Quad Octagon with Ground Defection Dual Band MSPA For WiMAX and WLAN Technologies

Rahmani Naveed Akhtar,[1] **Dr. Anupama A. Deshpande,**[2] **Dr. A. K. Kureshi,**[3]

[1]PhD. Research Scholar, Shri Jagdishprasad Jhabarmal Tibrewala University, Rajasthan, INDIA
[2]Professor, Shri Jagdishprasad Jhabarmal Tibrewala University, Rajasthan, INDIA
[3]Principal M. H. SabooSiddik Polytechnic, Mumbai, INDIA

Correspondence: Rahmani Naveed Akhtar; Email: rahmaninaveed2021@gmail.com

Received 3 May, 2022; Revised 27 July, 2022; Accepted 27 July, 2022
Available online 27 July, 2022 at www.atlas-tjes.org, doi: 10.22545/2022/00194

As huge number of applications have been found for a Micro-strip antenna due to its compact and small structure, a quad octagon-shaped dual-band and broadband Micro-strip antenna has been discovered for consumer applications such as (2.1GHz and 5.4GHz). This research work is obtained by combining four octagon-shaped patch structures with a micro-strip feed line and a partial ground structure. The presented microstrip antenna is suitable for providing dual-band output i.e., a frequency band from 1.672GHz to 2.788GHz and a frequency band from 4.876GHz to 6.232GHz. The resonance frequency of the projected antenna is at 2.58GHz and 5.39GHz. Results display that the antenna attains a good return loss(—S_11 —) outcome characteristics. The intended antenna can manage 1.116GHz impedance bandwidth (BW) and 50.04% & 24.41% fractional BW below -10dB making it more applicable for WiMAX and WLAN technologies. The antenna has been tested on an FR-4 substrate having a thickness of 1.6mm. The projected antenna has been also examined on CST Microwave Studio. To make the projected antenna for dual-band as well as for broadband the physical profile of four Octagon-shaped patches has been attached to the partial ground. It is important to note that transmitting with higher efficiency and lower return loss can be placed in a distant location from residential areas, which will decrease the chances of people getting affected by radiation.

Keywords: MSPA, WLAN, WiMAX, Quad Octagon Shaped Patch, DGS.

1 Introduction

Microstrip antennas are widely used in many applications such as aircraft and military because of their many advantages such as low cost, small volume, ease of implementation with circuitry, simple fabrication, and the ability to produce circular and linear polarization. The transmitting with higher efficiency and lower return loss can be placed in distant locations from residential areas, which will decrease the chances of people getting affected by radiation. The fringing fields between the patch edge and the ground plane are primarily responsible for the radiation of microstrip patch antennas. A thick dielectric substrate with a low dielectric constant is required for good antenna performance because it provides larger bandwidth (BW) [1-3], better radiation, and higher efficiency. A common configuration results in larger antenna size. To decrease the dimensions of the MSPA, substrates with large insulator constants must be used, which is inefficient and results in a narrow BW. As a result, a trade-off must be made between antenna outcomes and antenna profile [4].

The serious limitation of a narrow slot antenna is its small BW [5-8]. The BW of an antenna is enhanced by incorporating slots on the patch plane and ground plane. Those slots may change the position of transverse magnetic modes (TM10 and TM01) along with the higher modes (TM12 and TM20) [9]. For achieving broadband characteristics, micro-strip antenna with a star slot on a patch plane and a defected ground structure with Octagon Quad shaped tuning element is proposed for wireless applications (WLAN and WiMAX). They cover the BW from 1.672GHz to 2.788GHz and 4.876GHz to 6.232GHz for —S11— ¡ -10dB. In the First Stage, a four-octagon shaped microstrip antenna emerged along with star-shaped slot on a patch plane with a full ground structure has been analyzed. In the second stage, the ground structure is reshaped into defected ground structure (DGS) for analyzing the antenna. In the final stage, microstrip lines are added to the remaining three octagon-shaped patches, which can finally provide BW of 50.04% and 24.41% from band 1 and band 2 respectively.

1.1 Advantages of Microstrip Patch Antennas

Microstrip patch antennas are mostly used in wireless applications due to their low-profile structure [10-12]. Therefore, they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. Some of the principal advantages are listed below:

- Low fabrication cost allows for large-scale production due to its light weight and small volume.
- Allows for both linear and circular polarisation [13].
- A low-profile planar configuration that is easily conformal to the host surface.
- It is simple to integrate with microwave integrated circuits (MICs).
- Dual and triple frequency operation capability.
- Mechanical robustness when mounted on rough surfaces.

2 Material and Methods

2.1 Antenna Geometry

The proposed designed antenna's geometry and all dimensions are depicted below. The antenna structure presented here was designed and placed in the x-y plane, and it is symmetric about the longitudinal axis. Four Octagon-shapes have been combined to form a patch along with the 50-ohm microstrip line. Impedance matching on top of FR4 substrate (1.6mm thick) is the purpose of this component. The bottom plane of the substrate has a printed partial ground rectangular structure.

A microstrip feed line has been used to power the antenna's SMA connector. Figure 1 shows the optimized dimensions of the antennas that were developed. The whole volume of an antenna is $(60\times60\times1.6)$ mm^3.

All Optimized dimensions of the designed patch structure and partial ground structure have been displayed in Figure 1 along with the dimension labels. The antenna dimension and values are displayed in Table 1. All the values are in mm. The table consists of design parameters, like width, height, length, and gaps between different elements of patch and ground.

