Progress In Electromagnetics Research M, Vol. 81, 167–179, 2019

Design of High Gain Microstrip Antenna for Vehicle to Vehicle Communication Using Genetic Algorithm

V. Renuga Kanni* and R. Brinda

Abstract—A novel, simple, and inexpensive microstrip antenna is designed for vehicle to vehicle communication and specifically for blind spot detection in this work. The proposed antenna is $20.2\,\mathrm{mm} \times 24.1\,\mathrm{mm} \times 1.6\,\mathrm{mm}$ in size. Since offset feeding technique is used, manufacturing is simple and cheap. ANSYS Electromagnetics Suite 17.2 simulates the antenna. To suppress the losses, Defected Ground Structure is employed. In addition, the Genetic Algorithm is used to optimize the ground plane width to obtain high gain and omnidirectional characteristics. The simulated results conceive that the 'Dedicated Short Range Communication' (DSRC) band is covered by using the antenna. Moreover, the antenna is fabricated, and the measured results are found to be consistent with the simulated ones.

1. INTRODUCTION

Recently, vehicular communication has become a hot topic among the people, and a number of antennas are designed by researchers. IEEE 802.11y band (5.85 GHz $\sim$ 5.925 GHz) is used for vehicular communication systems [4]. Vehicular communication is a wireless technology that enables vehicles to interact with each other and share information about some road issues. The proposed antenna is specifically designed for detecting vehicles in the blind spot zone. Blind spot is an area that cannot be viewed directly when sitting on the driver's seat [2].

In [1], the feature of IEEE Standard 802.11p is explained. IEEE modified the IEEE 802.11 standard with IEEE 802.11p, the frequency band of 5.85–5.925 GHz in 2010. This frequency range particularly includes Wireless Access in Vehicular Environments (WAVE) and Dedicated Short Range Communications (DSRC) bands. The above mentioned bands can be used for vehicle to vehicle communication (V2V) and vehicle to infrastructure (V2I) communication. In [2], a hexagonal microstrip antenna is designed, and a fern fractal is incorporated. The slots and fractal nature here shift the antenna to operate at a lower resonant frequency. It also minimizes the antenna's size. The antenna resonates at 3.675 GHz with a gain greater than 5.16 dB and a 410 MHz impedance bandwidth. In [3], the antenna is intended to operate in vehicular communication band. The wheel-shaped fractal structure makes its appearance and functionality attractive. The antenna is made of both FR4 material and PVC material. When the antenna is designed using FR4, the obtained gain is 4.78 dB, and when it is designed with PVC material, the antenna gain is found to be 5.9 dB. In [4], the authors propose a hexagonal patch antenna for vehicle to vehicle communication. At first, the antenna design begins with a center-fed normal hexagon patch antenna. At that point, six shorting pins and two sets of V-shape slots with distinct size are carved on the normal hexagon patch. As a result, the pattern of antenna radiation in the H-plane is found omnidirectional, and a good matching impedance is also obtained. The maximum gain is conceived as 4.2 dB. For DSRC applications, a low-profile microstrip patch antenna with vertical polarization and an increased gain over 3 dB is proposed in [5]. Together with the center fed circular patch antenna, gain enhancing element is used to enhance gain in the horizontal plane. The peak gain

Received 5 April 2019, Accepted 22 May 2019, Scheduled 12 June 2019
* Corresponding author: V. Renuga Kanni (renugakanni.v@gmail.com).
The authors are with the Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi, India.

