A Dual-Polarized Microstrip Antenna with 2D Beam-Scanning Capability

(Invited paper)

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***Abstract*—A reconfigurable microstrip antenna with a dual-polarization beam-scanning feature is proposed in this paper. The proposed antenna is based on microstrip Yagi-Uda antenna comprised of a driven square patch and four parasitic square patches. Two different feed ports are utilized to separately excite two orthogonal modes for dual-polarization operation. The capability of beam-scanning is realized by loading a narrow loop slot and four varactors within each parasitic patch. By tuning the capacitance value of the varactors, the parasitic patch can act as a director or a reflector for the driven patch. Simulation results demonstrate that the beam can be scanned in 2D plane. The simulated cross-polarization discriminations are higher than 20 dB in all seven states presented in this paper. The proposed antenna is in fabrication and experimental results will be provided in the final submission.**

***Index Terms*—Dual-polarization, microstrip antenna, pattern reconfigurable antenna, Yagi-Uda antenna.**

I. INTRODUCTION

Dual-polarized antennas have been widely utilized in wireless communication systems to increase channel capacity and mitigate multipath fading effects. Generally, dual polarization can be achieved by using a pair of perpendicularly arranged dipoles [1], [2] or microstrip antenna with two feed ports to excite two orthogonal modes [3], [4]. Compared with the crossed dipoles placed above a large metal reflector with a distance about $0.25\lambda_0$ (where λ_0 is the free−space wavelength at its operating frequency) between them, the microstrip antennas are more advantageous in terms of antenna profile and design complexity. However, they normally have a fixed beam which limits their applications.

Recently, pattern reconfigurable antennas have attracted considerable interests owing to their capability in altering the beam direction, thereby improving the signal-to-noise-ratio (SNR) of various wireless systems. Generally, beam-scanning or beam-switching antennas could be achieved by phased arrays [5], which are too complex and costly. To meet the demands of low-cost, compactness and simple configuration, a beam-scanning microstrip Yagi-Uda antenna was proposed in [6] and indicated that the beam direction depended on the dimensions of the parasitic patch and the distance between the driven patch and parasitic patch. In [7], it was shown that the electric size of a patch antenna could be tuned by a varactor-loaded slot. Based on [6] and [7], a circularly polarized beam-scanning microstrip patch antenna was realized by using a parasitic patch with tunable electric size in [8]. However, its beam can be in scanned in only one direction.

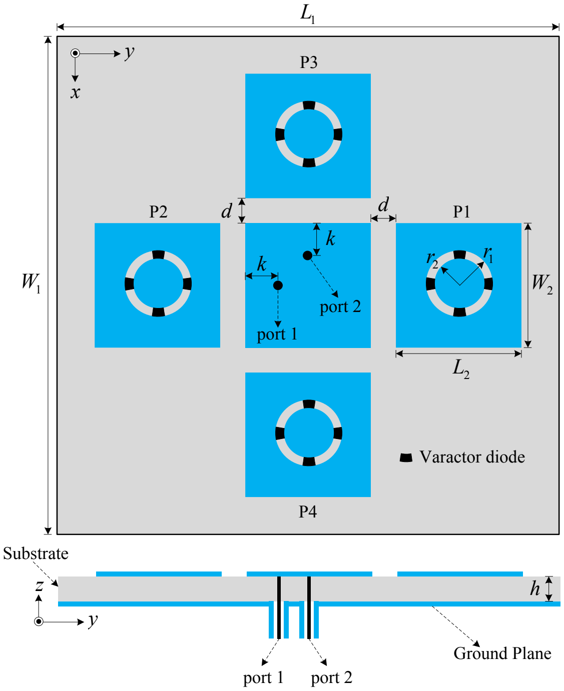

Fig. 1 Geometry of the proposed antenna.

In this paper, a dual-polarized microstrip antenna with 2D beam-scanning capability is proposed. The proposed antenna consists of a driven patch and four parasitic patches. A narrow loop slot is etched on each parasitic patch and four varactors are integrated in each loop slot. By tuning the capacitance value of varactors, the beam can be scanned in a two dimensional plane with dual polarization.