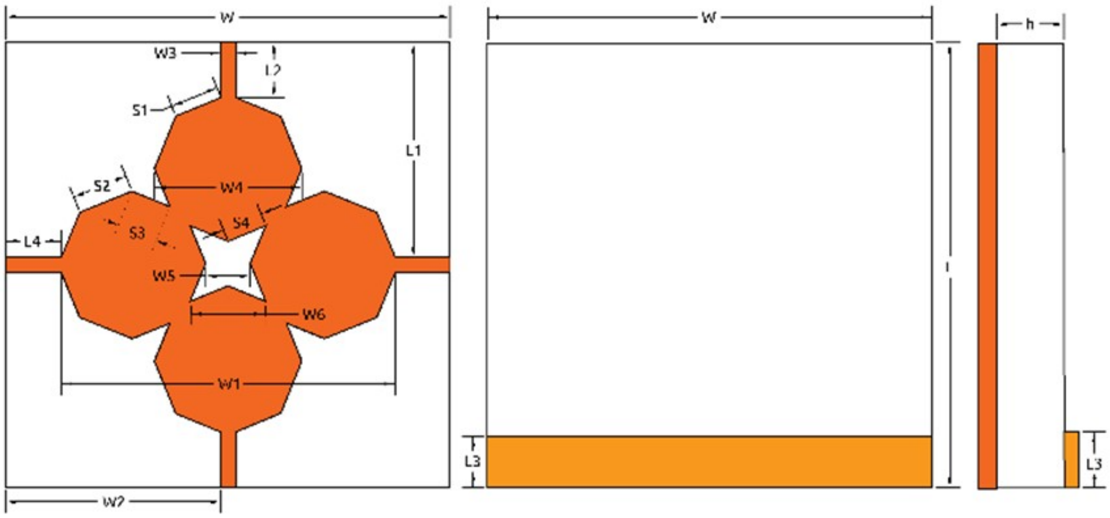

Figure 1: *Optimized designed Geometry of the Combined Patch and Ground Structure (Front, Back and Side View).*

Table 1: Antenna Design Parameter and Values

Parameter	Dimension (mm)	Parameter	Dimension (mm)
W	60	S_2	7.58
W_2	29	S_3	5.52
W_3	2	S_4	5.5
W_4	19.86	L	60
W_5	6	L_1	28.94
W_6	10	L_2	22
W_7	45	L_3	7
S_1	6.57	L_4	7.45

2.2 Antenna Evolution

In this section, we compare Antenna 1, Antenna 2, and Antenna 3. The $| S_{11} |$ in antenna 1 patch with full ground structure is not in the chosen frequency band because the impedance matching between patch and ground is not adequate (refer to figure 3 $| S_{11} |$ (dB) vs frequency (GHz)). The geometry of antenna evolution from antenna1 to antenna4 is depicted in Figure 2.

The ground structure in Antenna 2 has been made smaller in order to ensure impedance matching between Patch and ground, but the *return loss*($| S_{11} |$) curve still does not show the optimized value of impedance matching condition between Patch and ground.

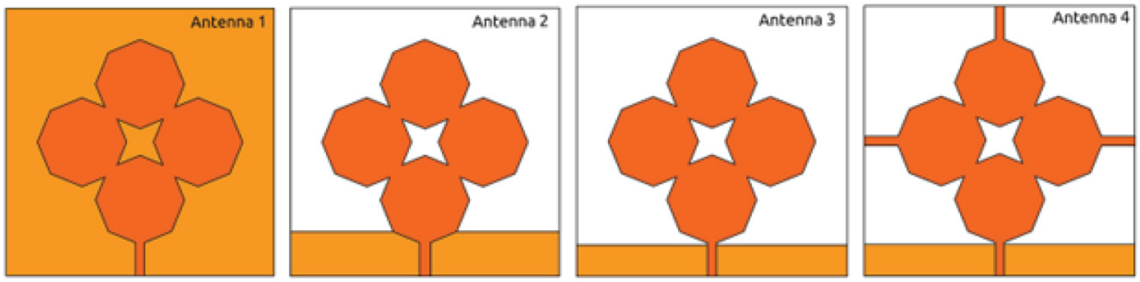

Figure 2: *Antenna Design Evolution of Quad Octagonal Patch with Defected Ground.*

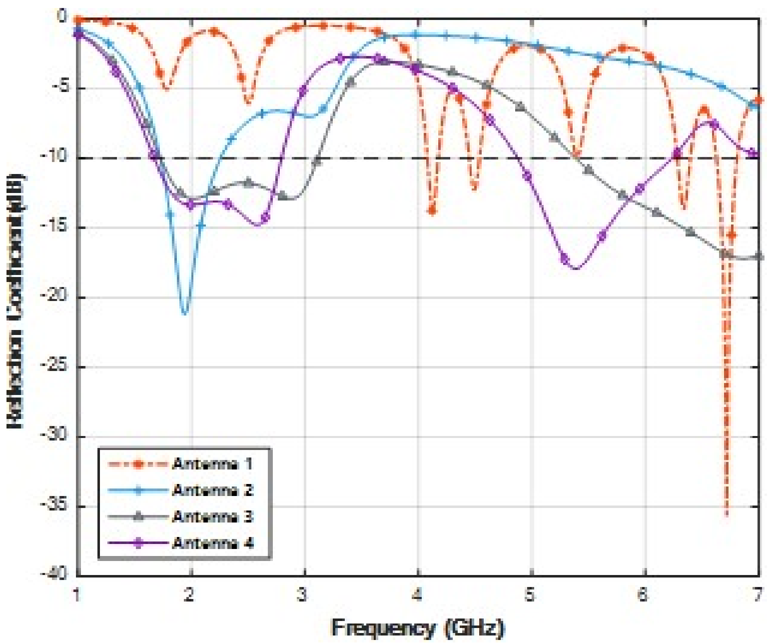

Figure 3: *Return loss(| S_{11} |) of optimized antenna 4 with antenna 1, 2 and 3.*

