Direction Controlled Planar Reconfigurable Antenna Using Flared Radiators

M.S. Alam, A.M. Abbosh
School of ITEE, The University of Queensland, St Lucia, QLD 4072, Australia
m.alam7@uq.edu.au

***Abstract*—A direction controlled reconfigurable antenna that has four switchable operating modes is presented. The direction of the main radiation beam can be changed from 0° to 180° at 45° angular steps in the azimuth plane. The proposed antenna consists of two flared radiators, truncated ground plane and two parallel strips near its edges. It is controlled using four PIN diodes. The antenna operates across the frequency range from 1.93 to 2.74 GHz to support Bluetooth, WiMax, WLAN and many other wireless services. The antenna has narrow radiation beams in the azimuth planes for reasonable selectivity and wide beams in the elevation plane for wide coverage. The designed antenna has a simulated peak gain of 3.5 dBi and simulated average gain of more than 2 dBi over the covered band. Despite using a simple structure and controlling mechanism, the antenna represents a suitable candidate compared to other antenna designs operating at the same frequency band. It has a compact dimension of 38 × 48 × 1.6 mm^3 using FR4 substrate.**

Keywords—Reconfigurable antenna; Pattern reconfigurable antenna.

I. INTRODUCTION

The rapid development of wireless communication systems demand antennas with multi-functionality to serve different purposes. The reconfigurable antenna is a promising way to replace multiple antennas if designed to meet the desired system requirements. Reconfigurability can be achieved in terms of frequency, polarization, pattern/direction and/or any combination of these. Pattern reconfigurable antennas are capable of switching the radiation between different directions and thus useful in noisy and multipath fading environment. They can be used to direct the main radiation to the intended directions while radiations from other directions are limited. The phased antenna array is traditional choice in this kind of situation; however their physical size, weight and feeding network complexity made their suitability limited to specific high-cost applications [1]. Thus, interests have been growing on designing planar reconfigurable antennas. Thus, different techniques have been investigated in the literature, such as using different radiators [2], changing characteristic modes of radiators [3], adding parasitic elements [4], using multilayer configuration [1, 5] etc.

Recently, a tapered-slot antenna is proposed in [6] to form reconfigurable antennas. To that end, the tapered slots work as radiator and four endfire patterns are realized by suitable operation of the PIN diodes. In [7], a circular antenna was designed using a disc radiator, four sector coupling elements and four sector radiating elements. It can rotate the main radiation beam by 90° in the azimuth plane. The beam switching antenna proposed in [8] is able to steer the beam in four directions except in the normal boresight radiation. It has a moderate gain but the beam steering angle in small. The antenna reported in [9] can produce three different patterns using three different combinations of monopole and loop antennas.

A wideband reconfigurable quasi-Yagi strip antenna consists of a driving circular monopole, two reflecting grounds and six parasitic director strips is presented in [10]. The design produces two endfire radiations along the *H*-plane and one broadside pattern. In [5] a co-planar waveguide (CPW) fed multilayer antenna was proposed. The operation of that antenna is interchangeable from monopole to slot mode. Thus, it produces two radiation patterns. A multilayer patch-slot-ring structure was investigated in [1]. An asymmetrical arrangement of PIN diodes was employed to switch the pattern in four directions at an angle of 25° to 30° from the boresight.

Despite achieving reasonable performance, the above designs occupy relatively large physical area. Also, those antennas are capable of rotating the main beam with 90° angular step at the most cases. In this work, a planar compact reconfigurable antenna, which can steer the mainbeam in the range of 0° to 180° at 45° angular step in the azimuth plane, is presented. The antenna consists of two flared radiators, truncated ground plane and two parallel strips near its edges. While the antenna has narrow beam in the azimuth plane, it has a wide beam in the elevation plane.

II. DESIGN CONCEPT AND ANTENNA CONFIGURATION

An antenna's radiation can be controlled by altering the current distribution on the radiating element and/or using parasitic elements to modify the direction of its radiation. Following the well-known Yagi antenna operating principle, microstrip-based structures can be used to realize reflector/director elements in planar forms. Placing two radiators on the either side of a centred microstrip line and activating them separately can give two similar radiation patterns but at two different directions. On the other hand, adopting microstrip lines as reflector or director, the radiation can be further controlled. Here, we consider two radiators, one ground, two parallel strips on the ground side of the antenna; one of them is used as reflector while the other one works as a director.

