Journal of Electromagnetic Analysis and Applications, **2013, 5, 182-188**
http://dx.doi.org/10.4236/jemaa.2013.54029 Published Online April 2013 (http://www.scirp.org/journal/jemaa)

Double-Sided Microstrip Circular Antenna Array for WLAN/WiMAX Applications

Ruwaybih Alsulami, Heather Song*

Department of Electrical and Computer Engineering, University of Colorado, Colorado Springs, USA.
Email: *hsong@uccs.edu

Received February 8th, 2013; revised March 10th, 2013; accepted March 25th, 2013

ABSTRACT

The design, fabrication, and characterization of the microstrip circular antenna arrays were presented. The proposed antennas were designed for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and 5.0 - 6.0 GHz to support WLAN/WiMAX applications. The proposed single and dual band antennas showed omnidirectional radiation pattern with the gain values of 3.5 dBi at 2.45 GHz, 4.0 dBi at 3.45 GHz, and 3.3 dBi at 5.5 GHz. The dual band antenna array was placed on both top and bottom layers to obtain the desired antenna characteristics. The proposed double-sided dual band antenna provides omnidirectional radiation pattern with high gain.

Keywords: Antenna Arrays; Circular Patch; Dual Band; Single Band; Omnidirectional; WLAN/WiMAX Applications; UWB

1. Introduction

Ultra-wideband (UWB: 3.1 to 10.6 GHz) frequency spectrum has been approved by the US Federal Communications Commission (FCC) for unlicensed short range wireless communications since 2002. In this frequency range, wireless local-area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN operates in 5.0 - 6.0 GHz band. In some European and Asian countries, world interoperability for microwave access (WiMAX) service is provided in the frequency range of 3.3 - 3.6 GHz [1-4]. To support the WLAN/WiMAX application, antenna arrays that provide omnidirectional radiation pattern are required. To respond to this need, recent antenna design efforts were focused on omnidirectional antennas with high gain and no sidelobes [5-8]. Rectangular arrays are common type used for antenna arrays. Studies on dual band antennas employing rectangular arrays were reported [9-12]. Compared to rectangular patch antenna arrays, there are limited numbers of studies performed on circular patch antenna arrays due to difficulties in fabrication [13]. Advantages of circular antenna array include high gain and narrow beam width [13].

In this paper, a new microstrip circular antenna arrays were designed, fabricated, and characterized to provide omnidirectional radiation pattern for WLAN/WiMAX applications. Two antenna arrays were designed—one for single band at 2.45 GHz and the other for dual bands at 3.3 - 3.6 GHz and 5.0 - 6.0 GHz. For single band operation, circular patch array was placed on the top layer of the microtrip and a small rectangular patch was placed on the bottom layer for ground connection. For dual band operation, similar circular patch array was placed on both top and bottom layers of the microstrip with larger rectangular patch placed on the bottom layer. Both single band (single sided) and dual band (double-sided) microstrip antenna arrays provided desirable antenna characteristics for the intended application.

*Corresponding author.

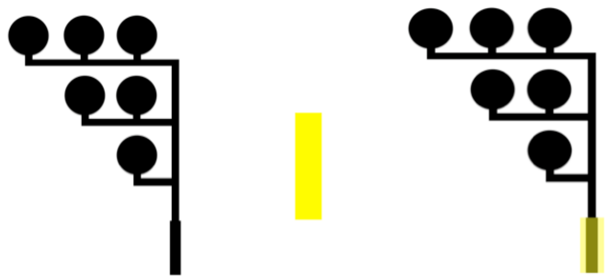
2. Design and Simulation

2.1. Single-Band Antenna at 2.45 GHz

The configuration of the proposed single band antenna at 2.45 GHz is shown in **Figure 1**. It consists of six circular patches which are placed only on the top layer. The small rectangular patch is placed on the bottom layer for ground connection.

