Low Profile Switched Beam Utilizing A Ring-Parasitic Antenna

Pichaya Chaipanya

Department of Electrical Engineering, Srinakharinwirot University, Nakhon Nayok, Thailand
pichayac@g.swu.ac.th

***Abstract*— This paper presents a low profile switched beam antenna for wireless communications at 2.45 GHz. There are eight-beam patterns, 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°, which can be controlled by shorted circuit at different positions of small circular elements of parasitic ring. The antenna is created in simulation from CST Microwave Studio. The obtain results show that the proposed antenna cannot only capable to beam switching but also increase gain of the antenna.**

Keywords*— *Switched beamforming, parasitic antenna, shorted circuit, patch antenna, wireless communication.

I. Introduction

Nowadays, the demand of wireless communications has been dramatically increased over the last decades. Wireless communications such as cellular phones and WLANs have a part of everyday life in most developed countries. One technique that is capable of increasing the wireless system capacity is switched beam antenna in smart antenna systems.

Switched beam antennas are constituted by antenna array and beamforming network. There are fixed numbers of main beam and a beamforming network is used to select its main beam to desired user. This system is easy to implement due to it is not complex and low of cost [1]. Comparison of radiation patterns of omni-directional antenna and switched beam antenna are shown in Fig. 1 and Fig. 2, respectively. As we can see, it cannot only reduce interference signal coming from neighboring areas and neighboring signal points but also enhance the signal in desired direction when switched beam antenna is applied in the system. Consequently, switched beamforming techniques are interested to utilize for improving the wireless systems performance. Moreover, parasitic antenna is one technique that is interested to use for increasing the gain of antenna. There is only one element which is energized directly by a feed transmission line while the others as parasitic elements whose currents are induced by mutual coupling [2]. Therefore, parasitic antenna can be provided high gain while the system is low of cost due to this antenna use only single feeder.

Several researchers have been proposed switched beamforming using parasitic antenna such as the works presented in [3] and [4], switched parasitic antenna on a finite ground plane with conductive sleeve and base-station tracking in mobile communications using a switched parasitic antenna array, respectively. These are only one active monopole element and six or three parasitic monopole elements operating near resonance. However, this antenna is considerably suitable for transmitter, not for receiver due to it is large of size. Next, planar array antenna with parasitic elements for beam steering control and beam steering antenna based on parasitic layer are presented in [5] and [6]. Beam pattern of small antenna size is switched by PIN diode which is simple scheme of beam switching. The antenna structure

Fig. 1. Interference signal coming from neighboring area and neighboring repeater when omni-directional antenna is employed.

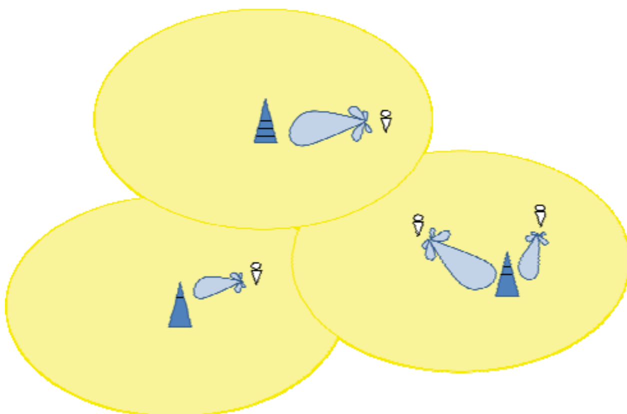


Fig. 2. Interference signal coming from neighboring area and neighboring repeater are reduced when switched beam antenna is employed.

consists of a driven microstrip-fed patch element and a parasitic layer located on top of the driven patch. However, this antenna has complex structure due to driven patch and parasitic antenna are not in a same layer. Moreover, it is able to switch the beam pattern for only three directions. The work presented in [7] has revealed a planar parasitic array antenna for tunable radiation pattern. A planar cross-type parasitic patch array antenna has been demonstrated to give tunable radiation patterns. A tunable radiation patterns is achieved by adjusting capacitances. However, capacitances of this scheme must be adjusted all time when users are moving. Also the work present in [8] has proposed reconfigurable Four-Parasitic-Elements Patch Antenna (FPPA) for high-gain beam switching application. The FPPA is designed with a single main radiator, four parasitic elements and a full ground plane. The reconfigurable beam switching ability is developed using PIN diode switches. This is considerably interesting as it is small of size and simple to switch the beam pattern. However, it is able to switch the beam pattern for only five directions. Therefore, this paper proposes a low profile switched beamforming using a ring-parasitic antenna which is able to switch beam pattern for eight different directions. As its structure is very simple and low of cost.

