Simulation and Fabrication of Single Element Rectangular Microstrip Patch Antenna for WiMAX Applications

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Abstract

This paper presents a single element rectangular microstrip patch antenna for worldwide interoperability for microwave access (WiMAX) applications. This antenna was designed to obtain high directivity with better gain and minimum return loss. The proposed antenna was designed for 2.5GHz frequency using Computer Simulation Technology (CST) software and then fabricated using copper material for the ground plane, patch, and feeding part and Isola FR408 material for the substrate. In experiments, the proposed antenna was tested using simulation parameters and a network analyzer. The proposed antenna was tested at different frequencies, including 2.5GHz, 4.5GHz, and 9.1GHz. The performance of the proposed antenna was measured in terms of return loss, gain, and directivity. Experimental results demonstrated that the rectangular patch antenna provided a return loss of –25.16dB at 2.5GHz with the use of a dielectric substrate with a $\mathcal{E}_r$ value of 4.4 and 1.5 mm height. Also, the gain of the antenna was 4.4144dB. Moreover, the resonant frequency of the designed antenna ranged from 2 to 4GHz, which is suitable for WiMAX applications.

Keywords: *Antenna fabrication, Microstrip antenna, Patch antenna, WiMAX, Network analyzer.*

1. Introduction

In recent times numerous wireless devices are used in our regular life. The antennas used in these wireless digital devices should be lightweight, simply mountable and must have a broad bandwidth [1]-[3]. These requirements can be achieved by using microstrip antennas and patch arrays. According to Balanis[4], an antenna should be low profile, simple and inexpensive to fabricate and it should be easy to mount on planar and non-planar surfaces. The microstrip patch antennas have the above advantages.

A microstrip patch antenna is a single layer design, which contains mainly four parts – such as patch, ground plane, substrate, and feeding part. This type of antenna is simple in construction and feed by a conventional microstrip line. The microstrip patch antenna can any shape but rectangular and circular configurations are frequently used. The ground plane of the patch can be finite or infinite according to the models (such as transmission line model, cavity model, and full-wave) used for the analysis of dimensions.

There are few microstrip patch antennas are designed for wireless devices. Tager et al.[5] designed an Industrial, Scientific, and Medical radio (ISM) band smart antenna system with4-element microstrip linear array along with the Butler matrix beamforming network. This antenna was designed in a completely planar structure without affecting power losses. However, this antenna is only focused on the ISM band. In [6], a microstrip patch antenna was studied and the results were simulated using IE3D simulator with an operating frequency of 3 GHz. AleksanderSynak et al.[7] designed a patch antenna for ultra-high frequency (UHF) applications. In[8], TruptiIngale et al. designed and simulated a rectangular microstrip patch antenna for 2.34 GHz operating frequency. However, this antenna was not tested under the real environment. H. Errifi et al.[9] designed and simulated a rectangular microstrip patch array using Ansoft-High Frequency Structure Simulator (HFSS). The performance of 2 elements, 4 elements, 8 elements, and 16 elements patch arrays was compared with a single patch for the same operating frequency. These antenna arrays are designed for an operating frequency of 10 GHz. In [10], a 16 element rectangular microstrip patch array antenna was designed using a particle swarm optimization method based on IE3D. This inset feed linearly polarized rectangular microstrip patch antenna array with sixteen elements was focused on S-band applications. SachinJadhav et al.[11] introduced a small rectangular and circular microstrip patch antenna for 2.4 GHz radio band applications such as mobile phone Bluetooth and its implementation is done using adhesive copper tape. The above review of microstrip patch antenna designs shows that there is a need for a microstrip patch antenna designfor WiMAX applications. Moreover, most of the existing microstrip patch antenna designs are not fabricated and tested for real environment requirements.

In this paper, we design and fabricate a single element rectangular microstrip patch antenna using copper and Isola FR408 materials for WiMAX applications. The proposed antenna is designed to obtain a high directivity, with better gain and minimum return loss, which is required for WiMAX applications. This paper is organized as follows. Section 2 explains the proposed single element rectangular microstrip patch antenna design and fabrication. Section 3 describes the experimental results and finally, Section 4 concludes the paper.