II. CONFIGURATION OF THE PROPOSED ANTENNA

The geometry of the proposed dual-polarized beam-scanning microstrip antenna is shown in Fig. 1. It consists of a driven square patch and four tunable parasitic square patches P1, P2, P3, P4, each with the same size of $L_2 \times W_2$. Both of the driven

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patch and the parasitic patches are printed on a 192 × 192 mm^2 grounded substrate with a relative permittivity of 2.2, a thickness h = 3.175mm and a loss tangent of 0.0009. The driven patch is fed by two 50 Ω coaxial probes, located on the midline with a distance k to the edge of the driven patch, to excite two orthogonal modes. Each parasitic patch is loaded by a loop slot and four varactors. The outer radius and inner radius of the loop slot are r_1 and r_2 respectively. For convenience, the four varactors embedded on the same parasitic patch have a common capacitance value C_n (where n indicates number of the parasitic patch). The detailed parameter values of the proposed antenna are listed in table I.

III. SIMULATION RESULTS AND DISCUSSION

According to [7], tuning the capacitance value of C_n can change the electric size of the parasitic patches, hence steering the radiation pattern. When the capacitance values of each varactor are given, the maximum radiation direction can be determined and marked as (φ, θ). For example, when C_1 = 2.4 pF, C_2 = 2 pF, C_3 = 3 pF and C_4 = 0.5 pF, the maximum radiation direction is (0°, 30°), which means the maximum beam is pointed to φ = 0° while θ = 30°. For the sake of simplicity, seven typical radiation pattern states at 2.45 GHz are investigated and listed in table II. The state 1, 2, 3, 4 and 5 represent the maximum scanning angle of the proposed antenna in the xz-plane and yz-plane. The state 6 and 7 demonstrate that the beam can also scan in other azimuth plane.

Fig 2 shows the simulated S-parameters under the seven states. State 1, 2, 3, 5, 6, 7 have a common bandwidth of 2.35 - 2.5 GHz, in which the reflection coefficients $|S_{11}|$ and $|S_{22}|$ are both under -10 dB and the $|S_{21}|$ is lower than -18dB. For state 4, the impedance bandwidth (S_{11} < -10 dB and S_{22} < -10dB) is 2.35 - 2.4 GHz and 2.44 - 2.5 GHz respectively for the two orthogonal polarizations, within which the $|S_{21}|$ is lower than -20 dB.