The directivity for the circular patch antenna is

$$D_0 = \frac{(k_0 a_e)^2}{120 G_{rad}} \quad (1)$$



(a) (b) (c)

Figure 1. Configuration of the proposed antenna for single band at 2.45 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

$$k_0 = \frac{2\pi}{\lambda_0} \tag{2}$$

$$a_e = a\left\{1 + \frac{2h}{\pi a \epsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \tag{3}$$

$$G_{\text{rad}} = \frac{\left(k_0 a_e\right)^2}{480}\int_0^{\pi/2}\left[J_{02}'^2 + \cos^2\theta J_{02}^2\right]\sin\theta \mathrm{d}\theta \tag{4}$$

$$J_{02}' = J_0\left(k_0 a_e \sin\theta\right) - J_2\left(k_0 a_e \sin\theta\right) \tag{5}$$

$$J_{02} = J_0\left(k_0 a_e \sin\theta\right) + J_2\left(k_0 a_e \sin\theta\right) \tag{6}$$

where a_e is the effective radius, a is the actual radius, ϵ_r is the relative permittivity of the microstrip dielectric substrate, h is the height of the microstrip substrate, and J_0 and J_2 are Bessel functions.

The gain of the antenna was calculated using

$$\text{Gain} = \text{Antenna Efficiency} \times \text{Directivity}\left(D_0\right) \tag{7}$$

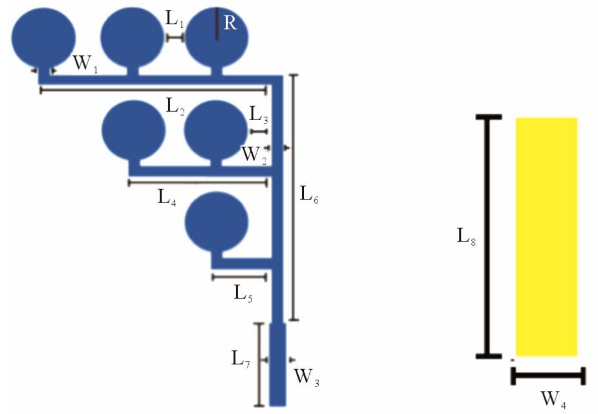
$$\text{Antenna Efficiency} = \frac{\text{Total Efficiency}}{\text{Reflection Efficiency}} \tag{8}$$

The variable corresponding to each dimensions and values for the dimensions of the proposed antenna are shown in **Figure 2** and **Table 1**, respectively. Here, *L*, *W*, and *R* represent the length, the width, and the radius of the circular patch, respectively.

The gain of the proposed antenna shown in **Figure 1** was calculated using (1) - (8) and the dimensions were optimized using ADS [14] which resulted in gain of 3.5 dBi at 2.45 GHz.

2.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The configuration for the doubled-sided microstrip dual band antenna is shown in **Figure 3**. The proposed microstrip antenna has circular arrays both on the top and bottom layers. It consists of three circular patched on each layer.

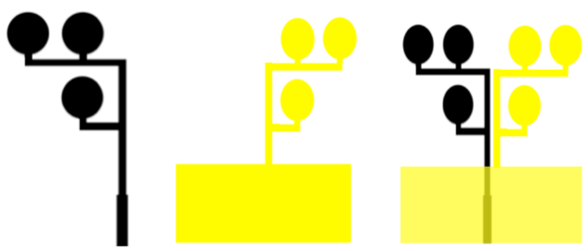


(a) (b)

Figure 2. Variables corresponding to each dimension of the proposed single band antenna: (a) Top layer; (b) Bottom layer.

Table 1. Dimensions for the proposed single band antenna at 2.4 GHz.

