A Low Profile Smart Antenna Design for DSRC Applications

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***Abstract*—This paper presents a low profile smart antenna system with 4 antennas operating in DSRC band and 1 antenna in GPS band for V2X communication. The DSRC antenna system is composed of 4 monopole antennas and 5 vertical walls inside a substrate with mainly horizontal radiation while the GSP antenna is placed in the center with vertical radiation. Each DSRC antenna can be considered as a special corner reflector (SCR). Based on antenna theory, this design can achieve a high directive gain and front-to-back ratio performance with simple structure. With this configure, the mutual coupling among DSRC antennas and GPS antenna can be minimized and their field of view can be optimized.**

I. Introduction

Intelligent Transportation System (ITS) has been attracting much attention globally in wide areas, including industrial, academic and government sectors. The operation of ITS system relies heavily on the safety message communication among all road users, which is currently based on the Dedicated Short Range Communication (DSRC) technology. This technology enables safety and efficient (real time) communication between vehicles (V2V) and infrastructures (V2I). Antennas for both vehicle and roadside infrastructures play vital roles in ensuring reliable communication in the system.

There have been lots of research works on DSRC antennas for on-board unit (OBU) and roadside infrastructures [1,2]. Most of them focus on omnidirectional radiation patterns for a 360-degrees-coverage in the horizontal plane. Some of them have investigated performance of directional antennas for roadside infrastructures [2,3]. As there is also a trend for future vehicles to have ability to adapt changing environment and guarantee safety with high probability, directional antennas with steering capability and high gain in desired directions are in high demand for vehicles in ITS system. In [4], a 4-element double-looped monopole array with relatively high gain was developed for roadside base station. However, this array is difficult to mount on infrastructures as it needs a large ground plane (90cm by 90cm) and high installation cost. An antenna array with beamforming capability was proposed in [5] for vehicles. However, it is complicated as it uses metamaterials and requires a group of feed networks to support the performance. Therefore, simple, low profile antennas with beam steering capability are needed for vehicles and infrastructures in V2X communication.

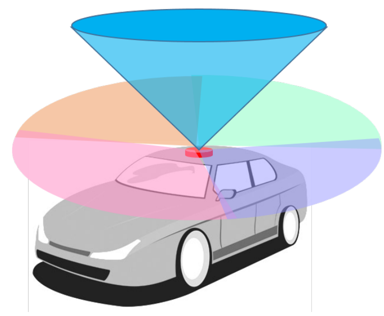


Fig. 1. Illustration of the proposed antenna system with 4 switched beams for horizontal radiation and 1 vertical beam for GPS reception.

In this paper, a low profile smart antenna system with 4 antennas operating in DSRC band (5.85-5.925GHz) and 1 GPS antenna for V2X communications. The proposed antenna design has DSRC radiating monopoles and reflecting walls embedded in a cheap substrate (for example FR4). A commercial GPS antenna can be placed in the centre sorrounded by a cylindrical wall for good GPS reception and better isolation with DSRC antennas. It is circular in shape and is able to provide high gains in 4 orthogonal directions and support beam steering those directions. It is expected to be suitable for both vehicles and infrastructures.

II. Antenna Design

A. Special Corner Reflector

The design of the antenna is based on special corner reflector (SCR) [6]. Three metallic walls and a monopole form a SCR. According to image theory, the monopole will have a mirror image with respect to the metallic walls. The total electric field will be the summation of the fields from original and image elements. By properly adjusting the distance of monopole to the metallic walls, the fields of the two will add constructively and achieve a high gain.

B. Antenna Geometry

The 4-port antenna geometry is shown in Fig. 2. The 4 ports are feeded with $\lambda/4$ monopoles. Additional 4 side walls (rectangular) and 1 center wall (cylindrical) in orange color are placed in between different ports. They work as reflectors. The center portion is empty, which provides a good structure

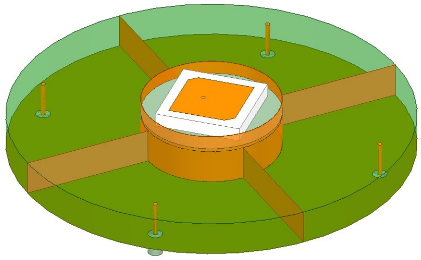


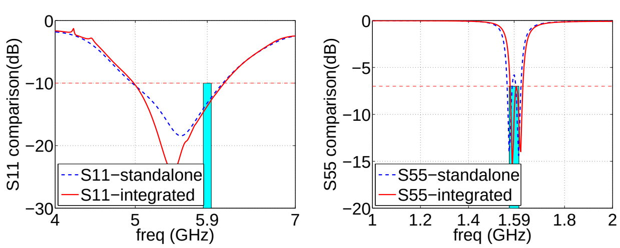
Fig. 2. Geometry of the proposed smart antenna with 4 DSRC ports (ports 1 to 4) and 1 GPS port (port 5).

for easy mounting onto a infrastructure or a good space to hold an GPS antenna for vehicles as illustrated in the figure. The substrate used can be low cost materials, such as FR4.

