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Research Article

Antenna Design and Performance Analysis for V2V Vehicular Intelligent Transportation System

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ABSTRACT

Research is carried out for antenna design for V2V communication for vehicular systems. Designed antenna has high efficiency, required for the higher data rate in V2V communication. The Gain, S11 and Efficiency are suitable for V2V communication. Antenna works at 5.9 GHz frequency for vehicular Communication. The placement of antenna is another factor which is analyzed by using field pattern of designed antenna. Designed Antenna efficiency is 89% for Vehicular Communication. The Antenna can be used for Vehicle-to-Vehicle communication for 802.11p. The Antenna is designed by using HFSS tool. The designed antenna has throughput variation appropriately as required for V2V communication and Autonomous vehicles.

Keywords: VSWR, Vehicular Communication, vehicle-to-vehicle communication (V2V), Patch Antenna, Gain

1. INTRODUCTION

Current research focuses on antenna design optimized for vehicular communication. Connected cars and autonomous vehicles domain is rising day by day, so vehicle-to-vehicle (V2V) communication has become crucial for road safety and improving driving experience [1]. Need of robust and efficient antenna designs for V2V communication is gaining significant attention in this context. Vehicular antennas have important role to play, due to improve data rates and reliability in vehicular communication [2]. However, designing efficient antennas for vehicular communication presents several challenges.

Major challenge is to achieve the compactness of antenna and throughput in antenna designs that can be integrated with vehicles without any loss in performance [3]. Maintaining consistent performance in dynamic and complex vehicular environments remains a significant hurdle. In present research, focus is on antenna design to be optimized for vehicular communication. Studies have been conducted on wideband communication and its performance improvements. The size of the antenna is crucial for fitting into small form factor devices, and techniques have been employed to reduce antenna size [4]. The connected cars sector is currently one of the fastest-growing domains.

Nowadays, vehicular communication is becoming increasingly significant for connected vehicles. The safety of vehicles and passenger is at prime in Vehicular Technology [5]. The connected car industry is poised for significant growth in the coming years [6]. These cars are equipped with infotainment systems that provide both information and entertainment. In the automotive sector, connectivity often includes WLAN, Bluetooth, and vehicle-to-vehicle (V2V) communication. Antennas play a critical role in ensuring reliable, accurate, and efficient communication within connected cars [7]. These antennas, integrated with Electronic Control Units (ECUs), are essential for internal communication. Therefore, designing and implementing MIMO antennas for infotainment and V2V communication is crucial to enhance collision avoidance capabilities [8]. In high end cars the Infotainment systems have WLAN and Bluetooth antennas to connect Bluetooth and WLAN devices within the vehicle. As the number of connected devices increases, there is a growing need for high-throughput antennas to maintain efficient communication [9].

The significance of antennas in the realm of connected cars cannot be overstated [10]. They are vital for ensuring reliable, accurate, and efficient communication. This necessitates the design and implementation of MIMO antennas for infotainment and vehicle-to-vehicle (V2V) communication, which are crucial for collision avoidance. Infotainment systems typically utilize WLAN and Bluetooth antennas to connect devices within vehicles, requiring high-throughput antennas as the number of devices increases [11].

The return loss value is important for antenna design and return loss value at the operating frequency gets dip. Return Loss RL represented by S11 [12]. Return loss is parameter is adjusted for the 5.8 GHz frequency for antenna design process. Return Loss parameter indicates value of power that is lost due to load and does not reflect back as reflection. The rapid growth in the automotive industry, particularly for driverless vehicles, ADAS systems and larger data processing of Vehicles, the important part is low latency for vehicular data communication [13]. Recently, V2V communication has become a hot topic in the automotive and Imbedded system design industry.

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Antennas used in mobile communication are highly advanced in terms of gain and bandwidth. But the vehicular Technology for antenna design is in evolving stage. The primary requirements in vehicular communication are low latency and stable communication for desired range [14]. The IEEE 802.11p standard is ideal for vehicular communication, operating in the frequency range of 5.8 GHz to 5.925 GHz. High Performance antenna designs for Vehicular technology is very essential with high gain and low Latency.

