Dual Band Microstrip Semicircular Slot Patch Antenna for WLAN and WIMAX Applications

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Abstract. *A dual band microstrip antenna for WIMAX and WLAN applications is analyzed and presented in this paper. The proposed antenna has semicircular slot in patch and Defected Ground Structure (DGS) technique for the improvement of its bandwidth and gain. Computer Simulation Technology (CST) software is used to design and simulate the performance characteristics. The proposed antenna has the dimensions as* $28 \times 26.6\,mm^2$. *The fabricated antenna provides a good reflection coefficient of –48 dB and –44.5 dB at a center frequency of 3.4 GHz and 5.5 GHz. Gain achieved by the antenna is 2.72 dB and 3.87 dB for WLAN and WIMAX application. Good agreements have been found between simulated and measured results. These results confirm that the fabricated antenna is very promising for WLAN and WIMAX applications.*

Keywords

WLAN, WIMAX, dual-band, DGS, CST

1. Introduction

Nowadays microstrip patch antennas are very demanding specifically in wireless communication applications, due to their several advantages like having simple structures, small size, low cost and easy fabrication. WLAN and WIMAX antennas are in trend for internet access in portable devices. However, microstrip antennas have several limitations such as having low gain, low efficiency as well as narrow impedance bandwidth. Modern communication networks are essential in the present day and age, for people to exchange information. In modern communication multiband antennas are on pivot consideration because multiband services are available in a single antenna [1]. Antennas play a vital role in communication which includes voice and video calling as well as texting in an easy manner. Microstrip antenna is very advantageous for portable devices and high data rate. Modern communication relies on miniaturization of communication technology, high data rate transfer and good operational efficiency. According to IEEE 802.11/ WLAN and 802.16/ WIMAX standards, researchers have proposed several antennas [2]. In designing antennas, parameters like low VSWR, high bandwidth, low reflection coefficient and good gain should be considered. WLAN and WIMAX antennas are in demand due to their dynamic properties like moderate to high data rate and internet access over a long range [3].

Many antennas had been designed by researchers for WIMAX and WLAN application. For instance, in [4] double inverted F-shaped dual wideband microstrip antenna for WLAN, WiMAX wireless communication is designed. To achieve good gain and bandwidth, two U-shaped patches on a same plane are joined and finally forming an inverted F antenna through modifying the length of patches. Reflection coefficient of –39.125 dB and –41.073 dB is obtained at respective resonant frequencies. In [5] a complementary split ring triple band antenna for WIMAX and WLAN application is proposed. Very low reflection coefficient of –15 dB, –15 dB and –20 dB is observed at pivot frequencies of 2.45 GHz, 3.56 GHz and 6.62 GHz respectively. An Inverted U-shaped radiating patch antenna is discussed for LTE/WIMAX applications in [6]. In [7] microstrip feed antenna for ISM and WLAN application is presented. In [8] a MIMO antenna is designed for WLAN and WIMAX application. In [9] an inkjet-printed antenna for WIMAX/WLAN application is proposed. Designed antenna can work at 2.42 GHz and 2.36 GHz, 3.64 GHz in on and off state respectively. In [10] a circularly polarized parasitic wide slot square patch antenna is designed. Radiation efficiency of 93% is obtained in frequency region. A circularly polarized antenna operating at 3.5/5.8 GHz is discussed in [11]. Antenna gives 3dB axial ratio of 3.1% and 4.3% at respective operating frequencies. A fork shaped patch with inverted U-shaped element for WLAN and WIMAX application is designed in [12]. Antenna is designed to work at 3.3–3.69 GHz and 5.15–5.25 GHz for dual band operations. A miniaturized metamaterial antenna for WLAN and WIMAX application is proposed in [13]. A single band monopole antenna for

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WIMAX application is proposed in [14]. Antenna operates at central frequency of 3.3 GHz with a maximum gain of 1.5 dBi is obtained. For gain enchantment and minimum reflection coefficient, array technique is applied in [15], [16] for WLAN and WIMAX application. A very low VSWR antenna is proposed in [17] for WIMAX application. Peak gain of 2.15 dBi is obtained at 3.5 GHz. VSWR of approximately 1 is obtained. In [18] a SIW cavity double line antenna for WLAN operation is designed. Proposed antenna resonates at 5.27 GHz. Good gain of 5.824 dB is achieved at central frequency. Proposed antennas show good agreements in term of bandwidth, gain and reflection coefficient for desired applications. In [19] a circularly polarized antenna for wireless application is proposed. In [20], a circularly polarized dual band antenna is proposed. Dual band and circular polarization is obtained by introducing square and L-shape slot in patch. Antenna operates at dual band 2.4–2.48 GHz and 5.25–5.85 GHz for WLAN and WIMAX. In [21] a cylindrical dielectric antenna with operating frequency at 3.75 GHz is proposed for WIMAX/WLAN applications. Reflection coefficient of –21.55 dB is observed at central frequency.