Variable	Value (mm)
L_1	1.15
L_2	28.9
L_3	1.13
L_4	17.6
L_5	6.60
L_6	35.3
L_7	18.4
L_8	18.4
W_1	1.02
W_2	1.52
W_3	3.30
W_4	6.86
R	5.10

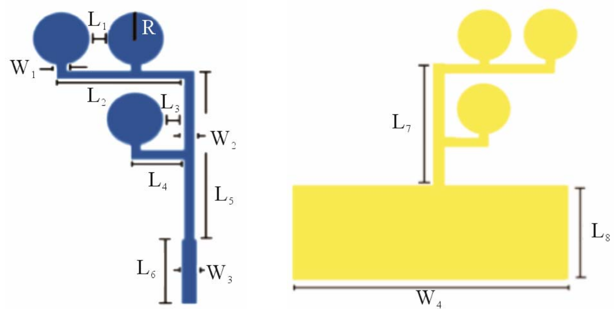


(a) (b) (c)

Figure 3. Configuration of the proposed antenna for dual band at 3.3 - 3.6 and 5.0 - 6.0 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

The configuration in **Figure 3(a)** is similar to the top layer of the single band antenna as shown in **Figure 1(a)** but with less circular patches. However, the bottom layer in **Figure 3(b)** is different compared to the bottom layer of the single band antenna shown in **Figure 1(b)**. The double-side nature of the antenna provides dual band characteristics. Identical equations were used for the single band antenna were employed in the design process. The variable corresponding to each dimensions and the dimensions for the proposed dual band antenna are shown in **Figure 4** and **Table 2**, respectively.

Simulation was performed using ADS for the configuration shown in **Figure 3(c)**. The simulated gains of the proposed dual band antenna were 4.0 dBi at 3.45 GHz and 3.3 dBi at 5.5 GHz. The double-sided configuration of the antenna provided higher gain compared to the singled-sided antenna.



(a) (b)

Figure 4. Variables corresponding to each dimension of the proposed dual-band antenna: (a) Top layer; (b) Bottom layer.

Table 2. Dimensions for the proposed dual band antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz.

Variable	Value (mm)
L_1	1.20
L_2	17.8
L_3	1.08
L_4	6.60
L_5	29.3
L_6	10.0
L_7	21.6
L_8	17.8
W_1	1.02
W_2	1.52
W_3	2.54
W_4	49.1
R	5.21

3. Measurement Results and Discussions

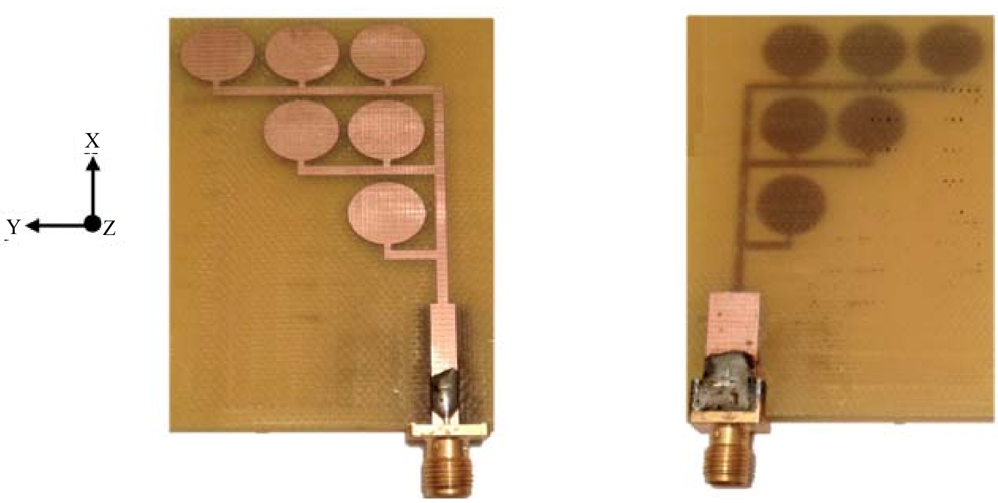
3.1. Single-Band Atnenna at 2.45 GHz

The antennas were fabricated using LPKF Protomat [15] on FR-4 material with height of 1.524 mm. The photos of the fabricated single band antenna are shown in **Figure 5** which has a size of 6.7 × 4.4 (in cm).

