

## Dual Band Fractal Antenna Design For Wireless Application

O.S Zakariyya<sup>1</sup>, B.O Sadiq<sup>2</sup>, A.A Olaniyan<sup>3</sup> and A.F Salami<sup>4</sup>

*Department of Electrical and Electronics Engineering,  
University of Ilorin, kwara1,4*

*Department of Electrical and Computer Engineering,  
Ahmadu Bello University Zaria*

*sikiruzakariyya@gmail.com, bosadiq@abu.edu.ng, olaniyanabdulrahman@gmail.com,  
salami.af@unilorin.edu.ng.*

### ABSTRACT

The objective of this paper was to design and analyse a dual wide band compact antenna for wireless application. Microstrip patch antenna limitation can be overcome by using fractal geometry. The proposed antenna was designed with a radius of 15mm on a FR4 lossy substrate with relative permittivity of 4.4 and loss factor of 0.025. Measurement result showed that the antenna has a dual band of operation with bandwidth for return loss below -10dB of 1.84GHz (2.2GHz-4.07GHz) and 2GHz (6GHz-8GHz) which can be applied to wireless local area network (WLAN) and Ultra wide band applications.

**Keywords:** Miniaturized, Compact and dual band antenna, Fractal geometries, Partial Ground Structure.

### 1. INTRODUCTION

Communication systems are growing rapidly with increase in technology. These systems operate at more than one frequency band which suggest there is a need for small antennas capable of resonating at multiple band [1]. To realize such communication system with a low profile, one of the critical factors is the antenna size. Hence, many different kinds of techniques have been applied to a patch antenna such as the use of substrate with high dielectric constant, use of reactive loading and antenna electrical length increment by optimizing its shape [2-4]. Microstrip antenna is suitable for the modern day communication system requirement due to its characteristics like small size, light in weight and low cost but has limitation of narrow bandwidth [1]. With the conventional antenna design using infinite ground plane, this narrower bandwidth limitation cannot be curtailed as the bandwidth can only be increase by a small percentage. The release of ultra wideband frequency band in the range of 3-10GHz by the FCC in 2002 [5] has urged researcher to find a new approach in designing an antenna with ultra wideband behaviour. Several literature have employed different technique such as the use of truncated ground plane and a rectangular patch tapered from the microstrip feed [6], also using of defected ground structure [7]. One of the techniques to reduce area of patch antenna is to make use of fractal geometry [8]. Applying fractal geometry techniques to conventional antenna structure increase the antenna electrical length which in turn reduces the overall size of the antenna hence optimize the antenna shape [9]. The design of fractal geometry can be in different shapes. The most commonly use

shapes are Minkowski Loop [10], Koch Island [11], Sierpinski carpet [12] and the Sierpinski gasket [13]. Using the self similarities properties of fractals, compact dual band ring monopole antennas was proposed by [14]. Using L- Feed probe technique, a circular patch antenna with fractal for C band application was proposed in [15]. Many other antennas were proposed for dual band applications [16-18]. Krishna et al proposed a dual band antenna suitable for WiMax and WLAN operations using Koch fractal [19]. Ghaliban and Kashani designed a dual band fractal antenna for RFID applications [20]. Dual-band fractal antenna for LTE applications was proposed by [21-22]. Although, the proposed antenna has a compact size and exhibit a dual band of operation. The bandwidth of operation is not wide enough for wideband applications. In this work, a circular face fractal antenna with slotted partial ground plane was proposed to meet the modern wireless communication demand of compact, light, multiband and wideband applications.

## 2. ANTENNA DESIGN

In circular patch antenna mode, the ground plane, patch and the material between them are treated as two circular cavity [1]. The substrate height of the circular patch is small ( $h \ll \lambda$ ). Unlike the rectangular patch antenna which is controlled by length and width of the patch, the circular patch antenna has only one degree of freedom to control the patch which is the patch radius. By changing the radius of the patch, the patch resonant frequency also changes but without having effect on the patch mode. The actual radius of the patch can be obtained using the given equation [1]:

$$R = \frac{F}{\sqrt{1 + \frac{2h}{\pi\epsilon_r F} [\ln\left(\frac{\pi F}{2h}\right) + 1.7726]}} \quad (1)$$

Where R is the radius of the patch, h is the substrate height and  $\epsilon_r$  is the relative permittivity.