In this paper, a dual band microstrip patch antenna is designed for WLAN and WIMAX application operating in C-band. For bandwidth and gain enhancement DGS technique is applied. Proposed antenna is simulated using CST STUDIO SUITE. FR-4 is used as a substrate with relative permittivity ($\epsilon_r = 4.3$) and tangential loss is 0.025. Antennas is excited by microstrip feed line. Good results in term of band-width (BW), gain, VSWR, reflection coefficient and radiation pattern are observed.

2. Design Methodology

The geometry of proposed dual band microstrip patch antennas is illustrated in Fig. 1. The proposed antenna has dimensions of $28 \times 26.8\,\text{mm}^2$. FR-4 material with relative permittivity $\epsilon_r = 4.3$ and $\tan\delta = 0.025$ is used as substrate. Thickness of the substrate is 1.6 mm. The journey of microstrip antenna starts after deciding its fixed parameters. Transmission line parameters can be found using following equations mentioned in [22].

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \tag{1}$$

where w is the width of the patch.

$$\epsilon_{r_{\text{eff}}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12\frac{h}{w}}} \tag{2}$$

where $\epsilon_{r_{\text{eff}}}$ is effective dielectric constant and h is the height of patch.

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{r_{\text{eff}}} + 0.3)(\frac{w}{h} + 0.264)}{(\epsilon_{r_{\text{eff}}} - 0.258)(\frac{w}{h} + 0.8)} \tag{3}$$

where ΔL is the increase in length of patch.

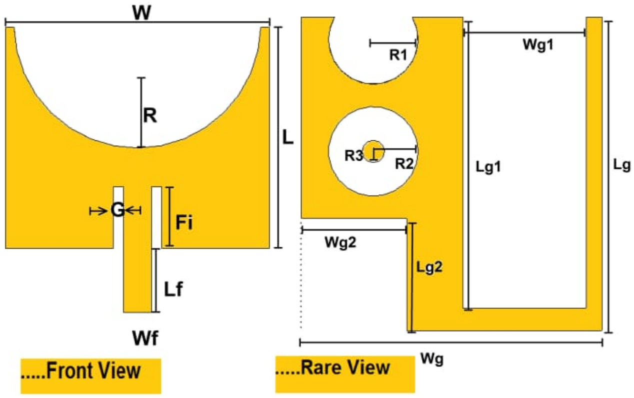


Fig. 1. Geometry of dual band semi circle slot microstrip antenna.

Parameters	W	L	R	G	F_i	L_f
[mm]	25.6	21.5	12	1	12	6.2
Parameters	W_f	R_1	R_2	R_3	L_g	W_g
[mm]	2.9	4	4	1	26.8	28
Parameters		L_{g1}	W_{g1}	W_{g2}	L_{g2}	
[mm]		26	11	9.4	10	

Tab. 1. Antenna structure dimension.

$$L = \frac{c}{2f_r\sqrt{\epsilon_{r_{\text{eff}}}}} - 2\Delta L \tag{4}$$

where L is the length of the patch.

$$L_g = 6h + L, \tag{5}$$

$$W_g = 6h + W \tag{6}$$

where L_g and W_g are length and width of ground.

A semicircular slot of radius R is removed from the radiating element. Two rectangular slots of dimension $L_{g1} \times W_{g1}$ and $L_{g2} \times W_{g2}$ are removed from the ground plane. Two circular defects of radius R_1 and R_2 are made on ground plane. Radius of inner circle is R_3. In Fig. 1, yellow colored portion shows conducting material. Mentioned parameters in Fig. 1 with dimensions are listed in Tab. 1.

3. Parametric Analysis

In order to understand the antenna performance, a parametric study is conducted. This mainly focuses on reflection coefficient for different parametric values. Parametric analysis is given on optimized values as mentioned above in Tab. 1 to achieve the dual band.

