3

A Reconfigurable Radial Line Slot Array Antenna for WiMAX Application

Mohd Faizal Jamlos
School of Computer and Communication Engineering,
University of Malaysia Perlis (UniMAP) to University Malaysia Perlis,
Kangar, Perlis,
Malaysia

1. Introduction

WiMAX refers to interoperable deployments of IEEE 802.16 protocol, in similarity with wireless fidelity (Wi-Fi) of IEEE 802.11 protocol but providing a larger radius of coverage. WiMAX is a potential replacement for current mobile technologies such as Global System Mobile (GSM) and High Speed Downlink Packet Access (HSDPA) and can be also applied as overlay in order to enlarge the capacity and speed.

WiMAX is a broadband platform and needs larger bandwidth compared to existing cellular bandwidth. Fixed WiMAX used fiber optic networks instead of copper wire which is deployed in other technology. WiMAX has been successfully provided three up to four times performance of current 3G technology, and ten times performance is expected in the future. Currently, the operating frequencies of WiMAX are at 2.3 GHz, 2.5 GHz, and 3.5 GHz whereas the chip of WiMAX that operated in those frequencies is already integrated into the laptops and netbooks. As transmitter, TELCO Company requires to prepare a better transmitting communication tower in providing better WiMAX's coverage and data rates. Hence, the need of superior reconfigurable WiMAX's antenna is extremely crucial to sustain the signal strength at the highest level (dB).

Traditional transmission line microstrip antenna has been widely used as a reconfigurable antenna due to its less complexity and easiness to fabricate. However, the reconfigurable beam shape application especially point-to-point communication required an antenna that can provide a better gain since incorporating a PIN diode switches has been known to deteriorate the gain characteristic of an antenna [1, 7]. A lot of efforts have been allocated to enhance the gain of the conventional microstrip antenna [2-3, 5, 9]. For high gain purpose, a radial line slot array (RLSA) antenna design is more beneficial [5]. An RLSA antenna has as much as 50% higher gain than the conventional microstrip antenna [6]. Conventionally, the RLSA antenna has no reconfigurable ability due to its feeding structure which is via coaxial-to-waveguide transition probe. However, it is made realizable by using feed line, PIN diodes and an aperture coupled feeding structure [7-8, 10-12].

Another significant problem of conventional microstrip antenna is the narrowing of half-power beamwidth (HPBW) which could only cover forward radiated beam from −50◦ to 50◦ [9]. This antenna also has another salient advantage where it can generate a broadside radiation pattern with a wider HPBW covering from −85° to 85°. Such wide HPBW is deemed as an interesting characteristic in which the antenna can function as WiMAX application.

As the proposed antenna is etched from FR4 substrate, it is inexpensive in terms of fabrication. Dimension wise, the proposed antenna length and width are 150 mm and 150 mm respectively, which is smaller than conventional microstrip antenna that could achieve the same function and performance [10]. In [3, 8, 9-13], switching mechanisms are utilized to alter the radiation pattern efficiently. The antenna, proposed in this paper, can dynamically be used in a beam shaping and broadside radiation pattern for WiMAX application.

This chapter is organized as follows: In Section 2, the RLSA radiating surface, aperture slots and feed line designs incorporates with PIN diode switches are explained and the effects of different configuration of the switches are investigated. The measurement and simulation of beam shaping and broadside radiation pattern using PIN diodes switching results will be shown in Section 3. Finally, conclusion will be drawn in Section 4.

2. Antenna structure

The proposed antenna structure, as shown in figure 1, has the ability to exhibit two major types of radiation patterns; the beam shape and the broadside radiation pattern. The 'circular' and a 'bridge' feed line are interconnected by switches, which consists of end-fire beam-shaped reconfigurable switches (EBRS) and broadside reconfigurable switches (BRS). The EBRS are referring to the first up to the fifth switches while the BRS are the first, fifth, sixth and seventh switches as shown in figure 1(a).

Four aperture slots are used to couple the feeding line to the radiating surface as shown in figure 1(b). Inaccuracy of alignment between the layer of feed line and aperture slots to the radiating surface can significantly deteriorate the antenna's performance especially on the gain characteristic. The aperture slots determine the amount of coupling to the RLSA radiating surface from the feed line of the proposed antenna. Hence, the feed line must be aligned beneath the aperture slots accurately as shown in figure 1(c). The length of the four aperture slots are 40 mm while their width are 3 mm.

The RLSA pattern that is used as the radiating surface in the proposed antenna has the arrangement as shown in figure 1(d) in order to provide a linear polarization along the beam direction. There are 96 slots, with 16 slots in the inner-most ring, and 32 slots in the outer-most ring. The width and length of the RLSA slots are 1.5 mm and 15 mm respectively. The gaps between the slots are mostly 8 mm. The diameter of the circular radiating surface is 150 mm.

Generally, by turning the EBRS ON and the sixth and seventh of the BRS OFF, it will result in a beam shape radiation pattern. The pattern will becomes narrower with an increasing number of EBRS switches turned ON. While by turning ON the BRS and the second up to fourth of EBRS turned OFF, a broadside radiation pattern will be obtained.

