A Quadri-Polarization Patch Antenna Based on a Novel Broadband Feeding Network

Hui Deng, Fa Huang, Bing-Zhong Wang, and Jiang Xiong
Computational Electromagnetics Laboratory
University of Electronic Science and Technology of China
Chengdu, China
denghui.uestc@outlook.com, huangfa1212@outlook.com, bzwang@uestc.edu.cn, xiongjiang@uestc.edu.cn

***Abstract*—In this paper, a broadband patch antenna with quadri-polarization states based on a novel feeding network has been proposed. With a careful design of each component and an elaborate topology arrangement, the four output ports of feeding network can transmit signals for antenna with four polarization states, i.e., left-hand circular polarization (LHCP), right-hand circular polarization (RHCP), +45º and -45º linear polarization (LP). The measured results show that the antenna has a bandwidth as wide as 22.7%, within which excellent input port impedance matching, port isolation, realized gain, and polarization purity are simultaneously achieved.**

Keywords—Patch antennas, feeding network, multi-polarization antennas.

I. INTRODUCTION

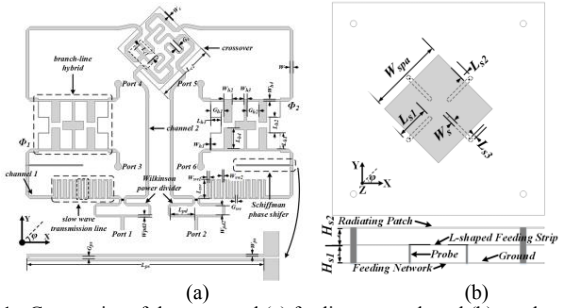
With the fast growing cutting-edge techniques and recent emerging systems such as cognitive radio, Multiple-input-multiple-output (MIMO) and ubiquitous communication, etc., flexibility and versatility of the devices and components are in an increasing demand. In particular, switchable multi-polarization systems are extremely attractive for their characteristics such as defying the channel fading, enhancing the communication reliability, and improving the channel capacity, etc. [1]-[4].

In recent years, a series of multi-polarization antennas, i.e., triple-polarized or even quadri-polarized, have been reported [1]-[4], and the methods for achieving the switchable polarization mainly fall into the three categories (i.e., using electrically controllable switches [1]-[2], loading artificial periodic structures [3] and using switch-free feeding network [4]).

In this paper, we have proposed a broadband quadri-polarized patch antenna based on a novel switch-free feeding network. With a combination of some passive components [5]-[9] and elaborate topology arrangement, the four output ports can have in total four amplitude and phase combinations, corresponding to four polarization states of the antenna. Based on the proposed feeding network, a patch antenna with L-probe feeding has been studied. The measured bandwidth of the antenna as wide as 22.7% has finally been obtained, within which excellent impedance matching, input port isolation, realized gain and low axial ratio of circular polarization can be simultaneously achieved.

II. ANTENNA CONFIGURATION

Geometries of the proposed feeding network and the L-shaped fed patch antenna are shown in Fig. 1 (a) and (b), respectively. Optimized parameters are summarized in Table I. The feeding network has two input (Port 1 and 2) and four output (Port 3-6) ports, and its topology can be divided into two symmetrical parts for two input signals. With different amplitude and phase of the excitation in the two input ports, the output ports can have in total four amplitude and phase combinations [10], which correspond to four polarization states of the antenna, i.e., LHCP, RHCP, +45º and -45º LP. Table II summarizes the four polarization states and their corresponding amplitude and phase of the excitation.



(a) (b)

Fig. 1. Geometries of the proposed (a) feeding network and (b) patch antenna .