ITS Connected vehicles, it is essential that data concerning the distance and position of each car is available to every device. This data needs to be communicated to the cloud, making use of real-time processing through the Internet of Things (IoT) [15]. While some of these antennas are easy to install on vehicles, they often have limited operating bandwidth and gain [16]. Additionally, many proposed antenna geometries for V2V communication are expensive to produce and large, making installation challenging. Microstrip antennas offer significant potential in automotive applications due to their lightweight, low cost, and easy integration.

2. Antenna Design

The design parameters for the antenna intended for vehicular communication are illustrated in Fig. 1, which provides a top view of the antenna. The physical dimensions of Patch antenna are as shown in Fig. 1.

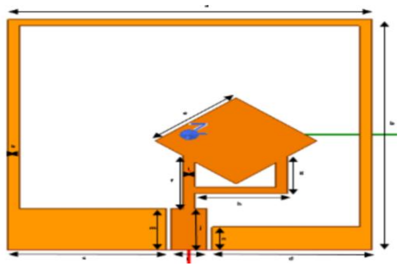

Fig.1 Top view of the antenna Design

Design steps for vehicular antenna:

1) Rectangular slot with a size of Length (L) 31.5mm and width (W) of 37.5mm on the substrate.

2) To reduce the antenna size, Orthogonal structure is used.

3) The antenna is able to generate 5.8 GHz Frequency.

4) The feedline width is kept fw = 0.6 mm.

5) By the variation of the distance r, we can observe in the changes in the S11-Return loss parameter can be varied.

a = 31.5	b = 37.5	c = 13.75	d = 13.75	e = 7	f = 8.5	g = 6	h = 8	i = 1
j = 6.75	k = 1	l = 3	m = 6.75	n = 3.75	o = 31.5	p = 2.8	q = 1.6	

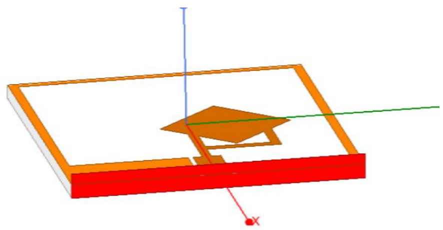

Fig. 2. Design antenna. with feed line

Antenna Designed stages are shown below image and FR4 material is used for the dielectric material. S11 values are shown for the stages in the figure.

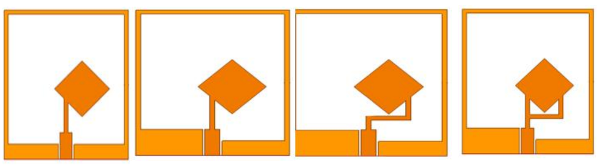

Fig. 3. Antenna Design Evolution Stages

Fig. 4. Antenna Fabricated with FR4

Antenna fabricated as shown below image and FR4 material is used for the dielectric material. SMA connector is soldered for the excitation to the antenna and Connecting to the VNA for the measurement [17]. Antenna fabricated with the Orthogonal distribution process of the Electric current is utilized. Circular polarization is achieved by getting > 3 dB axial ratio. FR4 dielectric material of height 1.6 mm is used for antenna fabrication. Fabrication images are shown as in figure.

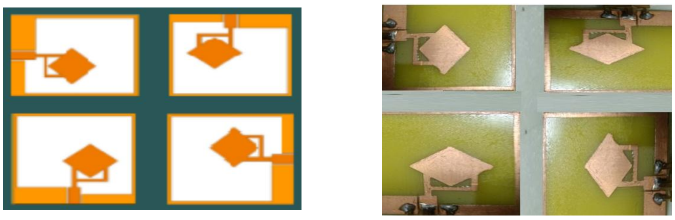

Fig. 5. Antenna MIMO Design for 5.9 GHz Frequency

3. SIMULATION RESULTS AND ANALYSIS

Connected cars domain is getting attraction for researchers. Due to the growth of the connected cars automotive domain has lot of chances of research in the field of antenna communication [18]. This domain deals with the vehicle-to-vehicle communication, in vehicle communication, vehicle to pedestrian communication and pedestrian to vehicle communication. So, for all these communications there is need of efficient antennas design, which can work in real time data handling. MIMO antenna architecture as shown has S11 vales, Gain and VSWR as shown in results. So, the through put should be high for connected cars domain.