Figure 6 shows the comparison between the simulated and the measured S_{11} results.

The measured operating frequency is close to 2.45 GHz with S_{11} value below −15 dB. The 3 dB bandwidth at 2.45 GHz was approximately 18%. The measurement and simulation are in fairly good agreement, and the differences are due to microstrip loss and fabrication errors.

Figure 7 shows the comparison between the simulated and measured radiation pattern in xy-plane at 2.45 GHz which is close to omnidirectional pattern.



(a) (b)

Figure 5. Photo of the fabricated single-band antenna: (a) Top layer; (b) Bottom layer.

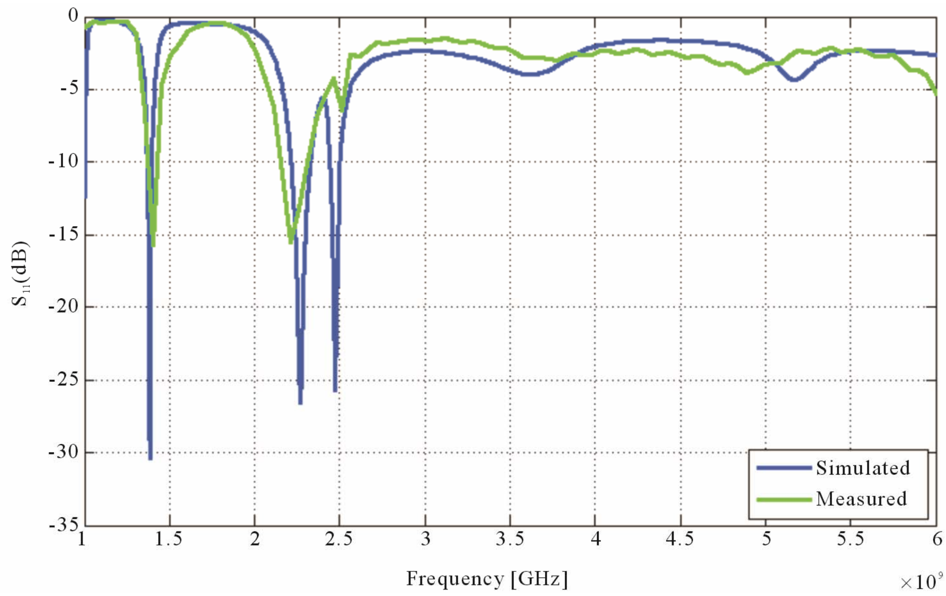


Figure 6. Simulated and measured return loss for the proposed single-band antenna.