TABLE I
DIMENSIONS OF THE FEEDING NETWORK AND PATCH ANTENNA (UNIT: MM)

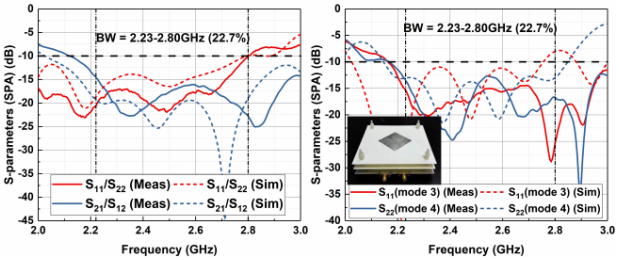
Components		Parameters				
Feeding Network	Power Divider	L_{pd}	W_{pd1}	W_{pd2}		
		8.02	0.66	3		
	Slow Wave Transmission Line	L_{sw}	W_{sw1}	W_{sw2}	G_{sw}	
		6.3	0.6	0.4	0.6	
	Phase Shifter	L_{ps}	W_{ps}	G_{ps}		
		17.49	0.2	0.1		
	Hybrid	L_{h1}	L_{h2}	L_{h3}	L_{h4}	W_{h1}
		5.28	4.95	3.41	6.85	0.11
		W_{h2}	W_{h3}	W_{h4}	G_{h1}	G_{h2}
		2.62	0.86	0.6	4.27	3.95
	Crossover	L_{c1}	L_{c2}	W_c	G_c	W
		6.3	19.11	0.1	1.26	1.1
Patch Antenna		W_{spa}	L_{s1}	L_{s2}	L_{s3}	W_s
		40	18	4.8	3.8	1.5
		H_{s1}	H_{s2}			
		7.74	8			

TABLE II
OPERATING MODES OF THE FEEDING NETWORK (UNIT: DEGREE)

Mode	Port	Input Port		Output Port				States
		1	2	3	4	5	6	
1	amplitude	1	0	1	1	1	1	LHCP
	phase	0	0	0	-90	-180	-270	
2	amplitude	0	1	1	1	1	1	RHCP
	phase	0	0	-270	-180	-90	0	
3	amplitude	1	1	1	0	1	0	+45°LP
	phase	0	-90	0	0	-180	0	
4	amplitude	1	1	0	1	0	1	-45°LP
	phase	-90	0	0	-180	0	0	

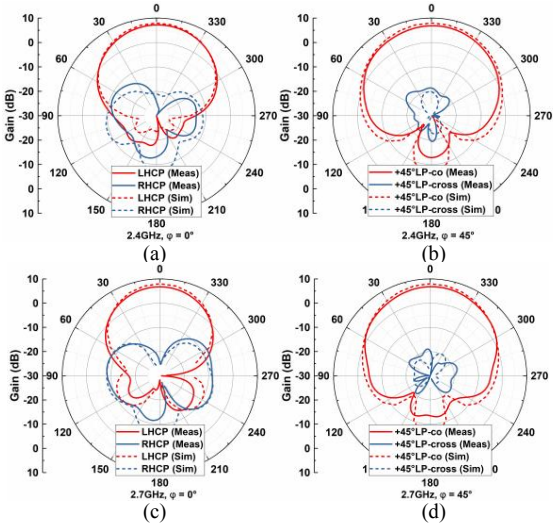
III. SIMULATED AND MEASURED RESULTS

Fig. 2 shows the impedance matching and isolation of the patch antenna across a wide band from 2.0 to 3.0GHz. Fig. 3 plots and compares the simulated and measured gain patterns in mode 1 (LHCP) and mode 3 (+45º LP) of the antenna at 2.4 and 2.7GHz within its operating band (the cases of mode 2 and 4 are similar due to symmetry). One sees all patterns are that of typical patch antennas, such as cross polarization at broadside is below -20dB and realized gain is around 7dB. Fig. 4 plots the simulated and measured axial ratio (AR) of the radiating LHCP wave (the RHCP case is similar and not shown for brevity) and one sees that the AR less than 3dB is from 2.0 to 3.0GHz. Consequently, a measured bandwidth (the region delimited by the vertical black dash dot lines in Figs. 2 and 4) as wide as 22.7% has been obtained, within which -10dB S_{11}, -15dB S_{21}, and 3dB AR can be simultaneously achieved for four polarized states.



