A reconfigurable dipole antenna based on bistable composite cylindrical shells for WiFi applications

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***Abstract*-This paper introduces a reconfigurable dipole antenna designed using bistable composite cylindrical shells. The proposed antenna is composed of a printed feed diploe and a parasitic strip, utilizing a balanced microstrip line for feeding. The dielectric substrate consists of bistable anti-symmetric cylindrical shells made of glass fiber-reinforced polymer (GFRP), enabling two distinct operating states. In different states, the antenna can operate under different WiFi bands, including the 2.4 GHz and 5.8 GHz. Additionally, the radiation patterns can switch between omnidirectional and directional modes depending on the state.**

Index Terms- reconfigurable antenna, frequency reconfigurable antenna, pattern reconfigurable antenna, bistable composite cylindrical shells.

I. Introduction

As wireless communication technology advances rapidly, there is an increasing demand for wireless communication devices to operate across multiple communication standards. As a crucial component of wireless terminals, antennas must meet high-performance requirements. Reconfigurable antennas, which integrate multiple antenna functionalities into a single device, have garnered significant attention. Typically, reconfigurability is achieved through electrical [1], or mechanical control [2] methods. In recent years, advancements in material science have introduced new materials like liquid metal [3], liquid crystal [4] or graphene [5] to achieve antenna reconfiguration. Bistable composite materials, characterized by their two stable configurations, light weight, and ability to maintain deformation without continuous external force, have been applied in antenna design to enable reconfigurable radiation patterns and polarization[6-8].

This paper proposes a reconfigurable antenna utilizing bistable column shell materials. The antenna features a printed dipole as its main radiating structure, with parasitic strip for impedance matching and directional control. The bistable column shell material can switch between the extended and coiled-up cylindrical configurations, causing the metallic radiators on the shell to undergo corresponding structural changes. This alters the current distribution on the metal surface, achieving reconfigurable radiation patterns and frequencies. The designed antenna has two stable operating states: in State 1, it operates at 2.4 GHz with omnidirectional radiation characteristics; in State 2, it operates at 5.8 GHz with directional radiation characteristics. This demonstrates the antenna's capability to function in both WiFi frequency bands, making it suitable for WiFi communication applications.

II. Antenna Configuration

The antenna presented in this paper utilizes a bistable cylindrical shells composite material as the dielectric substrate. The material, made from glass fiber resin with asymmetric lay-ups, allows the bistable composite cylindrical shell to maintain stability in both its extended and coiled-up forms. Moreover, the axes of these two configurations are perpendicular to each other. A physical representation of this material is shown in Figure 1(a)[9]. The material has a relative permittivity of 4.9, a loss tangent of 0.002, and a thickness of 0.49 mm.

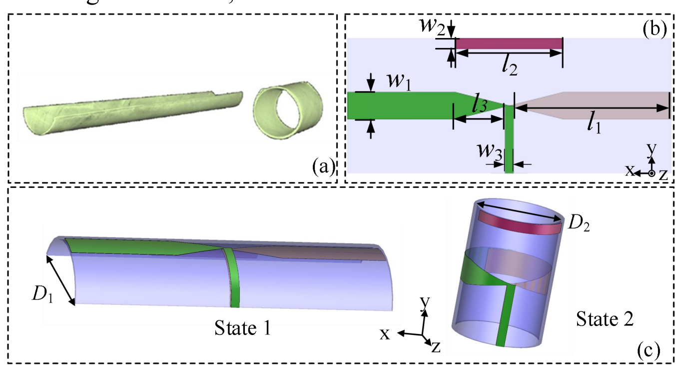


Figure 1. Design of the proposed antenna (Unit: mm). (a) Physical representation of bistable cylindrical shells. (b) Plane structure. (c) State 1. and State 2.

The antenna's structure is shown in Figure 1(b). A planar structure with dimensions 46.2mm×19.25mm serves as the reference for this antenna. The primary radiating element is a printed dipole fed by balanced microstrip lines, printed on the substrate's both sides. A parasitic strip is loaded above the dipoles to adjust matching and radiation patterns. The two proposed antenna states can be realized by bending the planar structure, which are achieved in this paper by bending along the x-axis and y-axis. In State 1, the antenna functions as a typical conformal dipole antenna, as shown in Figure 1(c). In State 2, the antenna transforms into a ring dipole, as illustrated in Figure 1(c). Each state operates at different frequency bands and exhibits distinct radiation patterns, with specific performance detailed in Table 1. The transition between the two antenna states is achieved by switching the two configurations of the bistable material. Table 2 provides the detailed dimensional parameters of the antenna.

