A Pattern Reconfigurable Quasi-Yagi Antenna with Compact Size

Pengkai Li[1], Zhenhai Shao[1], Yujian Cheng[2], Quan Wang[1], Long Li[1] and Yongmao Huang[1]
[1]Greating-UESTC Joint Experiment Engineering Center,
[2]Fundamental Science on Extreme High Frequency Laboratory,
University of Electronic Science and Technology of China,
Chengdu, 611731, P. R. China

Abstract- **A compact pattern reconfigurable quasi-Yagi antenna is presented. It consists of a driven element, which is simply realized by a microstrip monopole and only one parasitic element with four PIN diodes integrated on the arm. The effective electrical length of the parasitic element is controlled by changing the biasing voltages. This configuration allows two end-fire patterns with relatively high gain and opposite beam direction and an omnidirectional pattern to be maintained across a wide bandwidth. A commonly available impedance bandwidth of 12.65% is achieved corresponding to the same center operating frequency of 2.45 GHz for the three modes. As this antenna has reconfigurable pattern and relatively small size, it is very suitable for the indoor wireless communication systems.**

I. INTRODUCTION

Pattern diversity antenna has gained extreme attention in indoor wireless communication. Although most wireless local area network (WLAN) applications utilize omnidirectional antennas, directional and quasi end-fire antennas, such as Yagi antenna, have been employed to suppress unwanted radio frequency (RF) emissions as well as unwanted interference in other directions [1]. In addition, reconfigurable antenna patterns provide pattern diversity that could be used to provide dynamic radiation coverage and mitigate multi-path fading [2], [3]. The Yagi-Uda antenna is one of the most popular end-fire antennas which can be designed to achieve a medium gain with relatively low cross-polarization levels. A traditional Yagi-Uda antenna consists of a driven element, a reflector, and one or more directors. Many reconfigurable Yagi and quasi-Yagi antenna designs have been reported in the literature [4]-[8].

In this paper, a compact pattern reconfigurable quasi-Yagi antenna is proposed. The structure of the proposed antenna is simple and planar. It consists of a driven element, which is simply realized by a microstrip monopole and only one parasitic element with four PIN diodes integrated on the arm. The effective electrical length of the parasitic element is adjusted by changing the “on” and “off” state of the four PIN diodes to achieve three different radiation patterns, two end-fire patterns and an omnidirectional pattern over the same operating frequency. A well-designed microstrip feed monopole-like driven element is introduced to match the different impedance of the three operation modes [9]. The design procedure with integrated PIN diode switches and biasing circuitry is presented.

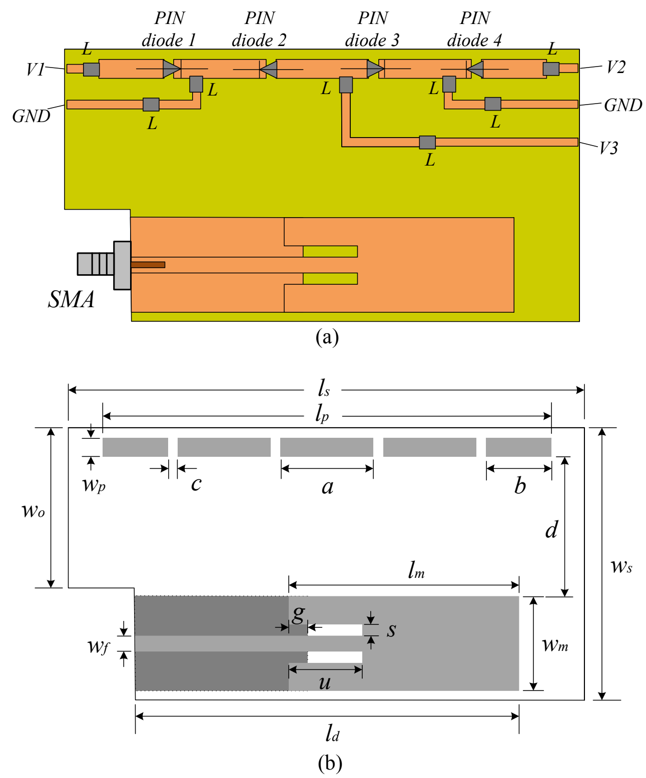


Fig. 1. (a) Antenna design layout. (b) Geometry and dimensions of the antenna

II. ANTENNA DESIGN

A schematic layout and dimensions of the proposed antenna are shown in Fig. 1. The parameters and dimensions of the antenna are given in Table I. The antenna metallization is etched on both sides of a 0.8mm-thick FR4 substrate with a dielectric constant of 4.4, and total dimensions of 55.09 × 29.00mm^2. The top metallization is composed of a microstrip fed driven monopole element and a metal strip parasitic element divided into five parts by four PIN diodes. The bottom side metallization is a truncated ground plane with the same width w_m as monopole element. The printed monopole functions as a driven element with broadband characteristics fed by a microstrip line. The microstrip line has signal width w_f of 1.6 mm to achieve the 50 Ω characteristic impedance feed line.