2. Antenna Design

2.1 Design Equations of a Single Element Rectangular Microstrip PatchAntenna

The three essential parameters for the design of therectangular microstrip patch antenna are:

(i) Frequency of operation (f_0) = 2.5GHz

(ii) The dielectric constant of the substrate (ε_r) = 4.4

(iii) Height of dielectric substrate ( ) = 1.5mm

Step 1: Calculation of width of the Microstrip patch antenna

The width(W) of the Microstrip patch antenna is calculated using Eqn. (1)

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

Step 2: Calculation of effective dielectric constant (ε_{reff})

The effective dielectric constant computed using Eqn. (2)

$$\varepsilon_{reff} = \frac{\varepsilon_r}{} + \sqrt{1 + 12} \qquad (2)$$

Step 3: Calculation of effective length (L_{eff}) of the patch

The effective length of the patch is calculated from Eqn. (3)

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon}} \qquad (3)$$

Step 4: Calculation of the length of extension

The length of extension is calculated from Eqn. (4)

$$\Delta L = \frac{0.412h\ (\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.2\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Step 5: Calculation of the actual length of patch

The actual length of the patch is computed from Eqn. (5)

$L = L_{eff} - 2\Delta L$ (5)

Step 6: Calculation of the width of the ground plane

The width of the ground plane is computed using Eqn. (6)

$W_g = 6h + W$ (6)

Step 7:Calculation of the length of the ground plane

The length of the ground plane is computed using Eqn. (7)

$$L_g = 6h + L \quad (7)$$

Using the above design Equations (1)- (7), the proposed antenna is designed using CST software. The CST STUDIO SUITE screenshot of the proposed single element rectangular microstrip patch antenna is shown in Figure 1.

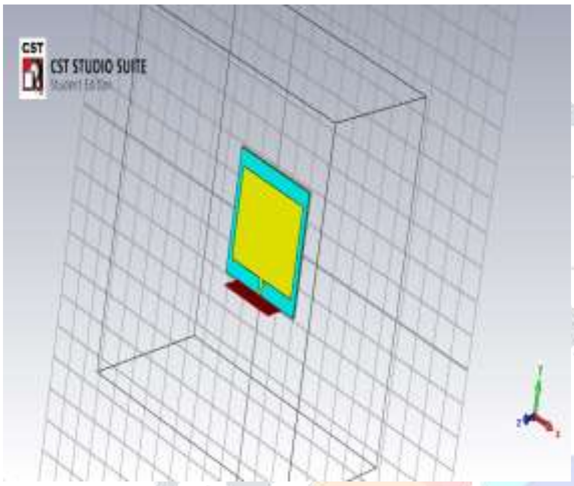


Figure 1. The CST STUDIO SUITE screenshot of the proposed single element rectangular microstrip patch antenna

2.2 Fabrication of Single Element Rectangular Microstrip Patch Antenna

In the antenna fabrication process, we have used copper (annealed) material for the ground plane, patch, and feeing part and Isola FR408 material for the substrate. The benchmark for the selection of substrates is based on its price, efficiency, and physical size. Minimum size is achieved by using a foam substrate. However, it is costlier and losses are higher in it, even the efficiency is much less than other materials. Maximum efficiency is achieved in Roger 4350, but the size and price are the issues in it. An optimal solution is an FR-4 substrate, but it dependents the design requirement. The substrate can also be made with Roger's material. Considering the cost of the material, availability, and efficiency we have designed with Isola FR408.

The proposed antenna is designed at 2.5GHz frequency and can be used in WiMAX applications. At 4.5GHz frequency,the same antenna model can serve for a wide range of Ethernet and C band applications. At 9.1GHz frequency, the same antenna model can be used for lower Ultra-Wide Band (UWB) applications. The fabricated single element rectangular microstrip patch antenna is shown in Figure 2.