3.1 Varying Radius of Patch R

Plot of frequency versus reflection coefficient in decibels is shown in Fig. 2, after changing the values of R. From the figure it is observed that upon decreasing value of R, single-band will be observed with a low reflection coefficient. Conversely upon increasing the value of R, very narrow and shifted bands are observed.

3.2 Varying Radius of Circle R_1

Plot of frequency versus reflection coefficient in decibels is shown in Fig. 3, after changing the values of R_1. From the figure it is observed that upon decreasing value of R_1, dual-band will be observed with a good reflection coefficient. Conversely upon increasing the value of R_1, WLAN band shifted at lower frequency and WIMAX band shifted at higher frequency with good reflection coefficient.

3.3 Varying Radius of Circle R_2

Plot of frequency versus reflection coefficient in decibels is shown in Fig. 4, after changing the values of R_2. Decreasing R_2 leads to very narrow bandwidth and it leads to shifting center frequency ahead for WLAN band. While increasing R_2, narrow bandwidth is observed as well as center frequency being shifted behind for WIMAX band. Very good reflection coefficient is observed for both bands.

3.4 Varying Width of Slot W_{g1}

Plot of frequency versus reflection coefficient in decibels is shown in Fig. 5, after changing the values of W_{g1}. From figure it is clearly observed that the decrease in the value of W_{g1}, the central frequency shifts backward for both WLAN and WIMAX bands. Bandwidth for WLAN decreases while WIMAX's bandwidth increases. Vice versa of these results are observed when we increase the value of W_{g1}.

3.5 Varying Length of Slot L_{g1}

Plot of frequency versus reflection coefficient in decibels is shown in Fig. 6, after changing the values of L_{g1}. As we decrease the value of L_{g1} it is observed that R loss increases leading to a narrow bandwidth. Increasing the value of L_{g1} leads to the decrease in reflection coefficient.

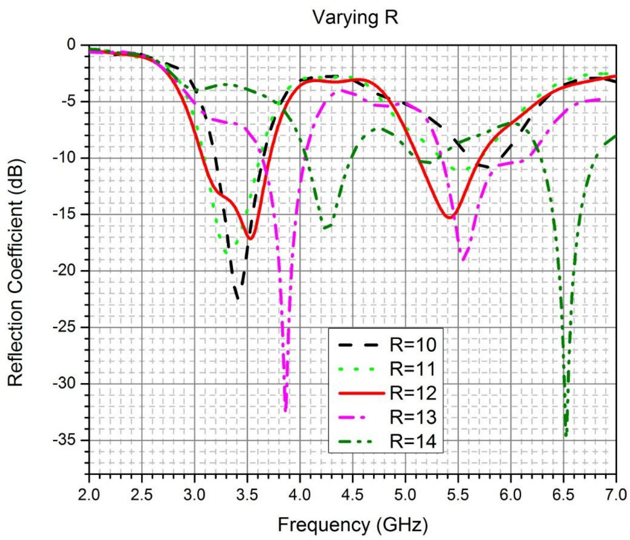


Fig. 2. S_{11} for varying values of radius of patch R.

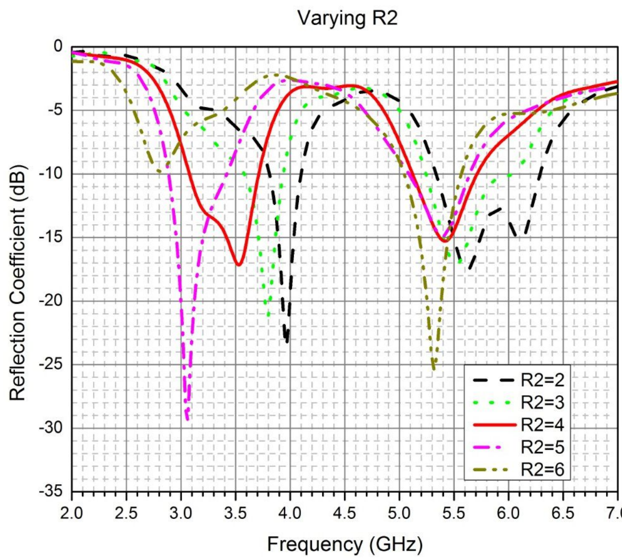


Fig. 4. S_{11} for varying values of R_2.

