Beam Reconfigurable Antenna Using Switchable Parasitic Elements for V2V applications

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***Abstract*—A pattern reconfigurable antenna is proposed for vehicle to vehicle (V2V) communication applications. The proposed antenna consists of a monopole antenna at the center of the equilateral triangle structure with three reconfigurable parasitic elements with a PIN diode at each sidewall of the structure. When the diode is on, the parasitic element becomes a reflective surface. When the diode is off, the parasitic element becomes transparent surface to a vertically polarized incident wave. Therefore the beam steering property of the proposed antenna can be implemented by controlling the on/off state of a PIN diode of each parasitic element. The -10 dB reflection coefficient bandwidth is 480 MHz from 5.66 GHz to 6.14 GHz. The gain at 5.9 GHz is 6.15 dBi with beam steering along the azimuth plane (θ = 90° plane).**

Keywords—Beam steering; radiation pattern reconfigurable; vehicle to vehicle (V2V); wireless access in vehicular environment (WAVE)

I. INTRODUCTION

Future vehicles will be integrated with numerous wireless communication devices to aid the driver and to actualize the efficient driving environment. Vehicles will be connected to each other to share traffic information for intelligent transportation systems (ITS). The IEEE 802.11p wireless access in vehicular environment (WAVE) standard is a fine solution for vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications. The WAVE band is from 5.85 to 5.925 GHz [1]. Especially in V2V, the antenna requires a directive radiation pattern in azimuth plane (θ = 90°) since the transmitter and receiver are usually placed at the same height. The performance of vehicular communications is affected by a deep multipath fading due to reflections and diffractions from surrounding objects and by degradation of the radiation pattern [2]. To reduce the multipath interference and enhance the communication link performance, beam steering antennas are necessary. Phased array antenna is most commonly used for beam steering. However, the use of phase shifters and power distribution network will increase the complexity of design and size [3]. Another promising way to achieve a beam steering antenna is using butler matrix, but it still needs a large area for distribution network and increases the design complexity [4]. On the other hand, a directive array based on reconfigurable antenna can modify its radiation pattern in azimuth plane without complex power distribution network [5]. This antenna consists of a cylindrical monopole antenna as a driven element at the center, surrounded by six parasitic elements with switch. The radiation pattern can be controlled by the on/off state of switch. But gain in azimuth plane at θ = 90° is not sufficient to apply to V2V communication, because tilt of beam towards the perpendicular direction of the ground is occurred due to the effect of large ground plane.

In this paper, a beam reconfigurable antenna using switchable parasitic elements for V2V applications is proposed. At the center of the equilateral triangle structure, a monopole antenna is positioned as a driven element. At each three sidewall of the structure, a reconfigurable parasitic element with PIN diode is placed. By controlling the on/off states of diodes, the radiation pattern reconfiguration can be achieved. The proposed antenna operates over the WAVE band with a maximum gain of 6.15 dBi at θ = 90°.

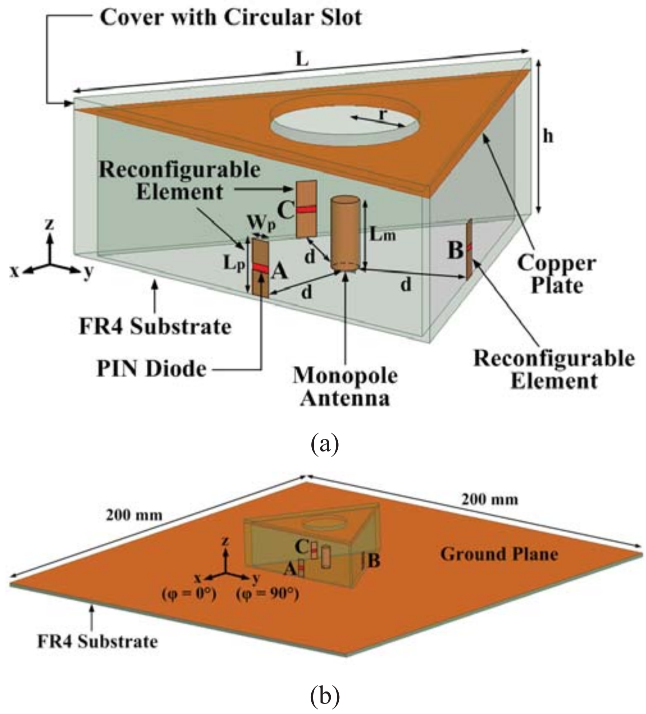


Fig. 1. Geometry of the proposed antenna (a) detailed view (L_m = 9.3 mm, d = 14.9 mm, L_p = 7.8 mm, W_p = 2.85 mm, h = 21.6 mm, L = 63.7 mm, r = 10 mm) (b) perspective view