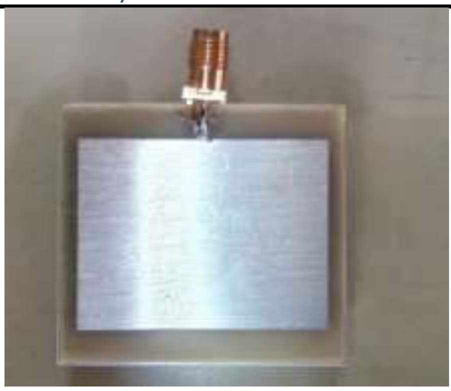
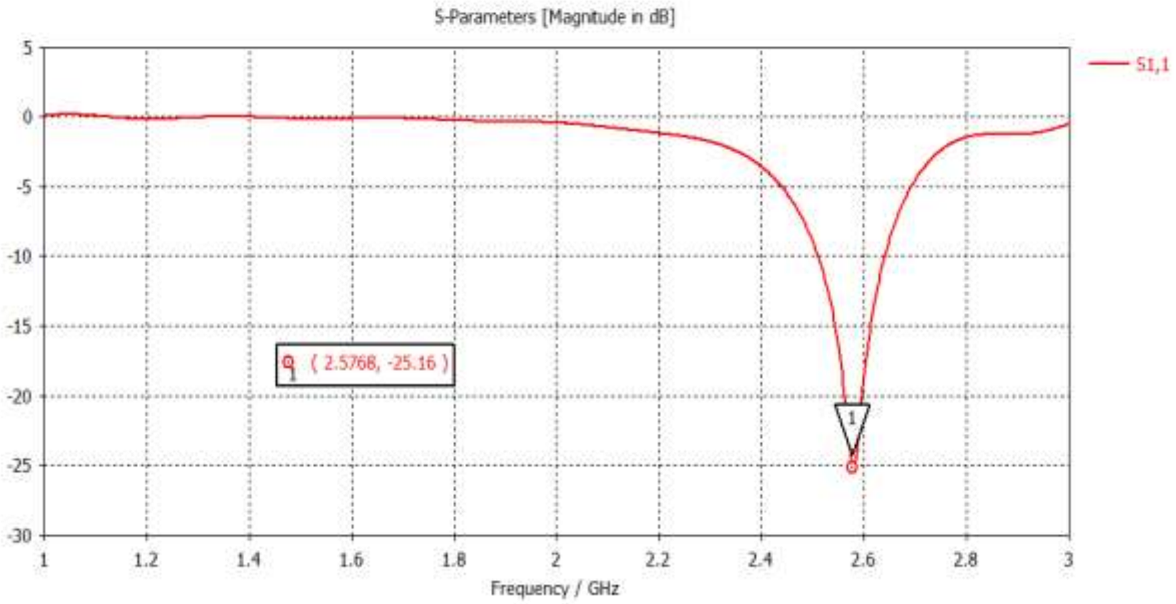


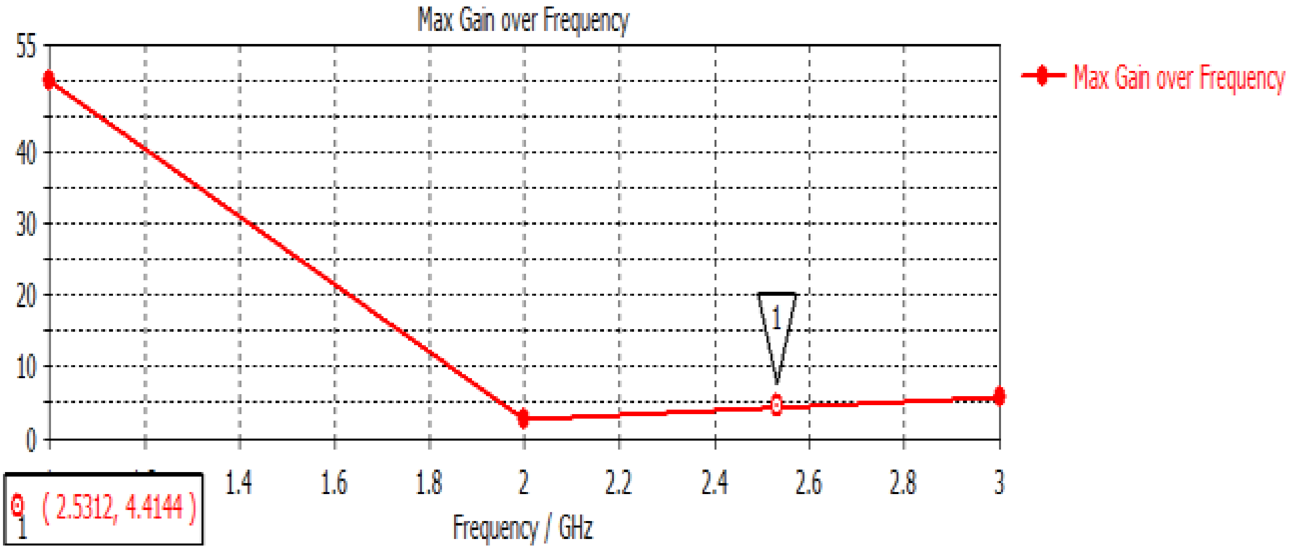
Figure 2.The fabricated single element rectangular microstrip patch antenna.