is found to be 4.71 dB when the antenna is manufactured on a common FR4 substrate, and it is found to cover the whole DSRC band. In [6], an integrated low-profile microstrip antenna is proposed for GPS and DSRC applications. It is designed based on the concept of dual-layer dual-patch antenna. A corner cut square microstrip antenna constitutes the lower patch, and a set of concentric arc slots surrounding the circular slot constitutes the upper patch. The lower patch resonates at 1.575 GHz GPS L1 frequency with circular polarization, and the upper patch resonates at 5.88 GHz with vertical linear polarization. It possesses a 5 dB gain at 5.9 GHz. Genetic Algorithm is used in [7] to reduce the size and enhance the antenna gain. In the mating pool, uniform crossover and polynomial mutation are performed to select the best survivor. As a result, the size is reduced to about 82 percent, achieving a peak gain around 5.82 dB. Various designs for microstrip antenna loss reduction are proposed in [8]. Multi-layered patches are used to improve antenna directivity, and hexagonal patches are used to reduce the antenna's return loss and mutual coupling. In microstrip patch antenna arrays, Double Negative Substrate is used to reduce mutual coupling, and Defected Ground Structure is used to decrease mutual coupling in patch antenna. In [9], Rahanandeh et al. design a planar UWB slot antenna fed with a fork-shaped transmission line. By adding three elliptical stubs in the ground plane, the antenna is made to operate in multiband (Bluetooth, WiMax, WLAN and ITU). It is found to possess omnidirectional characteristics and a constant gain in the passbands. In [10], Chaudhari designs a single-layer single-patch microstrip patch antenna, by inserting a pair of wide slots on the radiating edges of the patch. The antenna design is composed of an air substrate. It is concluded that by inserting a pair of wide slots with a space limit between them on the patch, good impedance matching over a wide bandwidth can be achieved. In [11], Li et al. propose two designs of planar elliptical slot antennas. These antennas are made to operate in the UWB range by using tapered microstrip or CPW feeding with a U-shaped tuning stub. They infer that the slot dimension, the distance between them, and the slant angle are the important parameters in the design point of view, which are responsible for determining the antenna performance. It is found that this antenna has omnidirectional radiation characteristics over most of the bandwidth. In [12], Naik et al. design a single rectangular patch antenna and its performance in terms of gain, directivity, efficiency and bandwidth, by forming 2×1, 4×1, and 8×1 arrays, respectively. It is found that the gain, directivity, and return loss improve as the number of elements in the array increases. However, radiation efficiency and antenna efficiency remain almost the same. Nguyen et al. in [13] design a square microstrip patch antenna and study the effects of its ground plane size on the antenna parameters (gain, return loss, half power beamwidth, and radiation pattern). They conclude that the gain and HPBW are the function of ground plane size and are out of phase with each other. They also found that the radiation pattern is a function of gain, and the height of the antenna affects the critical ground plane size for impedance matching which in turn, affects the radiation pattern. In [14], the authors propose a novel miniature folded square patch antenna for GPS application. They start the antenna design by using two layers of FR4 substrate. The slotted square patch is etched on layer1 and connected to layer2 by four via holes at the four edges of the square patch. The same FR4 substrate but without copper layers is attached to the bottom of the first FR4 substrate (Ground). As a result, they infer that the fluctuation of 'R' (radius of the hole) does not affect the return loss at the two resonating frequencies. When 'R' changes from 14 to 50 mm, the center frequency decreases, and when 'R' is greater than 50 mm, the center frequency is only slightly affected. In [15], the author describes the architecture and functional aspects of the DSRC protocol. The DSRC technology is proposed for standardization in Europe (CEC TC 278) and ENV standards. The DSRC protocol for vehicle to beacon communication is defined as a light-weight OSI communication stack. It reduces protocol overhead and meets timing constraints. Different DSRC protocol layers are introduced by paying attention to the application layer. The results show that the standards are well designed, free of server errors, and capable of fulfilling the requirements of different RTTT applications. In [16], the author proposes the requirements of ideal antenna placements. It summarizes that the antenna for vehicular communication should be capable of receiving from all directions around the vehicle. It should be well above the ground surface and should be at a shortest distance to the receiver. The author also concludes that the antenna should be away from the engine, to avoid its spurious noise effects. In [17], Kaul et al. present results from a study examining the effects of antenna diversity and placement of V2V link performance in vehicular and ad hoc networks. The experiments use roof and in-vehicle mounted omnidirectional antennas and IEEE 802.11a radios operating in the 5 GHz band. The experiments show that the radio reception performance is sensitive to antenna placement in 5 GHz band. It also shows that the antenna gain patterns of omnidirectional antennas become asymmetric in many mounting positions, and to create good omnidirectional characteristics, the antenna should be mounted in the center of the vehicle.

The proposed antenna is designed in such a way that it covers the DSRC band with reduced size, high gain, omnidirectional characteristics, and a good impedance matching by using Genetic Algorithm.

2. ANTENNA DESIGN

2.1. Materials and Methods

The mechanical support for the antenna is provided only by the substrate. Hence, it should consist of dielectric materials such as FR4, Rogers, and RT-Duroid. In this proposed antenna, FR-4 material is chosen as a substrate material considering the economical purpose. Offset feed is employed as the feeding technique to excite the patch. ANSYS Electromagnetic suite 17.2 is used to analyze the geometry and obtain the characteristics of the antenna.

2.2. Mathematical Formulation

The proposed antenna is designed with the following Equations (1)–(4):

The width of the micro strip patch is explained by,

$$W = \frac{c}{2f_o\sqrt{\varepsilon_r + 1/2}} \tag{1}$$

The effective dielectric constant is explained by,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \tag{2}$$

where ε_r = Dielectric constant; h = Height are substrate parameters; W = Width is the patch parameter.

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \tag{3}$$

The length of the feed line is explained by,

$$L_f = \frac{\lambda}{\sqrt{\varepsilon_{reff}}} \tag{4}$$

The structural parameters of the proposed antenna are mentioned in Table 1.

Table 1. Structural parameters of the proposed antenna.

