PR COMBINATIONAL PATCH ANTENNA DESIGNED FOR DEDICATED SHORT-RANGE COMMUNICATION (DSRC)

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***Abstract*—The proposed microstrip antenna with a combination of P and R shaped patch is designed for the applications of dedicated short-range communication of operating frequency 5.9GHz. The substrate material used is FR-4 epoxy with a permittivity of 4.4. This is done using the CST (Computer Simulation Technology) simulation tool for designing the patch antenna. Particle Swarm Optimization (PSO) is applied to calculate the optimized parameters of combinational Microstrip antenna. The antenna parameters such as return loss, VSWR, radiation pattern and the antenna gain of the proposed antenna are implemented to show that it has promising characteristics for the vehicle-to-vehicle communications. The minimum retransmission frequency of IEEE 802.11p based vehicle to vehicle protocols is required to prevent collisions of vehicles. These V2V protocols are interfaced with the antenna design to achieve road safety and security**

Keywords— microstrip antenna, P and R shaped patch frequency 5.9GHz, Particle Swarm Optimization, IEEE 802.11p, V2V protocols.

I. INTRODUCTION

There has been a need to prevent accidents, according to a survey; one serious road accident in our country occur every minute and approximately 16 people die on Indian roads every hour. Around 1214 road accidents occur every day in India and nearly 20 children under the age of 14 die every day due to road crashes in the country causing nearly 377 people to die.

A Dedicated short-range based vehicle to vehicle communication protocol interfaced with a microstrip patch antenna can give a possible solution to avoid road accidents. In this communication, there is a set of protocols designed for vehicle communication to improve the efficiency of traffic flow and reduce traffic accidents. This communication method transmits data between vehicles thereby indicating if there is a possibility of collision or if the vehicle is in a blind spot.

DSRC is a wireless communication technology that is based on 802.11p which enables vehicles to communicate with other road users. Being an 802.11p-based wireless communication technology it enables highly secure, high-speed direct communication between vehicles and the surrounding without including other infrastructure. DSRC provides a base for V2V safety by enabling connectivity between road users and a common safety standard for vehicles. IEEE 802.11 slightly altered to IEEE 802.11p standard helps to support the applications of ITS i.e. Intelligent Transportation Systems.

Tools used for achieving the goals:

- CST: Used for designing the antenna.
- OMNETPP: This tool is a network simulator used for simulation of computer networks i.e. protocols.
- Veins: A VANET simulator used to interface mobility simulator and network simulator.

SUMO: It is a Mobility simulator which is a free, open source and continuous road traffic simulation, designed to handle large road networks.

II. MICROSTRIP PATCH ANTENNA

A. Microstrip patch

A microstrip patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. The microstrip patch antenna is designed that covers a huge portion of wireless systems such as Wi-Fi, Bluetooth, WLAN, etc.
This microstrip patch antenna is widely used as it is well suited for all frequencies especially the microwave satellite communication and wireless communication applications [5]. They can be comfortably used in polar and non-polar surfaces [2]. The major advantages of microstrip antenna are of light weight, low profile, capable of operating at multiple frequencies [1, 3] and inexpensive to fabricate the antenna. The microstrip patch antenna can be designed in various geometry and variations of the shape are helpful for the compactness of the patch antenna in its applications.
There are many techniques involved in which transmission line modelling is just not simple in technique its also in easy implementation.

B. Substrate Selection

The substrate is present between the patch and ground plane. There are four different substrate materials that are used in designing in microstrip antenna. The four materials are FR-4, RO-4003, Duroid 5880 and GML1000 each are having the dielectric constant values. The antenna performance is affected based on the substrate material chosen or indirectly depends on the dielectric constant. The lower dielectric constant values provide better bandwidth and the higher dielectric constant values provide better gain and directivity this was observed in [1].

C. Feeding Techniques

Microstrip patch antennas have various kinds of feeding techniques. There are four most famous and commonly feeding techniques used are the microstrip line, coaxial probe feed (contacting techniques), aperture coupling, and proximity coupling (non-contacting techniques), they are classified into two main categories:

(a) Contacting methods: The RF power is directly fed to the patch (radiating patch) using a connecting element such as a microstrip line, for such techniques it is called contacting methods. The contact feeding technique schemes are a microstrip line and coaxial probe feeding.

(b) Non – contacting methods: In non – contacting method, to transfer power between the microstrip line and the radiating patch electromagnetic field coupling is done. Proximity and aperture coupling are non – contacting methods.