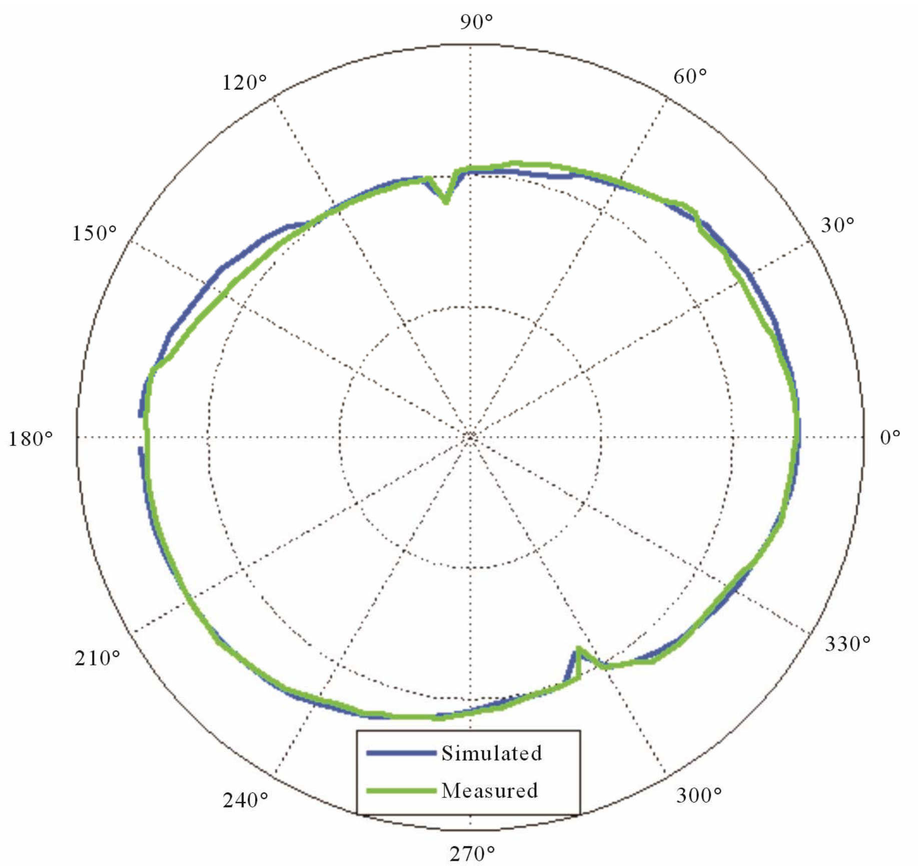


Figure 7. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 5) at 2.45 GHz.

3.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The antennas were fabricated using LPKF Protomat [15] on double-sided FR-4 materials. The photos of the fabricated dual band antenna are shown in **Figure 8** which has a size of 6.6 × 5.2 (in cm).

Figure 9 shows the comparison between the simulated

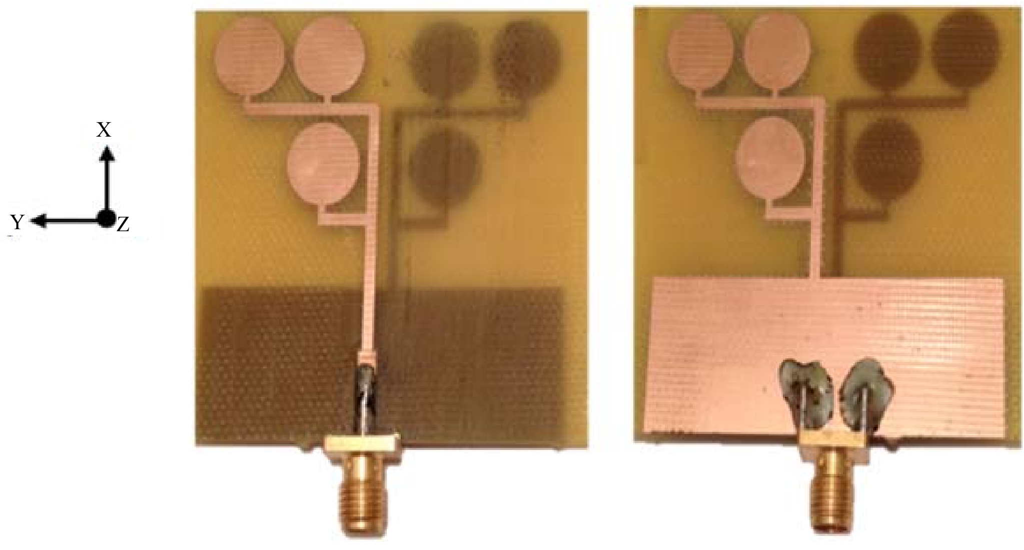


Figure 8. Photo of the fabricated dual-band antenna: (a) Top layer; (b) Bottom layer.