The radius of the center wall, the distance from the center wall to the feeding position and the length of the side wall play major roles in antenna performance optimization. Specially, center radius and distance of feed controls the matching and dominates the pattern shapes of the element.

III. Experimental Simulations

HFSS software is used for simulation. Due to symmetrical property, only results at port 1 (facing $\phi = 90°$) are shown. Comparison results of standalone performance and integrated performance with GPS antenna have been presented in Figs. 3 and 4. The GPS antenna is 25mm×25mm×4mm in size. As shown in Fig. 3(a), port 1 works well within DSRC band. The gain at port 1 in horizontal plane achieves 5.1dBi and beamwidth is 106° in Fig. 4(a). The GPS port is denoted as port 5. Fig. 3(b) and Fig. 4(b) show that the GPS can work well in the required band (1.57-1.61GHz<–7dB) and has very good gain in the high-elevation direction. The antenna also expresses very good isolation performance (below –18dB across the bands) among all the ports (as shown in Fig. 5). In fact, length and height of metallic walls in the antenna can also be controlled to have different beamwidths and gains. This provides another degree of freedom to the antenna.

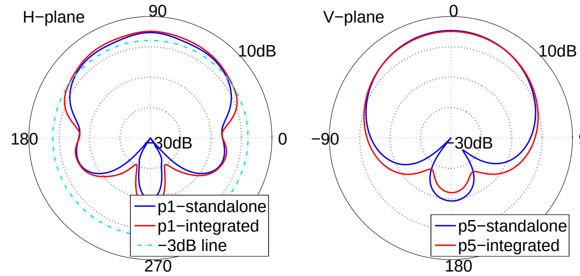


(a) (b)

Fig. 3. Simulated (a) S11 at port 1 (DSRC) and (b) S55 at port 5 (GPS).

IV. Conclusion

This paper presents a low profile 4-port smart DSRC antenna design for DSRC applications, either on vehicles or on infrastructures. Simulation results show promising high performance with higher gain and better front/back ratio compared to conventional V2X antennas in the market. More results with fabrication and measurement comparison will be presented in the final paper and at the symposium.



(a) (b)

Fig. 4. Simulated radiation patterns at (a) port 1 (DSRC) and (b) port 5 (GPS) of the proposed smart antenna.

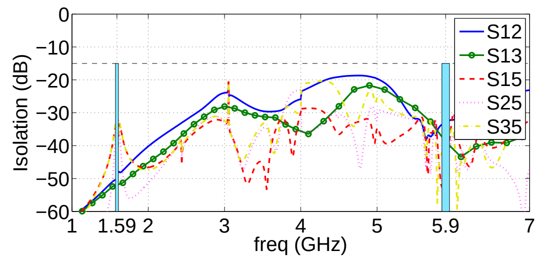


Fig. 5. Isolation among different ports (ports 1 to 4: DSRC antennas; port 5: GPS antenna).

Acknowledgement

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References

[1] C. Y. Liou and et. al, "Compact and low-profile conical antenna for automotive DSRC application," *2016 IEEE APSURSI*, Fajardo, 2016, pp. 117–118.

[2] V. Shivaldova and et. al, "On roadside unit antenna measurements for vehicle-to-infrastructure communications," *2012 IEEE 23rd PIMRC*, Sydney, NSW, 2012, pp. 1295–1299.

[3] K. Xu, B. Garrison, and K.-C. Wang, "Performance modeling for IEEE 802.11 vehicle-to-infrastructure networks with directional antennas," *in IEEE Vehicular Networking Conference*, December 2010, pp. 215-222.

[4] Y. Kim and et. al, "Design of a double-looped monopole array antenna for a DSRC system roadside base station", *Microw. Opt. Technol. Lett.*, vol. 37, pp. 74–77, 2003.

[5] M. K. Khattak and S. Kahng, "Enhanced gain metamaterial-based Leaky-wave beam-forming antenna for the V2X communication," *2015 ICET*, Peshawar, 2015, pp. 1–2.

[6] Y. Lu, X.F. Cai and Z.Y. Gao, "Optimal design of special corner reflector antennas by the real-coded genetic algorithm," *2000 APMC*, Sydney, NSW, 2000, pp. 1457–1460.