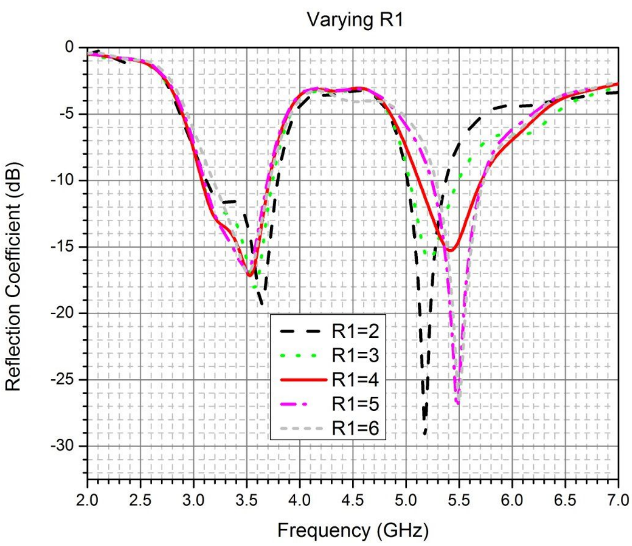


Fig. 3. S_{11} for varying values of R_1.

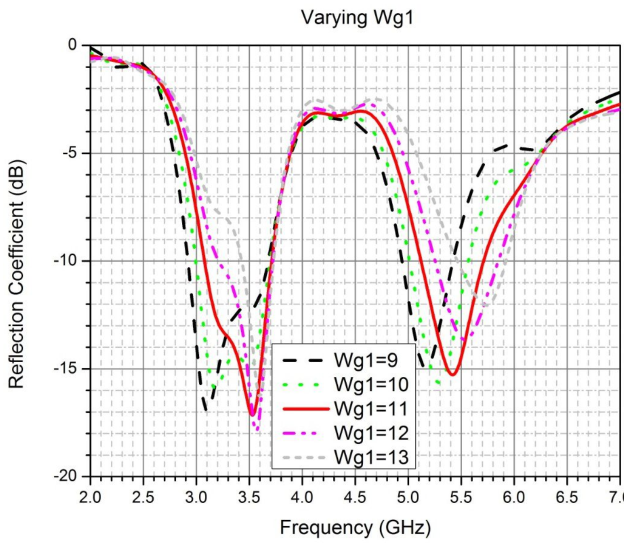


Fig. 5. S_{11} for varying values of W_{g1}.

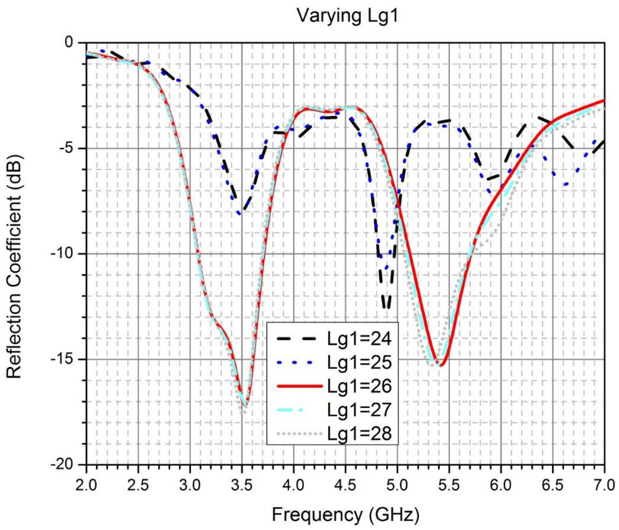


Fig. 6. S_{11} for varying values of L_{g1}.

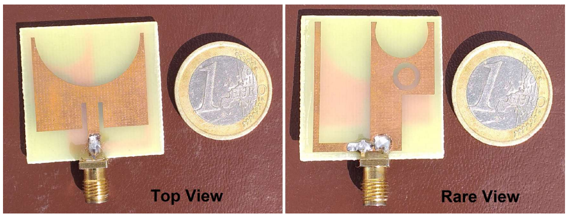


Fig. 7. Fabricated dual band microstrip patch antenna.

4. Simulated and Measured Results

The proposed fabricated prototype of dual band microstrip patch antenna for WLAN and WIMAX is depicted in Fig. 7.

4.1 Reflection Coefficient of Proposed Antenna

For WLAN and WIMAX applications, a dual band microstrip patch antenna is proposed, fabricated and tested. S-parameters were measured for the proposed antenna on VNA (Anritsu MS46122B). Figure 8 depicts a comparison of reflection coefficient of simulated and measured results. From observing Fig. 8, good comparison can be observed between measured and simulated results, which shows that the measured results hold better values and are more efficient in their working.