The ground structure in Antenna 3 has been cut down below the patch but not below the microstrip feed line. The simulation results of this antenna's *return loss*(| S_{11} |) curve show that the Impedance matching between Patch and ground has been achieved with a *return loss*(| S_{11} |) of -10dB. However, this characteristic does not reach the desired level. Every stage of antenna evolution has been simulated and the respective return loss characteristics are displayed in Figure 3. From the figure, it can be analyzed that the antenna4 has the characteristics which are suitable to find our desired application frequency band.

3 Result Analysis

The prototype of the designed fabricated antenna is displayed in Figure 4 and a comparison of calculated and experimental characteristics is displayed in Figure 5. The detailed frequency analysis is displayed in Table 2.

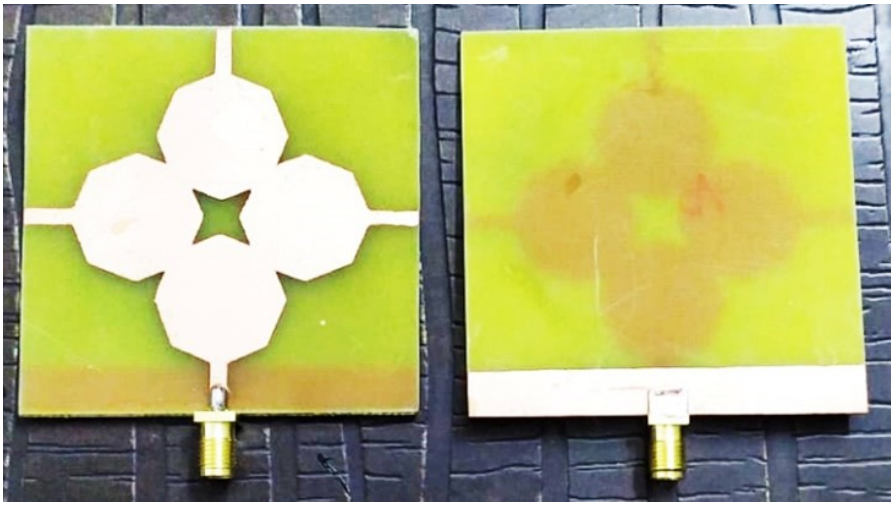

Figure 4: *Photograph of the fabricated antenna. Front view (left) and back view(right).*

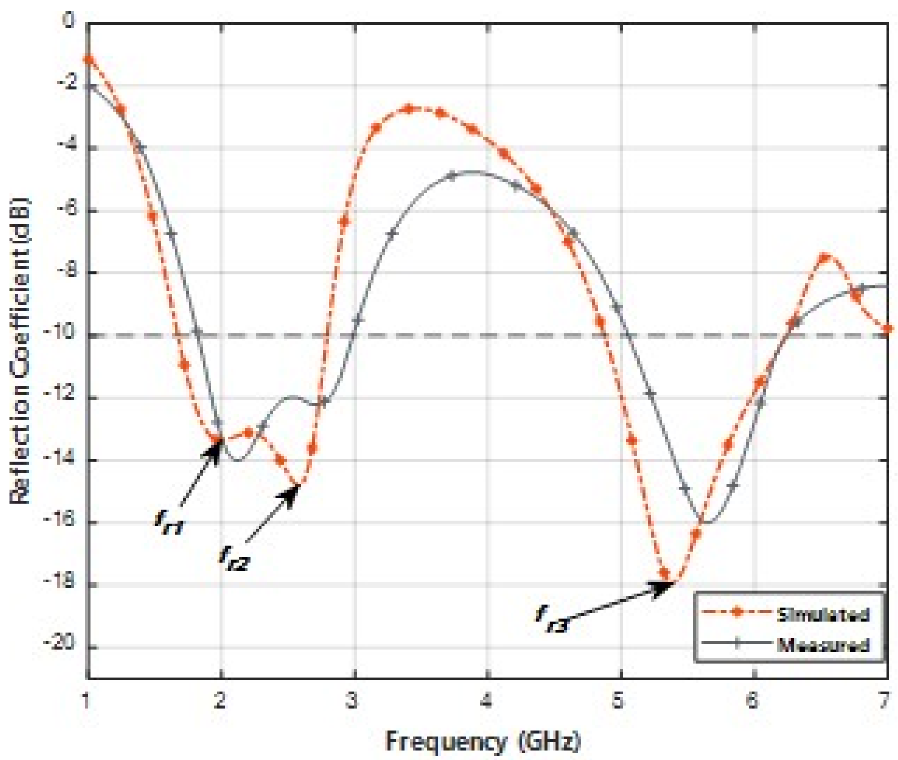

Figure 5: *Comparison of the S_{11} parameter (experimental and calculated) of QOPDG.*