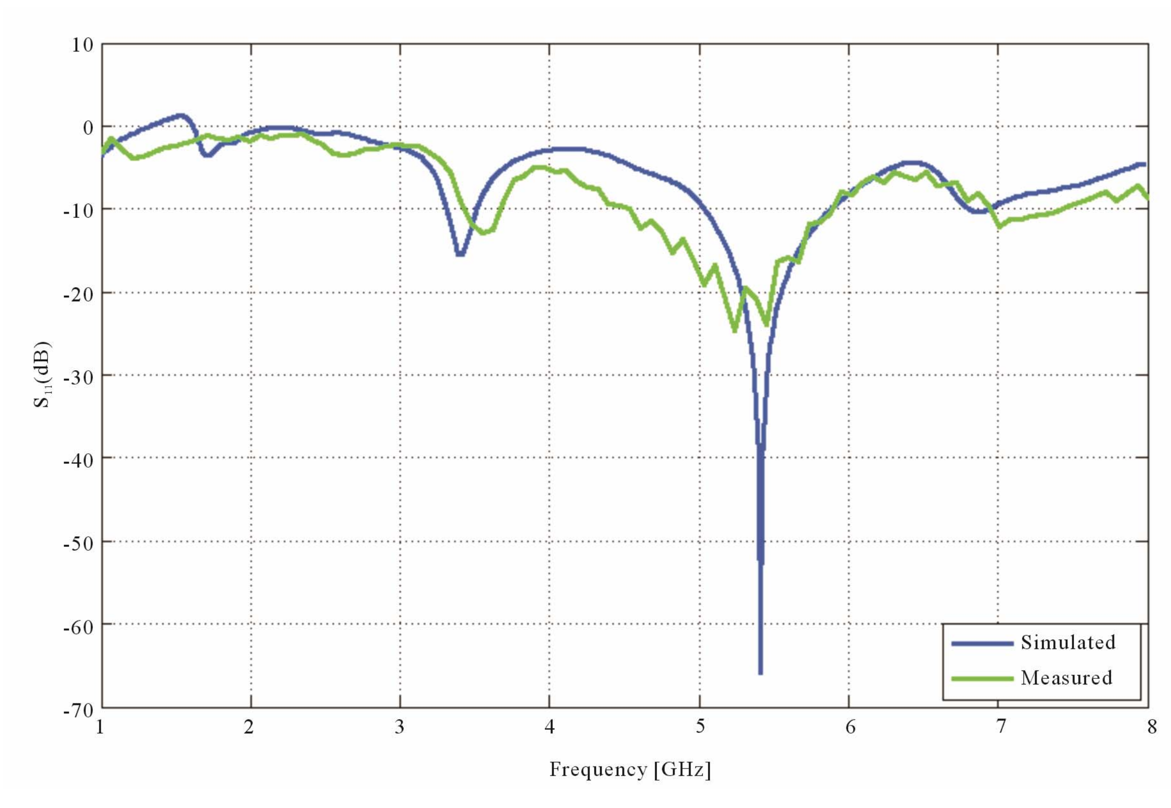


Figure 9. Simulated and measured return loss for the dual band antenna.