The rest of this paper as follows. After brief introduction, the proposed antenna designed is discussed in Section II. The structures of antenna, parasitic ring and shorted-circuit switching are revealed. Next, computer simulation is performed to show its beam switching capability in Section III. Finally, Section IV concludes the paper.

II. Antenna Design

The proposed antenna has been designed on FR4 with dielectric constant of 4.7 and substrate thickness of 1.57 mm. The antenna consists with the circular antenna on the center of the patch with radius of a which can be given by [2]

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (1)$$

where

$$F = \frac{8.791\times10^{9}}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

where ε_r is dielectric constant, f_r stands for resonant frequency and the height of substrate h in cm. However, $a=16.31$ mm is small of size thus there is low gain of antenna. Therefore, size of circular patch is increased to $2a$, $3a$ and $4a$. However, size of $4a$ is large then it cannot induce current by mutual coupling. Therefore, the size of $3a$ is used in this paper. Next, the SMA feed probe is attached from one side through another side at the patch center which is symmetrically positioned along the E-plane. There is a parasitic antenna which is a ring surrounding the circle antenna patch with outer and inner radius of $3a+7$ mm and $3a+2$ mm, respectively. This positions of ring is closed to induced currents by mutual coupling. Please note that this antenna is designed at 2.45 GHz.

In this paper, the beam switching is controlled by shorted circuits at a ring. The ring is consisted of eight small circular elements which diameter of $0.75a$ and punctured into eight holes which are open circuits on a parasitic antenna. However, this shape of antenna cannot operate at 2.45 GHz due to the total area of antenna is added from small circular elements and a ring. Therefore, the size of antenna add parasitic are adapted to near 2.45 GHz as shown in Fig. 3. The positions of small circular elements and hole are changed to the best directivity. Also, the proposed antenna without shorted circuit is shown in Fig. 4. Then, seven holes of parasitic are shorted circuit and the other one is opened circuit. Therefore, there are 8 directions of beam switching as discussed in next Section.

III. Simulation Results

Next, the surface currents and radiation patterns obtained from CST Microwave Studio are shown in Fig. 5 to Fig. 14. In

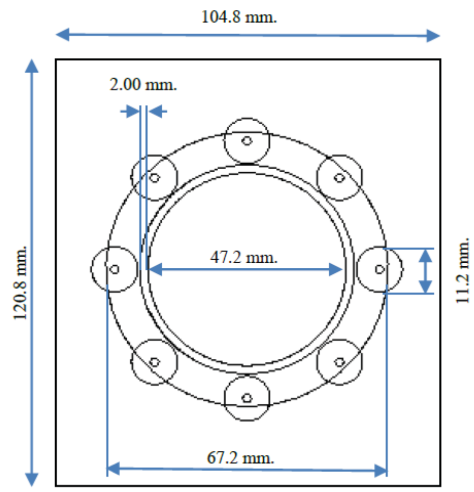


Fig. 3. Dimension of antenna.

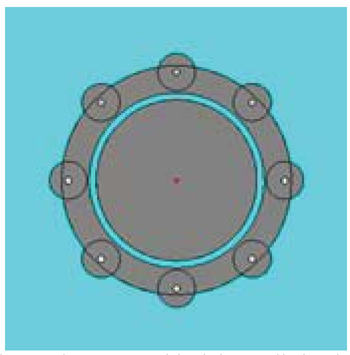
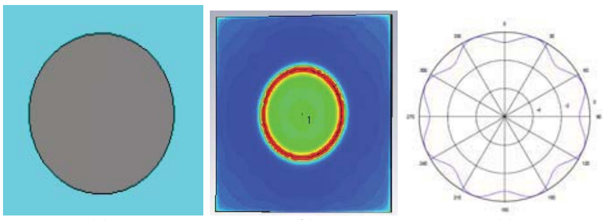


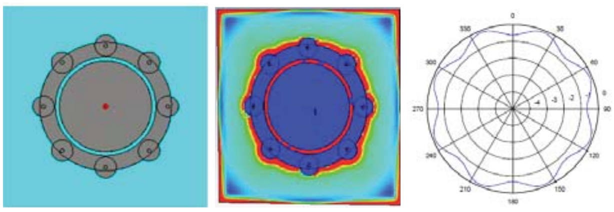
Fig. 4. Circular patch antenna with eight small circular elements of parasitic ring without shorted circuit.