As the numbers of applications are being increased in V2V Communication systems, the need of antenna design for higher efficiency and throughput increased significantly.

In the V2V communication, there is need of all Cars to be connected to each other. So, the real time data as the location of each vehicle (car) should be known to other Vehicle (car). Except location there are other parameters also need to be communicated to other connected cars to each other as Latitude and longitude of cars, Car Lanes information, Speed Information. The role of antenna designed for V2V communication plays an important role for Software defined Vehicles (SDV) and Autonomous cars. The Important factor for such communication is Latency and Throughput and Antenna design in the research is solution for the Throughput.

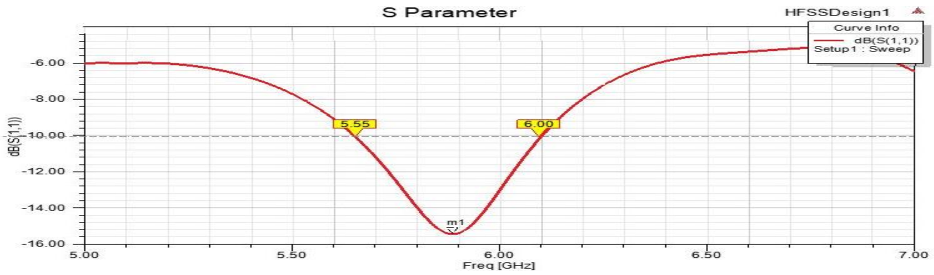

Fig. 6. Return Loss at frequency 5.85 GHz.

AXIAL RATIO

SN	Frequency GHz	Axial Ratio
1	5.9	3.4

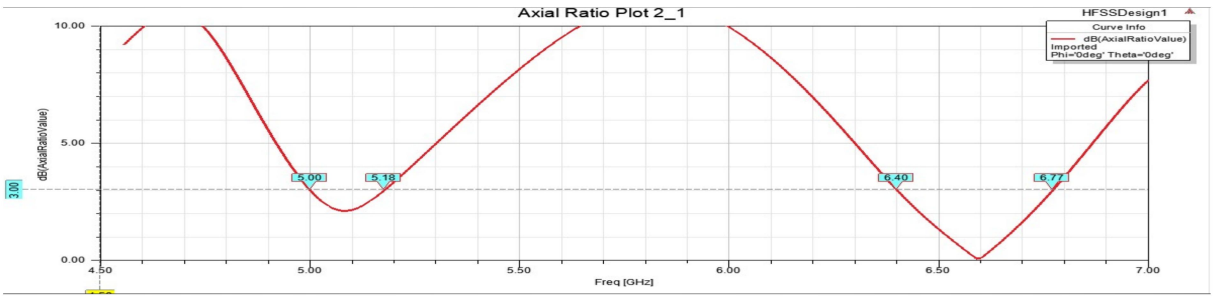

Fig. 7. Return Loss at frequency 5.9 GHz.