III. Optimization Of Antenna

Optimization of the antenna becomes essential such that the designed antenna obtains very high parameters such as high gain, VSWR, and return losses without compromising the functionality of the antenna to radiate at the given operating frequency 5.9GHz [7]. There are many optimizing algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Finite Integration Technique (FIT) that can be used to achieve better performance and results of the antenna design.

Based on the theoretical calculations, satisfactory results are obtained. In order to achieve better results, Particle Swarm Optimization Technique is implemented. The particle swarm optimization algorithm is one of the EM optimization methods [5] that is integrated with many of the antenna tools such as HFSS, CST, etc.

A. Introduction To PSO

Particle Swarm Optimization is an intelligent optimization algorithm. It belongs to a class of optimization algorithm called metaheuristics. PSO is based on the paradigm of swarm intelligence and it is inspired by the social behaviour of animals like fish and birds. PSO is a simple but yet powerful optimization technique and it is successfully applied to enormous applications in various fields.

B. Flowchart of PSO

PSO is an iterative algorithm and population-based stochastic optimization method. Every particle is a candidate solution to the optimization problem. The average particle has a position in space search of the optimization problem. The search space is the set of all possible solutions to the optimization problem. The particles have certain values called fitness values, evaluated from the fitness function that has to be optimized [12].

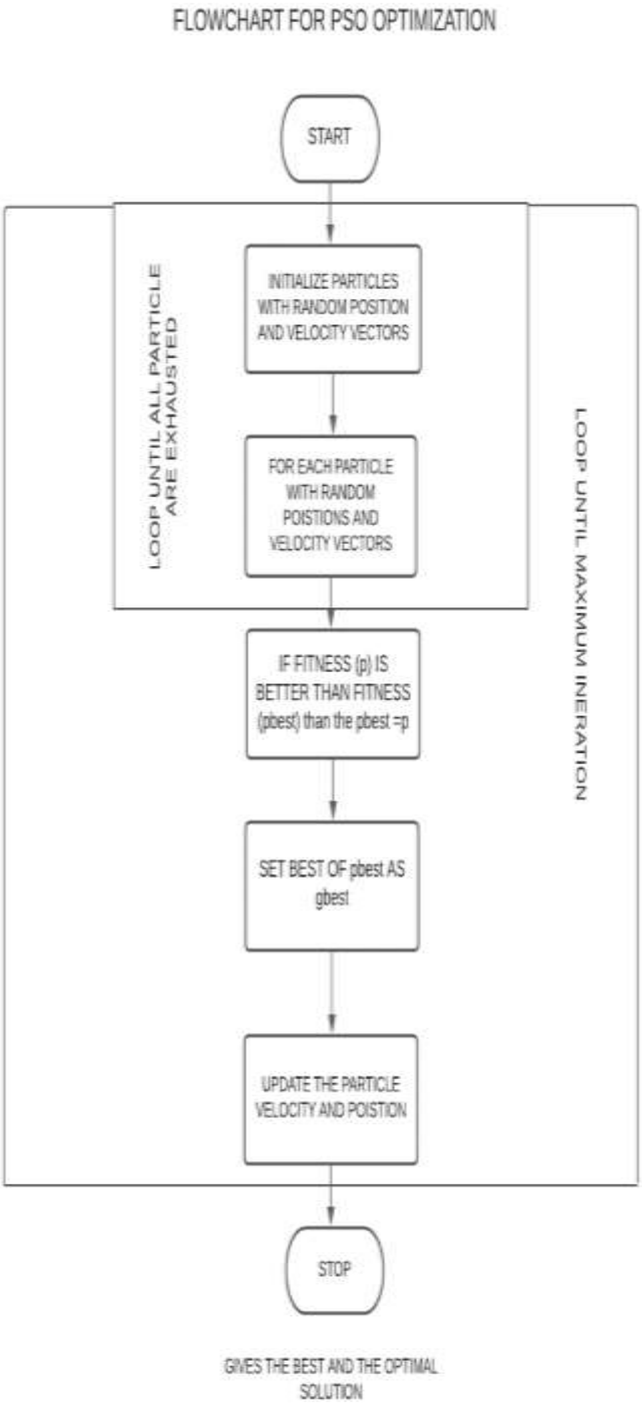

Fig. 1. Flowchart for PSO Optimization

Steps involved for Particle Swarm Optimization:

Step 1: Initialize each particle vector with a random position and random velocity.

Step 2: Calculate the cost for every single particle present.

Step 3: If the cost function found is less than the fitness value or the best value obtained so far then the position (pbest) is marked or remembered.

Step 4: If the fitness (p) is better than the fitness (pbest) then the value is pbest = p.