Table 2: Resonance, Cutoff Frequencies, FBW and IBW of Calculated and Experimental Return loss($|S_{11}|$)

Tool	Res. Freq. (GHz)	CF ($f_L - f_H$) (GHz)	FBW (%)	IBW (GHz)
Sim.	1.996, 2.578, 5.386	1.672 - 2.788	50.05	1.116
		4.876 - 6.232	24.42	1.356
Meas.	2.114, 2.706, 5.643	1.823 - 2.983	48.28	1.160
		5.054 - 6.233	20.89	1.179

* CF – Cutoff Frequencies, FBW – Fractional BW, IBW-Impedance BW

3.1 Return Loss ($| S_{11} |$) Characteristics

S-parameter characteristics display that the optimized Antenna 4 is providing lower loss at lower cut-off frequencies 1.672GHz and 4.876GHz and the higher cut-off frequencies are 2.788GHz and 6.232GHz. So, this antenna became a dual Broadband Antenna. It can be observed that the projected antenna is resonating at 2.58GHz and 5.39GHz as shown in Figure 5.

$$\begin{aligned} \text{Antenna} \quad \text{Bandwidth} &= 2\left(\frac{f_H - f_L}{f_H + f_L}\right) \times 100\% \\ &= 2\left(\frac{2.788 - 1.672}{2.788 + 1.672}\right) \times 100\% \\ \text{Antenna} \quad \text{BW} &= 50.04\% \end{aligned}$$

The proposed antenna has provided the impedance BW of 50.04% from 1.672 to 2.788GHz frequency band.

$$\begin{aligned} \text{Antenna} \quad \text{Bandwidth} &= 2\left(\frac{f_H - f_L}{f_H + f_L}\right) \times 100\% \\ &= 2\left(\frac{6.232 - 4.876}{6.232 + 4.876}\right) \times 100\% \\ \text{Antenna} \quad \text{BW} &= 24.41\% \end{aligned}$$

From 4.876 to 6.232 GHz, the impedance BW is 24.41%. This antenna is a good candidate for WiMAX and WLAN applications due to its above dual impedance BW.

3.2 Radiation Patterns (2D and 3D)

Figure 6 depicts the 2D radiation pattern of the projected antenna. The far-field radiation pattern has E-plane and H-plane views, and from the H-plane it can be seen that the pattern is omni directional. The omnidirectional pattern is good for antenna performance.