The driven monopole element is broadband designed by cutting two slits on the feeding edge and well optimized to match the different impedance of the three operation modes. The proposed antenna has a very simple feeding structure without the need of any external balun, transition, tapered or truncated structures.

TABLE I
DIMENSIONS OF THE PROPOSED RECONFIGURABLE QUASI-YAGI ANTENNA

Parameter	l_s	w_s	l_d	l_p	w_p
Value (mm)	55.09	29.00	41.09	48.00	2.00
Parameter	a	b	c	d	l_m
Value (mm)	9.80	6.90	1.20	15.00	24.57
Parameter	w_m	g	s	u	w_f
Value (mm)	10.00	1.48	1.30	7.90	1.60

The bias line is printed on the upper surface of the substrate, as shown in Fig. 1(a). Eight 330nH inductors (L) are used as RF choke to separate the RF signal. Four PIN diodes (GMP4201, Microsemi) are used as switches in the parasitic element. According to the PIN diode datasheet [10], the diode represents a resistance of 2.3 Ω for the “on” state and a parallel circuit with a capacitance of 0.18 pF and a resistance of 30kΩ for the “off” state [11]. The length of the parasitic element can be adjusted by changing the different states of the diodes. When the diodes are all on, the RF current can flow across the whole arm which acts as a reflector. The antenna operates at the quasi-Yagi mode and has a $-y$ beam direction. When the diodes are all off, the parasitic element is separated into five parts and the parasitic current on them is not significant. The antenna operates at the monopole mode and has an omnidirectional radiation pattern. When the diode 1, 4 are off and diodes 2, 3 are on, the RF current can only flow across the three middle parts of the parasitic element which acts as a director. The antenna operates at the Quasi-Yagi mode and has a $+y$ beam direction. The operation modes and possible beam direction along with the corresponding diode states are summarized in Table II.

TABLE II
OPERATION STATES OF THE PROPOSED RECONFIGURABLE QUASI-YAGI ANTENNA

	PIN 1, 4	PIN 2, 3	Mode	Beam Direction
State 1	ON	ON	Quasi-Yagi	$-y$
State 2	OFF	OFF	Monopole	Omnidirectional
State 3	OFF	ON	Quasi-Yagi	$+y$

III. SIMULATED RESULTS AND DISCUSSION

Optimization of the antenna was carried out using HFSS 14. The simulated S_{11} for the three modes are given in Figs. 2. According to the simulation results, the 10-dB impedance bandwidth commonly available to all modes is 310 MHz from 2.35 to 2.66 GHz, which is 12.65% with respect to the designed frequency at 2.45GHz. As can be seen from Fig.2, the bandwidth of state 1 or state 3 is narrower than state 2. This is due to the reactance introduced by the parasitic element, which acts as a reflector or a director. At state 2, when all the diodes are off, the influence of the parasitic element is not notable, thus the antenna bandwidth is mainly depending on the driven monopole, which is broadband designed to overcome the impedance variety of different operating modes.

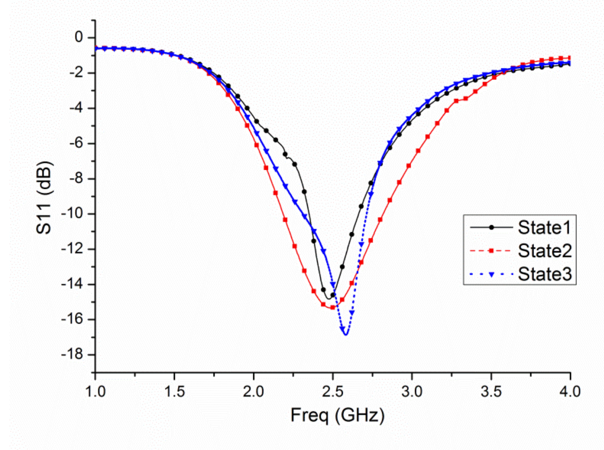
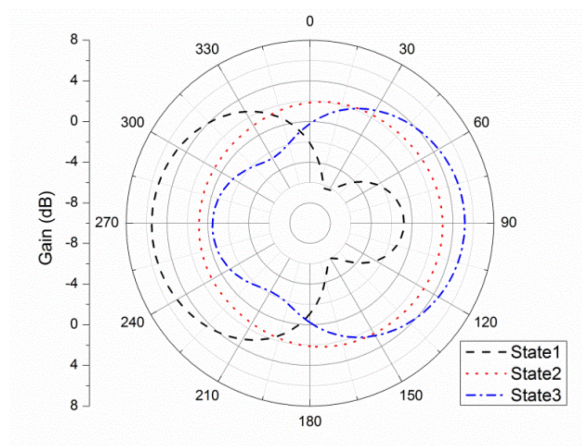
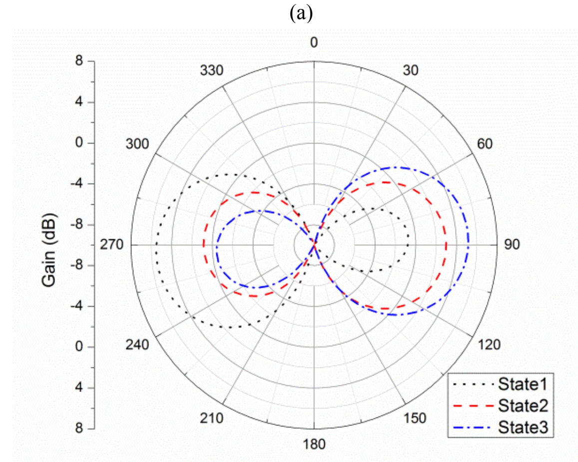