Simulated results show that the proposed antenna has central frequency of 3.5 GHz and 5.45 GHz with reflection coefficient < -10 dB. The antenna covers impedance bandwidth of (3.08–3.71) GHz for WLAN and (5.12–5.68) GHz for WIMAX. Reflection coefficient of prototype is measured using vector network analyzer (VNA) Anritsu MS46122B. Measured reflection coefficient at corresponding frequencies is < -10 dB, which is –48 dB at 3.4 GHz and –44.5 dB at 5.5 GHz that assures excellent impedance matching between antenna and feed line. Actual measured bandwidth covered by antenna is (3.12–3.58 GHz) 460 MHz and (5.17–5.85 GHz) 680 MHz at respective frequencies.

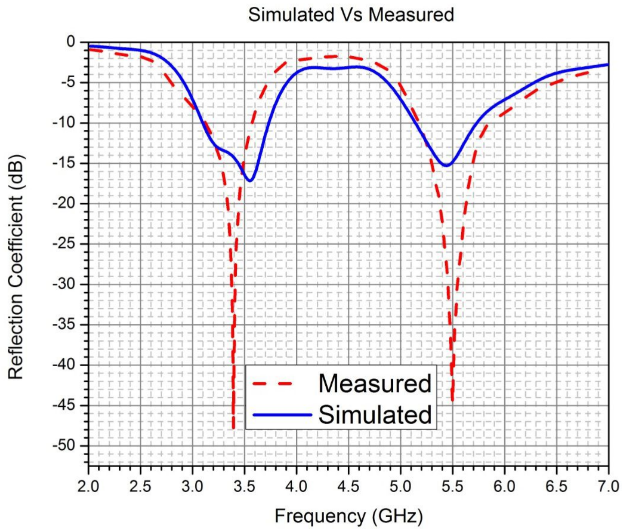


Fig. 8. Simulated and measured reflection coefficient of proposed antenna.

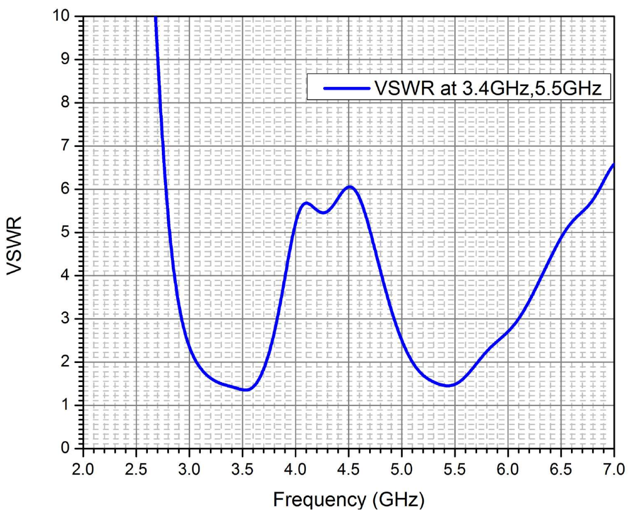


Fig. 9. VSWR of proposed antenna.

4.2 VSWR of Proposed Antenna

Simulated plot of VSWR versus frequency of dual band proposed antenna is depicted in Fig. 9. Lowest value of VSWR = 1.4, 1.5 is obtained at 3.4 GHz and 5.5 GHz respectively. This confirms that there is good impedance matching between load and antenna.

4.3 Gain of Proposed Antenna

3-D simulated gain of antenna is shown in Fig. 10 at 3.4 GHz with 2.34 dB and at 5.5 GHz with 4.35 dB. Standard gain antenna's (SGAs) were used to measure the gain of antenna. Measured gain of proposed antenna is 2.72 dB at 3.4 GHz and 3.87 dB at 5.5 GHz that shows good agreement with the simulated results. Results show that measured gain values of antenna is promising for practical applications of WLAN and WIMAX.

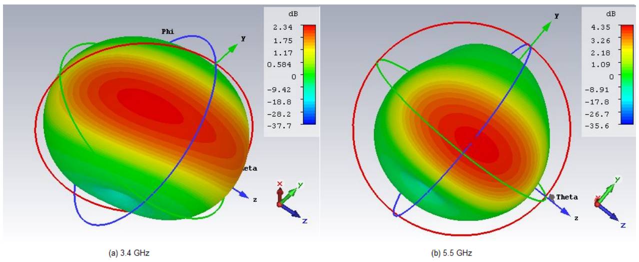


Fig. 10. 3-D simulated gain of proposed antenna at 3.4 GHz and 5.5 GHz.