Antenna Gain

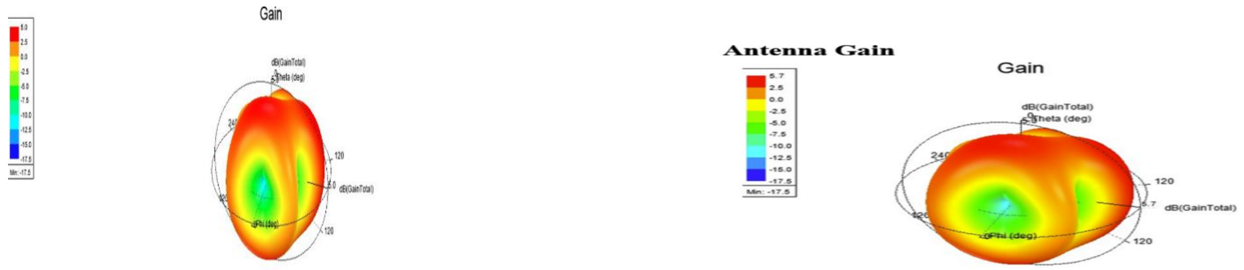

Fig. 8. Antenna Gain parameter polar plot

Antenna VSWR

SN	Frequency GHz	VSWR
1	5.9	1.4

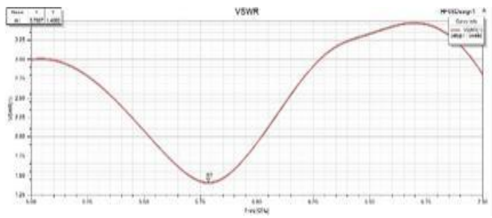

Fig. 9. VSWR at frequency 5.8 GHz.

Antenna Electric Field

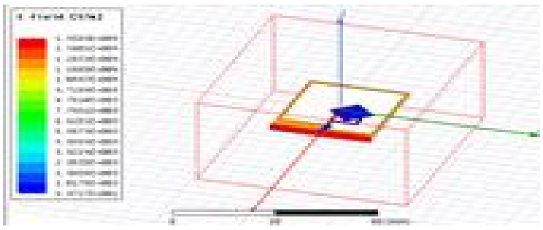

Fig. 10. Antenna Designed Electric Field at 5.8 GHz

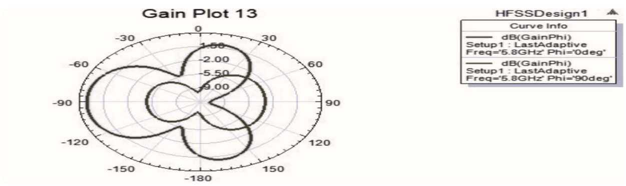

Fig. 11. Antenna Radiation Pattern

Measured Return Loss Results

S11 and Simulated Antenna S11 Values are shown in the table. The shift in frequency is find at 5.8 GHz for the fabricated antenna and measured S11 return loss is -15.1dB.

SN	Frequency GHz	S11(dB)
1	5.85	-15.4 Simulated
2	5.9	-15.1 Measured

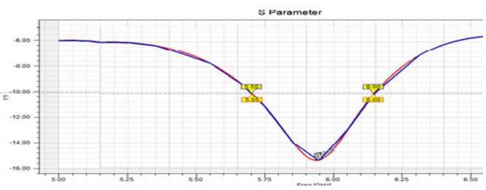

Fig. 12. S11Return Loss for Antenna Measured and simulated

Antenna Efficiency

SN	Frequency GHz	Simulated Efficiency %	Measured Efficiency %
1	5.9	89	84.3

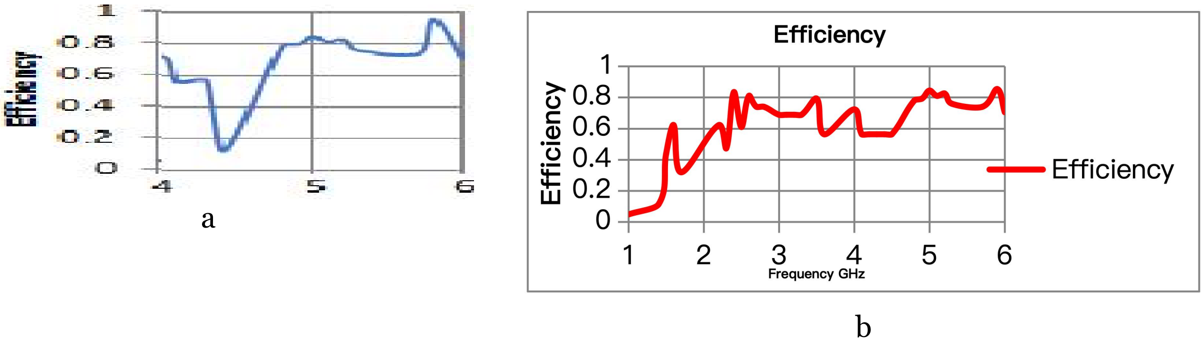

Fig. 13 Antenna Efficiency (a) MIMO (b) Single Element

Throughput Measurement

IPERF is the tool can be utilized to measure the data rate. CMW used for measurement.