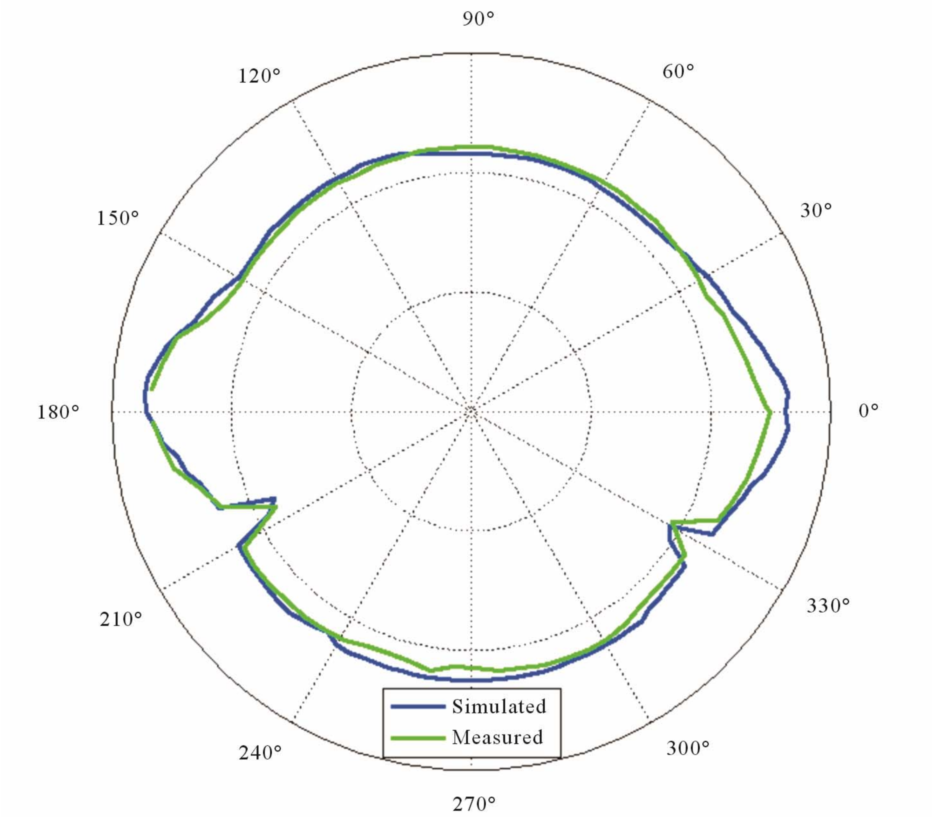
and the measured S_{11} results.

The measured S_{11} shows dual band near the designed bands with S_{11} values below −10 dB for both bands. The simulated and measured results give fairly good agreement, and the differences are due to board loss and fabrication errors.

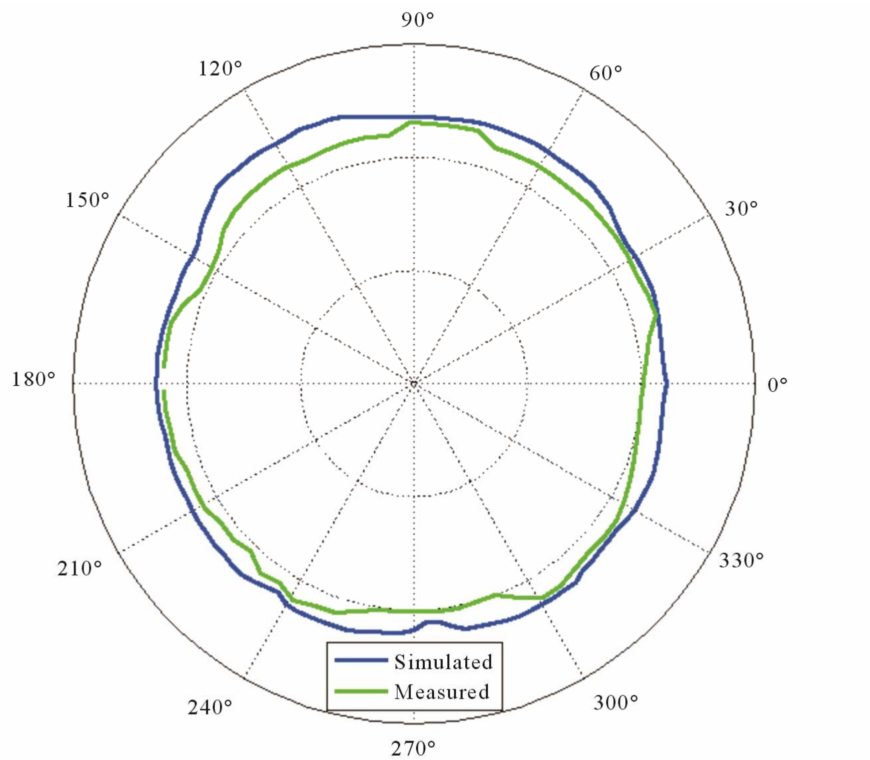
Figure 10 shows the comparison between the simulated and measured radiation pattern in xy-plane at 3.45 and 5.5 GHz which is close to omnidirectional pattern.