Step 5: Choose the particle with the lowest cost of all the particles. Then the position of these particles is considered as the (gbest-global best)

Step 6: Repeat the same by calculating for each and every particle, by updating the new position and velocity.

This process can be done for either maximizing or minimizing the problem statement based on the requirement. This is can be done for n- number of iterations to obtain the best fit results to the proposed problem.

IV. PROTOCOLS DESIGNING

The protocol designing consists of 3 different kinds of simulation namely,

a) Mobility Simulation: It consists of two types, i.e microscopic and macroscopic. In Microscopic the movement and vehicular behaviour of the individual car are important. Macroscopic mainly focuses on the flow mobility of cars, not on individual cars. Hence, this simulation is carried out in simulators like SUMO.
b) Network Simulation: Used for simulating VANETs by evaluating the performance of network protocols for the mobility of nodes and other required techniques. Developed for MANET and required VANET extension.
c) VANET Simulator (VEINs): A Vehicular ad-hoc Network (VANET) that efficiently combines both network simulator and traffic simulator such as SUMO. This mainly refers to the moving vehicles of a different kind and also to the connecting device that comes in contact over a wireless channel which helps in exchanging useful information between the two. This small network behaves as a node that acts as created at the same moment with other vehicles and the devices connected over the same network. The wide application of VANET is that it ensures safety at the blind crossing and avoids collisions. This kind of simulation is well suited for real traffic condition monitoring.

A. SUMO-Traffic Simulator

Simulation of Urban Mobility is a traffic simulator that is designed to handle large traffic in large networks. SUMO allows modelling of traffic systems including vehicles, public transport, and pedestrian. SUMO handles tasks such as virtualization, network import, route finding and emission calculation.

V. RELATED WORK

The microstrip patch antenna is extensively used for various narrowband communication at ultra-high and microwave frequency applications. This is used because of its low cost, easy fabrications and the major advantage of the microstrip patch antenna is that it can be designed for different shapes. Different substrate materials are having different dielectric constants for which they can be designed as per the requirements [1]. There are various methods for analysing the microstrip patch antenna, the transmission line model is predominantly used for many applications because of its simplicity and accuracy [3], and the design calculations are mentioned for designing the antenna. The P shaped patch slit antenna is designed and the results such as VSWR, Return Losses, Radiation pattern, and gain are obtained using a finite integration technique based on the CST simulation software [2]. The output performance can be improvised by optimizing the input parameters. There are many optimization techniques in which genetic algorithm and Particle Swarm Optimization or Discrete Particle Swarm Optimization [5, 12].

The major application of Dedicated Short-Range Communication is the vehicle-to-vehicle communications for which it can be designed using various protocols for rear-end collision avoidance applications which are capable of maintaining the high efficiency and reliability for the network conditions [4]. The vehicle-to-vehicle communication method is adopted as it is a new communication technique that was developed and was made more efficient for the traffic flow on roads and reduces traffic accidents. Due to lack of security concerns with the earlier implementation of protocols which is achieved in this paper [6] ensures the security by using the Dedicated Short Range Communication protocols.

The paper proposes a decentralized architecture allowing in creating, maintaining, and dissolving heterogeneous platoons including necessary platoon maneuvers and the corresponding message flow. Inter-vehicle distances are determined individually by each vehicle accounting for changing environment and vehicles' properties. This architecture evaluates the highway entry and an emergency brake scenario implemented in Omnet++: Showing a dynamic and individual adaptation of the inter-vehicle distance it allows targeting specific traffic scenarios and guarantees safety even in lossy communication networks. The realization of the dynamic distance is performed using smooth trajectory planning [10, 11].

VI. METHODOLOGY

The antenna designing is divided into 3 stages; the initial stage begins with the construction of the ground and substrate plane with the respective calculated theoretical value that is calculated in the table below. The second stage is designing the patch with various geometry like rectangle, ellipse, and triangle. The patch design consists of alphabets P& R, which is constructed using a semi ellipse, rectangle and right-angled triangle. The final stage is adding feed and port to the design as mentioned in the table-01 below.