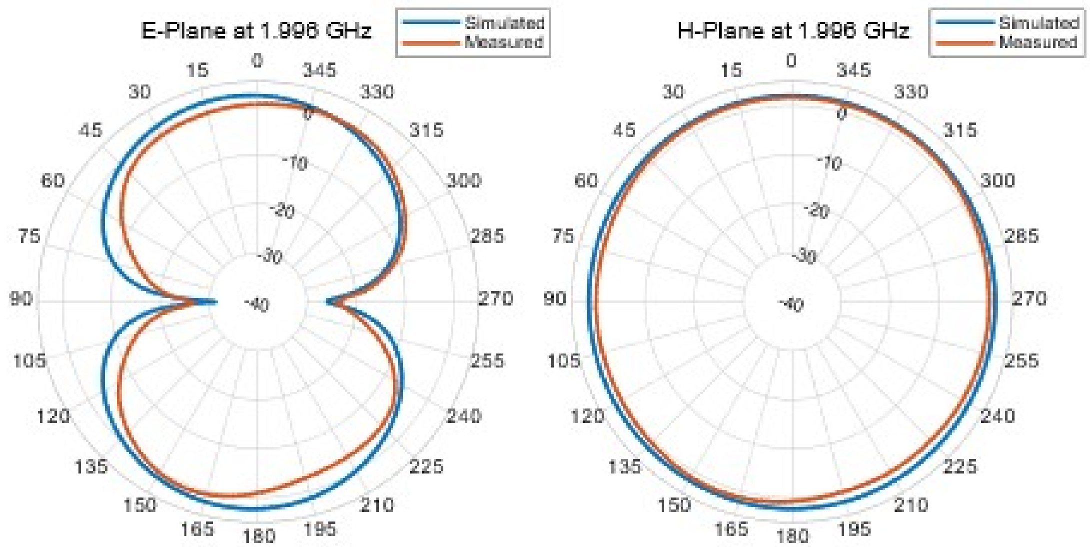

Figure 6: *2D Radiation Field Pattern at Resonating Frequency 1.996GHz.*

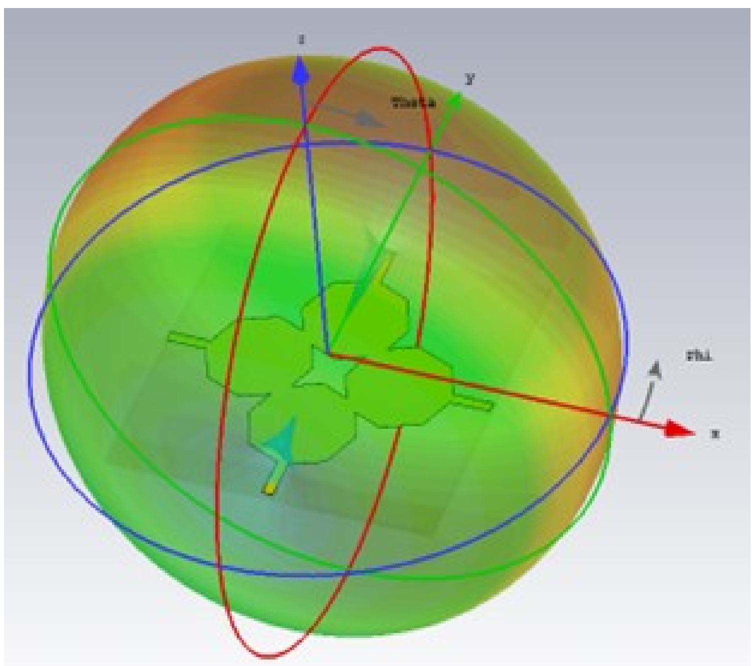

Figure 7: *Radiation Field Pattern at Resonating Frequency 1.996GHz.*

Figure 7 depicts the 3D Radiation Pattern of the projected antenna. This figure shows the three dimensional distribution of radiation pattern around the antenna and it clearly shows the maximum value around y-axis in xz-plane from zero degree to 360 degrees.

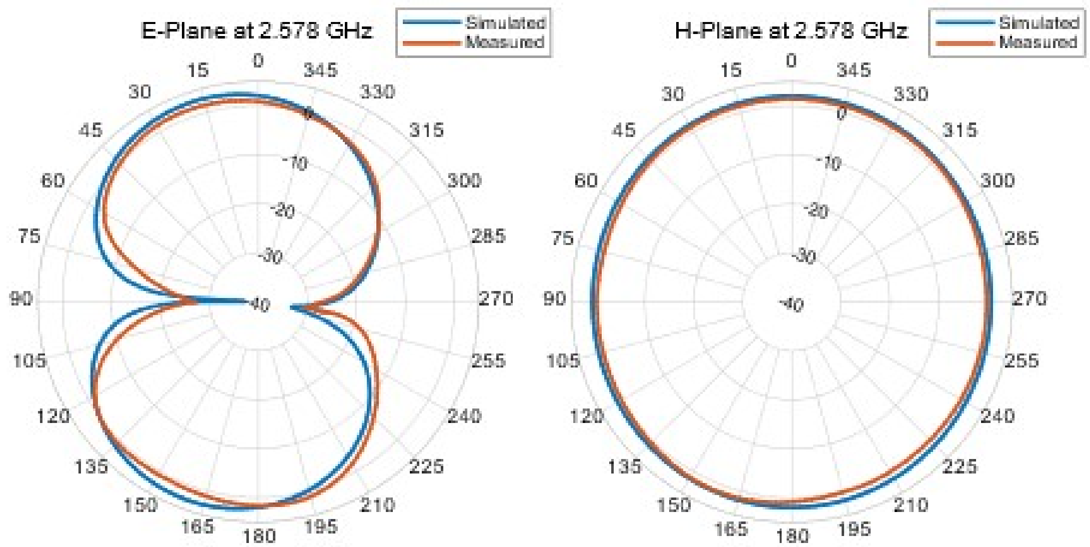

Figure 8: *Radiation Field Pattern at Resonating Frequency 1.996GHz.*

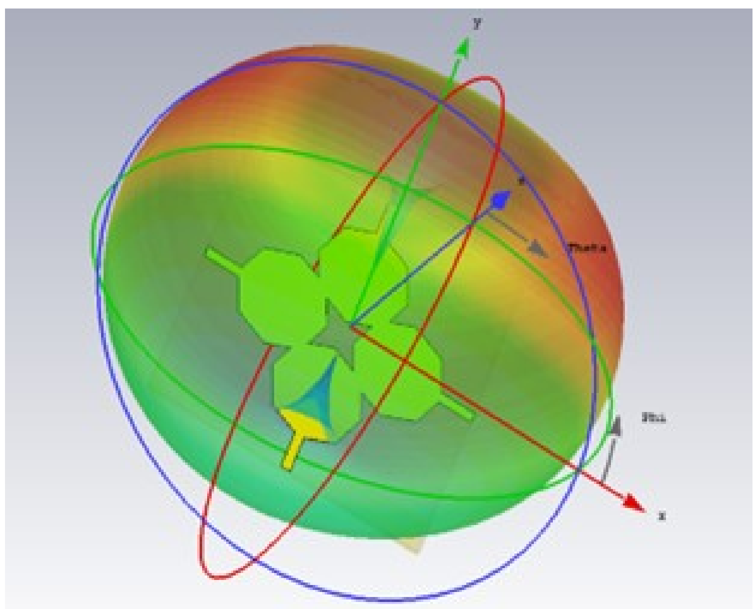

Figure 9: *3D Radiation Field Pattern at Resonating Frequency 2.58GHz.*

The 2D Radiation Pattern of the projected antenna has been displayed in Figure 8. At 2.58GHz Omni-directional radiation pattern has been analyzed. The Omni-directional pattern is in H-Plane which is good for the radiation. Radiation parallel to y-axis is has lower directivity than in the perpendicular direction. The 3D Radiation Pattern of the projected antenna has been displayed in Figure 9. At 2.58GHz Omni-directional radiation pattern has been analyzed. Similar to the 3D pattern at 1.996GHz, here also the H-Plane pattern is near omni directional or can say quasi-omni directional but a little bit inclined towards the positive y-axis.