Fig. 2. Simulated S_{11} for the three different operating modes.



(a)



(b)

Fig. 3. Simulated radiation patterns for the three different operating modes. (a) *y-z* plane and (b) *x-y* plane.

The simulated radiation patterns (*y-z* and *x-y* plane) of the proposed antenna for three operating modes at 2.45 GHz are shown in Fig. 3. The simulated peak gains for the –*y*, omnidirectional and +*y* modes are 5.53, 2.9 and 5.17 dBi, respectively. The front-to-back ratio is 6.3 dB for –*y* mode and 5.6 dB for +*y* mode. The maximum ripple level of *H*-plane for state 2 is 2.2 dB. Since the ripple level is quite low, this antenna at state2 has nearly omnidirectional *H*-plane pattern. To sum up, the proposed antenna has significant characteristics of pattern reconfiguration.

IV. Conclusion

A pattern reconfigurable quasi-Yagi antenna using integrated pin diodes is presented. The effective electrical length of the parasitic element is adjusted without changing the driver monopole when the operating frequency is constant by varying the biasing voltages. This configuration allows two endfire patterns with relatively high gain and opposite beam direction and an omnidirectional pattern to be maintained across a wide bandwidth. The impedance bandwidth are 12.65% at state 1, 25.51% at state 2 and 16.33% at state 3 with the same center operating frequency of 2.45 GHz. The simulated peak gain for the –*y*, omnidirectional and +*y* modes is 5.5, 2.9 and 5.2 dBi, respectively. The pattern reconfigurable quasi-Yagi antenna has the advantages of compact and easy to manufacture, which makes it a good candidate for adaptive beam switching in indoor wireless applications.

References

[1] Z. Shi, R. P. Zheng, J. Ding, and C. J. Guo, "A Novel Pattern-Reconfigurable Antenna Using Switched Printed Elements," *IEEE Antennas Wireless Propag. Lett.*, vol. 11, pp. 1100–1103, 2012.

[2] O. N. Alrabadi, J. P. Carrier, and A. Kalis, "MIMO Transmission Using a Single RF Source: Theory and Antenna Design," *IEEE Trans. Antennas Propag.*, vol. 60, no. 2, pp. 654–664, Feb. 2012.

[3] Y. Y. Bai, S. Q. Xiao, M. C. Tang, Z. F. Ding, and B. Z. Wang, "Wide-Angle Scanning Phased Array With Pattern Reconfigurable Elements," *IEEE Trans. Antennas Propag.*, vol. 59, no. 11, pp. 4071–4076, Nov. 2011.

[4] Y. Cai, Y. J. Guo, and A. R. Weily, "A Frequency-Reconfigurable Quasi-Yagi Dipole Antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 883–886, 2010.

[5] H. A. Majid, M. K. A. Rahim, M. R. Hamid and M. F. Ismail, "Frequency and Pattern Reconfigurable Yagi Antenna," *Journal of Electromagnetic Waves and Applications*, vol. 26, no. 2-3, 379-389, 2012.

[6] J. W. K, S. Pyo, T. H. Lee, and Y. S. Kim, "Switchable Printed Yagi-Uda Antenna with Pattern Reconfiguration," *ETRI Journal*, vol. 31, no. 3, Jun. 2009.

[7] B. H. Sun, S. G. Zhou, Y. F. Wei, and Q. Z. Liu, "Modified Two-element Yagi-Uda Antenna with Tunable Beams," *Progress In Electromagnetics Research*, PIER 100, 175-187, 2010.

[8] S. Lim and H. Ling, "Design of electrically small, pattern reconfigurable Yagi antenna," *Electron. Lett.*, vol. 43, no. 24,1326-1327, Nov. 2007.

[9] H. D. Lu, L. M. Si and Y. Liu, "Compact planar microstrip-fed quasi-Yagi antenna," *Electron. Lett.*, vol. 48, no. 3, 140-141, Feb. 2012.

[10] GMP4201 datasheet. Available online at http://www.microsemi.com

[11] A. Edalati, and T. A. Denidni, "Frequency Selective Surfaces for Beam-Switching Applications," *IEEE Trans. Antennas Propag.*, vol. 61, no. 1, pp. 195–200, Jan. 2013.