandwidth of a UWB Circular Microstrip Patch Antenna,” International Journal of Scientific & Engineering Research, Volume 5, Issue 10, October-2014.

[11] S. Satthamsakul, N. Anantrasirichai, C. Benjangkaprasert and T. Wakabayashi, “Rectangular Patch Antenna with Inset Feed and Modified Ground-Plane for Wideband Antenna,” SICE Annual Conference 2008, August 20-22, 2008

[12] Fan Yang, Xue-Xia Zhang, Xiaoning Ye, and Yahya Rahmat-Samii,“Wide-Band E-Shaped Patch Antennas for Wireless Communications,” IEEE Transactions on Antennas and Propagation, Vol. 49, No. 7, July 2001.

[13] Rajesh Kr. Raj, Sanjay Gurjar, Mayank Sharma, “Design of Stair and Slotted UWB Antenna using Stepped-Feed with Modified Slotted Ground Plane,” International Journal of Computer Application (0975-8887), National Seminar on Recent Advances in Wireless Networks and Communications, NWNC-2014

[14] Atser A. Roy, Joseph M. Mom, Gabriel A. Igwue, “Enhancing the Bandwidth of a Microstrip Patch Antenna using Slots Shaped Patch,” American Journal of Engineering Research (AJER), Volume-02, Issue-09, pp-23-30.

[15] M. Ramesh and YIP KB, “Design Formula for Inset Fed Microstrip Patch Antenna,” Journal of Microwaves and Optoelectronics, Vol. 3, No. 3, December 2003.

[16] Liton Chandra Paul, Nahid Sultan, “Design, Simulation and Performance Analysis of a Line Feed Rectangular Micro-Strip Patch Antenna,” International Journal of Engineering Sciences & Emerging Technologies, Volume 4, Issue 2, pp: 117-126, Feb. 2013.

[17] C. A. Balanis, Antenna Theory, Analysis and Design, Third Edition, John Wiley and Sons, New York, USA, 1997.

[18] Gaurav Walia, Kuldip Pahwa, “The Effect Of Variation in Notch Width on Return Loss of Inset – Fed Rectangular Microstrip Patch Antenna for Wi-Fi Applications,” International Journal of Current Engineering and Technology, Vol.3, No.1, March 2013.
[19] Mahdi Ali, Abdennacer Kachouri and Mounir Samet, “Novel method for planar microstrip antenna matching impedance,”Journal of Telecommunications, Volume 2, Issue 2, May 2010.
[20] Hayat Errifi, Abdennaceur Baghdad, Abdelmajid Badri and Aicha Sahel, “Radiation Characteristics Enhancement of Microstrip Triangular Patch Antenna using Several Array Structures,” I.J. Wireless and Microwave Technologies, vol. 3, pp: 1-17, May 2015.

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