Parameters	L_s	W_s	W_g	L	W	L_f	W_f
Dimension in mm	20.283	24.136	23.8367	10.6	16.572	2	6

2.3. Structure and Design

The substrate, patch, and ground plane of the antenna are designed as per the dimensions mentioned in Table 1. The proposed antenna design can be explained in three stages. Initial stage begins with the design of a microstrip patch antenna to resonate at 5.9 GHz. However, it possesses poor return loss, due to the imperfect impedance matching of antenna impedance to 50 ohms. Hence slots have been introduced to match the antenna impedance to 50 ohms. A circular ring slot of radius 0.5 mm is embedded at the center of the patch, and surrounding it, concentric semicircular ring slots of radius 0.5 mm are embedded at the four sides of the radiating element (Figure 1). The presence of the circular ring slot increases the length of electrical current. This increase in the electrical current length changes

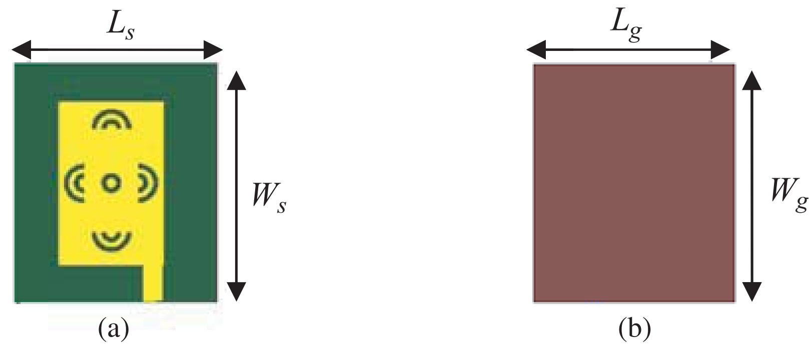


Figure 1. Geometry of the proposed antenna in initial stage. (a) Front view. (b) Back view.

the current distribution and hence changes the resonant frequency. The circular ring slot produces surface magnetic current distribution, and the concentric semicircular ring slots are responsible for making this current distribution uniform which in turn enhances the parameters in the azimuthal plane. The proposed antenna is excited with a microstrip line feed with the dimension $L_g \times W_g$ since it is simple to model and provides easy fabrication.

2.4. Defective Ground Structures

Even though the proposed antenna at the initial stage resonates at 5.9 GHz, in order to improve other parameters such as gain, return loss, and Voltage Standing Wave Ratio (VSWR), Defected Ground Structure (DGS) has been introduced. The ground plane confines the waves which influences the directivity of the antenna. Partial ground plane reduces the directivity. In other words, a partial ground plane tends to spread the radiation around the antenna, rather than concentrating it in a particular direction. DGS is nothing but embedding a single or a number of periodic or a-periodic slots in the ground plane. The slot is put specifically under the transmission line, and it is adjusted for efficient coupling to the line. The slot in the ground plane alters the current distribution of the transmission line, and this disturbance changes the effective capacitance, inductance, and resistance of the transmission line by including the slot resistance, capacitance, and inductance which change the overall characteristics of the antenna. A parallel tuned circuit, coupled with a transmission line in series, can represent the equivalent circuit of DGS. In the proposed antenna, an arrow-shaped slot of length 1 mm is introduced on the ground plane (Figure 2). Slots in the ground plane can be viewed as a magnetic dipole. This introduced slot acts as a load, and the input impedance of the antenna approaches the characteristic impedance and thus, results in less losses. This gives rise to the improvement in the return loss, gain, and VSWR of the antenna. The change in the radiation pattern is due to the diffraction that occurs at the edges of the ground plane. In addition, the component weight and size of the antenna are also

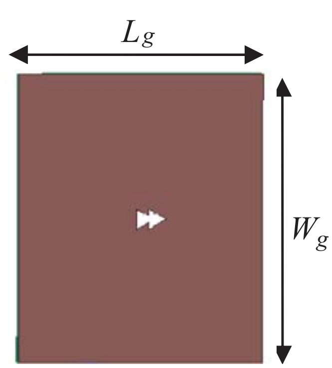


Figure 2. Geometry of the DGS.

conceived to be reduced. The gain and VSWR are found to increase due to the arrow slot. Since the ground plane has a greater effect on the antenna parameters, parametric analysis is performed to view the change in the resonant frequency due to the change in the ground plane dimension. Figure 11 shows the result of the parametric analysis with respect to the ground plane.

2.5. Genetic Algorithm Optimization

Since the parameters of the antenna change with the change in the ground plane dimension, it is very important to choose an optimized ground plane width such that the antenna possesses a high gain, VSWR, and return loss at 5.9 GHz without sacrificing the omnidirectionality. To obtain a prominent change in the antenna parameters, the dimension along the radiating edge of the patch should not be altered. Since the radiating edge of the proposed antenna is along the length, the width of the ground plane is altered to get better results. Thus, optimization parameter is chosen as the ground plane width (W_g). Many optimization techniques such as Genetic Algorithm, ACO, and Pattern Search Algorithm are available. Among them, genetic algorithm has been chosen for optimizing since it does not require any derivative function for optimization, and it also has parallel processing capabilities. Compared with the conventional strategies, it is speedier and more proficient. Figure 3 depicts the genetic algorithm.