3. Results & Discussion

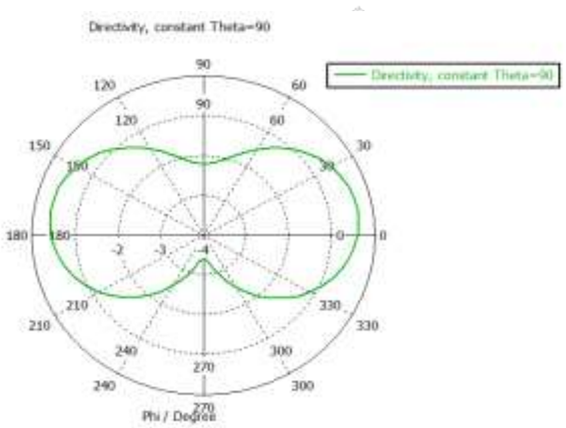
The proposed antenna was designed using CST MW studio software. The designed antenna was fabricated and testing was done using simulation performance measures and a Network Analyzer. In experiments, performance measures such as return loss, gain, directivity, and Voltage Standing Wave Ratio (VSWR) were computed for 2.5GHz, 4.5GHz, and 9.1GHz frequencies. The return loss, gain, directivity, and VSWR plots of the proposed antenna at 2.5 GHz is shown in Figure 3. From Figure 3, the return loss is found to be -25.16dB at 2.5GHz and the gain is found to be 4.4144dB. The return loss, gain, directivity, and VSWR plots of the proposed antenna at 4.5 GHz and 9.1GHz frequencies are shown in Figures 4&5.



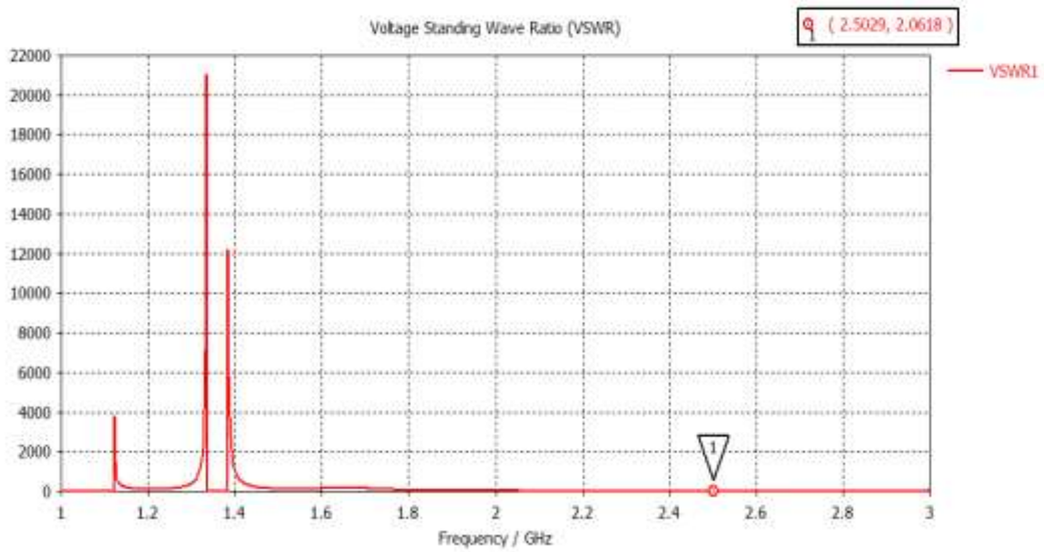
(a)



(b)

