A New Pattern Reconfigurable Loop Antenna with Wide Beam Width

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***Abstract*—A new pattern reconfigurable loop antenna of 2GHz with wide beam width is proposed. The antenna applies an Alford loop structure, and 4 reconfigurable beams are generated by switching the status of 4 pins between the gaps of the loop structure. The 3dB beam width of each mode is 196° in H plane and can cover over half of the vertical plane, and it is 144° in E plane and can cover over a quarter of the horizontal plane. Thus, all four reconfigurable beams can cover the whole 3D space, which means the proposed antenna can be regarded as an equivalent isotropic radiator.**

Keywords—pattern reconfigurable; wide beam width; equivalent isotoipic radiation

I. INTRODUCTION

Phased array has been utilized in a variety of military and civilian applications for its unique non-inertial beam scanning, convenient beam controlling and energy management advantages [1]. Micro-strip antenna is the most commonly used element formats for a phased array due to its small size, light weight, low profile, conformal structure and easy integration with RF circuits. However, the scanning angle of a typical micro-strip phased array is limited to ±50°, with gain reduction of 4-5dB compared with the maximum array gain, which limits the application of phased array in wide angle scanning platforms [2].

Reconfigurable antenna has attracted wide attention in recent years. An antenna that integrates with RF switches to provide flexibility in terms of operating frequency, polarization and radiation pattern performance is called a reconfigurable antenna [3]. Among all these reconfigurable antennas, pattern reconfigurable antenna has agility beams and can significantly extend the beam width, which provides a new element design method to form a wide angle scanning phased array. Many researchers shave been working on corresponding antenna element and have put forward abundant pattern reconfigurable antennas [3-6]. Most of these works apply a Yagi structure with a driven element and several parasitic elements serving as either a reflector or a director controlled by PIN diodes [4, 5]. The antenna employs a stacked structure, with its driven element embedded and then surrounded by 4 parasitic elements on the top layer in [3]. The array applies a Hybrid High Impedance Surface(HHIS) base and a pattern reconfigurable square loop antenna(SLA) serves as the unit element in [6]. Each SLA has four feeding ports and can provide four off bore-sight tilted beams in four quadrants of space.

A new pattern reconfigurable loop antenna of 2GHz based on omnidirectional Alford loop is presented in this paper. The paper begins with the structure and radiation mechanism of the antenna, followed by simulation results. Then a comparison between the original Alford loop and the proposed reconfigurable loop is made. Finally, the advantages of the pattern reconfigurable loop antenna is concluded.

II. Antenna Structure and Radiation Mechanism

Alford loop is an electrically large loop antenna that can generate omnidirectional radiation that parallel the plane where the loop lays by its unique feeding structure[7]. A typical Alford loop is composed of 3 parts, a loop, a reduced ground and four pairs of feeding arms that connect the loop and the ground together, as is shown in Fig.1. In this paper, 4 pins are installed between the gaps of the loop structure, as are shown by the circled areas. By switching the status of these 4 pins, 4 beams with the maximum radiation along right, up, left and down direction are generated when overlooking the loop plane, and these 4 beams are called R mode, U mode, L mode and D mode for short, respectively. Take R mode as an example to illustrate the working mechanism of the antenna. The pin-R is at "on" state and the other three pins are at "off" state, which makes the current on the loop not as uniformly distributed as Alford loop. The left 2 portions of the loop are connected by pin-R and thus serves as a reflector, so the radiation is squeezed to the right area and the main beam direction is along the positive x axis.

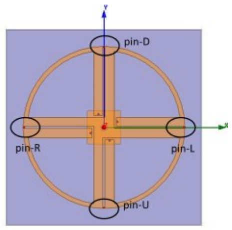


Fig. 1. Pattern reconfigurable loop antenna structure.

III. SIMULATION RESULTS

This section shows the simulation results of the pattern reconfigurable loop. The operating frequency is set to be 2GHz for convenience. Also a comparison between the original Alford loop and the pattern reconfigurable loop is made to demonstrate the advantages of the proposed antenna.

The antenna is printed on the Rogers RO4003C substrate with the constant permittivity of 3.38 and thickness of 1.5mm. The loop is of radius 38mm and is 2mm in width. The width of the feeding arms is 4.4mm. And the side length of the ground is 16mm.

Fig.2 shows the return loss of the Alford loop and the proposed antenna. The black dash curve is the return loss of Alford loop and the -10dB bandwidth is 50MHz. The other 4 curves are the return loss of the 4 working modes of the proposed loop. Since the 4 working modes are structurally symmetrical, the 4 curves are of the same resonant frequency 2GHz and are with the same -10dB bandwidth of 140MHz.

Fig.3 shows the current distribution of the Alford loop, and the it is uniformly distributed in the four sectors, which can generate omnidirectional radiation. While Fig.4 shows the current distribution of the 4 working modes of the antenna. With the different working status of pins, the current is no longer uniformly distributed but is guided to the corresponding directions, just as section Ⅱ stated.