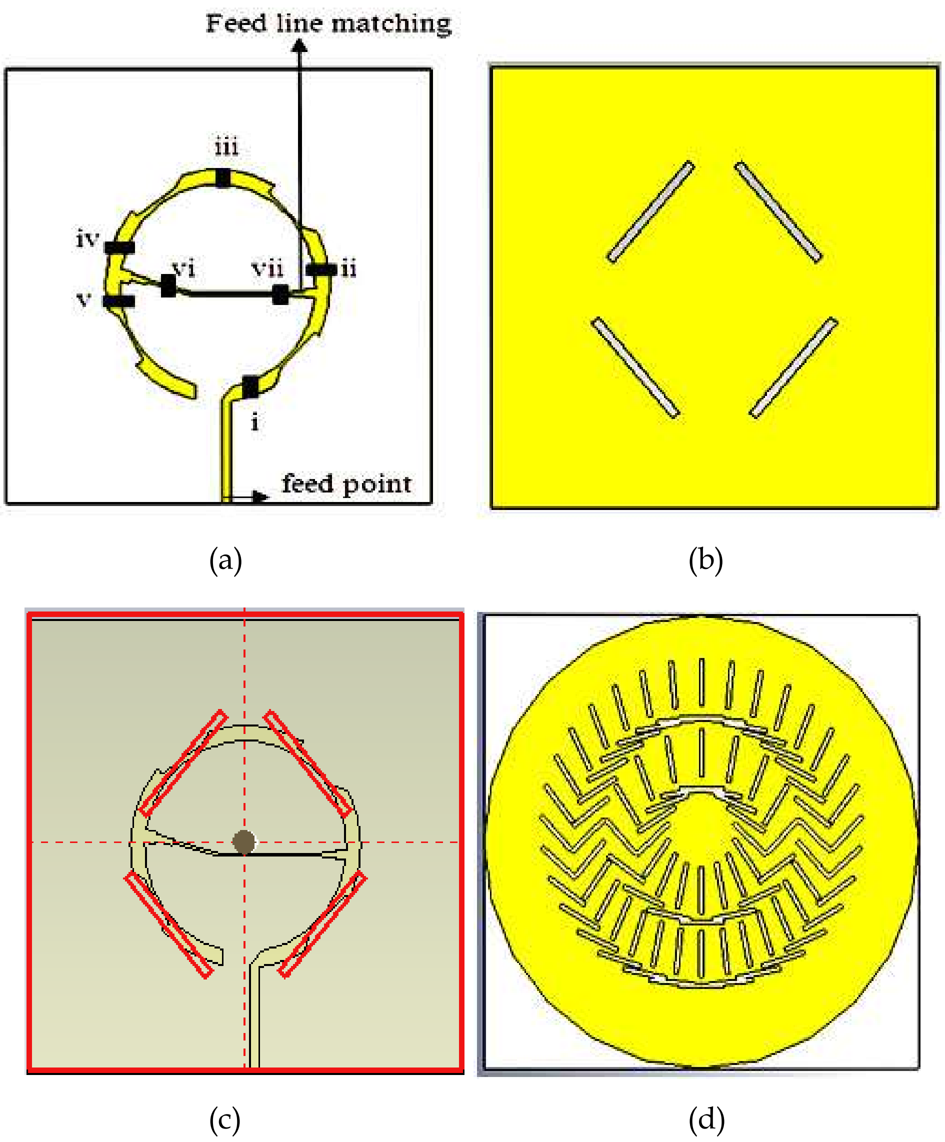
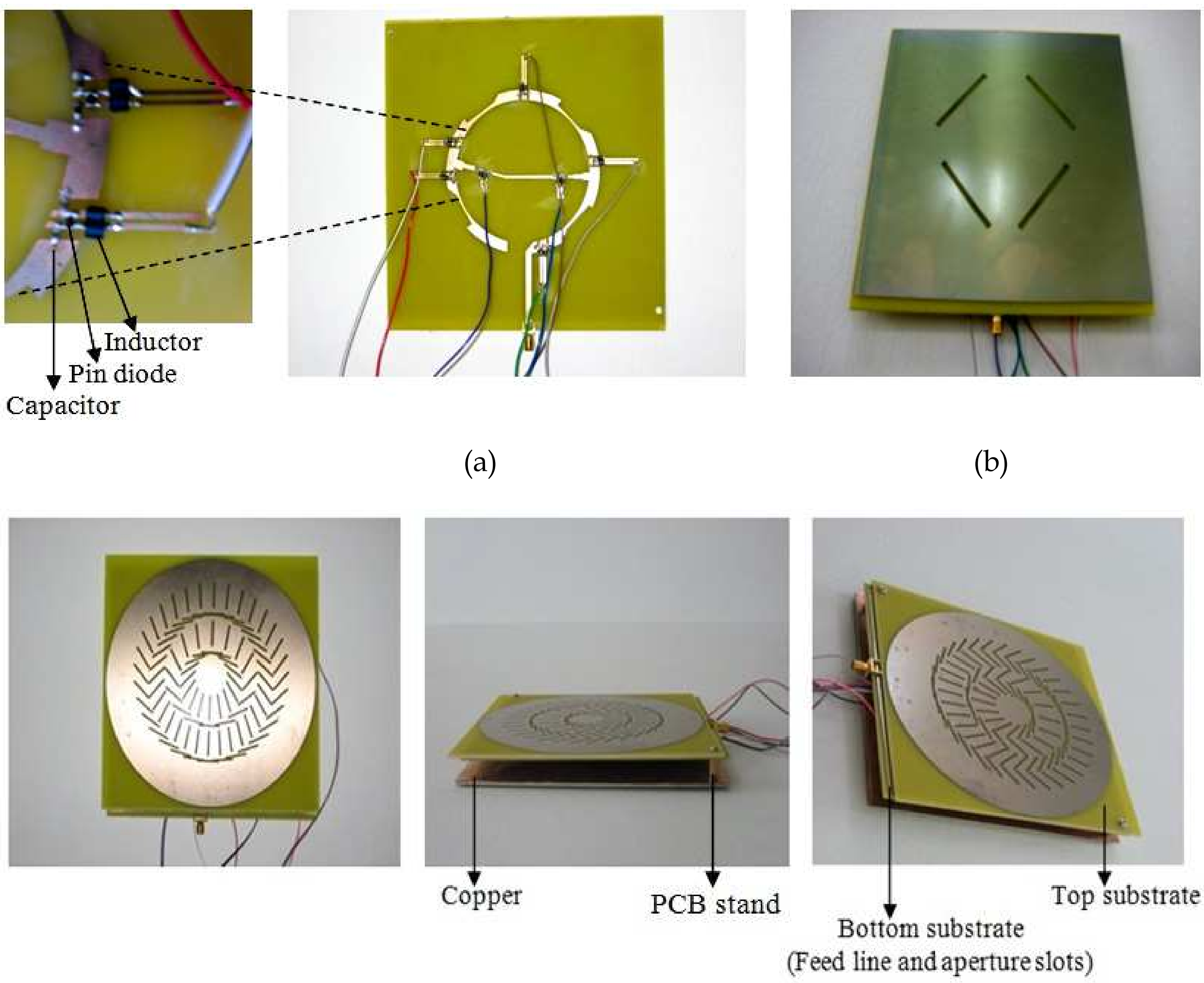