II. ANTENNA DESIGN AND ITS PERFORMANCE

A. Antenna Structure

The proposed antenna comprises a monopole antenna at the center of the equilateral triangle structure and three reconfigurable parasitic elements at each sidewall as shown in Fig. 1. A monopole antenna operates as a driven element at 5.9 GHz. Three reconfigurable parasitic elements (A, B and C) with PIN diode are located vertically on the ground plane with a same distance *d* from the monopole in each direction. Three possible modes of operation are illustrated in Table I. The ground plane size is 400 mm^2. To increase the gain at $\theta = 90°$, the cover with a circular slot is added on the structure with a height of *h* from the ground plane. The circular slot at the center of the equilateral triangle is essential for impedance matching. For all elements in the structure, FR4 ($\varepsilon_r = 4.4$, $\delta = 0.02$) substrates are used.

B. Results of Simulation

Fig. 2 shows the simulated -10 dB reflection coefficient of the proposed antenna. As can be seen from the figure, covering the antenna with a top plate with circular slot slightly affects the bandwidth. However, it does not significantly deteriorate the bandwidth performance and the proposed antenna fully covers the WAVE band (BW: 480 MHz, 5.66 ~ 6.14 GHz). Fig. 3 (a) shows that the simulated realized gain increases at 5.9 GHz by covering the circularly slotted cover for case 1. The gain increases 1.29 dB at $\theta = 90°$ comparing to uncovered case, because the cover makes the main beam tilt to azimuth plane. Fig. 3 (b) shows the simulated radiation patterns of the proposed antenna for three cases at 5.9 GHz in azimuth plane at $\theta = 90°$. It shows the beam steering towards the transparent surface direction is achieved when one diode is off and others are on. The gain and direction of the main beam at $\theta = 90°$ for three cases are shown in Table I.

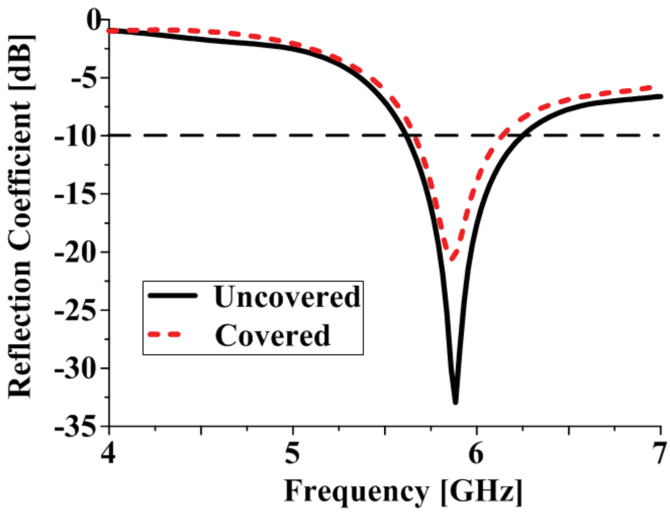
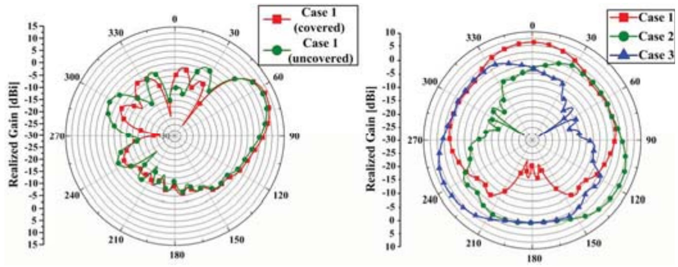


Fig. 2. Simulated reflection coefficient of the proposed antenna covered and uncovered with top plate for three cases



(a) (b)

Fig. 3. Simulated radiation pattern of the proposed antenna at 5.9 GHz (a) with or without cover for case 1 for elevation cut ($\varphi = 0$ plane) (b) with cover for three cases for azimuth cut ($\theta = 90°$ plane)

TABLE I. GAIN CHARACTERISTICS OF THREE CASES

Case	PIN diode states			Gain (dBi)		Direction of main beam ($\theta = 90°$) (Deg.)
	A	B	C	uncovered	covered	
1	OFF	ON	ON	4.83	6.12	$\varphi = 0$
2	ON	OFF	ON	4.83	6.14	$\varphi = 120$
3	ON	ON	OFF	4.80	6.19	$\varphi = 240$

III. CONCLUSION

In this paper, a beam reconfigurable antenna utilizing switchable parasitic elements for V2V applications is proposed. The antenna has a -10 dB reflection coefficient bandwidth to cover 5.9 GHz WAVE band. On average, the simulated gain is 6.15 dBi at beam steering direction in $\theta = 90°$ plane. Thus, the proposed antenna is a good candidate for V2V applications.

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