A Vertically Polarized Tapered Monopole Antenna with Reconfigurable Patterns for WiFi Applications

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Abstract—**This article presents a compact vertically polarized tapered monopole antenna with pattern reconfigurable capability for WiFi applications. The antenna is based on the Yagi-Uda principle, and achieves reconfigurable patterns by switching the states of the PIN diodes connected to the passive stubs. In addition, in order to improve the bandwidth of the antenna, the tapered monopole is properly designed, which can cover the WiFi band (5.15-5.85 GHz) well. Simulation results show that the peak gain of the proposed antenna is 7.3dBi, and the radiation efficiency is stable. Due to the simple structure and good radiation characteristics, it is suitable for WiFi indoor applications.**

Index Terms—**pattern reconfigurable antenna, tapered monopole antenna, WiFi antennas**

I. Introduction

With the increasing number of communication devices nowadays, the communication environment is becoming more and more complex, and the transmission of electromagnetic waves will face various kinds of interferences, which leads to the attenuation of signals and the degradation of communication quality. Pattern reconfigurable antennas are able to switch beams flexibly for improving anti-interference capability as well as the channel capacity, which attracts great interests [1].

In the past few years, a variety of antennas able to achieve pattern reconfiguration have been proposed. There are different methods to realize such kind of pattern reconfigurable antenna. The first method is to select the excitation of different operating modes of a single antenna and use the different operating modes to generate different current distributions to achieve pattern reconfiguration. But this method has the problem of complex feeding network or limited reconfiguration capability [2] [3]. The second method is to switch different feeding ports to change the radiation direction of the beam, which requires a rather complex control circuit [4].The third method is to use liquid metal as the parasitic elements to generate different current distributions, achieving beam switching. But this requires complex liquid control devices, which is costly [5].

In this paper, a pattern reconfigurable antenna based on the Yagi-Uda principle is proposed for WiFi applications. The proposed antenna consists of a tapered monopole and four T-shaped passive stubs around the tapered monopole. Pattern reconfiguration can be achieved by switching the states of the PIN diodes connected to the passive stubs. Furthermore, good impedance matching can be achieved by properly designing the tapered monopole, which increases the bandwidth. The proposed antenna can achieve beam switching with eight different beams, while maintaining full-space beam coverage.

II. Antenna Configuration and Operating Principles

A. Antenna Configuration

The configuration of the proposed antenna is given in Fig. 1(a)-(c). Two crossed substrates are fixed vertically at the center of the grounded substrate as shown in Fig. 1(a). All the three substrates are F4BM with a ε_r of 2.2, and a loss $tan\delta$ of 0.001. The thickness of the crossed vertically placed substrate is 0.8 mm and the thickness of horizontally placed substrate is 1.2mm. In the center, two tapered monopoles are printed on the cross-positioned substrates, and properly design the tapered monopole for improving impedance matching. In addition, around the tapered monopoles, four T-shaped stubs are connected to four PIN diodes (MA4AGP907). The PIN diodes are connected to the metalic ground surface through the metal via holes of the horizontally placed substrate. By switching the "ON/OFF" states of the PIN diodes, the differ-ent current distributions can be controlled, thereby achieving pattern reconfigurable patterns.

B. Working Principle

When the four PIN diodes are switched into the "OFF" states, the tapered monopole printed on the cross-substrate is directly excited. By switching the "ON/OFF" states of the PIN diodes, the different current distributions and 3-D radiation patterns can be generated as shown in Fig.2(a)-(c). Besides, due to the reflection of the ground plane, the generated beam deviates from the endfire with an angle about 50°.

When the PIN diode D1 is switched into "ON" state, the passive stubs connected to D2, D3 and D4 have strong current distributions. Under this radiation condition, it can generate the beam along y-axis shown in Fig.2(a).

Then, the two neighbouring PIN diodes(D1 and D2) are switched into "ON" states, which generates the strong current distributions on the passive studs connected to D3 and D4. Therefore, the main beam is generated along the bisector line (φ= 135°), which is shown in Fig. 2(b).