Setup is shown as below. Set up is useful for real time Vehicular communication, how much data will be lost

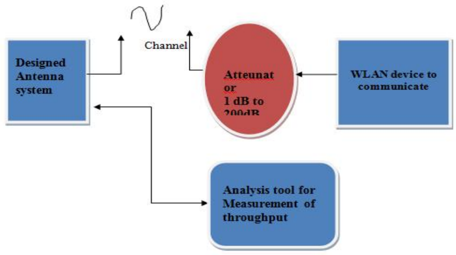

Fig. 14 Setup for Analysis of Throughput Measurement using IPERF

Throughput is measured by using IPERF tool with CMW for TX of data. The distance and the Data rate are measured as below for distance in meters.

SN	Throughput Kbps	Distance (m)
1	765	10
2	854	8
3	886	6
4	894	4
5	917	2
6	942	1

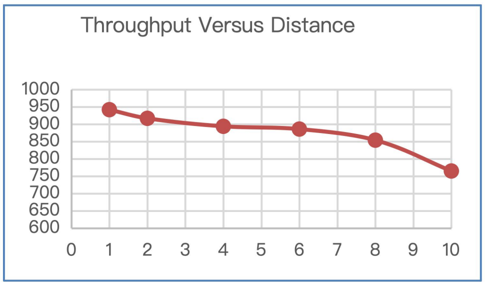

Fig. 15. Measured data rate and distance

Data Rate and distance are in not linearly proportional, when the distance from the antenna is increased the data rate gets reduced. For the MIMO antenna is the envelope correlation coefficient (ECC), which determines how the antenna pattern is independent of one another. The ECC value for the MIMO antenna is less 0.3.

Data rate goes higher when the antenna distance from the destination is decreased. As shown in Fig. 15 set up has antenna and the WLAN device connected to the antenna. IPERF is the tool which is used for throughput measurement. CMW has IPERF tool for measurement of throughput. Fig.16 shows Radiation pattern of antenna on the car model.

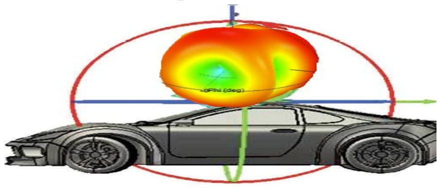

Fig: 16. Radiation pattern of the designed antenna on the car model

4. Conclusion

In this Research, CPW fed antenna is designed for Vehicular communication and antenna fabricated results are measured for return Loss, VSWR and Antenna Throughput. The antenna size is compact 31.5mm X 37.5mm and antenna design shows 5.7 dB gain, which is promising for vehicular communication. The antenna can be used for V2V communication for SDV and Autonomous vehicles. Circular Polarization is achieved as getting Axial ratio of 3.4. Antenna efficiency is 89 % for Vehicular communication.

The proposed antenna is suitable and utilized for vehicular communication as gain is promising value and return loss is as appropriate for Vehicular communication. The future research can be to further improve the data throughput with better efficiency.

References

[1] R. Author and S. Author, "Design and Analysis of a Wideband MIMO Antenna for Vehicular Communication," IEEE Trans. Antennas Propag., vol. 64, no. 6, pp. 2345-2356, Jun. 2024

[2] U. Author, V. Author, and W. Author, "Embedded Wideband Metaresonator Antenna on a High-Impedance Ground Plane for Vehicular Applications," IEEE Access, vol. 11, pp. 3456-3467, Sep. 2023

[3] Y. Zhang, X. Li, and J. Wang, "Design and Analysis of a CPW-Fed MIMO Antenna for Vehicular Communication," IEEE Transactions on Antennas and Propagation, vol. 70, no. 4, pp. 2345-2356, Apr. 2022.