4.4 Normalized Radiation Pattern

Radiation pattern measurements were carried out in anechoic chamber. Test setup image of anechoic chamber is shown in Fig. 11. Wide band horn antenna (WBHA) from 0.8 GHz to 18 GHz was used at transmitting end. To measure the far field radiation patterns, proposed antenna was mounted on Rx unit at distance of 3.4 m. Radiation patterns were measured for the azimuth and elevation plane. Step size of 2° was used within the span of 360°. A comparison between simulated and measured radiation pattern of azimuthal and elevation plane at different frequencies is depicted in Figs. 12–15.

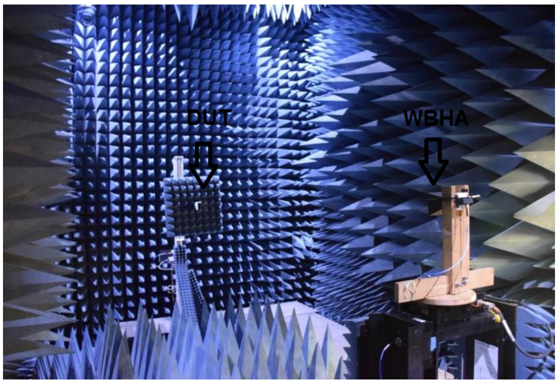


Fig. 11. Measurement setup of the radiation pattern in anechoic chamber.

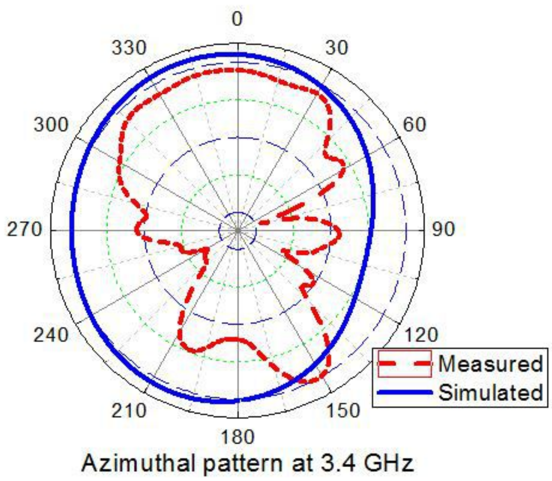


Fig. 12. Simulated and measured azimuthal plane radiation pattern at 3.4 GHz.

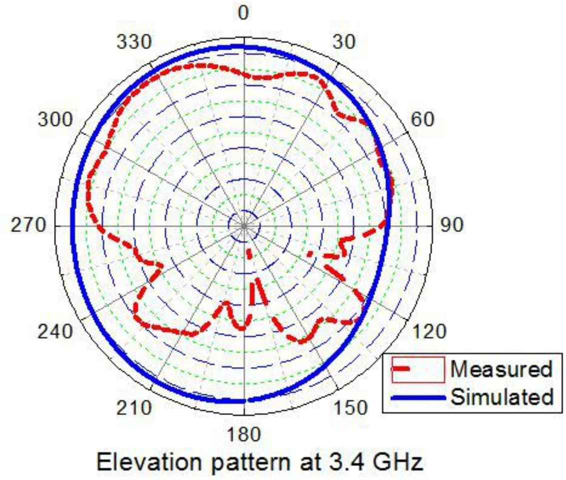


Fig. 13. Simulated and measured elevation plane radiation pattern at 3.4 GHz.

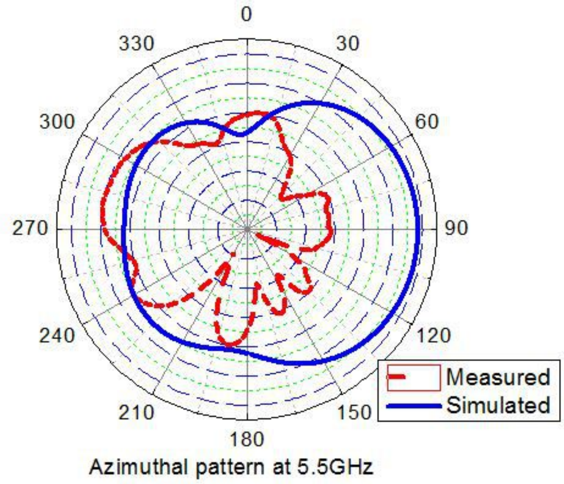


Fig. 14. Simulated and measured azimuthal plane radiation pattern at 5.5 GHz.