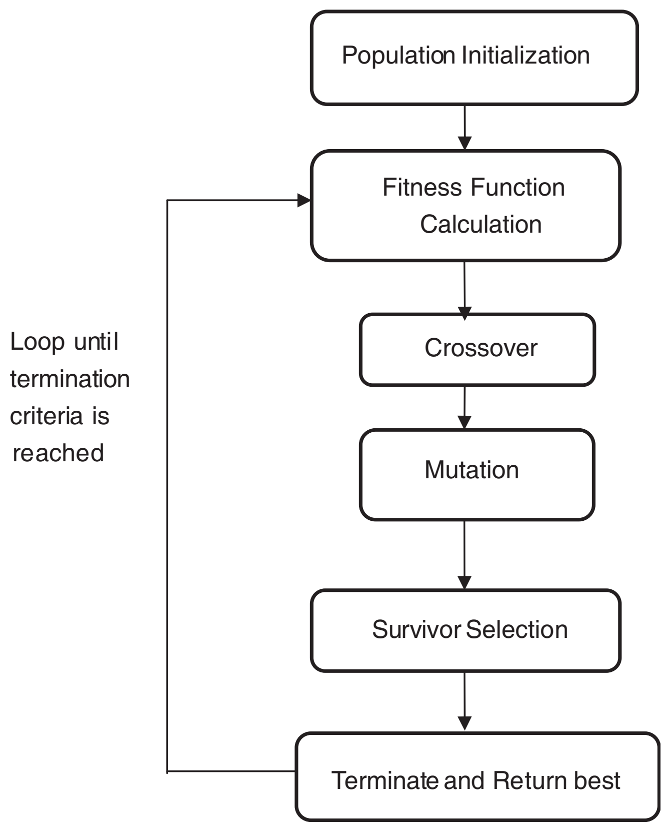


Figure 3. Flow diagram of genetic algorithm.

In this work, the initial population is taken to be 50. Next, a fitness function is calculated based on Equation (5), to determine how fit the individuals are. In the proposed work, gain is set as the goal.

$$F_G = \sum_{i=1}^{N} G(f_i, \theta_o) - G_o \tag{5}$$

where $G(f_i, \theta_o)$ = Antenna gain at frequency f_i at an elevation angle θ_o, and G_o = Desired goal.

Here, to pull the population towards the goal and to avoid premature convergence, "Simulated Binary Crossover" (SBC) and "Polynomial Mutation" are performed respectively in the mating pool. 'Roulette Wheel Selection" is employed to propagate the fittest individual to the next generation. If the desired goal is reached, the process is terminated, and the current best value is returned. Else, the loop is repeated until the specified criteria is reached.

Since the ground plane plays a major role in determining the gain and radiation characteristics, the ground plane width (W_g) is optimized in this work to get the optimal gain. After 50 iterations, the solution is found to converge, and the specified criteria are reached at $W_g = 23.8367$ mm. Figure 4 shows the defected ground structure of the optimized width (W_g).

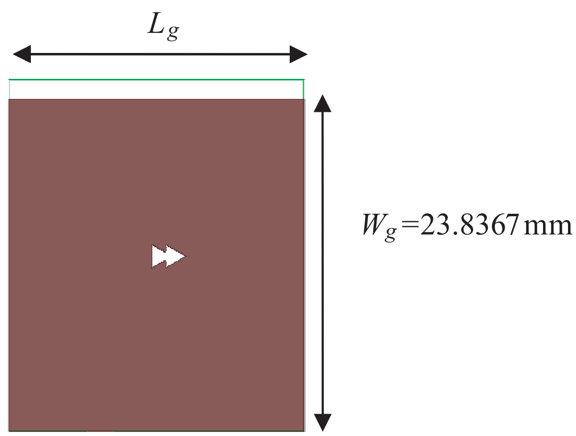


Figure 4. Defected ground structure of the optimized width W_g.

3. RESULTS AND DISCUSSIONS

3.1. Simulated Results

To study the performance characteristics of the proposed antenna before DGS, after DGS, and after optimization, the simulated results are obtained for the reflection coefficient, gain, VSWR, impedance matching, surface current distribution, and the radiation pattern. At the initial stage with only circular and semi-circular ring slots, the antenna is found to resonate at a frequency of 5.9 GHz with a return loss of −39.05 dB (Figure 5), gain of 4.73 dB (Figure 6), and VSWR of 1.0225 (Figure 7). At this stage, the antenna is found to have a better impedance matching with $47.91 - 0.43j\Omega$ (Figure 8). In Figure 8,