[4] Jiang, D.; Delgrossi, L. Towards an international standard for wireless access in vehicular environments. In Proceedings of the VTC Spring 2008—IEEE Vehicular Technology Conference, Singapore, pp. 2036–2040; 11–14 May 2008.

[5] Arora, A.; Mehra, A.; Mishra, K.K. Vehicle to vehicle (V2V) VANET based analysis on waiting time and performance in LTE network. In Proceedings of the 3rd International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, pp. 482–489, 23–25 April 2019.

[6] Artner, Gerald. Kotterman, Wim, Del Galdo, Giovanni (2019), “ Automotive Antenna Roof for Cooperative Connected Driving” IEEE Acess, Volume 7, pages 20083-20090, 2019.

[7] Yang, L.; Mo, T.; Li, H. Research on V2V communication based on peer to peer network. In Proceedings of the 2018 International Conference on Intelligent Autonomous Systems (ICoIAS), Singapore, pp. 105–110, March 2018.

[8] M. G. Doone, S. L. Cotton, D. W. Matolak, C. Oestges, S. F. Heaney, W. G. Scanlon, (2018), “Pedestrian-to-vehicle communications in an urban environment: Channel measurements and modeling “ IEEE Trans. Antennas Propag., 2018.

[9] Soon-Soo Oh et. Al.., (2018), “Design of a Bidirectional Antenna inside a Vehicle and Measurement of Power Link for Vehicle-to-Vehicle Communication at 5.8GHz” International Journal of Antennas and Propagation Volume 2018, Article ID 6306273, https://doi.org/10.1155/2018/6306273.

[10] N. Adhikari, A. Kumar, and S. Noghanian, “Multiple antenna channel measurements for car-to-car communication,” IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 674– 677, 2016.

[11] Funke, J., Brown, M., Erlien, S.M., et al., 2017, “Collision avoidance and stabilization for autonomous vehicles in emergency scenarios”, IEEE Transactions on Control Systems Technology 25 (4), 1204-1216.

[12] Biddlestone, S., Redmill, K., Miucic, R., et al., 2012, “An integrated 802.11 p WAVE DSRC and vehicle traffic simulator with experimentally validated urban (LOS and NLOS) propagation models”, IEEE Transactions on Intelligent Transportation Systems 13 (4), 1792-1802.

[13] Milanes, V., Perez, J., Onieva, E., et al., 2010, “Controller for urban intersections based on wireless communications and fuzzy logic”, IEEE Transactions on Intelligent Transportation Systems 11 (1), 243-248.

[14] Mondal, T., S. Maity, and R. Ghatak, “Compact circularly polarized wide-beam width fernfractal-shaped micro strip antenna for vehicular communication,” IEEE Transactions on Vehicular Technology, Vol. 67, No. 6, 5126–5134, June 2018.

[15] Ucar, S.; Ergen, S.C.; Ozkasap, O. Multihop-cluster-based IEEE 802.11p and LTE hybrid architecture for VANET safety message dissemination. IEEE Trans. Veh. Technol. 65, 2621–2636. L, 2016.

[16] Herbert, S., Loh, T.-H., Wassell, I., and Rigelsford, J. (2014). On the Analogy Between Vehicle and Vehicle-Like Cavities With Reverberation Chambers. IEEE Transactions on Antennas and Propagation, 62(12):6236–6245.

[17] Congsi Wang, Yan Wang, Xiaodong Yang, Wei Gao, Chao Jiang, Lu Wang,5 Yiqun Zhang, Meng Wang (2018), “Effect of Randomness in Element Position on Performance of Communication Array Antennas in Internet of Things” Wireless Communications and Mobile Computing Volume 2018, Article ID 6492143.

[18] Roque-Cilia, S.; Tamariz-Flores, E.I.; Torrealba-Meléndez, R.; Covarrubias-Rosales, D.H. Transport tracking through communication in WDSN for smart cities., 139, 205–21; Measurement 2019.