Fig. 1. Simulation structure of the proposed antenna (a) feed line (b) Aperture slots (c) Alignment of aperture slots and feed line (d) RLSA radiating surface

Figure 2 shows the photographs of the proposed antenna. Each of the PIN diodes is surrounded by two inductors and two capacitors forming the switching circuit as shown in figure 2(a). The inductors intend to choke off the alternating current (AC) and radio frequency (RF) signals from flowing into the feeding line while the capacitors allow the flow of the AC and block the direct current (DC) simultaneously.

The proposed antenna is developed using an aperture coupled configuration where the upper and bottom substrate are made of FR4 dielectric substrates (relative permittivity = 4.7, loss tangent = 0.019). The sizes of the substrates are 150 mm x 150 mm. The feed probe's radius is 0.5 mm while the heights of the substrates are 1.6 mm. The back plane reflector is a made up of copper foil with 0.035 mm thickness. The foil is attached on a piece of 2 mm thickness wood. The reflector is placed under the proposed antenna by using PCB stands of 5 mm height, as shown in figure 2(d). The height between the reflector and the feed line is influential in determining the operating frequency of the antenna. If the height is larger than its optimized height, which is 5 mm for this antenna, the operating frequency will be shifted to a lower centre frequency, and vice versa. The reflector width and length are both 150 mm, thus making its surface area the same as the size of the antenna. The proposed antenna is operating at frequency of 2.3 GHz.



(c) (d) (e)

Fig. 2. Photograph of the proposed antenna (a) Feed line with PIN diodes switches (b) Aperture slots (c) RLSA radiating surface (d) side view (e) Layout view

3. Result and discussion

Measurement shows that four different types of beam shape radiation pattern can be well reconfigured with the configuration of the EBRS. Different activation of EBRS will results in different gain and HPBW. By turning ON the first switch of the EBRS, gain and HPBW of 4.85 dB and -65° to 70° are obtained respectively, as shown in figure 3(a). While in figure 3(b), turning ON the first and second switches of the EBRS will narrow the HPBW from -40° to 45° with a gain of 7.2 dB. Figure 3(c) demonstrates the beam shape of the radiation pattern with the HPBW from -15° to 20° and a gain of 9.9 dB by turning ON the first, second and third switch of the EBRS simultaneously.