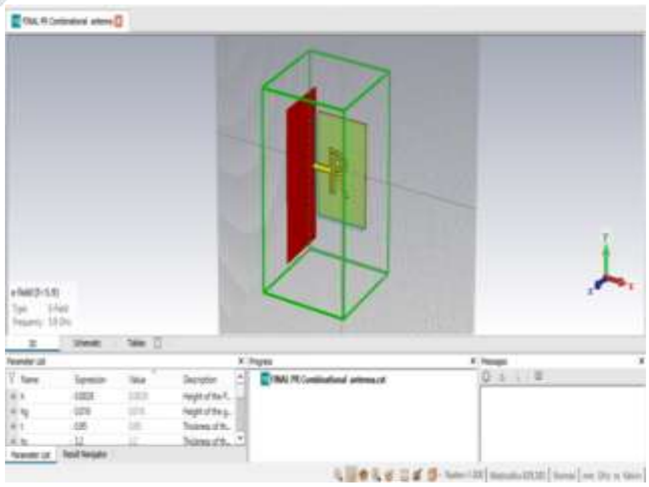

Fig. 2. Side View of the proposed antenna

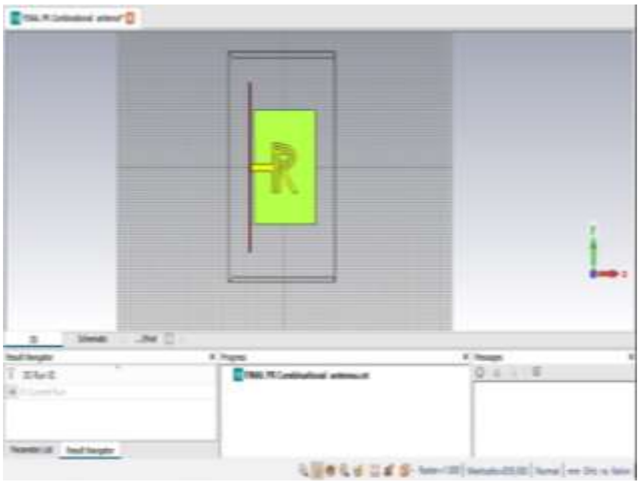

Fig. 3. Front View of the proposed antenna

The P R shape microstrip antenna is designed using the FR-4 as the substrate material using the CST simulation tool. The first step for designing any antenna is done by building the ground plane with the given theoretical values. Then it is further designed by constructing the substrate on the ground plane over a certain height, the substrate dielectric material is FR-4. The dimensions of the substrate and the ground plane are the same except the height. The microstrip consists of a very thin metal placed on a ground plane with a dielectric material present in-between. The design is carried out further by etching the patch which is made of copper material. The design can be conveniently figures shaped as per the purposed design based on the geometrical structures such as right-angled triangle and ellipse as seen in Fig. 2 and Fig. 3. The antenna feed is a location on the antenna where the transmission line connects the transmitter or receiver. For the purposed design offset feed or transmission line is used to feed the antenna to transfer power efficiently to the antenna. This must be done at a particular point (feed) where the impedance of the antenna matches with the transmitter. After designing the antenna with the empirical values obtained from the antenna designed calculations mentioned below in the section VII.

The output parameters such as gain, VSWR, radiation efficiency and return losses are obtained after simulating the proposed antenna design. The results are evaluated based on the performance and the output obtained. The antenna is optimized using particle swarm optimization technique to improve the results of the parameters which is seen in the results and table-02 mentioned below.

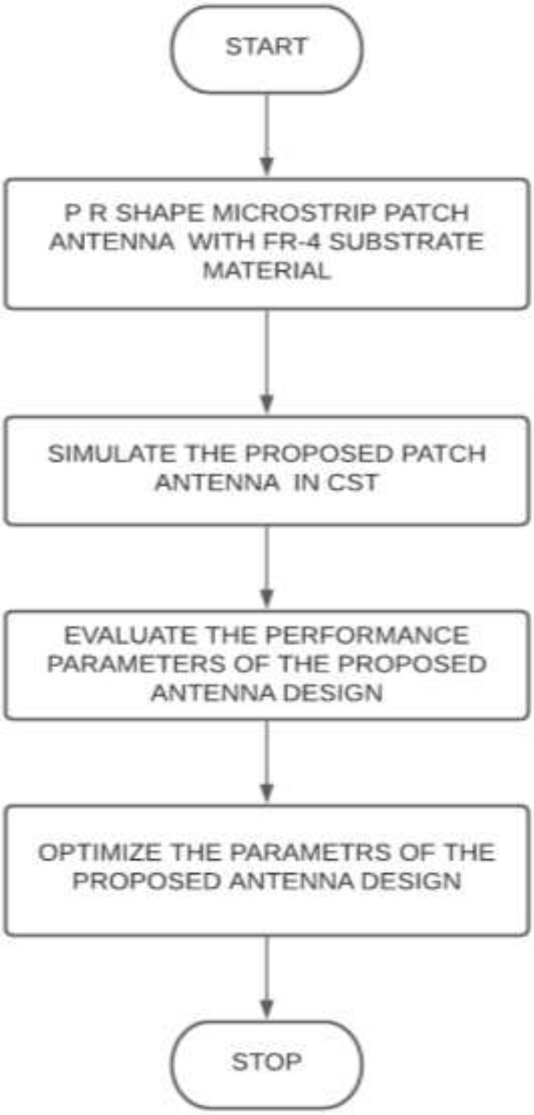

Fig. 4. Process flow of antenna design

VII. ANTENNA CALCULATION

The antenna design is done based on rectangular calculations and other geometry calculations.