In addition, when three PIN diodes (D2, D3 and D4) are also switched into "ON" states, the passive stubs connected to D1 has strong current distributions, which generates the beam along negative y-axis as shown in Fig.2(c). Besides, compared
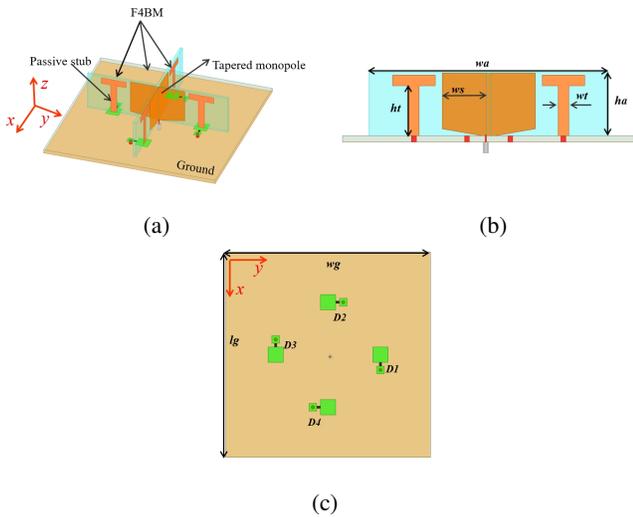
Fig. 1: The structure of the proposed antenna. (a) 3D view, (b) side view, (c) top view of horizontally placed substrate.(wg= 55mm, lg= 55mm, ha = 12mm, wa= 45mm, wt = 2mm, ht = 10.6mm, ws= 8.8mm)

with one PIN diode into "ON" state, three PIN diodes into "ON" states have better reflection coefficients as shown in Fig.3, so three PIN diodes into "ON" states are chosen as a state.
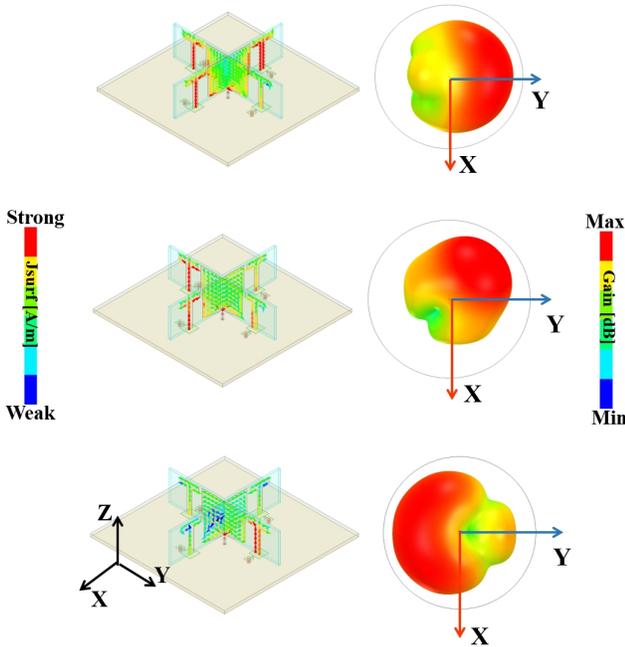

Fig. 2: Simulated current distributions and their corresponding 3-D radiation patterns. (a) D1 in "ON" state. (b) D1 and D2 in "ON" state. (c) D2, D3 and D4 in "ON" state.
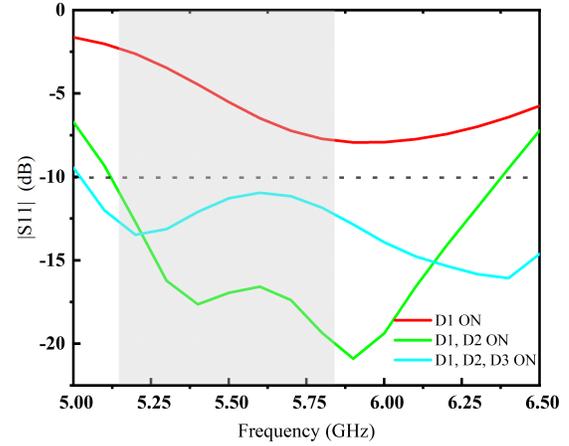
Fig. 3: Reflection coefficients of different states.

III. RESULTS AND DISCUSSIONS

Since the antenna structure is symmetrical, beams can be generated by switching the states of the PIN diodes as shown in Table I. The 3-D radiation patterns are shown in Fig.4, which reveals the main beam pointing to eight different directions with 45°step.

The reflection coefficients, peak gains and radiation efficiencies of the proposed antenna in different states are shown in Fig. 5. It is obvious that the proposed antenna can cover the band (5.15-5.85 GHz) well with stable radiation efficiency and a peak gain of 7.3 dBi. In addition, Fig. 6 shows the 2-D radiation patterns for different states, and it is clear that proposed antenna can achieve 360° beam coverage.