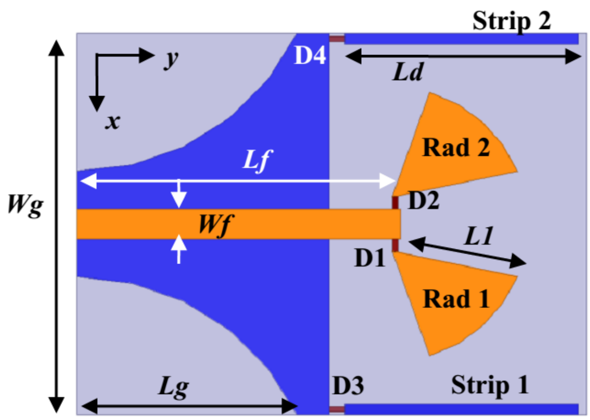

Fig. 1. Proposed antenna geometry

As depicted in Fig. 1, the proposed antenna consists of two bowtie flare type radiators (Rad 1 and Rad 2), truncated ground plane and two parallel strips (Strip 1 and Strip 2) near the edges along *y*-axis. A microstrip line is used to feed the radiator on the top side of a 1.6 mm thick FR4 substrate. The radiators are placed symmetrically along *y*-axis, on the left and right sides of the feeding line. The ground plane and the parallel strips are located on the back side of the same substrate. The design parameters are (in mm): *L1* = 11, *Ld* = 22, *Lg* = 23, *Wg* = 38, *Lf* = 31, *Wf* = 3. The overall size of the antenna is 38 × 48 × 1.6 mm^3. Two PIN switches (D1 and D2) are placed between the feed line and radiators to activate/connect one radiator at a time, while two other PIN switches (D3 and D4) are used to change the lower and upper strip's role between being a reflector or director. When a strip is shorted to the ground it acts as a reflector; otherwise, it operates as a director. Certain combinations of the radiators and directors are used to select the required radiation direction. The radiator is to be chosen first and then the director/reflector selection will guide the radiation in a certain direction. For example, if Rad 1 is connected to the central microstrip line though D1 and Strip 1 is disconnected from the ground through D3, the antenna works in Mode 1. In this case, the radiation beam aligned in Phi = 0˚ plane and the main beam direction is (0˚, 90˚). Similarly, the antenna can operate in other modes by changing the switching combinations and can produce radiation beams in other directions too.

III. Direction Controlled Operation

The antenna operates in four modes and the main beam directions are controlled by changing the radiator and reflector/director switching status. The switching conditions regarding the mode of operations are listed in Table 1. Following those conditions, the antenna can be operated in any of the four modes without changing the structure and any other parameters. As shown in Fig. 2, the antenna has almost similar S11 responses at the four states. The -10 dB impedance bandwidth is 1.93-2.74 GHz. Fig. 3 shows the simulated peak gain over the operating band in the four operating modes. The peak gain is more than 3.5 dBi at around 2.4 GHz, whereas it is greater than 2 dBi over the whole operating frequency band. S11 responses and the gain are stable in all the operating modes. This is an important requirement for the smooth operation of a reconfigurable antenna in all cases.

TABLE I. Switching Conditions For The Four Operating Modes

Operating Modes	Switching Status			
	D1	D2	D3	D4
Mode 1	ON	OFF	OFF	ON
Mode 2	OFF	ON	OFF	ON
Mode 3	ON	OFF	ON	OFF
Mode 4	OFF	ON	ON	OFF

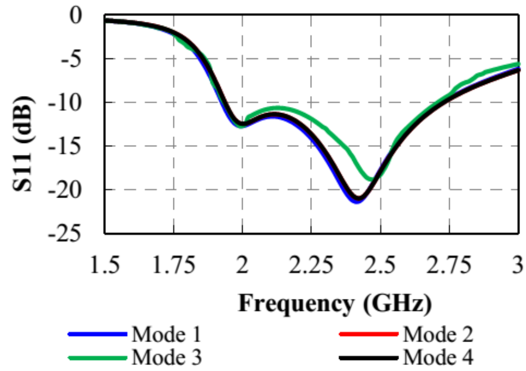

Fig. 2. Reflection coefficient (S11) responses from simulation in different operating modes.

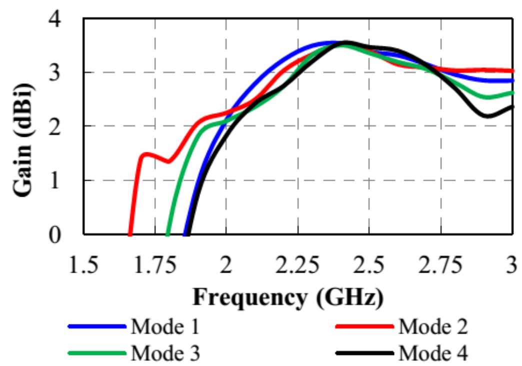

Fig. 3. The simulated gain in the four operating modes.