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \quad (2)$$

Where  $f_r$  is the resonant frequency.

The proposed antenna which has a radius of 15 mm was designed on a FR4 substrate. The relative permittivity of the substrate is 4.4 and loss factor of 0.025. The substrate has a size of 43 mm x 40 mm with height of 1.59mm. Quarter wave line of 10.2 mm in length and width of 3mm was used in feeding the antenna. This is called the initial stage without iteration (zero iteration).

The first iteration was achieved by making two circles of radius 7mm whose centre lies on the diameter of the main radiating patch (15 mm). These two circles form the face of the first iteration and they are subtracted from the main patch. The second iteration was achieved by creating a circle of radius 3.5 mm whose center lies on the diameter of the main radiating patch. Two circles of radius 1.725 mm were created and subtracted from the new face created. This forms the second

iteration. In order to increase the electrical length, the fractal elements have been repeated up till four times.

The first stage of the proposed antenna is shown in Figure. 1 showing a microstrip fed infinite ground plane configuration. The second stage shows the final iteration with partial ground plane in Figure. 2.

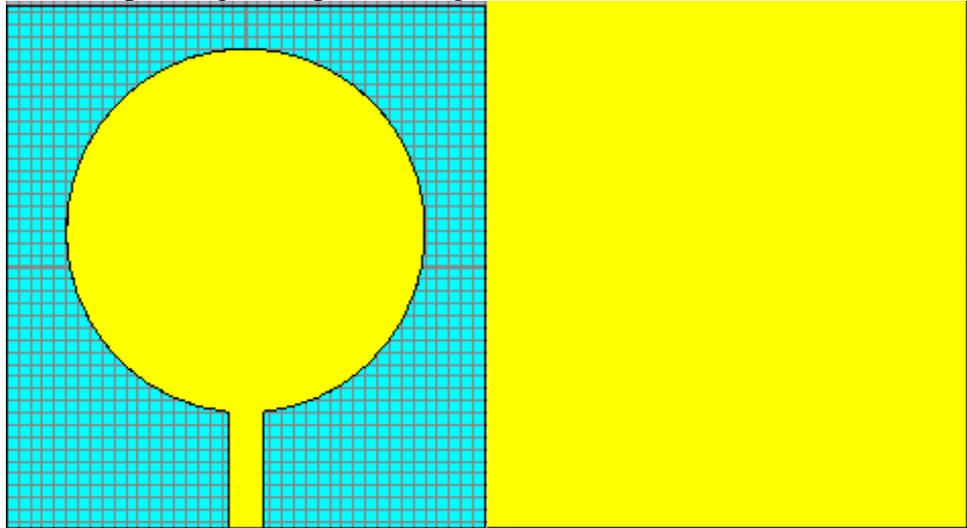