A. *Basic Calculations for Rectangular Patch:*

i. Calculations of Width (w):

$$W_p = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$$

ii. Calculation of Effective dielectric constant (εeff):

$$\varepsilon_{eff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\left[\frac{1}{\sqrt{1+12\frac{h}{w}}}\right]$$

iii. Calculation of effective length (Leff):

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

iv. Calculation of the length extensions or fringing length (*ΔL):*

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0258)(\frac{w}{h}+0.8)}$$

v. Calculation of the actual length of the patch (L):

$$Lp = Leff\ - 2\,\Delta L$$

B. Ground and Substrate Calculation

The ground plane is a flat plate, the shape and size of the ground will affect the impedance matching and the performance of the antenna design. The dimensions of the substrate and ground plane are same except the height of the substrate and ground. The design calculation of ground and substrate is mentioned below.

i. The Length of the Ground and substrate:

$$L = L_s = L_g = 6 * h + L_p$$

ii. The Width of the Ground and substrate:

$$W = W_s = W_g = 6 * h + W_p$$

TABLE I. ANTENNA PARAMETERS

PARAMTER DESCRIPTION	PARAMTERS	UNOPTIMIZED PARAMETER VALUES (mm)	OPTIMZED PARAMETER VALUES (mm)
Length of the Ground	L	29.79	27.1089
Width of the Ground	W	34.67	35.9412
Height of the Ground	Hg	0.0016	0.0016
Width of the substrate	W	34.67	35.9412
Length of the substrate	L	29.79	27.1089
Height of the substrate	h_s	0.016	0.016
Width of the patch	W_p	15.47	15.6247
Length of the patch	L_p	10.59	9.9193
Height of the patch	H	3.2	3.2
Length extensions	ΔL	0.873	0.873
Effective di-electric constant	ε_{eff}	3.7	3.7
Semi-major axis of ellipse	R_x	7.0	7.3033
Semi-minor axis of ellipse	R_y	4.5	4.245
Thickness of the patch	T	0.95	0.95
Width of the feed	W_f	2	2

VIII. RESULTS

A. Antenna Results

The table II below explains about the results obtained before and after the optimization and the performance is analysed using the CST Simulating software at the operating frequency of 5.9GHz.

PARAMETERS	DIRECTIVITY	VSWR	RADIATION EFFICIENCY	RETURN LOSSES
UNOPTIMIZED PARAMTERS	6.93dB	2.493dB	-9.840 dB	-1.5487dB
OPTIMZED PARAMETERS	6.93dB	11.247dB	-9.840 dB	-9.077dB

TABLE II. OUTPUT RESULTS

B. Return loss

The return losses are the loss of power in the signal returned by the discontinuities in the transmission line. The higher return losses mean more power is transmitted or sent to the antenna. The S – parameter obtained is -1.5487dB at 5.9 GHz and after optimization -9.0776 dB 5.9 GHz that are seen in the Fig. 5 and Fig. 6.