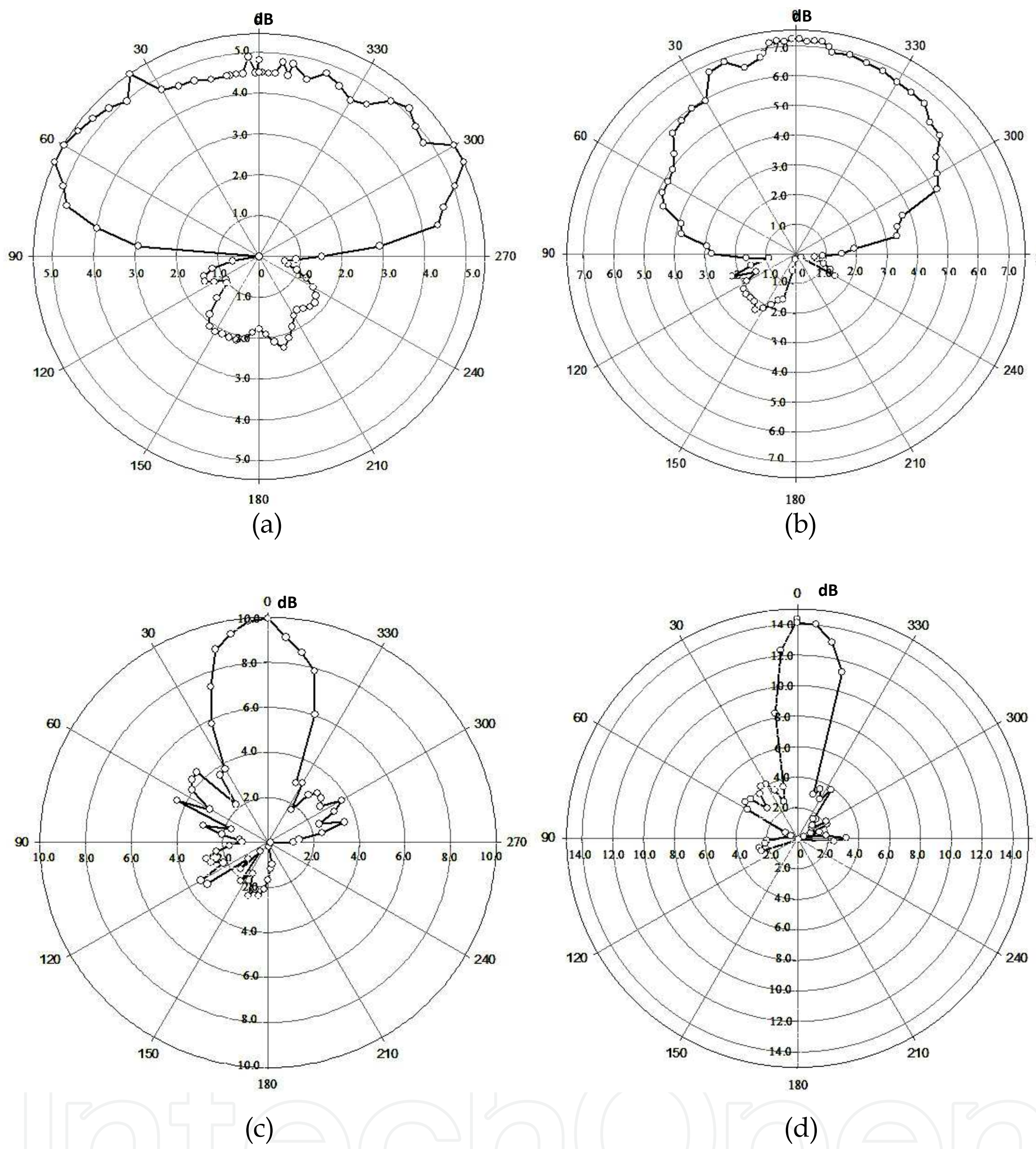
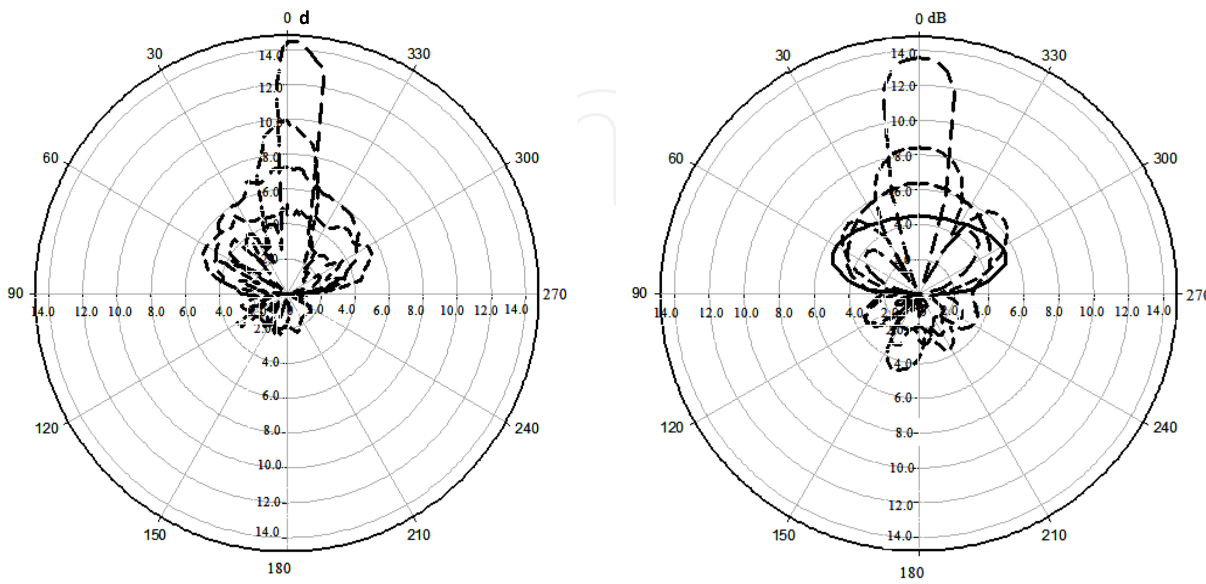