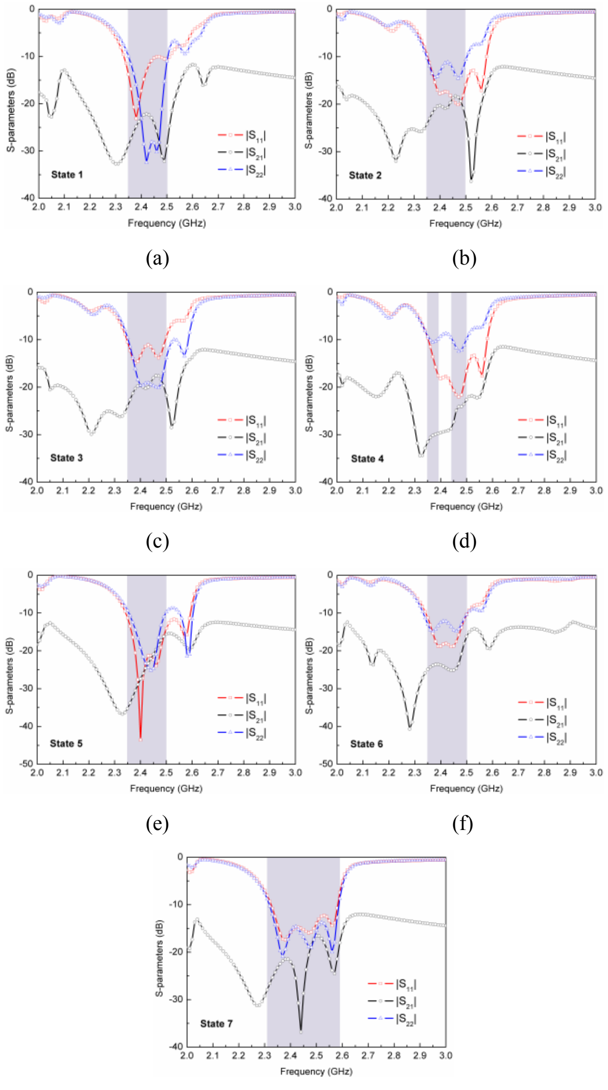
Fig. 3 and Fig. 4 show the simulated radiation patterns of the proposed antenna under seven different states at 2.45 GHz. There are some differences between the radiation patterns when port 1 and port 2 is excited separately under state 6 and state 7. When port 1 is excited, the maximum radiation direction of state 6 points to (148°, 20°), while the beam direction is (170°, 24°) when port 2 is excited. The reason is that once the capacitance values of the varactors are determined, the structure of the proposed antenna is not a fully symmetric for port 1 and port 2, resulting in different radiation patterns and gain. But it does not affect the normal operation of the antenna. The simulated results demonstrated that when port 1 is excited, the antenna gains are 11.22 dBi, 9.44 dBi, 10.04 dBi, 9.34 dBi, 10.49 dBi, 8.63 dBi and 11.61 dBi under the seven states, respectively. When port 2 is excited, the gains are 8.65 dBi, 10.20 dBi, 9.39 dBi, 10.11 dBi, 9.15 dBi, 10.42 dBi and 11.55 dBi. From Fig. 3 and Fig. 4 it is shown that the simulated cross-polarization discriminations (XPDs) are higher than 20 dB in each state, which is promising for the application in wireless communications.

TABLE I
GEOMETRICAL PARAMETERS FOR THE PROPOSED ANTENNA

Parameter	W_1	L_1	W_2	L_2	r_1
Value(mm)	192	192	39.8	39.8	7
Parameter	r_2	d	k	h	
Value(mm)	6.5	3	7.6	3.175	