For 5.39GHz 2D Radiation Pattern of projected antenna has been displayed in Figure 10. The H-Plane pattern is not omnidirectional but quasi-omni which is less significant in terms of the antenna performance, and respective 3-dimensional radiation pattern has been depicted in Figure 11.

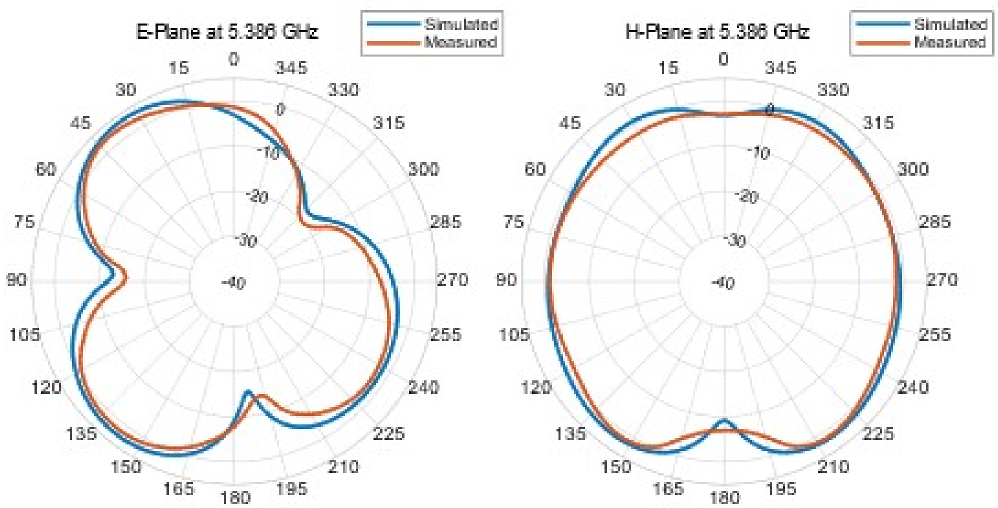

Figure 10: *2D Radiation Field Pattern at Resonating Frequency 5.39GHz.*

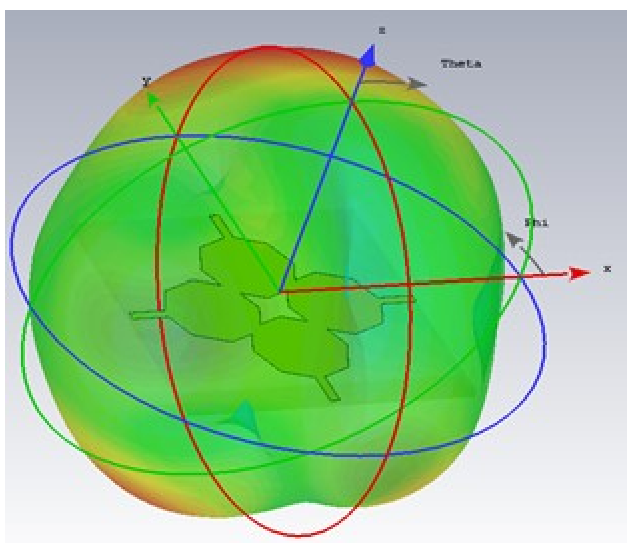

Figure 11: *3D Radiation Field Pattern at Resonating Frequency 5.39GHz.*

The 3D Radiation Pattern of the projected antenna has been displayed in Figure 11 at 5.39GHz. It is clear from the picture that the radiation is front and in back both directions. The directivity is lower around the sides of the antenna in xy-plane.

3.3 Gain, Directivity, VSWR and Efficiencies

The suggested QOPDG antenna was tested for gain in both simulation and experiment, and the results revealed peak gains of 4.31dBi and 4.15dBi, respectively, which are in excellent accord with the antenna's performance. Figure 12 depicts the calculated and experimental gain of the antenna across the frequency range of 1GHz to 7GHz. The directivity of the antenna is 5.104dBi for simulation and measurement, and 4.968dBi for both simulation and measurement displayed in Figure 13. The suggested antenna has a BW of 50.05% (between 1.672GHz and 2.788GHz) and a BW of 24.42 percent (between 4.876GHz and 6.232GHz) when the VSWR is less than two (refer to Figure 14).