Fig. 3. The measurement of beam shape radiation patterns by turning ON the EBRS (a) switch i (b) switches i and ii (c) switches i, ii, and iii (d) switches i, ii, iii, iv and v

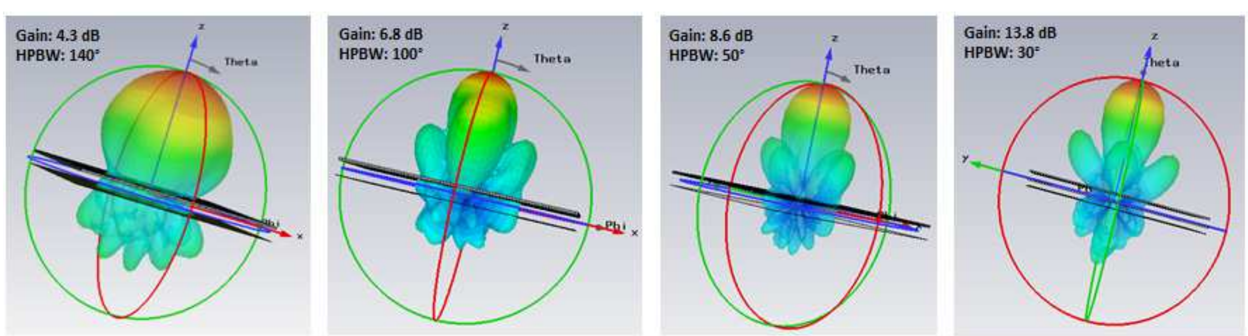
In figure 3(d), the HPBW of the radiation pattern is from -10° to 15° and antenna gain of 14.64 dB are obtained when the first until the fifth switches of the EBRS are turned ON. It is obvious that the proposed antenna can be tuned to have a wide HPBW which covered from -65° to 70° beam angle range, compared to conventional microstrip antenna that can only cover from -50° to 50° beam angle range. The maximum gain of the proposed antenna is 14.64 dB, which can be considered high for an antenna of such size. Computer Simulation Technology (CST) Studio Suite 2009 is used as a platform to design and simulate the radiation pattern of the proposed antenna. It is clearly shown that the simulations have the same behaviour with the measurements where the higher the produced gain, the antenna's

HPBW will becomes narrower as shown in figure 4(a) and figure 4(b). 3D representation of the far field radiation patterns are shown in figure 5. The measurement has comparable results with the simulations. Nevertheless, the measured antenna's gain is slightly higher than simulation results but smaller in terms of HPBW.



(a) (b)

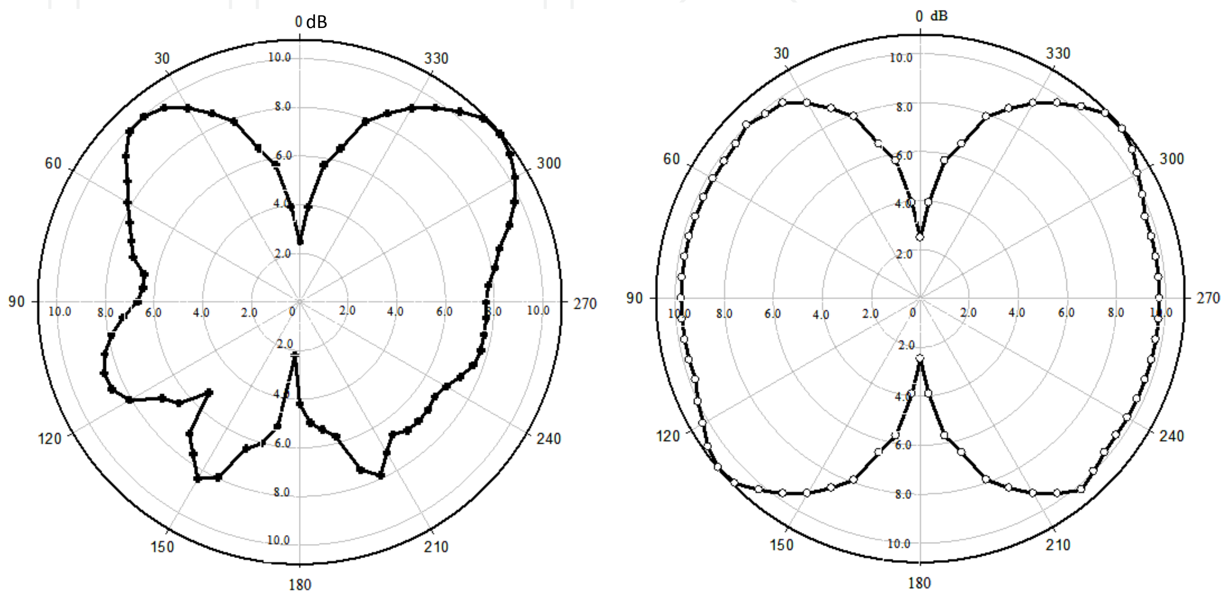
Fig. 4. The complete beam shape radiation patterns (a) Measured (b) Simulation