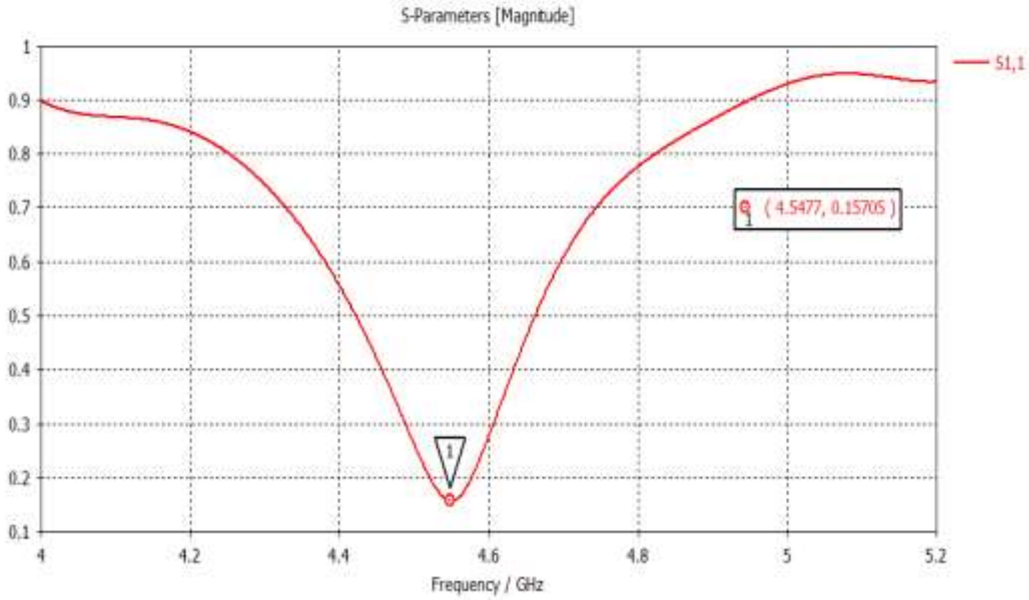


(c)

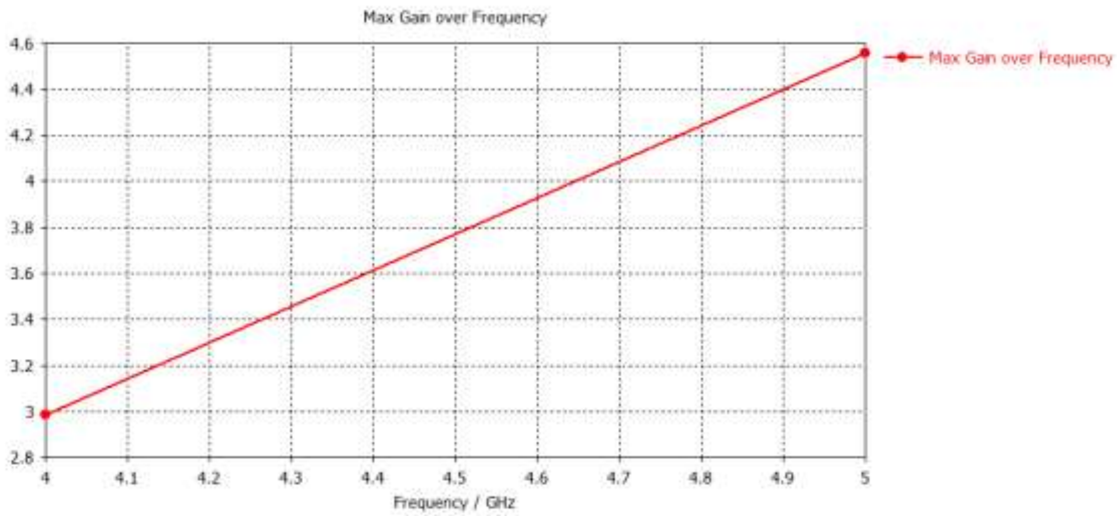


(d)