FIGURE 1: Front and back view of conventional circular patch

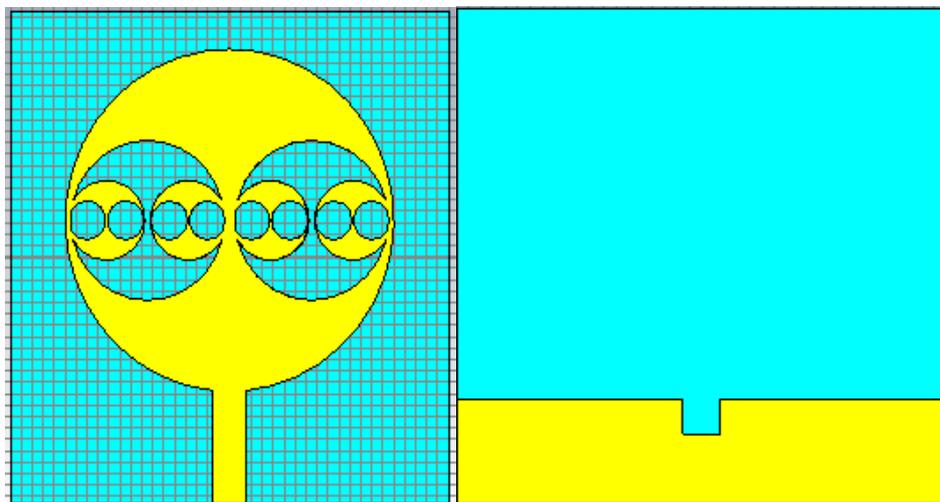


FIGURE 2: Front and back view of the proposed patch

### 3. RESULTS AND DISCUSSIONS

CST Microwave Studio 2014 was used in simulating the proposed antenna. The return loss (S11), VSWR, gain and radiation pattern was used in analysing the antenna performance. A physical prototype of the proposed antenna was designed physically and measurement was carried out using a commercial microwave vector network analyzer. The simulated return loss plot results shows the antenna demonstrate a dual band operation having two resonant frequencies of 2.54 GHz and

**O.S Zakariyya, B.O Sadiq, A.A Olaniyan and A.F Salami  
Dual Band Fractal Antenna Design For Wireless Application**

6.47GHz with return loss of -22.6dB and -18.9dB respectively. The impedance bandwidths at the two bands of operation are 2.42GHz in the first band and 2.19GHz in the second band.

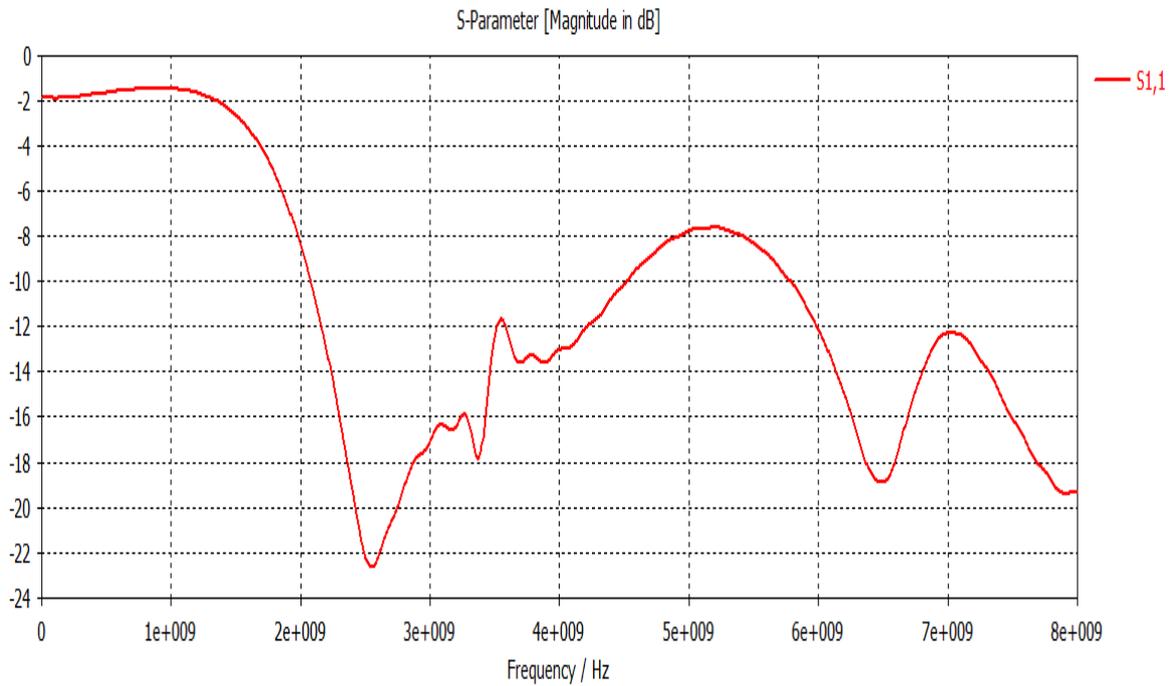


FIGURE 3: Return loss plot of Circular face fractal

The three dimensional radiation pattern of the proposed antenna which shows the directivity at the two operating frequencies is represented in Figure 4(a) and Figure 4(b). At 2.54GHz, the antenna has a directivity of 2.79dBi and 5.62 dBi at 6.47 GHz. It was observed that the antenna has better directivity at higher frequency.