(a) (b) (c) (d)

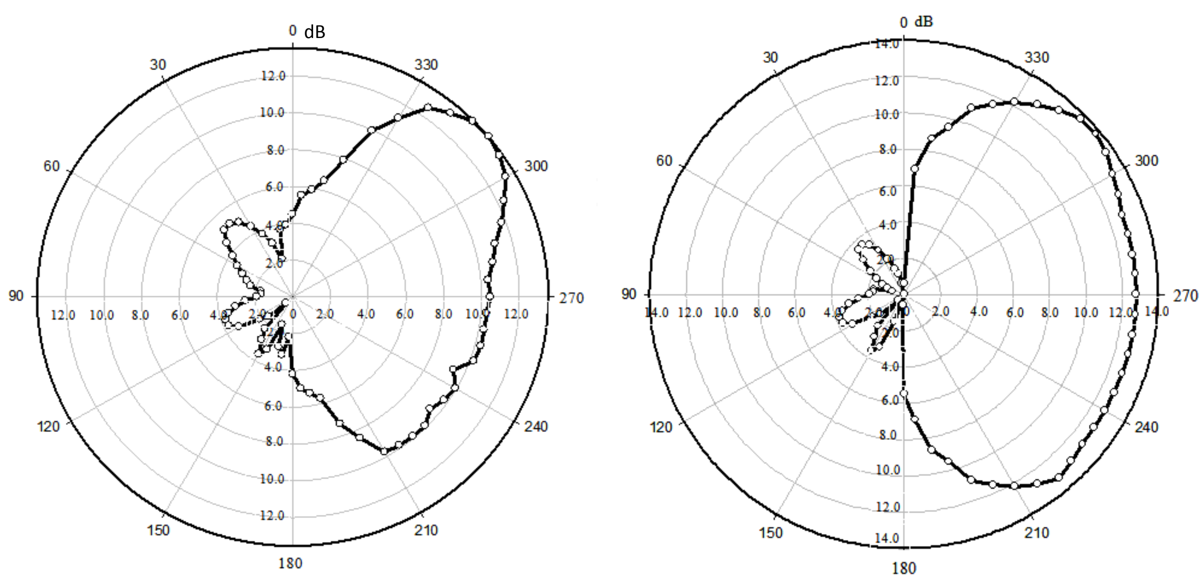
Fig. 5. 3D-polar plot of beam shape radiation patterns by turning ON the EBRS (a) switch i (b) switches i and ii (c) switches i, ii, and iii (d) switches i, ii, iii, iv and v

The BRS configuration has the ability to turn the radiation pattern from the beam shape to broadside radiation pattern perfectly as shown in figure 6 and figure 7. Figure 6 shows a divisive broadside radiation pattern with a maximum gain of 10.8 dB and a wider HPBW of -85°- 85° when turning all of the BRS ON simultaneously. Certain combination configuration between the BRS and EBRS are able to generate another radiation pattern which is a broadside single-sided radiation pattern. This kind of pattern is lean to the right with HPBW of -80°- 80° when turning ON the sixth and seventh of BRS and the first up to fourth of EBRS concurrently with a maximum gain increased up to 12.8 dB as shown in Figure 7. Since in this switching configuration the direction of radiation pattern is focused on one side, it achieves a higher gain in comparison to the divisive broadside pattern. Figure 8 depicts the 3D simulation of the far field radiation patterns of the proposed antenna which is aligned with the measured radiation patterns as shown in figure 6 and figure 7. However, the measured gain and HPBW are slightly less compared to the simulations due to CST simulation's ideal and free loss environment.



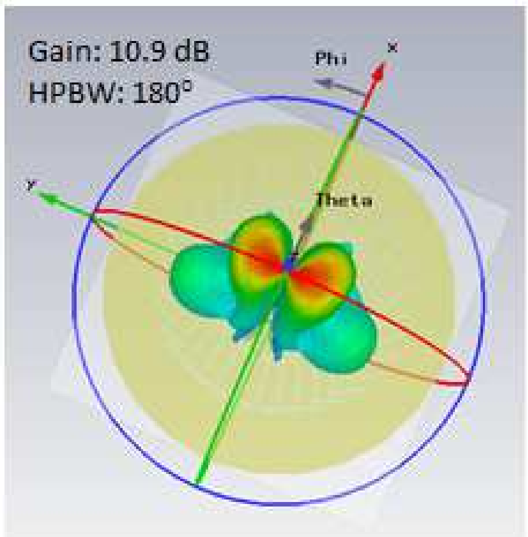
(a) (b)