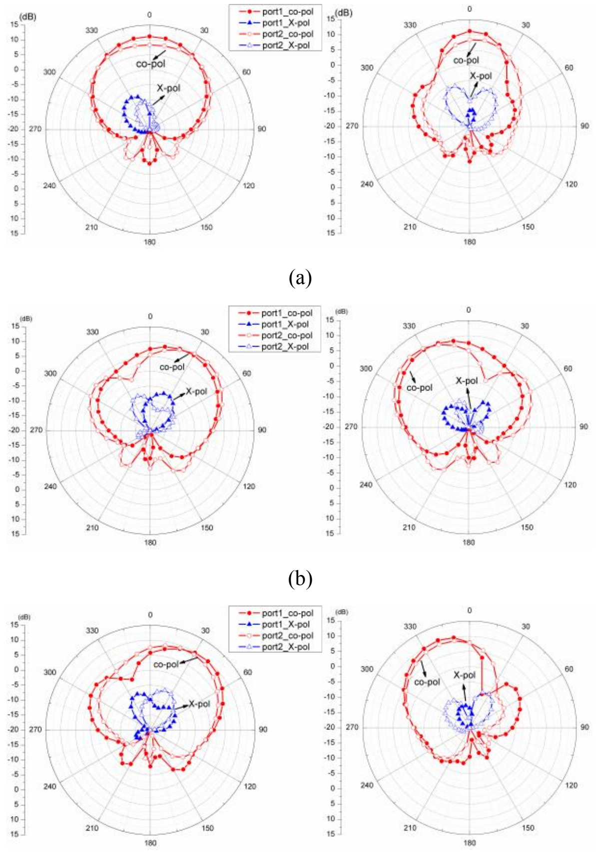
TABLE II
MAXIMUM RADIATION DIRECTION VARIED WITH THE CAPACITANCE VALUE

	C_1(pF)	C_2(pF)	C_3(pF)	C_4(pF)	port 1 (φ, θ)	port 2 (φ, θ)
State 1	2.6	2.4	2	2	(0°, 0°)	(0°, 7°)
State 2	2.4	2	3	0.5	(0°, 30°)	(0°, 37°)
State 3	3	0.5	2.4	2	(90°, 37°)	(90°, 24°)
State 4	2.4	2	0.5	3	(180°, 30°)	(180°, 37°)
State 5	2	2.6	2	2	(270°, 19°)	(270°, 18°)
State 6	2.5	1.5	2	3	(148°, 20°)	(170°, 24°)
State 7	2	2.6	3	2	(312°, 22°)	(340°, 22°)



(a) (b) (c) (d) (e) (f) (g)

Fig. 2 Simulated S-parameters under the seven states: (a) State 1; (b) State 2; (c) State 3; (d) State 4; (e) State 5; (f) State 6; (g) State 7.

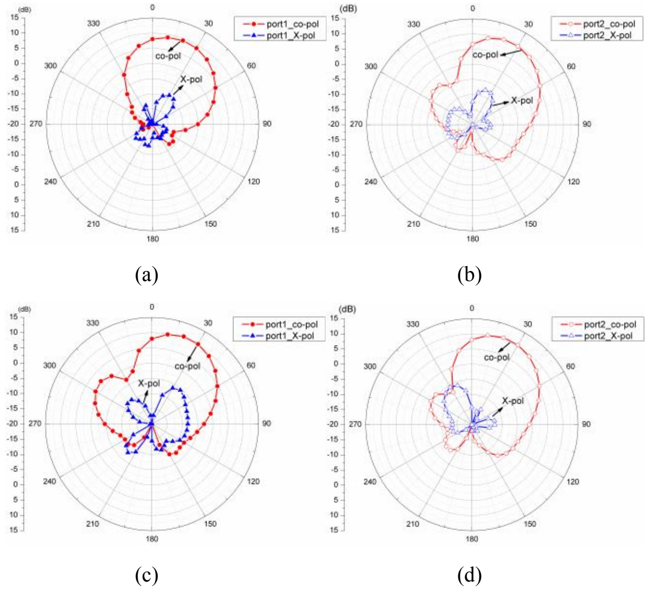


(a)

(b)

(c)

Fig. 3 Simulated radiation patterns under the state 1, 2, 3, 4 and 5 at 2.45 GHz: (a) State 1 in *xz*-plane and *yz*-plane; (b) State 2 and state 4 in *xz*-plane; (c) State 3 and state 5 in *yz*-plane.



(a)

(b)

(c)

(d)

Fig. 4 Simulated radiation patterns under the state 6 and 7 at 2.45 GHz: (a) State 6 in $\varphi = 148°$ plane when port 1 is excited; (b) State 6 in $\varphi = 170°$ plane when port 2 is excited; (c) State 7 in $\varphi = 312°$ plane when port 1 is excited; (d) State 7 in $\varphi = 340°$ plane when port 2 is excited.

IV. CONCLUSION

In this paper, a dual-polarized beam-scanning microstrip antenna has been presented. The 2D beam-scanning feature of the proposed antenna is realized by tuning the capacitance value of the varactors embedded in the antenna. The maximum scanning angle is from -30° to +30° in the *xz*-plane and -19° to +37° in the *yz*-plane when port1 is excited. Meanwhile, -37° to +37° beam scanning range in the *xz*-plane and -18° to +24° beam scanning range in the *yz*-plane can be obtained when port2 is excited. Moreover, the beam of the proposed antenna can also scan in azimuth planes. In addition, the proposed antenna demonstrates good performance in terms of impedance bandwidth, port isolation and XPDs under all states, which makes it a suitable candidate for various wireless applications.

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