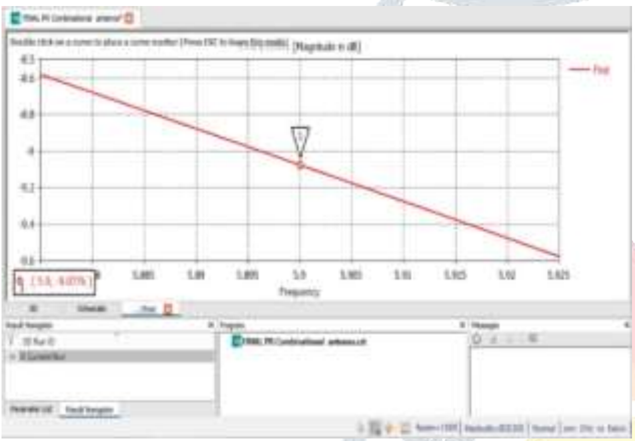

Fig. 5. Return losses before optimization

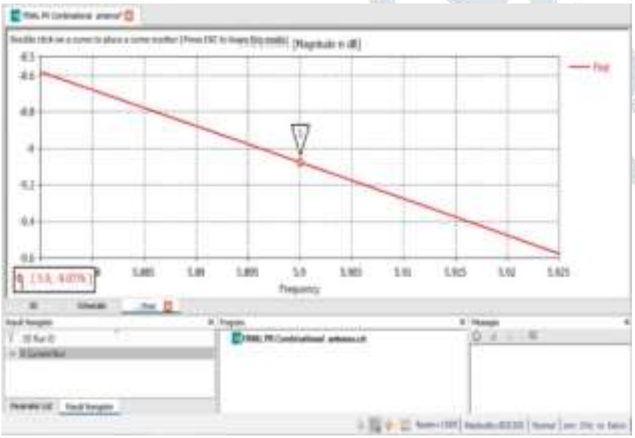

Fig. 6. Return losses after optimization0

C. VSWR

VSWR estimates the impedance matching of the loads with the characteristic impedance which is regarded as Zo of an uniform transmission line or waveguide (such that the wave travels in one direction in the absence of reflections in the other direction). The VSWR also represents the efficiency of the RF power transferred to the load via a transmission line from the power source [2]. The VSWR obtained at 5.9GHZ is 2.493 dBi and after optimization 11.247 dBi as shown in Fig. 7 and Fig. 8.

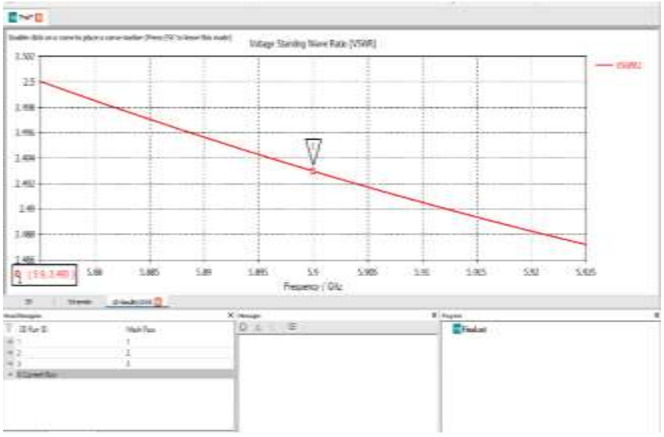

Fig. 7. VSWR values obtained before optimization

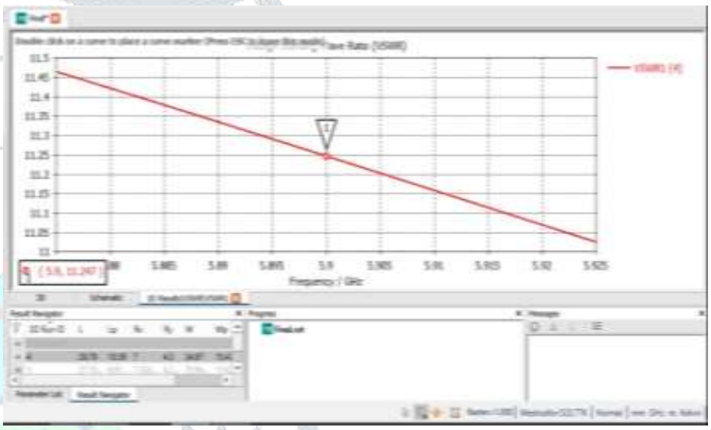

Fig. 8. VSWR values obtained after PSO

D. Efficiency

Total efficiency =-10.72 dB including all the internal losses and the Radiation efficiency obtained from the proposed design is - 9.840 dB. Efficiency is the ratio of the radiated power to the power supplied from the transmission lines. The Fig 8 and Fig 9 shows the efficiency in 1D and 2D results.