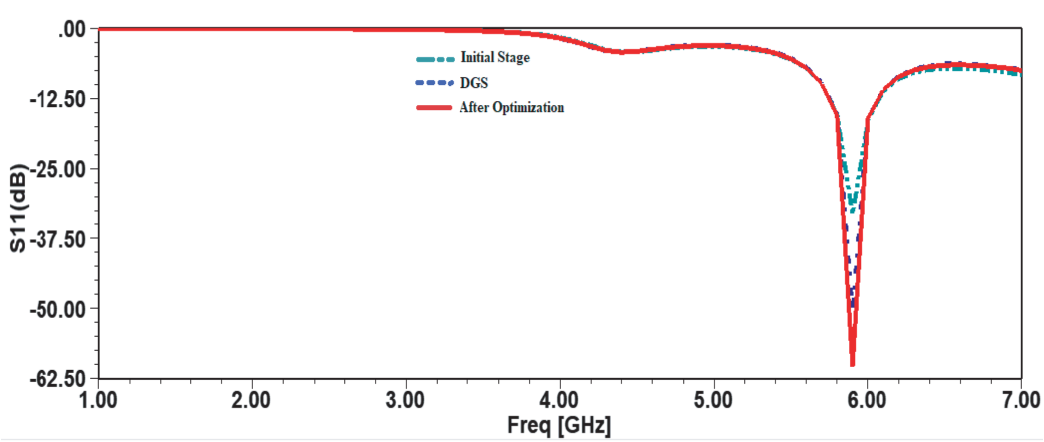


Figure 5. Return loss versus frequency curve.

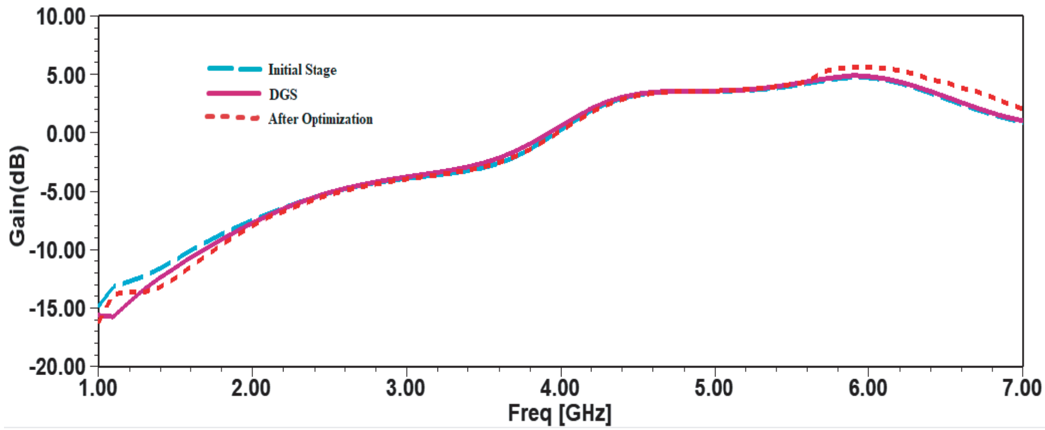


Figure 6. Gain versus frequency curve.

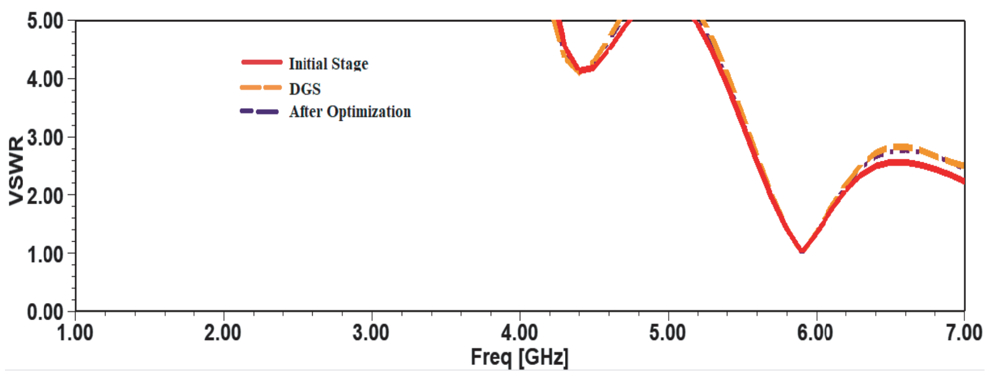
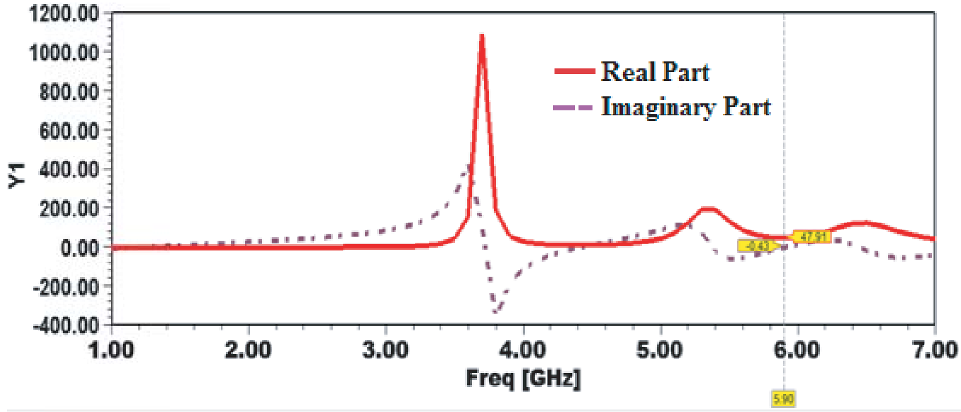