(a) (b)

Fig. 2. Simulated and measured S-parameters of the patch antenna at (a) CP mode and (b) LP mode. Fabricated prototype is shown in the inset.



(a) (b)

(c) (d)

Fig. 3. Simulated and measured gain patterns of the patch antenna at (a) 2.4GHz and (b) 2.7GHz in mode 1 (LHCP) and mode 3 (+45º LP).

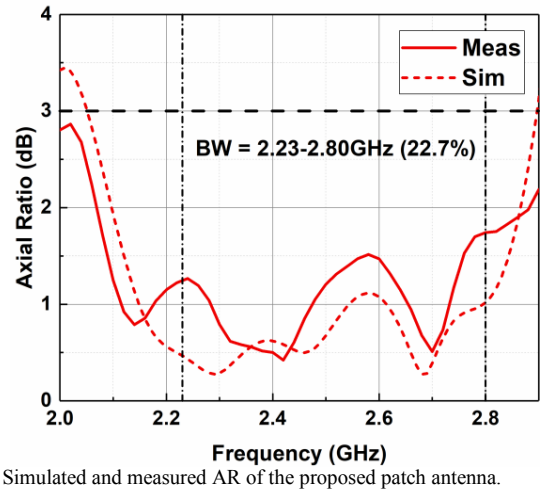


Fig. 4. Simulated and measured AR of the proposed patch antenna.

CONCLUSION

A broadband patch antenna with quadri-polarization states based on a novel switch-free feeding network has been proposed. With a careful design and topology arrangement of several passive components for feeding network that also appropriately integrated with the radiating patch, the patch antenna has simultaneously wide impedance, ports isolation, realized gain and polarization bandwidth for in total four polarization states. The proposed patch antenna is a promising candidate for future multi-polarization applications.

REFERENCES

[1] K. M.-J. Ho and G. M. Rebeiz, "A 0.9–1.5 GHz microstrip antenna with full polarization diversity and frequency agility," IEEE Trans. Antennas Propag., vol. 62, no. 5, pp. 2398–2406, 2014.

[2] F. Wu and K. M. Luk, "Single-port reconfigurable magneto-electric dipole antenna with quad-polarization diversity," IEEE Trans. Antennas Propag., vol. 65, no. 5, pp. 2289–2296, 2017.

[3] W. Yang, W. Che, H. Jin, W. Feng, and Q. Xue, "A polarization-reconfigurable dipole antenna using polarization rotation AMC structure," IEEE Trans. Antennas Propag., vol. 63, no. 12, pp. 5305–5315, 2015.

[4] Y.-J. Chi and F.-C. Chen, "A novel quadri-polarization-agile microstrip antenna with polarization synthesizing feeding network," Int. J. Microw. Wirel. Technol., vol. 8, no. 2, pp. 385–394, 2016.

[5] D. M. Pozar, Microwave Engineering. New York, NY, USA: Wiley, 1998.

[6] W. S. Chang and C. Y. Chang, "A high slow-wave factor microstrip structure with simple design formulas and its application to microwave circuit design," IEEE Trans. Microw. Theory Tech., vol. 60, no. 11, pp. 3376–3383, 2012.

[7] B. M. Schiffman, "A new class of broad-band microwave 90-degree phase shifters," IRE Transcations Microw. Theory Tech., vol. 6, no. 2, pp. 232–237, 1958.

[8] S. S. Liao and J. T. Peng, "Compact planar microstrip branch-line couplers using the quasi-lumped elements approach with nonsymmetrical and symmetrical T-shaped structure," IEEE Trans. Microw. Theory Tech., vol. 54, no. 9, pp. 3508–3514, 2006.

[9] C. W. Tang, K. C. Lin, and W. C. Chen, "Analysis and design of compact and wide-passband planar crossovers," IEEE Trans. Microw. Theory Tech., vol. 62, no. 12, pp. 2975–2982, 2014.

[10] J. Huang, "A technique for an array to generate circular polarization with linearly polarized elements," IEEE Trans. Antennas Propag., vol. 34, no. 9, pp. 1113–1124, 1986.