Fig.5 shows the 3D radiation pattern of the R, U, L and D modes of the proposed antenna. The maximum radiation is squeezed to the corresponding right, up, left and down direction, which coincides with the current distribution shown in Fig.4.

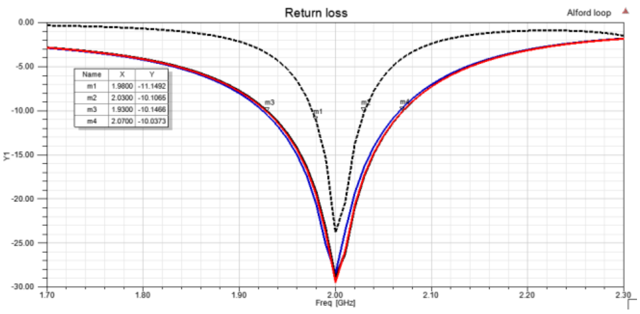


Fig. 2. Return loss of the Alford loop and the proposed antenna.

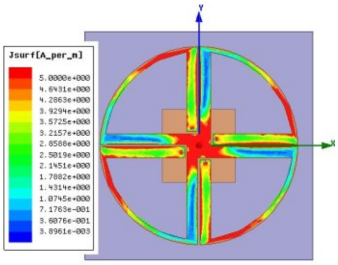
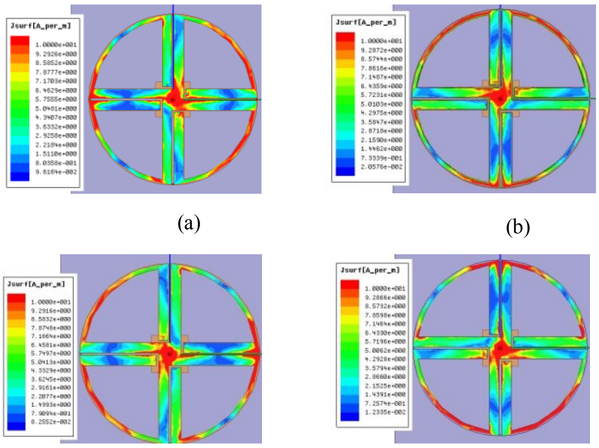
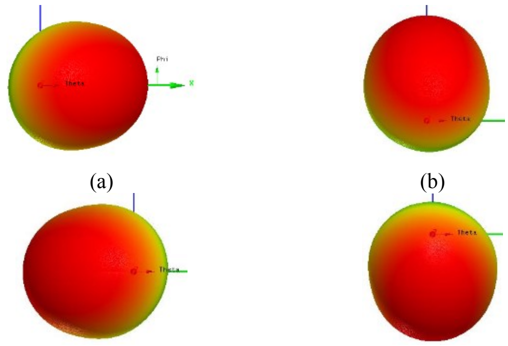


Fig. 3. Current distribution of the Alford loop.



(a) (b) (c) (d)

Fig. 4. Current distribution of the 4 working modes. (a)R mode (b)U mode (c)L mode (d)D mode.



(a) (b) (c) (d)

Fig. 5. 3D pattern of 4 modes of the proposed antenna. (a)R mode (b)U mode (c)L mode (d)D mode .

Fig.6 shows the radiation in E plane and H plane of R mode. The 3dB beam width in E plane is 144° and cover over a quarter in the loop plane. The 3dB beam width in H plane is 196° and cover over a half region in the vertical plane that is perpendicular to the loop.

Fig.7 depicts E pattern of all four modes of the proposed antenna in one figure. With the help of wide beam width in H plane, it is obvious to find that the 4 beams can cover the whole 3D space, which indicates that the proposed antenna can be regarded as an equivalent isotropic radiator in the whole 3D space with greatly increased gain.

(a) (b)

Fig. 6. E pattern and H pattern of R mode. (a)E pattern (b)H pattern.

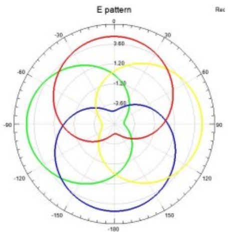


Fig. 7. E pattern of all four modes of the proposed antenna.

TABLEⅠ is a comparison between the original Alford loop and the pattern reconfigurable loop. And it is clearly shown that the proposed antenna has more flexible beams, wider beam width, higher gain and larger bandwidth.

TABLE I. COMPARISON BETWEEN THE TWO ANTENNAS

	Alford loop	***Proposed antenna***
Reconfigurable modes	No	R mode, U mode, L mode, D mode
Beam width in vertical plane	112°	196°
Gain	1.62dB	4.52dB
Bandwidth	50MHz	140MHz

IV. CONCLUTION

This paper presents a new pattern reconfigurable loop antenna operating at 2GHz with four beam modes. The reconfigurable patterns cover nearly the whole 3D space, so the proposed antenna can be regarded as an equivalent isotropic radiator and can be used for wide angle scanning phased array.

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