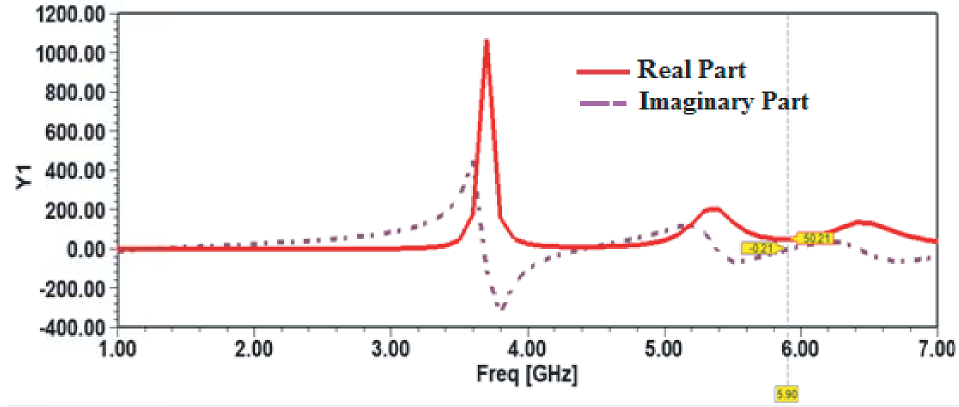
Figure 7. Voltage standing wave ratio versus frequency curve.

Y-axis represents the impedance and reactance of the proposed antenna. A strong current distribution is also observed (Figure 9). Even though the antenna resonates within the vehicular communication band, the gain and VSWR are found to be low. Hence, to improve these parameters and achieve perfect omnidirectionality, DGS is employed. The simulated radiation pattern of the proposed antenna at the initial stage, after DGS and after optimization is shown in Figure 10. After employing DGS, the change in the current distribution changes the antenna parameters. The return loss is improved from -39.05 dB to -50.63 dB (Figure 5). The gain is found in uptrend to 4.88 dB (Figure 6), and VSWR is improved to 1.0059 (Figure 7). An improvement in the impedance matching is also observed (Figure 8). The surface current distribution is also found to improve since the slot in the ground plane increases the electrical path length. Figure 9 shows the current distribution of all the three stages. The directivity is increased which results in the distortion of the omnidirectional pattern (Figure 10). Since the ground plane has a great effect on the antenna parameters, a parametric analysis is done to view the shift in the frequency. Result of parametric analysis of ground plane width is shown in Figure 11.

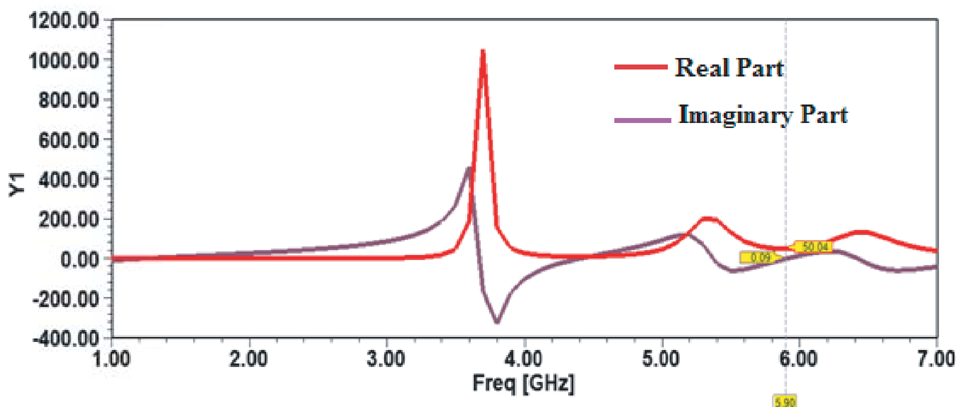
It is very important for an antenna to possess all the required characteristics at the resonant frequency. In order to achieve still higher gain and to bring back the omnidirectional characteristics, the ground plane width is optimized using genetic algorithm. After optimization, 23.8367 mm is found to be the optimum ground plane width with a resonant frequency of 5.9 GHz (Figure 13). Also parameters such as return loss, gain, and VSWR are found to still increase at 5.9 GHz. The return loss of the proposed antenna is conceived as -60.3 dB (Figure 5), the gain found to be 5.6 dB (Figure 6), and the VSWR found to be 1.0019 (Figure 8). The impedance matching is improved more to $57.04 + 0.09j\,\Omega$ (Figure 8). The omnidirectionality of the antenna is also recovered. Thus, from VSWR, which is nearly equal to 1, and impedance matching curve, which is nearly equal to $50 + 0j\,\Omega$, it can be said that this



(a)



(b)