4. Conclusion

A microstrip circular antenna arrays were presented for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and



(a)



(b)

Figure 10. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 8) at (a) 3.45 GHz and (b) 5.5 GHz.

5.0 - 6.0 GHz for WLAN/WiMAX applications. Both antennas were designed with ADS, fabricated on a FR-4 microstrip material, and characterized. Both single band (single sided) and dual band (double-sided) antenna arrays provided omnidirectional pattern with desired gain.

REFERENCES

[1] C.-Y. Pan, T.-S. Horng, W.-S. Chen and C.-H. Huang, "Dual Wideband Printed Monopole Antenna for WLAN/ WiMAX Applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 6, 2007.

[2] A. C. Rao and R. Pandeeswari, "A CPW-Fed Antenna for Dual Band WiMAX/WLAN Applications," *IEEE International Conference on Recent Trends in Information Technology ICRTIT*, 2011.

[3] H.-Y. Lai, Z.-Y. Lei, Y.-J. Xie, G.-L. Ning and K. Yang, "UWB Antenna with Dual Band Rejection for WLAN/ WiMAX Bands Using CSRRs," *Progress in Electromagnetics Research Letters*, Vol. 26, 2011, pp. 69-78. doi:10.2528/PIERL11070112

[4] D. Parkash and R. Khanna "Design of a Dual Band Monopole Antenna for WLAN/WiMAX Applications," *IEEE Wireless and Optical Communications Networks*, 2010.

[5] L. Wang, K. Wei, J. Feng, Z. Zhang and Z. Feng, "A Wideband Omnidirectional Planar Microstrip Antenna for WLAN Applications," *IEEE*, 2011.

[6] J. Li, "An Omnidirectional Microstrip Antenna for WiMAX Applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, 2011.

[7] O. Tze-Meng and T. K. Geok, "A Dual-Band Omni-Directional Microstrip Antenna," *Progress in Electromagnetics Research*, Vol. 106, 2010, pp. 363-376. doi:10.2528/PIER10052411

[8] M. B. Bicer and A. Akdagli, "A Novel Microstrip-Fed Monopole Antenna for WLAN/WiMAX Applications," *Journal of Electromagnetic Waves and Applications*, Vol. 26, No. 7, 2012, pp. 904-913. doi:10.1080/09205071.2012.710372

[9] N. AbWahab, Z. Bin Maslan, W. N. W. Muhamad and N. Hamzah, "Microstrip Rectangular 4 × 1 Patch Array Antenna at 2.5 GHz for WiMAX Application," 2*nd International Conference on Computational Intelligence*, *Communication Systems and Networks*, 2010.

[10] Z. Zhong-xiang, C. Chang, W. Xian-liang and F. Ming-gang, "A 24 GHz Microstrip Array Antenna with Low Side Lobe," Springer, Berlin, 2012.

[11] A. K. Sahu and M. R. Das, "4 × 4 Rectangular Patch Array Antenna for Bore Sight Application of Consial Scan S-Band Traching Radar," *Antenna Week* (*IAW*), 2011.

[12] J. Das, T. A. Khan and M. K. Pal, "Rectangular Patch Antenna Array for Wireless Application," *International Journal of Engineering Science and Technology*, 2012.

[13] T. I. Huque, A. Chhowdhury, K. Hosain and S. Alam, "Performance Analysis of Corporate Feed Rectangular Patc Element and Circular Patch Element 4 × 2 Microstrip Array Antennas," *International Journal of Advanced Computer Science and Applications*, Vol. 2, No. 7, 2011, pp. 74-79.

[14] http://www.home.agilent.com/en/pc-1297113/advanced-design-system

[15] http://www.lpkf.com/protomat