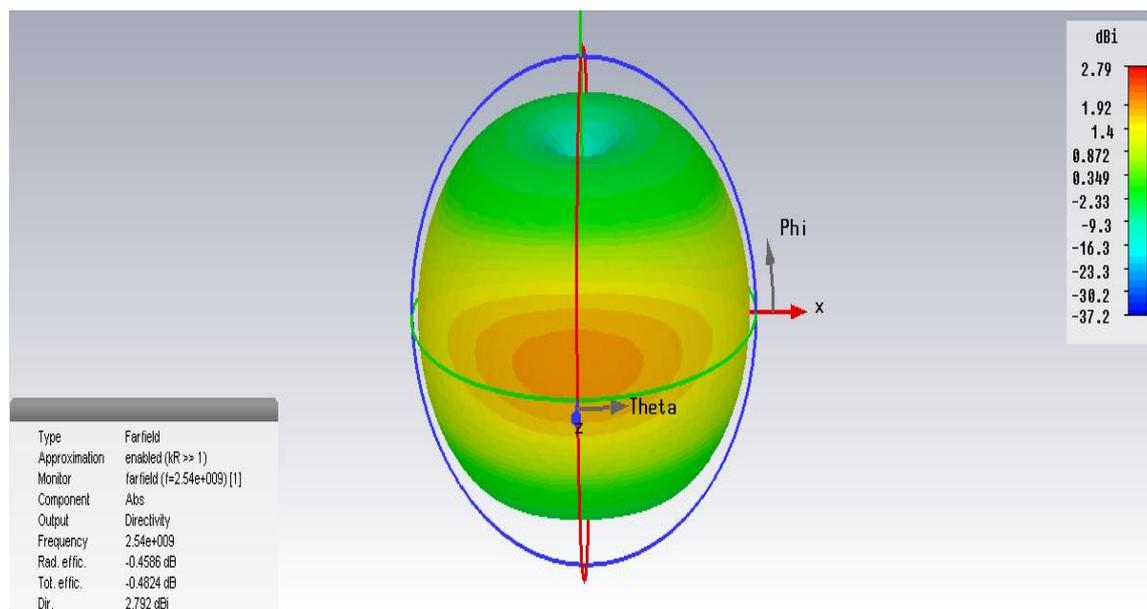


Figure 4(a): Directivity of Circular face fractal at 2.54 GHz

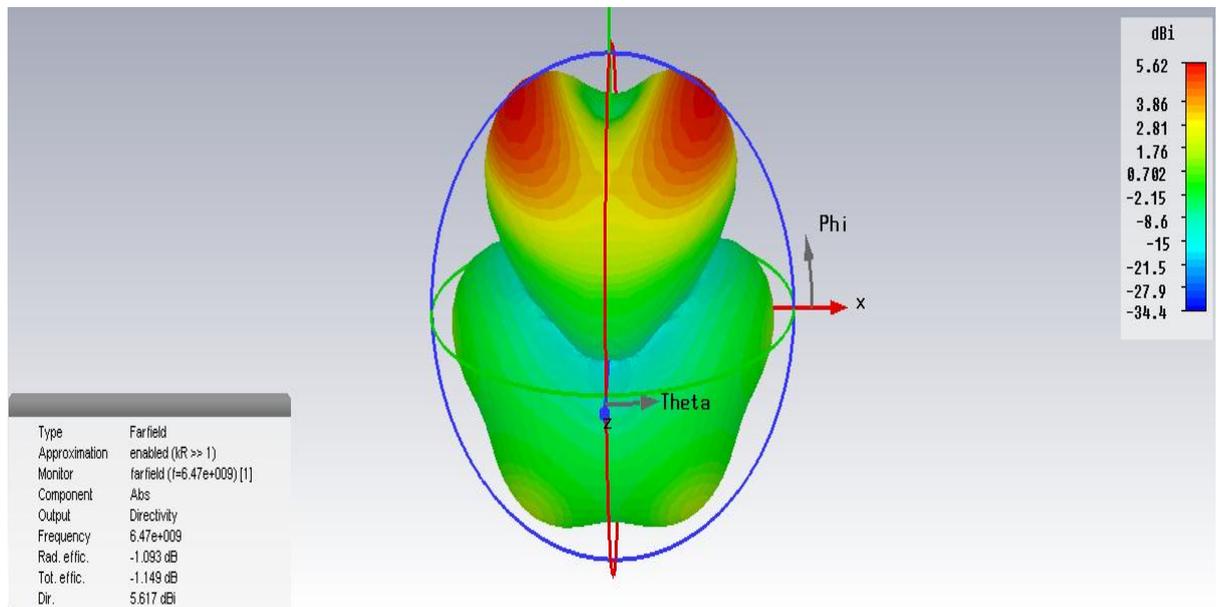


FIGURE 4(b): Directivity of Circular face fractal at 6.47 GHz

Figure 5 shows the simulated plot of VSWR for the proposed antenna. For a microstrip patch antenna to work efficiently, the minimum value of VSWR should be less than 2. It was observed from the results that the antenna operate satisfactorily with VSWR of 1.15 in the first band and 1.25 in the second band.