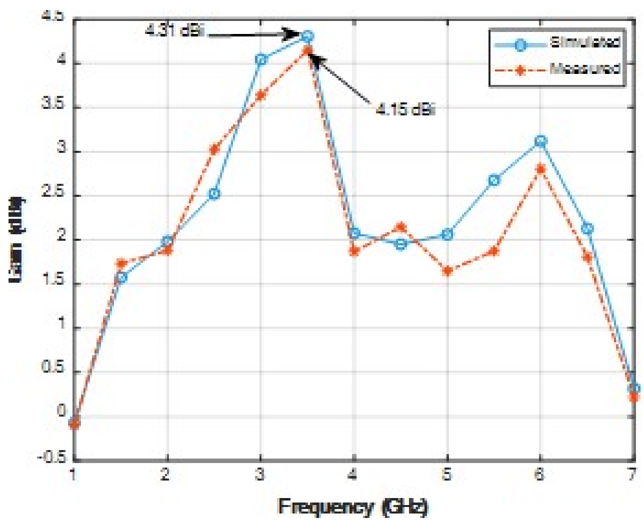

Figure 12: *Comparison of calculated and experimental Gain of QOPDG.*

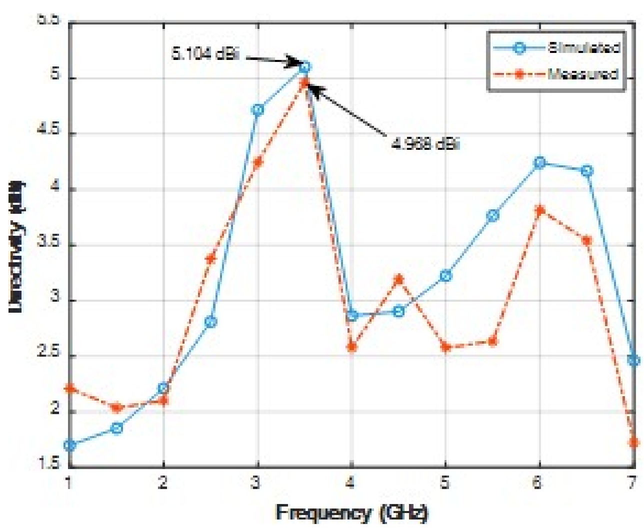

Figure 13: *Comparison of calculated and experimental directivity of QOPDG.*

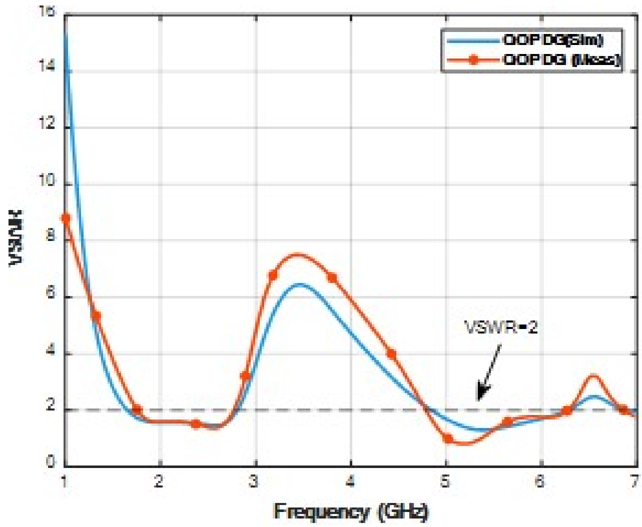

Figure 14: *Comparison of calculated and experimental VSWR of QOPDG.*

Figure 15 shows the antenna's radiation and total efficiency. The highest radiation efficiency is 95%, and the total efficiency is greater than 90%, which is sufficient for the antenna.

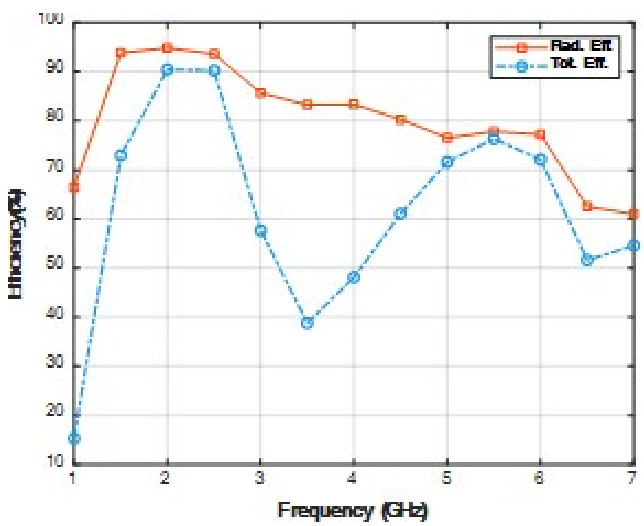

Figure 15: *Radiation and Total Efficiencies of QOPDG.*

4 Conclusion

Octagon Quad Shaped Dual Band Broadband Antenna has been designed, fabricated, and analyzed in this research work. The results show that the presented or developed antenna has dual-band characteristics, a low *return loss*($| S_{11} |$) , and an omni-directional radiation pattern. The projected antenna's reflection coefficient exhibits good agreement in resonant frequency and BW. As displayed in Table 3, the results show that the designed antenna has an overall performance of less than -10dB, impedance BWs of 50.04%, and a BW of 24.41% better than previous designs.

$Dual\ Impedance\ BWs = 50.04\%$ and 24.41%

These made the antenna applicable for WiMAX and WLAN applications.

Table 3: Comparative analysis Table with four different antennas.

References	f_l (GHz)	f_h (GHz)	BW (%)	Size (mm^2)
[1]	1.347	1.533	12.91	80x80
[5]	4.53	7.47	49	42x32
[10]	3.4	5.6	49.4	70x70
[12]	1.639	1.907	15.11	110x110
[15]	1.80	6.09	108.74	61x51.5
Proposed	1.672, 4.876	2.788, 6.232	50.04%, 24.41 %	60x60

Funding: There is no funding provided to prepare the manuscript.

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors Contribution: Co-authors contributed equally.

References

[1] K.-L. Wong, C.-C. Huang, and W.-S. Chen, 2002. Printed ring slot antenna for circular polarization, *IEEE Transactions on Antennas and Propagation,* vol. 50, no. 1, pp. 75–77, doi: 10.1109/8.992564.