Fig. 6. Broadside divisive radiation patterns (a) Measured (b) Simulation

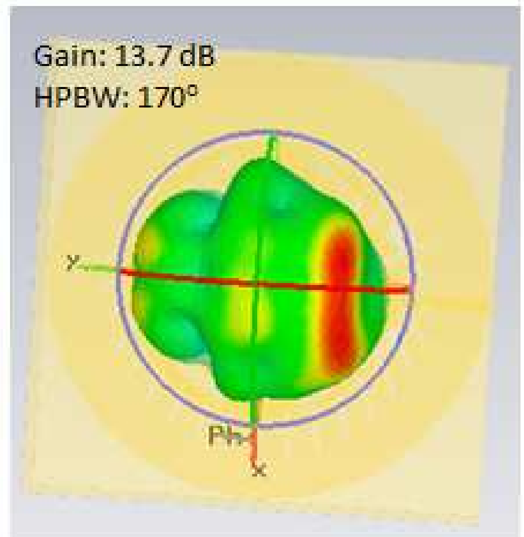


(a) (b)

Fig. 7. Broadside single-sided radiation patterns (a) Measured (b) Simulation



(a)



(b)

Fig. 8. 3D-polar plot of broadside radiation patterns (a) Divisive (b) Single-sided

The measurements show a very good agreement with simulations where the radiation patterns are formed successfully with respect to the beam shaping and broadside characteristics. The high gain measurements and simulations of the proposed antenna can be attributed to the good coupling from the feed line to the RLSA radiating surface through the appropriate sizing, positioning and shape of aperture slots. The outputs of the PIN diodes switching scheme involving the EBRS and BRS are summarized in table 1. All the radiation patterns of the proposed antenna are relatively at frequency 2.3 GHz as depicted by figure 9.

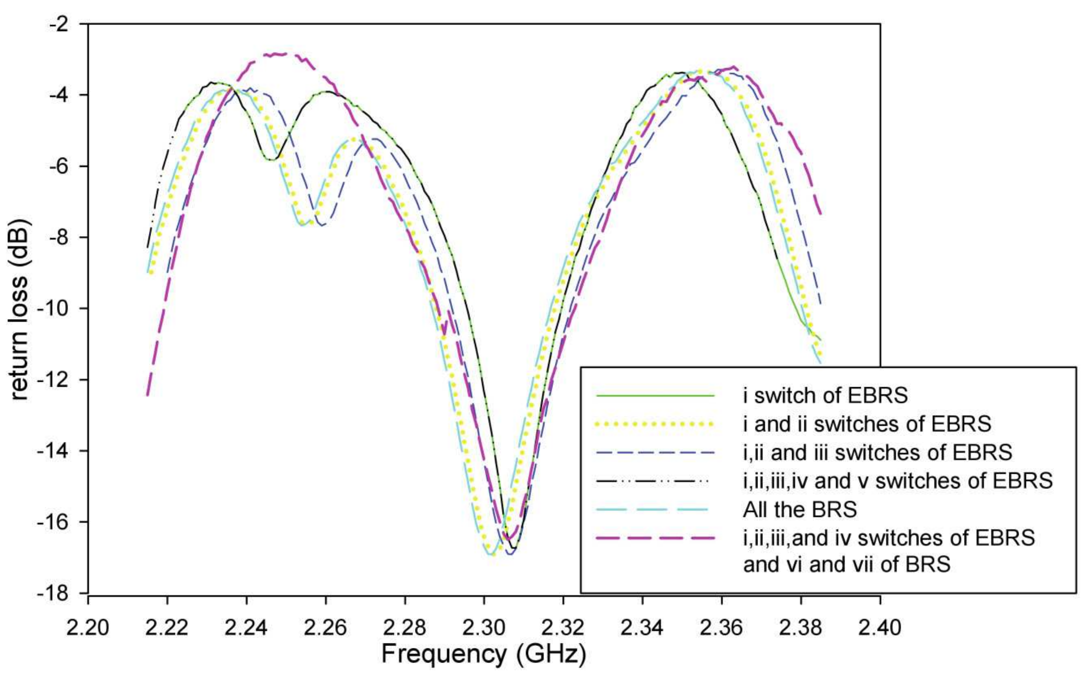


Fig. 9. The measurement of return loss by variation activation of the EBRS and BRS

Type of switch	Number of PIN diode switch	PIN diode status					
End-fire beam-shaped reconfigurable switches (EBRS)	i	ON	ON	ON	ON	ON	ON
	ii	OFF	ON	ON	ON	OFF	ON
	iii	OFF	OFF	ON	ON	OFF	ON
	iv	OFF	OFF	OFF	ON	OFF	ON
	v	OFF	OFF	OFF	ON	ON	OFF
Broadside reconfigurable switches (BRS)	vi	OFF	OFF	OFF	OFF	ON	ON
	vii	OFF	OFF	OFF	OFF	ON	ON
Gain (dB)		**4.85**	**7.2**	**9.9**	**14.64**	**10.8**	**12.8**
HPBW(°)		**-65°- 70°**	**-40° to 45°**	**-15° to 20°**	**-10° to 15°**	**-85°- 85°**	**-80°- 80°**
Type of radiation pattern		**Beam shaping**				**Divisive radiation pattern**	**Single sided radiation pattern**

Table 1. Configuration of PIN diode switches of the measured proposed antenna at 2.3 GHz

4. Conclusion

A novel reconfigurable radiation pattern microstrip antenna using RLSA is introduced in this paper. This chapter has taken advantages of the high performances of RLSA in terms of gain and less signals reflection, to make the proposed antenna becomes more efficient. This antenna is designed based on aperture coupled structure. The ability of the beam shape and broadside radiation pattern is attributed with the usage of PIN diode switches that integrated in the feed line of the proposed antenna. It is shown through the measurements that the radiation patterns can be well reconfigured through the assist of the orientation and geometry of the RLSA slots. The proposed antenna which has a dimension size of 150 mm X 150 mm, can be tuned to reach a high gain of 14.64 dB. The antenna can also provide wider value of HPBW that covered from -85° to 85° which is far better than -50° to 50° HPBW of a conventional microstrip antenna. The broadside patterns are achieved by turning ON selected configuration of the combination between the BRS and EBRS. The structure of the proposed antenna which is not bulky compared to the conventional microstrip antenna would be greatly suitable for beam shape and broadside radiation pattern application such as WiMAX.