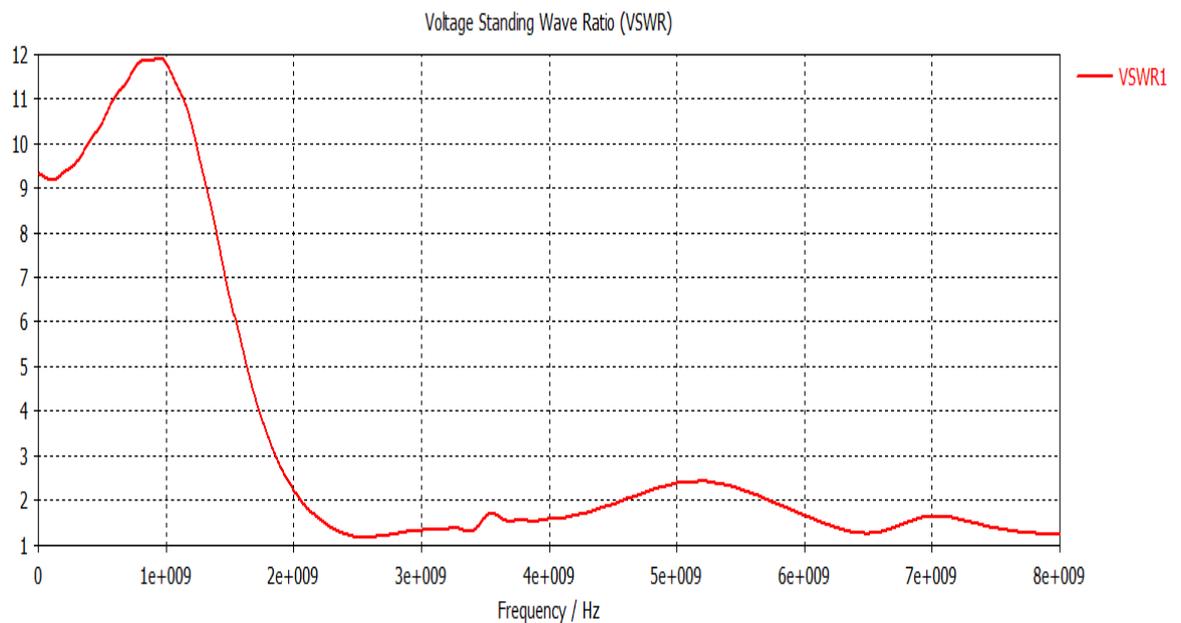


FIGURE 5: VSWR for the circular face fractal antenna

#### 4. FABRICATED ANTENNA DESIGN AND PRACTICAL RESULTS

Figure 6 provides a photograph of the fabricated antenna, assembled with an SMA connector on the feed line for purposes of testing. Evaluation of S11 was carried out using a commercial microwave vector network analyzer. As shown in Figure 7, this measured results are close to the simulated values showing a dual band of operation with bandwidth for return loss below -10dB of 1.84GHz (2.2GHz-4.07GHz) and 2GHz (6GHz-8GHz). Little variation was found between the simulated and measured value. This might occur due to manufacturing tolerance, dielectric constant of the circuit or quality of the SMA connector. This antenna can find application in wireless local area network (WLAN) and Ultra wide band applications. The prototype design and the measured S11 are shown in the next figures below.