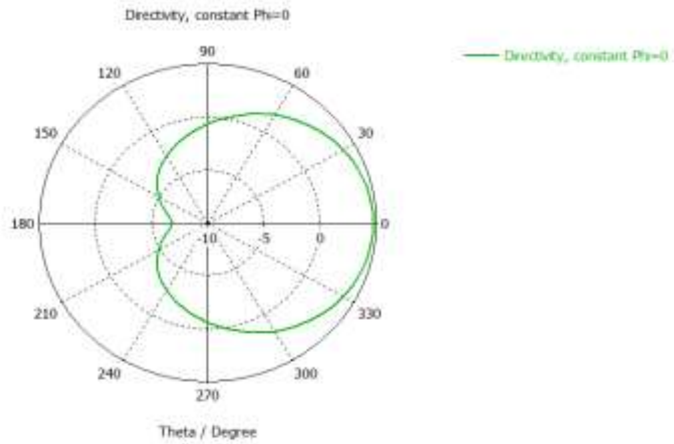
Figure 3. Performance measures of the proposed antenna at 2.5 GHz frequency. (a) Return loss, (b) Gain plot, (c) Directivity plot, (d) VSWR plot.


S-Parameters [Magnitude]
S1,1
(4.5477, 0.15705)
Frequency / GHz

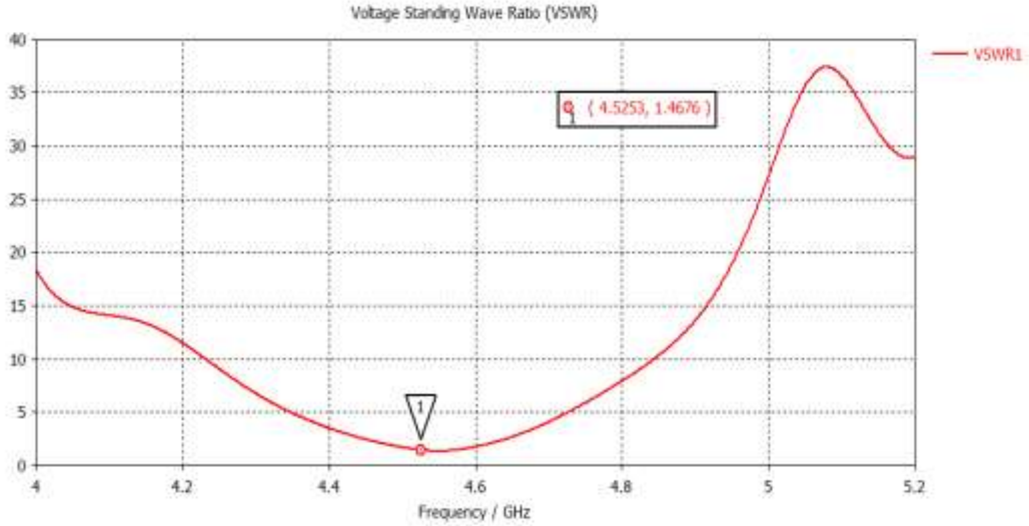
(a)


Max Gain over Frequency
Max Gain over Frequency
Frequency / GHz

(b)

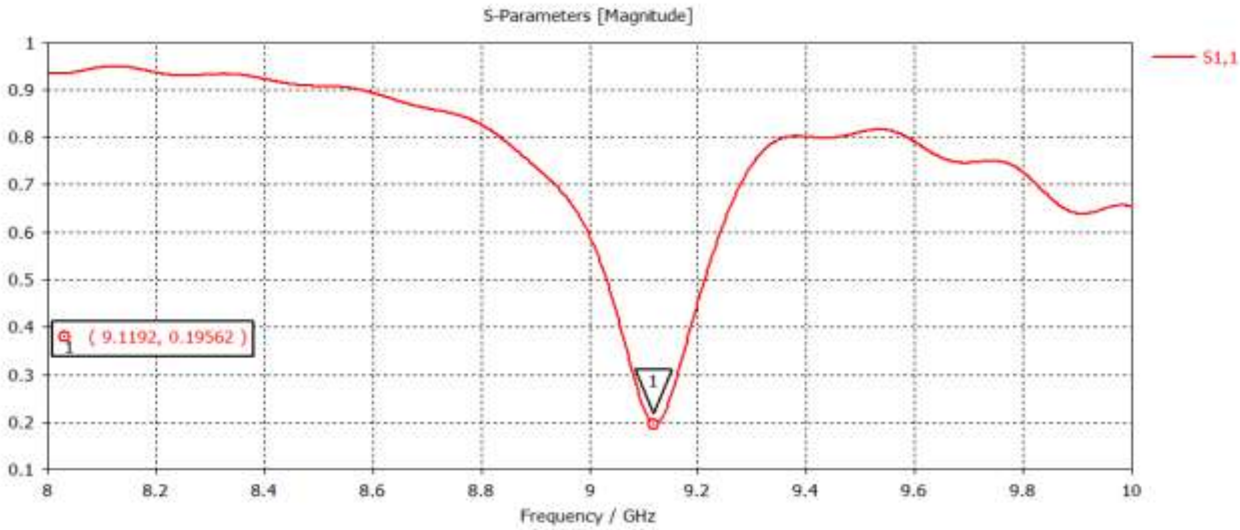

Directivity, constant Phi=0
Directivity, constant Phi=0
Theta / Degree

(c)