5. References

[1] G. Monti, R. De Paolis, and L. Tarricone, "Design of a 3-state reconfigurable crlh transmission line based on mems switches," *Progress In Electromagnetics Research*, PIER 95, 283-297, 2009.

[2] M. T. Islam, M. N. Shakib and N. Misran, "Design Analysis Of High Gain Wideband L-Probe Fed Microstrip Patch Antenna" *Progress In Electromagnetics Research,* PIER 95, 397-407, 2009.

[3] X. Li, L. Yang, S.-X. Gong, and Y.-J. Yang, "Bidirectional High Gain Antenna for Wlan Applications," *Progress In Electromagnetics Research Letters*, Vol. 6, 99-106, 2009.

[4] N. Romano, G. Prisco and F. Soldovieri, "Design Of A Reconfigurable Antenna For Ground Penetrating Radar Applications" *Progress In Electromagnetics Research,* PIER 94, 1-18, 2009.

[5] O. Beheshti-Zavareh and M. Hakak, "A Stable Design Of Coaxial Adaptor For Radial Line Slot Antenna", *Progress In Electromagnetics Research,* PIER 90, 51–62, 2009.

[6] Paul W. Davis and Marek E. Bialkowski, "Experimental Investigations into a Linearly Polarized Radial Slot Antenna for DBS TV in Australia", *IEEE Transactions on Antennas and Propagation*, vol. 45, No. 7, July1997.

[7] J. L. Masa-Campos and F. Gonzalez-Fernandez, "Dual linear/circular polarized plannar antenna with low profile double-layer polarizer of 45^o tilted metallic strips for wimax applications," *Progress In Electromagnetics Research*, PIER 98, 221-231, 2009.

[8] G. M. Rebeiz, RF MEMS: Theory, Design, and Technology. Hoboken, NJ: Wiley-Interscience, 2003.

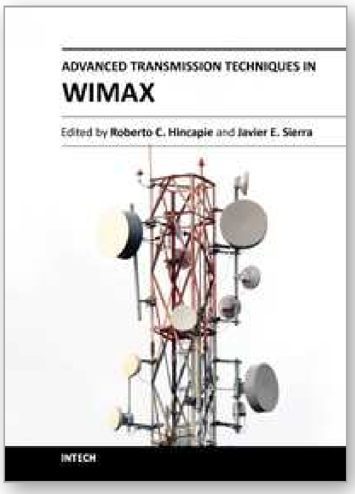
[9] J. Ouyang, F. Yang, S. W. Yang, Z. P. Nie and Z. Q. Zhao., "A novel radiation pattern and frequency reconfigurable microstrip antenna on a thin substrate for wide-band and wide-angle scanning application", *Progress In Electromagnetics Research*, PIER 4, 167–172, 2008.

[10] M. F. Jamlos, O. A. Aziz, T. A. Rahman and M. R. Kamarudin "a beam steering radial line slot array (rlsa) antenna with reconfigurable operating frequency" J. of Electromagn. Waves and Appl., Vol. 24, 1079–1088, 2010

[11] M. F. Jamlos, T. A. Rahman, and M. R. Kamarudin "a novel adaptive wi-fi system with rfid Technology" *Progress In Electromagnetics Research, Vol. 108, 417-432, 2010*

[12] M. F. Jamlos, T. A. Rahman, and M. R. Kamarudin "adaptive beam steering of rlsa antenna with rfid technology," *Progress In Electromagnetics Research, Vol. 108, 65-80, 2010*

[13] Huff, G. H., J. Feng, S. Zhang, and J. T. Bernhard, "A novel radiation pattern and frequency reconfigurable single turn square spiral microstrip antenna," *IEEE Microwave Wireless Components Letter*, Vol. 13, 57–59, February 2003.



Advanced Transmission Techniques in WiMAX

Edited by Dr. Roberto Hincapie

ISBN 978-953-307-965-3
Hard cover, 336 pages
Publisher InTech
Published online 18, January, 2012
Published in print edition January, 2012

This book has been prepared to present the state of the art on WiMAX Technology. The focus of the book is the physical layer, and it collects the contributions of many important researchers around the world. So many different works on WiMAX show the great worldwide importance of WiMAX as a wireless broadband access technology. This book is intended for readers interested in the transmission process under WiMAX. All chapters include both theoretical and technical information, which provides an in-depth review of the most recent advances in the field, for engineers and researchers, and other readers interested in WiMAX.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821