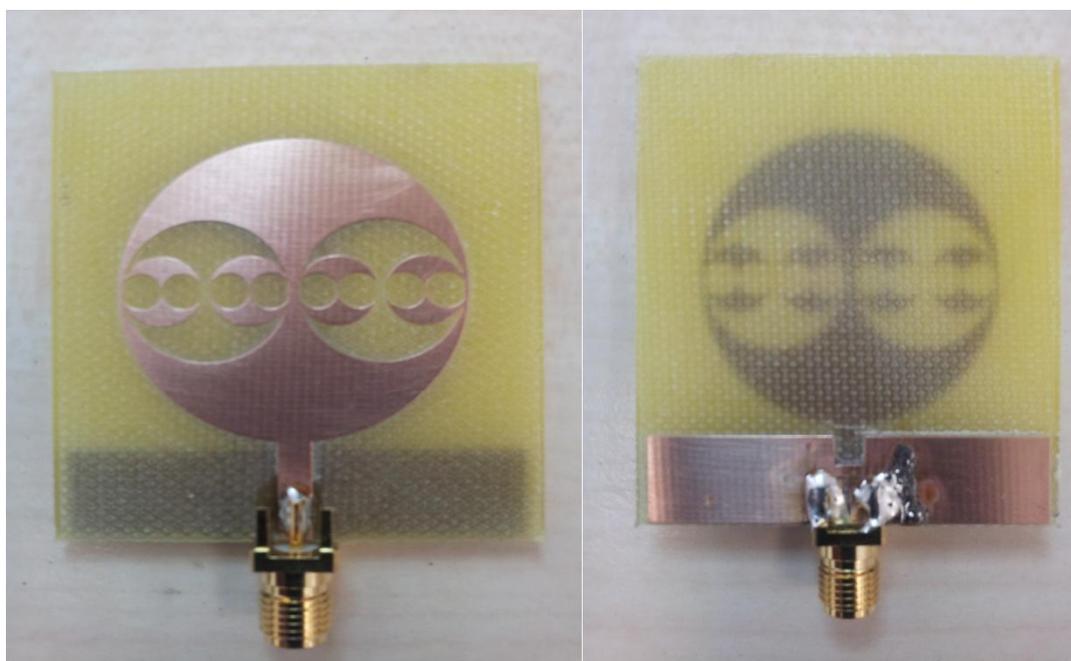


FIGURE 6: Fabricated Circular face fractal Antenna

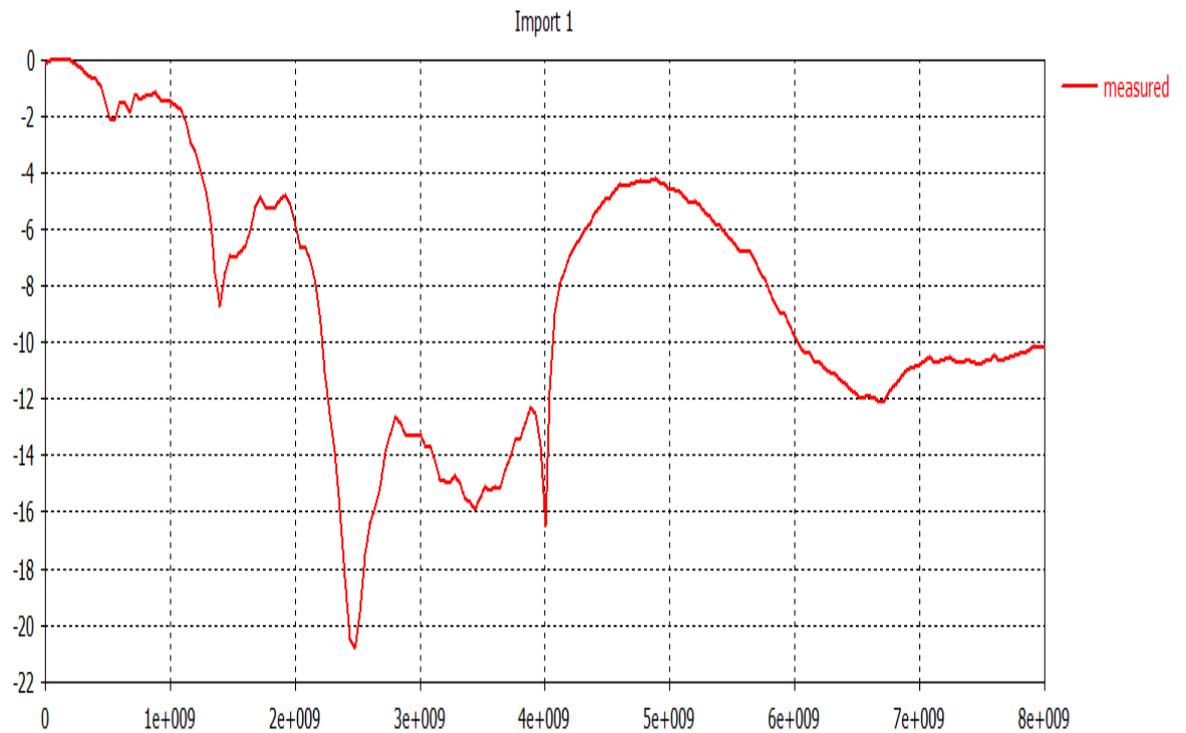


FIGURE 7: Return loss plot of Fabricated Circular face fractal

## 5. CONCLUSION

A compact dual band circular face fractal antenna was designed and fabricated. Measurement result shows that the proposed antenna exhibit a dual band of operation having bandwidth for return loss ( $S_{11}$ ) below  $-10\text{dB}$  of  $1.84\text{GHz}$  ( $2.2\text{GHz}-4.07\text{GHz}$ ) and  $2\text{GHz}$  ( $6\text{GHz}-8\text{GHz}$ ) which can be applied to wireless local area network (WLAN) and Ultra wide band applications. The antenna was design using the CST studio software.

## REFERENCES

- [1] A. Balanis, *Antenna Theory Analysis and Design* (3rd ed.), New york: New Jersey: John Wiley & Sons, 2005.
- [2] T. K. Lo, and Y. Hwang, "Microstrip antennas of very high permittivity for personal communications," in *Asia-Pacific Microwave Conference*, 1997, pp. 253–256.
- [3] N. Herscovici, M. F. Osorio, et al., "Miniaturization of rectangular microstrip patches using genetic algorithms," *IEEE Antennas and Wireless Propagation Letters*, vol. 1, pp. 94–97, 2002.
- [4] W. Chen and G. M. Wang, "Small Size Edge-Fed Sierpinski Carpet Microstrip Patch Antenna," *Progress in Electromagnetics Researches*, vol. 3, pp. 195-202, 2008.
- [5] FCC, First Report and order 02-48, February 2002.
- [6] B. Kasi, L.C. Ping and C. K. Chakrabarty "A Compact Microstrip Antenna for Ultra wideband Applications," *European Journal of Scientific Research*, vol.67 (1), pp. 45-51, 2011.