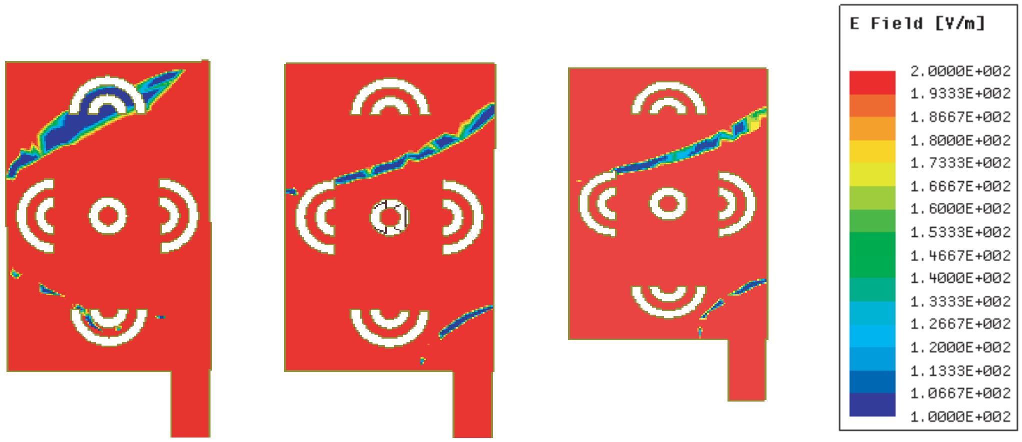
(c)

Figure 8. Impedance matching curve. (a) Initial stage. (b) DGS. (c) After optimization.

antenna is perfectly matched with the transmission line. The simulated results of all the three stages of the proposed antenna are compared in Table 2. From this table, it can be inferred that the proposed antenna after optimization satisfies the requirements for Vehicle to Vehicle Communication, and its performance is also improved compared with the other two stages of the proposed antenna.

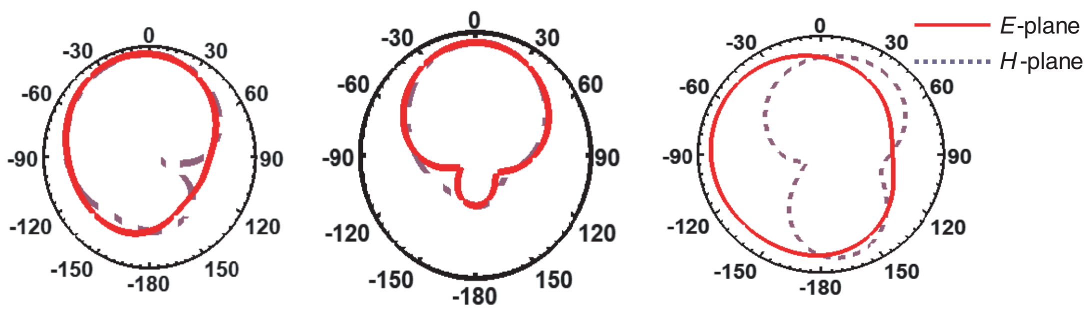
3.2. Measured Results

The proposed antenna is fabricated and tested. It is terminated with a 50 ohm SMA connector. Figure 12 shows photographs of the fabricated antenna. By using VNA, the frequency versus reflection coefficient curve is obtained for the fabricated antenna. Figure 13 shows the frequency versus reflection coefficient



(a) (b) (c)

Figure 9. Current distribution. (a) Initial patch antenna. (b) DGS. (c) Optimized DGS.



(a) (b) (c)

Figure 10. Simulated radiation characteristics in E-plane and H-plane. (a) Initial stage with only slots. (b) DGS. (c) After optimization.

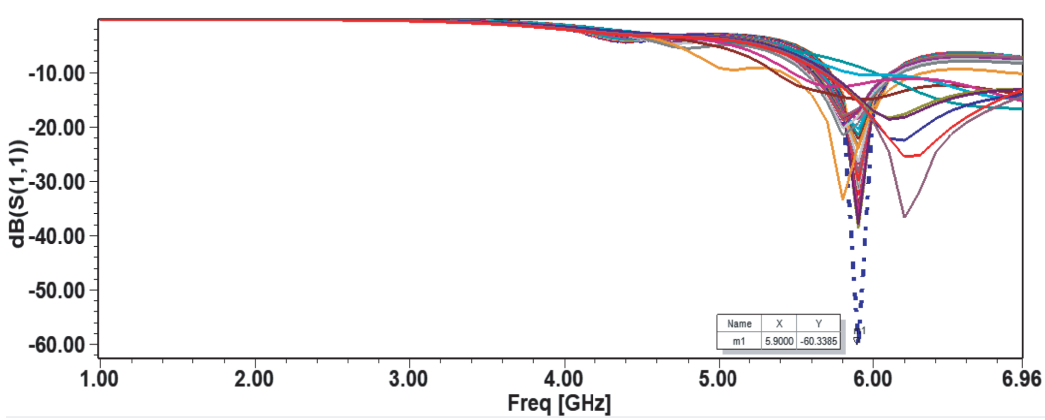


Figure 11. Parametric analysis of DGS.

curve of the fabricated and simulated antennas. From the figure, it can be seen that the resonance frequency is slightly moved to 5.92 GHz, and the reflection coefficient is found to be −35 dB for the fabricated antenna. The simulated VSWR is 1.0024, whereas the measured VSWR is conceived to be 1.02 (Figure 14). It covers the frequency range for the V2V communication. Considering the manufacturing defects, the difference between the simulated and measured result is accepted.