TABLE I
Reconfigurable states of the proposed reconfigurable antenna

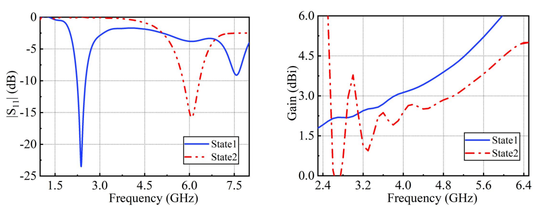
State	Frequency (GHz)	Radiation Pattern
1	2.24-2.53	Omnidirectional
2	5.79-6.34	Directional

TABLE II
Optimized antenna geometry parameters (unit: mm)

Parameter	Value	Parameter	Value	Parameter	Value
w_1	3.85	l_1	22.48	D_1	14.65
w_2	1.54	l_2	15.4	D_2	12.9
w_3	1.25	l_3	7.08		

III. Simulation Results

The simulated results of the antenna's reflection coefficient in its two states are presented in Figure 2(a). The -10 dB impedance bandwidths for the two states are 12.16% from 2.24 to 2.53 GHz and 9.07% from 5.79 to 6.34 GHz, respectively. In State 1, the antenna functions at 2.4 GHz and has a gain of 1.92 dBi (Figure 2(b)). In State 2, the antenna operates at 5.8 GHz with a gain of 4.12dBi (Figure 2(b)). Figure 4 illustrates the antenna's radiation patterns in the two states, demonstrating that in State 1, the antenna demonstrates the radiation characteristics as omnidirectional, while in State 2, it shows directional radiation characteristics. Table 3 compares the proposed antenna with other antennas using bistable materials. The suggested antenna demonstrates superior efficiency.



(a) (b)

Figure 2. Simulated (a) S-Parameter and (b) gains of the suggested antenna.

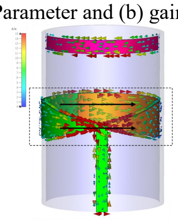


Figure 3. Distribution of current on the suggested antenna in State 2 at 5.8GHz.

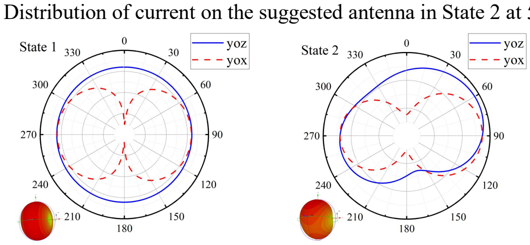


Figure 4. Radiation patterns modeled under 2.4 GHz and 5.8 GHz.

To analyze the reconfigurable characteristics of the suggested antenna, Figure 3 shows the distribution of the current at 5.8 GHz in State 2. It can be seen that on the feed dipole along the x-axis, the coupling causes the currents on the dipole divided into two parts along the z-axis (front part and back part)to be in phase, enhancing far-field radiation and achieving directional radiation characteristics. Additionally, compared to State 1, the current path is shorter, enabling frequency reconfiguration. Figure 4 shows the simulated normalized radiation patterns of the antenna in both states, illustrating that the antenna achieves reconfigurable radiation patterns in both states.

TABLE III
A comparison of this work with other antennas

Ref.	Bandwidth of two states	Peak Gains of two states (dBi)	Reconfigurability of patterns
[6]	12.6% and 11.9%	6.11 and 5.48	30°
[7]	4.32% and 5.48%	-1.52 and 9.72	Omnidirectional and directional
This work	12.2% and 9.1%	1.92 and 4.12	Omnidirectional and directional

IV. Conclusion

A bistable composite cylindrical shell based reconfigurable dipole antenna. It uses a composite cylindrical shell dielectric substrate composed of bistable anti-symmetric glass fiber-reinforced polymer (GFRP), enabling two distinct operating states. In State 1, it operates at 2.4 GHz with omnidirectional radiation characteristics; in State 2, it operates at 5.8 GHz with directional radiation characteristics. This antenna is suitable for WiFi communication applications.

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