**O.S Zakariyya, B.O Sadiq, A.A Olaniyan and A.F Salami**  
**Dual Band Fractal Antenna Design For Wireless Application**

- [7] C. Y. Pan, J. H. Duan, and J. Y. Jan, "Coplanar Printed Monopole Antenna using Coaxial Feedline for DTV Application," *Progress In Electromagnetics Research Letters*, vol. 34, pp. 21 - 29, 2012.
- [8] N. Lu and X. Xu , "Sierpinski carpet fractal antenna in third iteration," in *IEEE International Conference on Microwave Technology & Computational Electromagnetics (ICMTCE)*, 2013, pp 164- 167.
- [9] D. V. Karunakar and G. "Kumar, Analysis of microstrip rectangular carpet shaped fractal antenna", in *International Conference on Signal Processing and Communication Engineering Systems (SPACES)*, *IEEE Conference Publications* 2015, pp. 531- 535.
- [10] J. K. Ali, "A New Reduced Size Multiband Patch Antenna Structure Based on Minkowski Pre-Fractal Geometry," *Journal of Engineering and Applied Sciences*, vol. 2, (7) pp. 1120-1124, 2007.
- [11] C. Borja and J. Romeu, "On the Behavior of Koch Island Fractal Boundary Microstrip Patch Antenna," *IEEE Transactions on Antennas and Propagation*, vol. 51, (6) 2003.
- [12] S.S Mohammed, K. Ramasamy, and T. Shanmuganatham, "A Sierpinski Fractal Based Microstrip Patch Antenna for Wireless Power Transmission System," *International Journal of Computer Applications*, vol. 1, (13) pp. 0975 – 8887.
- [13] J. Anguera, E. Martínez, C. Puente, C. Borja, and J. Soler, "Broad-Band Dual-Frequency Microstrip Patch Antenna With Modified Sierpinski Fractal Geometry," *IEEE Transactions on Antennas and Propagation*, vol. (1) 2004.
- [14] K.H. Sayidmarie and T.A. Nagem, "Compact dual band dual ring monopole antennas for wlan applications", *Progress In Electromagnetic Research B*, vol. 43, pp. 313-331, 2012.
- [15] N. Bisht and P. Kumar, "A dual band fractal circular microstrip patch antenna for C-band application", in *PIERS Proceedings*, Suzhou, china, 2011.
- [16] S. S. Zhong and X. L. Liang, "Dual-band printed T-shaped slot antenna for WLAN application", in *Asia-Pacific Microwave Conference, APMC*, 2006 pp. 1730-1734.
- [17] L. Liu, S. Zhu, and R. Langley, "Dual-band triangular patch antenna with modified ground plane", *Electronics Letters*, vol. 43, (3) pp. 140-141, 2007.
- [18] S. Behera, and K. J. Vinoy, "Microstrip square ring antenna for dual-band operation", *Progress In Electromagnetics Research*, vol. 93, pp. 41-56, 2009.
- [19] D. D. Krishna, M. Gopikrishna, C. K. Anandan, P. Mohanan, and K. Vasudevan, "CPW-fed Koch fractal slot antenna for WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 389–392, 2008.
- [20] J. Ghalibafan and F. H. Kashani, "A circularly polarized fractal microstrip antenna for RFID applications," in *Proceedings of the IEEE International Symposium on Radio-Frequency Integration Technology (RFIT '09)*, 2009 pp. 319–322.
- [21] F. Viani, "Dual band Sierpinski pre-fractal antenna for 2.4 GHz-WLAN and 800 MHz-LTE wireless devices" *Progress In Electromagnetics Research C*, vol. 35, pp. 63–71, 2013.
- [22] L. lizzi and A. Massa "dual-band printed fractal monopole antenna for LTE applications", *IEEE Antenna and Wireless Propagation*, vol. 10 pp. 760-763, 2011.