TABLE I
Radiation Pattern States of The Proposed Antenna And The Corresponding Diode States

State	D1	D2	D3	D4	Beam Direction(in φ-plane)
State 1	ON	ON	OFF	OFF	135˚
State 2	OFF	ON	ON	OFF	225˚
State 3	ON	OFF	OFF	ON	45˚
State 4	OFF	OFF	ON	ON	315˚
State 5	ON	ON	ON	OFF	180˚
State 6	ON	ON	OFF	ON	90˚
State 7	ON	OFF	ON	ON	0˚
State 8	OFF	ON	ON	ON	270˚

IV. CONCLUSION

In this paper, a pattern reconfigurable antenna using tapered monopoles and PIN diode loaded stubs is proposed. The proposed antenna achieves the bandwidth of 5.15-5.85 GHz,
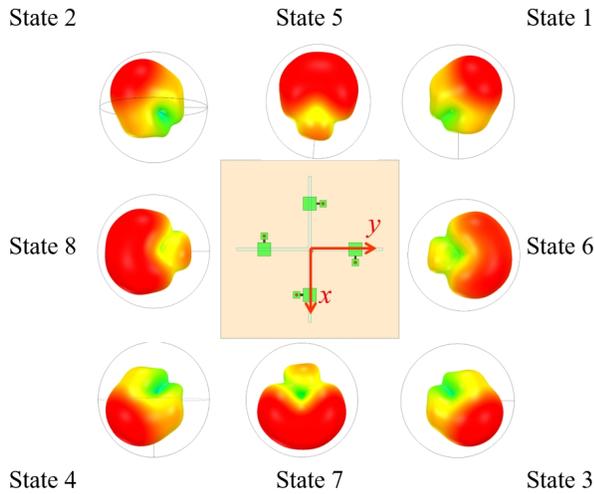
Fig. 4: Simulated 3-D radiation patterns for the proposed antenna at 5.5 GHz.

(a)

(b)

Fig. 6: Simulated radiation patterns at 5.5GHz. (a) states 1/2/3/4 and (b) states 5/6/7/8.
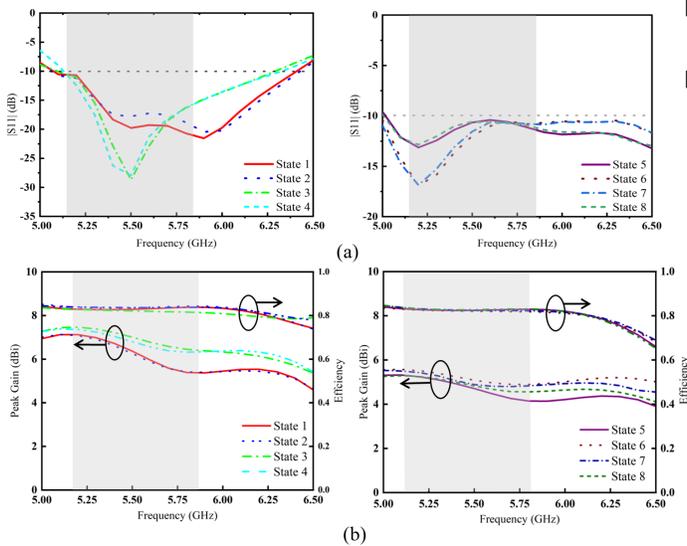

(a)

(b)

Fig. 5: Simulated results under different switch states. (a) reflection coefficients and (b) peak gains and efficiencies.

a peak gain of 7.3 dBi and eight different beams. Besides, the proposed antenna is of simple structure and low cost. Therefore, it is suitable for WiFi applications.

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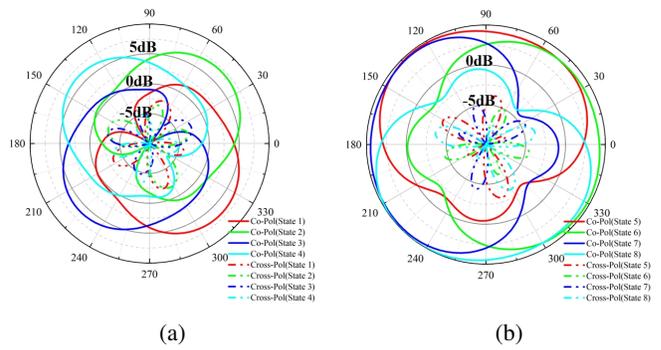[1] Z. Wang and Y. Dong, "Theory, Design, and Verification of Miniaturized Phase-Controlled Huygens Antenna for 360° Continuous Beam Scanning," IEEE Transactions on Antennas and Propagation, vol. 71, no. 4, pp. 3104-3113, April 2023

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