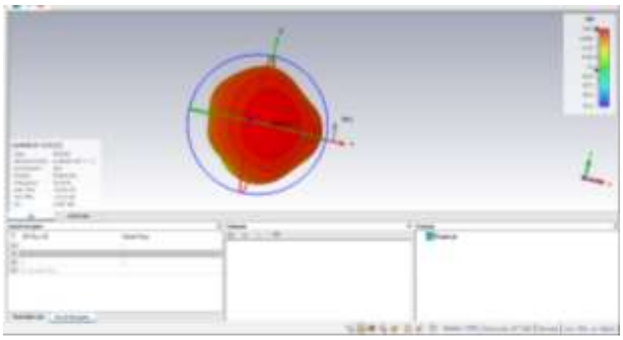

Fig. 9. 2D/3D far fields results of efficiency

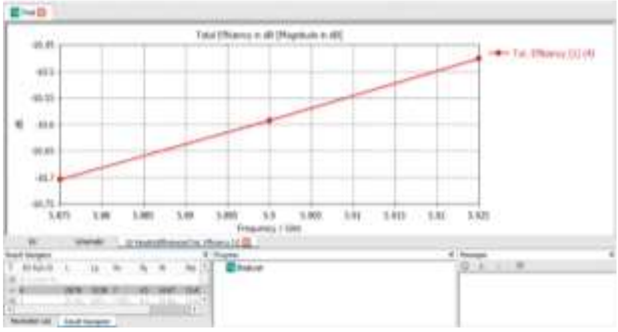

Fig. 10. 1-D far fields results of the Efficiency

E. Directivity

Directivity tells about how directional the antenna. The directivity: main lobe magnitude is 6.93dbi is obtained after optimization at (theta=0) as seen in the Fig. 11.

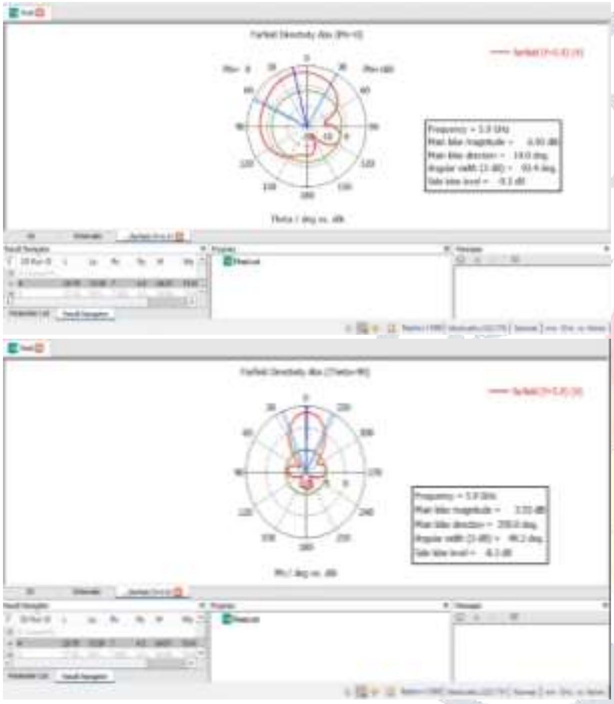

Fig. 11. Directivity of the proposed antenna design at different orientations

F. Protocols Outputs

i. Veins

AODV is regarded as a loop-free routing protocol designed to be self-starting in an environment of mobile nodes. AODV also called Ad-hoc On-demand Distance Vector maintains a routing table at each node. This contains three essential fields that is a next-hop node, a sequence number and a hop count. Destined to the destination all the packets are sent to the next-hop node. The sequence number behaves as a time-stamping and measures the freshness of a route. The current distance to the destination node is defined by the hop count. An AODV network is a pre-step required for creating a VANET network. This network output at different hosts are obtained in Fig. 12.

Fig. 12. Veins Output

ii. RSU

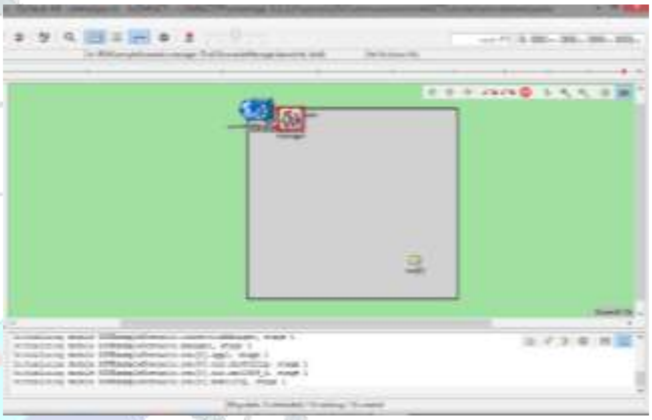

Fig. 13. Road side unit

RSU i.e. Road Side Units are used to ensure continuous data flow and connectivity between vehicles and for communication with other RSUs and is located aside the roads. RSUs are a gateway between on board units and the infrastructure. A special wireless communicating device present along the side of the roads helps in providing connectivity and information to passing vehicles, mainly the information related to the safety warnings and traffic which is observed in Fig. 13.

iii. SUMO

Here a scenario from sumo where a study area is considered and the V2V protocols are tested and in the tabular column the list of parameters like no. of vehicles, collision avoided, etc are shown in Fig. 14.