Fig. 5, the results of antenna without parasitic are shown. In this case, the low gain of omni-directional antenna is provided. Next, the results of antenna with parasitic without shorted circuit are shown in Fig. 6. Afterward, the small circular elements of parasitic ring are shorted circuit on different positions in eight cases as shown in Fig. 7 to Fig. 14, so called case A to case H, respectively. As we can see, the direction of beam patterns depend on the positions of shorted circuit on small circular elements of parasitic ring. The average gain of antenna when case A to H are applied is 4.758 dBi as described in TABLE I. Please note that the position of open circuit (number 1 to 8) is shown in Fig. 7 (a) to 14 (a). As a result, gain of antenna can be increased when beam patterns are switched using parasitic ring. The directions are 180°, 225°, 270°, 315°, 0°, 45°, 90° and 135° in case A to H, respectively. According to this, this simulation results are able to confirm its beam switching capability.



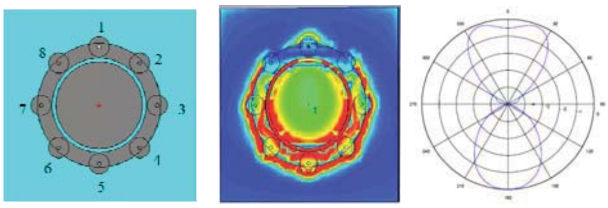
(a) (b) (c)

Fig. 5. (a) top-view configuration (b) surface current and (c) radiation pattern.



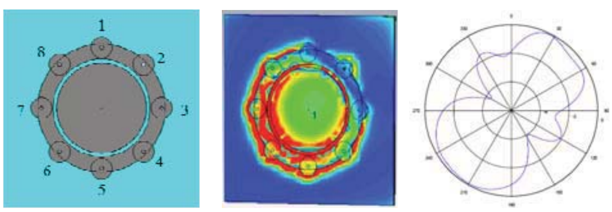
(a) (b) (c)

Fig. 6. (a) top-view configuration (b) surface current and (c) radiation pattern.



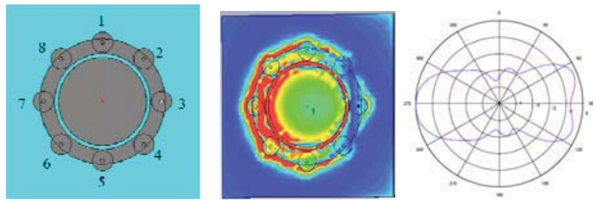
(a) (b) (c)

Fig. 7. (a) top-view configuration (b) surface current and (c) radiation pattern of case A.



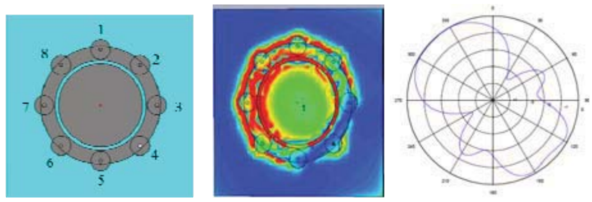
(a) (b) (c)

Fig. 8. (a) top-view configuration (b) surface current and (c) radiation pattern of case B.



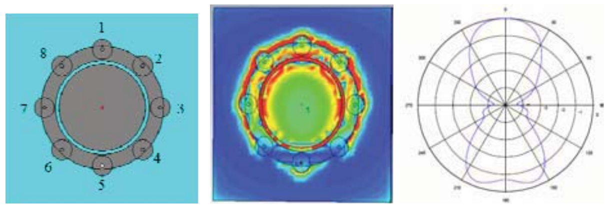
(a) (b) (c)

Fig. 9. (a) top-view configuration (b) surface current and (c) radiation pattern of case C.



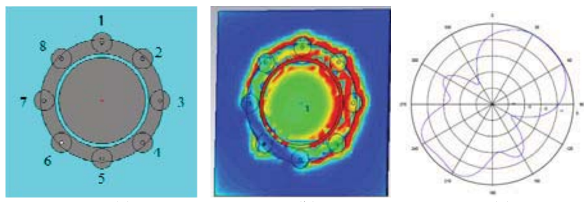
(a) (b) (c)

Fig. 10. (a) top-view configuration (b) surface current and (c) radiation pattern of case D.



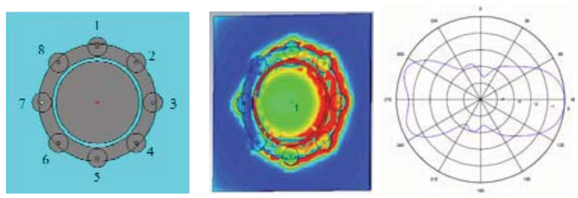
(a) (b) (c)

Fig. 11. (a) top-view configuration (b) surface current and (c) radiation pattern of case E.