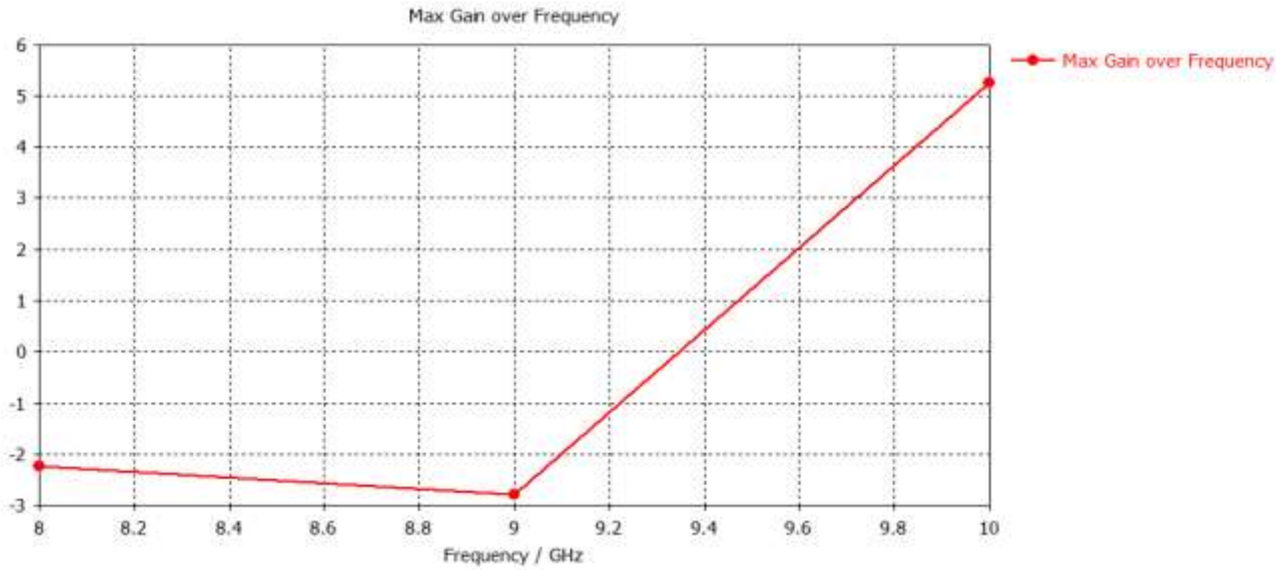


(d)

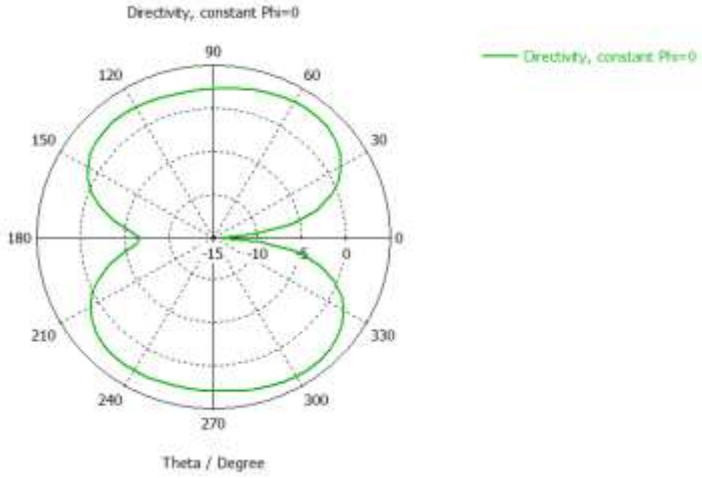
Figure 4. Performance measures of the proposed antenna at 4.5 GHz frequency. (a) Return loss, (b) Gain plot, (c) Directivity plot, (d) VSWR plot.