Fig. 4 depicts the 2D radiation patterns in the azimuth and elevation planes in the four modes at 2.4 GHz. The main beam is directed to (phi, theta) = (0˚, 90˚) (45˚, 90˚) (135˚, 90˚) (180˚, 90˚) in Mode 1, Mode 2, Mode 3 and Mode 4, respectively. The 3D view of these radiation patterns are shown in Fig. 5. The direction of the main beam is rotated at 45˚ in the azimuth (phi) plane. In the elevation plane the beam width is about 245˚ and it is approximately 95˚ in the azimuth plane. The beam is narrow in the azimuth plane where the direction is rotated. Thus, the antenna offers better direction selectivity, while the wide beam in the elevation plane gives wide area coverage. So, the simultaneous narrow beam in one plane and wide beam in the orthogonal plane is advantageous when a large area, in a particular direction is to be served.

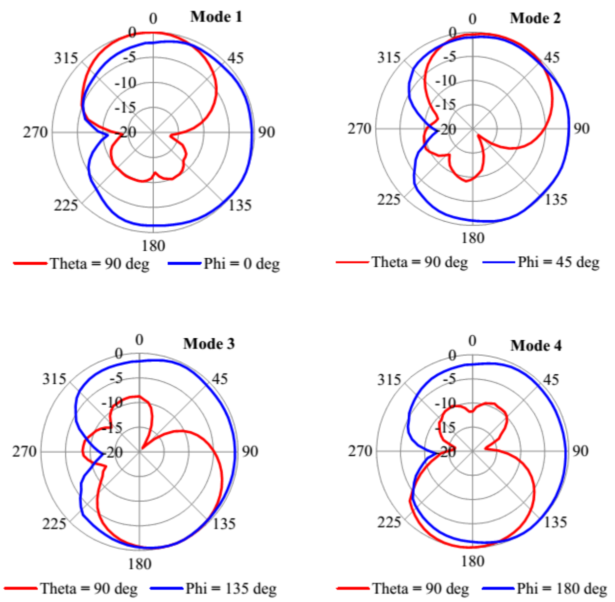

Fig. 4. Simulated 2D radiation plots in the azimuth and elevation planes.

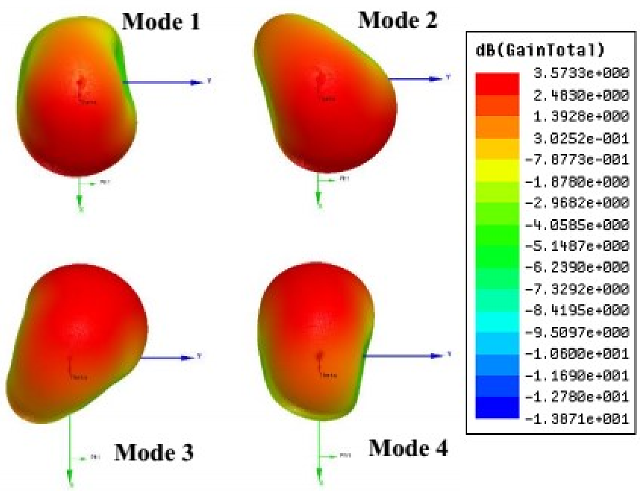

Fig. 5. Simulated 3D radiation patterns showing the main beam rotation.

TABLE II. RECONFIGURABILITY PERFORMANCES

Modes	BW (GHz)	Peak gain (dBi)	Beam direction (φ, θ)	Beam Width	
				Azim. plane	Elev. plane
Mode 1	1.92-2.74	3.54	(0°, 90°)	95	245
Mode 2	1.93-2.74	3.52	(45°, 90°)	100	247
Mode 3	1.93-2.73	3.55	(135°, 90°)	96	245
Mode 4	1.93-2.74	3.52	(180°, 90°)	97	248

Table II gives an overview of the proposed antenna's performances. Due to the symmetry of the structure, the four states of the antenna have almost similar results except the beam direction rotation at those four operating modes.

IV. CONCLUSION

A planar reconfigurable antenna is presented. The antenna can steer the main radiation beam in four directions following the appropriate radiator-director selection. The antenna consists of two flared radiators, truncated ground plane and two parallel strips near its edges. Four PIN switches are used to choose the radiator-director combination which in turn produces four different directions. The antenna operates in the frequency range 1.93-2.74 GHz. It can rotate the main beam direction with 45° angular step starting from 0° to 180° in the azimuth plane. It has narrow beam in the azimuth plane with reasonable selectivity and wide beam in the elevation plane for wide coverage. Moreover, it has a compact size, simple structure and controlling mechanism and thus it is a potential candidate for Bluetooth, WiMax, WLAN and many other wireless services. The future works are to further improve the antenna design and testing the practical performances.

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