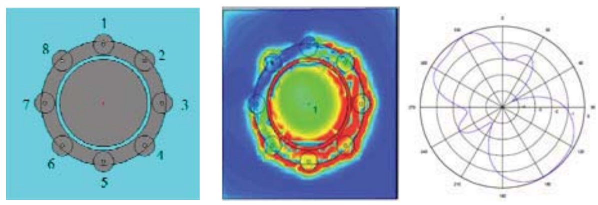
(a) (b) (c)

Fig. 12. (a) top-view configuration (b) surface current and (c) radiation pattern of case F.



(a) (b) (c)

Fig. 13. (a) top-view configuration (b) surface current (c) radiation pattern and (d) S_{11} of case G.



(a) (b) (c)

Fig. 14. (a) top-view configuration (b) surface current (c) radiation pattern and (d) S_{11} of case H.

TABLE I. CONCLUSION OF SHORTED CIRCUIT POSITIONS AND RESULTS

Position of open circuit	**Case**				
	Open circuit	**A**	**B**	**C**	**D**
1	open	open	shorted	shorted	shorted
2	open	shorted	open	shorted	shorted
3	open	shorted	shorted	open	shorted
4	open	shorted	shorted	shorted	open
5	open	shorted	shorted	shorted	shorted
6	open	shorted	shorted	shorted	shorted
7	open	shorted	shorted	shorted	shorted
8	open	shorted	shorted	shorted	shorted
Direction (°)	-	180	225	270	315
Frequency (GHz)	12.2	2.449	2.448	2.449	2.452
Gain (dBi)	3.74	5.28	4.62	4.48	4.6
S_{11} (dB)	-	-24.98	-23.10	-20.62	-24.96

TABLE I. CONCLUSION OF SHORTED CIRCUIT POSITIONS AND RESULTS (CONTINUE)

Position of open circuit	**Case**				
	E	**F**	**G**	**H**	**Mean**
1	shorted	shorted	shorted	shorted	
2	shorted	shorted	shorted	shorted	
3	shorted	shorted	shorted	shorted	
4	shorted	shorted	shorted	shorted	
5	open	shorted	shorted	shorted	
6	shorted	open	shorted	shorted	
7	shorted	shorted	open	shorted	
8	shorted	shorted	shorted	open	
Direction (°)	0	45	90	135	
Frequency (GHz)	2.455	2.452	2.449	2.448	2.450
Gain (dBi)	5.38	4.6	4.48	4.62	4.758
S_{11} (dB)	-33.69	-24.96	-20.62	-23.10	-24.50

IV. CONCLUSION

This paper has proposed a new design for switched beam using eight small circular elements of parasitic ring. This parasitic element is capable of beam switching for eight different directions. Beam direction can be changed by shorted circuit on difference small circular elements of parasitic ring. The advantages of this antenna are that it is small of size, easy to manufacturing and high gain. According to this, low profile switched beam utilizing a ring-parasitic antenna can be achieved.

ACKNOWLEDGEMENT

The author acknowledge the financial support from Srinakharinwirot University and Suranaree University of Technology, Thailand.

REFERENCES

[1] C. A. Balanis, Antenna Theory Analysis and Design, J. Wiley & Sons, 1997.

[1] B. G. Frank, Smart Antenna for Wireless Communications with MATLAB, McGraw-Hill, 2005.

[3] R. Schlub, Thiel, and V. David, “Switched parasitic antenna on a finite ground plane with conductive sleeve,” 2004 IEEE Antenna and Propagation Society, pp. 1343-1347, May 2004.

[4] S. L. Preston, Thiel, V. David, T. A. Smith, S. G. O'Keefe, and W. L. Jun, “Base-station tracking in mobile communications using a switched parasitic antenna array,” 1998 IEEE Transaction on Antenna and Propagation, Vol. 46, pp. 841-844,1998.

[5] M. T. Ali, T. A. Rahman, M. R. Kamarudin, M. N. Md Tan, and R. Sauleau, “Planar Array Antenna with Parasitic Elements for Beam Steering Control,” 2009 Progress In Electromagnetics Research Symposium Proceedings, pp. 181-185, August 2009.

[6] Z. Li, H. Mopidevi, O. Kaynar, and B. A. Cetiner, “Beam-steering antenna based on parasitic layer,” 2012 IEEE Electronics Letters, Vol. 48, pp. 59-60, 2012.

[7] J. Seongheon ; D. Ha, and W. J. Chappell, “A planar parasitic array antenna for tunable radiation pattern,” 2009 IEEE Antennas and Propagation Society International Symposium, pp. 1-4, 2009.

[8] M. Jusoh, T. Sabapathy, M. F. Jamlos, and M. R. Kamarudin, “Reconfigurable Four-Parasitic-Elements Patch Antenna for High-Gain Beam Switching Application,” 2014 IEEE Antennas and Wireless Propagation Letters, Vol. 13, pp.79-82, 2014.