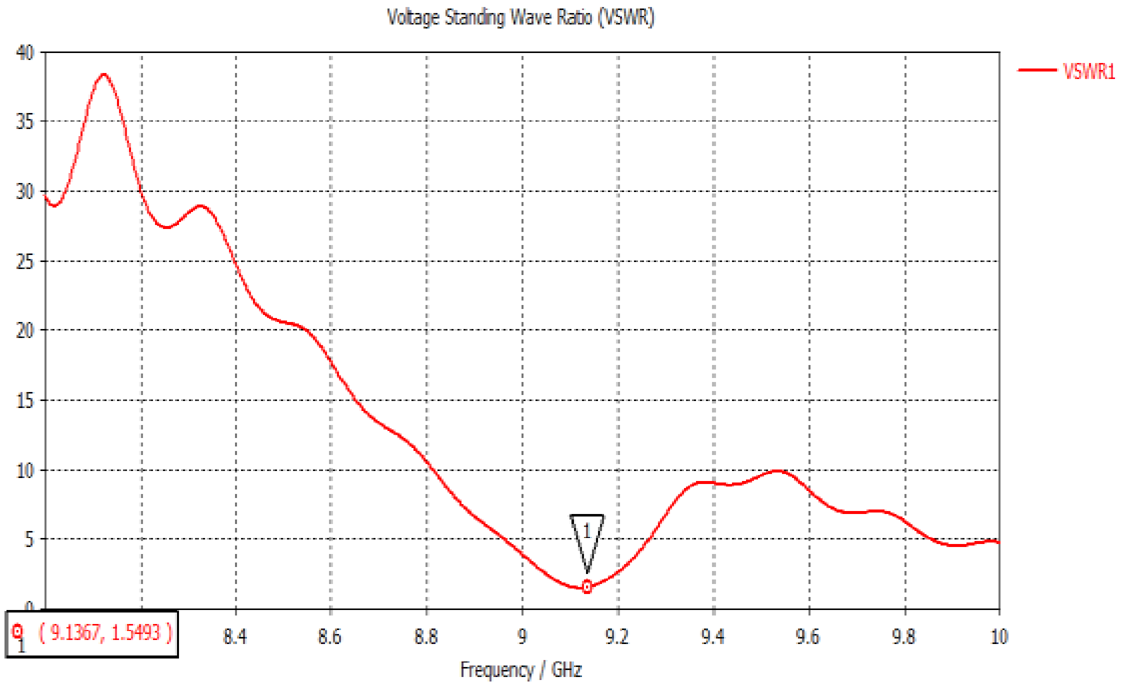
(a)



(b)



(c)



(d)

Figure 5. Performance measures of the proposed antenna at 9.1 GHz frequency. (a) Return loss, (b) Gain plot, (c) Directivity plot, (d) VSWR plot.

The fabricated antenna was tested using a network analyzer. The sample photographs ofthe testing process of thefabricated rectangular patch antenna using a network analyzer are shown in Figure 6. The complete testing results are summarized in Table 1. The testing results of the fabricated antenna using a network analyzer confirm the efficiency of the proposed antenna.

(a)

(b)

Figure 6. Testing of the fabricated antenna using a network analyzer. (a) Return loss measurement, (b) VSWR measurement.

Table 1. Proposed antenna's performance measurement using a network analyzer

PARAMETERS	Values
Gain	4.4dB
Directivity	4.062dBi
VSWR	2.061
Return Loss	-25dB
Radiated Efficiency	-1dB
TotalEfficiency	-11dB

4. Conclusion

A single element rectangular microstrip patch antenna for WiMAX applications was designed and tested. The performance of the proposed antenna was tested using simulation parameters as well as a network analyzer. The experimental results show that the designed antenna achieved a gain of 4.4144 dB with a return loss of –25.16 dB at 2.5 GHz frequency. To confirm the effectiveness of the proposed antenna the performance measures at 2.5 GHz are compared with 4.5 GHz and 9.1 GHz frequencies. Furthermore analysis, the antenna was tested by a network analyzer. The testing results by the network analyzer confirm that the designed antenna can be used for real environment WiMAX applications.

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