[2] Y. Yoshimura, 1972. A Microstripline Slot Antenna (Short Papers). *IEEE Transactions on Microwave Theory and Techniques*, vol. 20, no. 11, pp. 760–762, doi: 10.1109/TMTT.1972.1127868.

[3] J.-F. Huang and C.-W. Kuo, 1998. CPW-fed bow-tie slot antenna. *Microwave and Optical Technology Letters*, vol. 19, no. 5, pp. 358–360, doi: 10.1002/(SICI)1098-2760(19981205)19:5¡358::AID-MOP14¿3.0.CO;2-X.

[4] A. A. Deshmukh and K. P. Ray, 2012. Formulation of Resonance Frequencies for Dual-Band Slotted Rectangular Microstrip Antennas. *IEEE Antennas and Propagation Magazine,* vol. 54, no. 4, pp. 78–97, doi: 10.1109/MAP.2012.6309159.

[5] Kamakshi, J. Ansari, A. Singh, and and M. Aneesh, 2014. Desktop Shaped Broadband Microstrip Patch Antennas for Wireless Communications. *Progress In Electromagnetics Research Letters,* vol. 50, pp. 13–18, doi: 10.2528/PIERL14092903.

[6] A. A. Deshmukh and G. Kumar, 2006. Broadband compact V-slot loaded RMSAs. *Electronics Letters,* vol. 42, no. 17, pp. 951–952, doi: 10.1049/el:20061141.

[7] Y. W. Jang, 2000. Broadband cross-shaped microstrip-fed slot antenna.*Electronics Letters,* vol. 36, no. 25, pp. 2056–2057, doi: 10.1049/el:20001477.

[8] Y.-W. Jang, 2003. A circular microstrip-fed single-layer single-slot antenna for multi-band mobile communications.*Microwave and Optical Technology Letters,* vol. 37, no. 1, pp. 59–62, doi: 10.1002/mop.10824.

[9] V. A. Shameena, S. Mridula, A. Pradeep, S. Jacob, A. O. Lindo, and P. Mohanan, 2012. A compact CPW fed slot antenna for ultra wide band applications,. *AEU - International Journal of Electronics and Communications,* vol. 66, no. 3, pp. 189–194, doi: 10.1016/j.aeue.2011.03.015.

[10] J.-Y. Jan and J.-W. Su, 2011. Bandwidth enhancement of a printed wide-slot antenna with a rotated slot. *IEEE Transactions on Antennas and Propagation,* vol. 53, no. 6, pp. 2111–2114, doi: 10.1109/TAP.2005.848518.

[11] P. N. Shinde and J. P. Shinde, 2015. Design of compact pentagonal slot antenna with bandwidth enhancement for multiband wireless applications. *AEU - International Journal of Electronics and Communications,* vol. 69, no. 10, pp. 1489–1494, doi: 10.1016/j.aeue.2015.07.001.

[12] J.-Y. Sze and K.-L. Wong, 2001. Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna. *IEEE Transactions on Antennas and Propagation,* vol. 49, no. 7, pp. 1020–1024, doi: 10.1109/8.933480.

[13] D. S. Javan, M. A. Salari, and O. H. Ghoochani, 2008. Cross-Slot Antenna with U-Shaped Tuning Stub for Ultra-Wideband Applications. *International Journal of Antennas and Propagation,* vol. 2008, p. e262981, doi: 10.1155/2008/262981.

[14] W. J. Lui, C. H. Cheng, Y. Cheng, and H. Zhu, 2005. Frequency notched ultra-wideband microstrip slot antenna with fractal tuning stub.*Electronics Letters,* vol. 41, no. 6, pp. 294–296, doi: 10.1049/el:20058420.

[15] J.-Y. Jan and L.-C. Wang, 2009. Printed Wideband Rhombus Slot Antenna With a Pair of Parasitic Strips for Multiband Applications. *IEEE Transactions on Antennas and Propagation,* vol. 57, no. 4, pp. 1267–1270, doi: 10.1109/TAP.2009.2015859.H

About the Authors

Rahmani Naveed Akhtar is pursuing his Ph.D. from Shri JagadishPrasad Jhabarmal Technical University (JJTU), Rajasthan. He completed his Master of Technology in Microwave and Millimeter Engineering from RGPV, Bhopal in 2015 and Bachelor of Engineering in Electronics and Communication from North Maharastra University, Jalgaon, Maharastra in 2004. His research interests are Radio and Microwave Communications, Antenna Design Methodologies, and Wireless Communications.

Dr. Anupama A. Deshpande is currently serving as an Internal Faculty and Ph.D. Guide in JJTU, Rajasthan. She completed her PhD. from IIT Bombay in Systems & Control in the year 2006 and Master of Engineering in Instrumentation Engineering from Sri Guru Gobind Singh College of Engineering Nanded in 1997 and Bachelor of Engineering in Electrical Engineering from Government College of Engineering, Aurangabad. She was the Principal of Atharva College of Engineering, Mumbai from 2007 to 2013. She has an interest in electric material, planning, and industrial outreach activities.

Dr. A. K. Kureshi has completed his Ph.D. from Aligarh Muslim University with VLSI Design in 2010 and Master of Engineering in Electronics from JN College of Engineering, B.A. Marathwada University, Aurangabad in 2004 and Bachelor of Engineering in Electronics from STB College of Engineering, Tuljapur B.A. Marathwada University, Aurangabad in 1994.