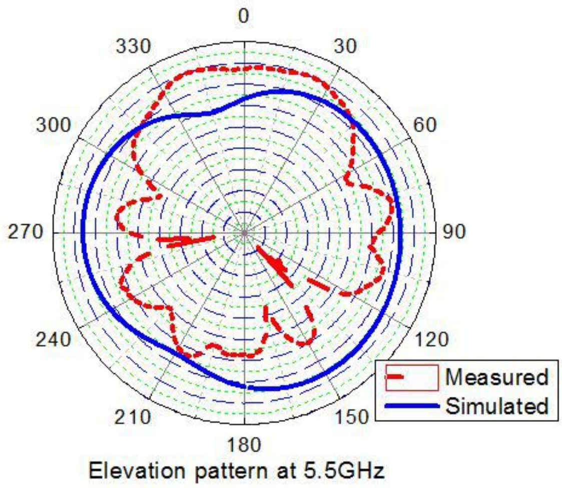
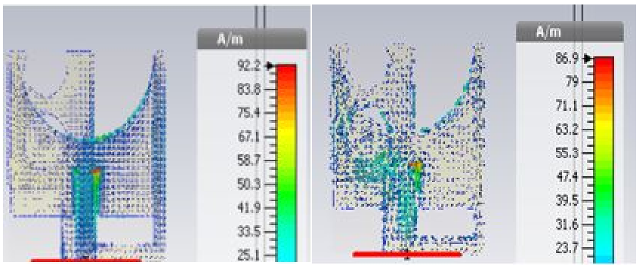


Fig. 15. Simulated and measured elevation plane radiation pattern at 5.5 GHz.



(a) 3.4 GHz (b) 5.5 GHz

Fig. 16. Simulated current distribution at 3.4 GHz and 5.5 GHz.

The simulated and measured radiation pattern of azimuthal and elevation plane at 3.4 GHz shows a good agreement, whereas the simulated and measured radiation pattern of azimutahal and elevation plane at 5.5 GHz shows a some variation due to the mis-alignment of the AUT and horn antenna.

4.5 Surface Current Density

Surface current density of proposed antenna is depicted in Fig. 16 at central frequencies that shows the basic principle of proposed antenna. The proposed antenna activates when current flows through the feedline. The WLAN band is achieved by exciting the semicircle of top structure with the right etched rectangular of bottom structure. The WIMAX band is achieved by exciting the semicircle of top structure with bottom left rectangle with etched circles.

5. Comparison with Literature

Proposed antenna has shown very promising results compared to existing work of antennas for WLAN and WIMAX applications. Overall size of the proposed antenna has reduced with good bandwidth and relatively high gain from the existing literature. The comparison with the literature work is given in Tab. 2.

6. Conclusion

The design, simulation and testing of rectangular inset feed dual band microstrip antenna for WLAN and WIMAX is carried successfully using CST STUDIO and VNA. With optimized parameters of antenna reflection coefficient of –48 dB and –44.5 dB is observed at central frequencies of 3.4 GHz and 5.5 GHz. Antenna achieves impedance bandwidth of 460 MHz and 680 MHz at central frequencies operating in C-band. Peak gain of 2.72 dB at 3.4 GHz and 3.87 dB at 5.5 GHz is measured. VSWR of antenna is < 2, validating good impedance matching between load and antenna. Thus the proposed antenna has potential to be applied for WLAN and WIMAX applications.

Ref.	**Year**	**Size in wavelength**	f_c [GHz]	**BW** [MHz]	**Gain** [dB]
[5]	2016	0.31×0.34	2.45, 3.56, 5.62	100, 66, 65	1, 5.1 5.04
[9]	2016	0.81×0.43	2.42, 2.36, 3.64	160, 180, 270	1, 0.7, 0.9
[20]	2017	0.6×0.6	2.45, 5.5	66, 121	1.94
[21]	2019	0.91×0.73	3.75	1510	3.56
Prop. Work	2021	0.57×0.54	3.4, 5.5	460, 680	2.72, 3.87

Tab. 2. Comparison table with the literature work.

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