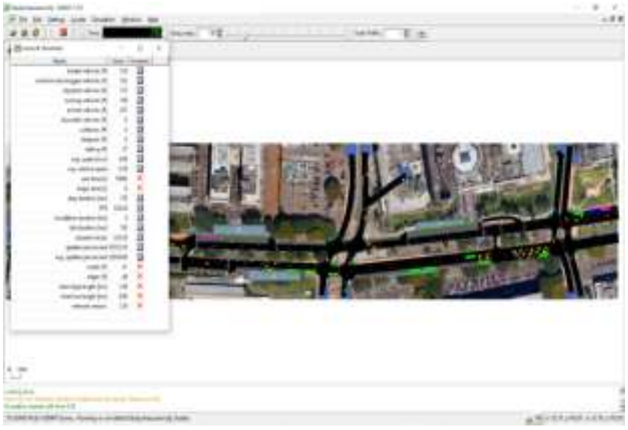

Fig. 14. SUMO Output

CONCLUSION AND FUTURE ENHANCEMENT

The goal of the project is to design and achieve the customized P and R shaped combinational patch antenna by using transmission line method. By obtaining the results with high gain, increased directivity, and other parameters. The V2V protocols are designed by using VANET for the application of dedicated short-range communication. In future this can be implemented by mapping the protocols to the antenna design and model it to operate on real-time application.

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REFERENCES

[1] M.Meena and P. Kannan "Analysis of microstrip patch antenna for four different shapes and substrates" April 2018-ICTACT Journal on microelectronics,

DOI: 10.21917/ijme.2018.0092

[2] Md. Jubaer Alam, Mohammad Rashed Iqbal Faruque, Md. Moinul Islam "Design of a split P-shaped multi bands microstrip patch antenna for moderns communication systems" 2016 IEEE international conference on computer and Information technology,

DOI: 10.1109/ICCITECHN

[3] Victor Benard, John Paul Izuchukwu Iloh "Microstrip Antenna Design Using Transmission Line Model", International Journal of Emerging Technology and Advanced Engineering,

ISSN 2250-2459, ISO 9001:2008

[4] Rajesh Hooda,Tripatjot Singh Panag,Dr Hardeep Singh Ryait "Design and Simulation of MIMO Elliptical Shaped Microstrip Patch Antenna at 5GHz frequency for Wi-Fi Network"- IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)

ISSN: 2278-2834, p- ISSN: 2278-8735.Volume 9, Issue 4, Ver. II

[5] Swarnaprava Sahoo, Laxmi Prasad Mishra, Mihir Narayan Mohanty "Optimization of Z-Shape Microstrip Antenna with I- slot Using Discrete Particle Swarm Optimization (DPSO) Algorithm" 2nd International Conference on Intelligent Computing, Communication & Convergence.

DOI: 10.1016/J.PROCS.2016.07.328

[6] A. Rajput, M. Kushwah and J. Dodiya, "Microstrip antenna design using transmission line model in hexagonal shape with probe feed," *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*.

DOI: 10.1109/ICEEOT.2016.7755475.

[7] V. Renuga Kanni and R. Brinda "Design of high Gain Microstrip Antenna for vehicle to vehicle communication using Genetic Algorithm" *Progress In Electromagnetics Research M,* Vol. 81, 2019.

[8] Maziar Nekovee "Quantifying Performance Requirements of Vehicle to Vehicle Communication Protocols for Rear- End Collision Avoidance" VTC Spring 2009 - IEEE 69th Vehicular Technology Conference.

DOI:10.1109/VETECS.2009.5073822

[9] H.Noori, B.Badihi Olyaei "A Novel Study on Beaconing for VANET-based Vehicle to Vehicle Communication"-2013 International Conference on Smart Communications in Network Technologies (SaCoNeT).

DOI:10.1109/SaCoNeT.2013.6654589

[10] Yu. A. Vershinin,, Yao Zhan "Vehicle to Vehicle Communication: Dedicated Short-Range Communication and Safety Awareness" 2020 Systems of signals of Generating and Processing in the Field of on board Communication.

DOI:10.1109/IEEECONF48371.2020.9078660

[11] Tobias Renzler, Michael Stolz, Daniel Watzenig "Decentralized Dynamic Platooning Architecture with V2V Communication Tested in Omnet++"-2019 *IEEE International Conference on Connected Vehicles and Expo (ICCVE)*

DOI:10.1109/ICCVE45908.2019.8965224

[12] Rajesh Bera and J. S. Roy "Thinning of Elliptical and Concentric Elliptical Antenna Arrays Using Particle Swarm Optimization"- 2013