The gain of the proposed antenna is compared with the existing works in the literature and tabulated

(a) (b)

Figure 12. Photograph of the fabricated antenna. (a) Front view. (b) Back view.

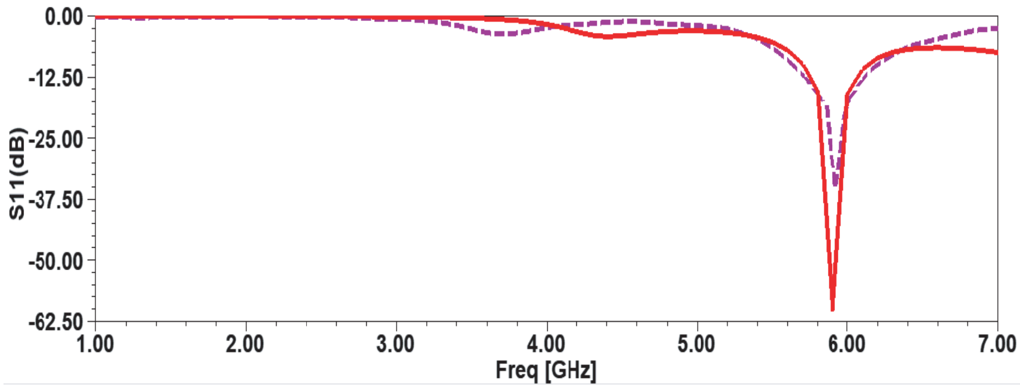


Figure 13. Return loss versus frequency curve for the fabricated and simulated antenna.

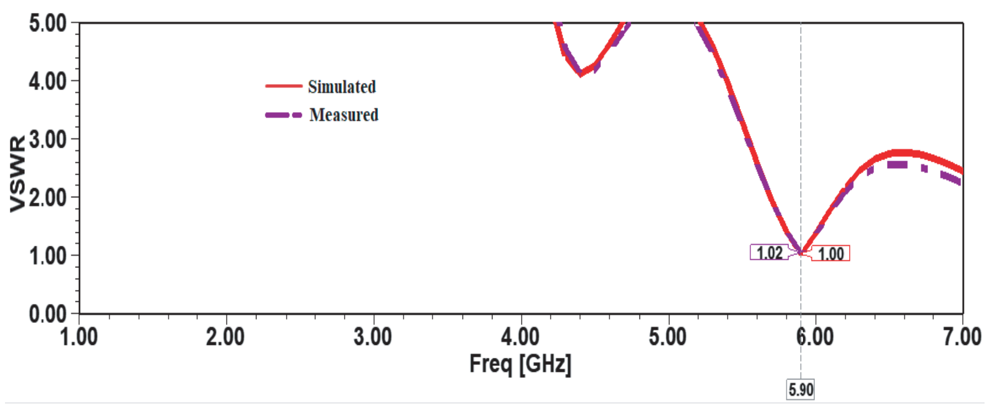


Figure 14. VSWR plot for the fabricated and simulated antenna.

in Table 3. From this table it is found that the proposed antenna possesses high gain compared with the existing antennas fabricated on the same substrate and for the same application.

4. INFLUENCE OF VEHICLE ROOF

The antenna can be placed in any vehicle even on a motorcycle, a car, or a truck. The height of the proposed antenna is 1.6 mm, and it can be easily fitted on the vehicle roof. The antenna should be placed on the vehicle such that it is well above the Earth's surface and far away from the engine in

Table 2. Comparison of all the three stages of the proposed antenna.

	Resonant Frequency (GHz)	**Return Loss (dB)**	**Gain (dB)**	**Radiation Efficiency (%)**	**Impedance Matching (Ω)**	**VSWR**
Patch Antenna	5.9	-39.05	4.73	77	$47.91 - 0.43j$	1.0225
DGS	5.9	-50.63	4.88	78	$50.21 - 0.21j$	1.0059
DGS (GA)	**5.9**	**−60.33**	**5.6**	**78**	**50.04 + 0.09j**	**1.0019**

Table 3. Comparison of gain with the existing methods.

References	**Substrate Material**	**Gain**
[2]	FR4	5.16
[3]	FR4	4.78
[4]	FR4	4.2
[5]	FR4	4.71
[6]	FR4	5
Proposed	**FR4**	**5.6**

Table 4. Influence of antenna parameters by the metal body of the car.

Roof Dimension (mm)	**Resonance Frequency (GHz)**	**Return Loss (dB)**	**Gain (dB)**
30×30	6	-23.00	5.43
40×30	6	-19.50	5.78
50×30	6	-19.40	4.42
100×50	6	-19.89	5.63
200×100	6	-23.38	6.94
300×150	6	-23.51	7.57
400×200	6	-24.06	8.24
500×250	6	-23.69	7.98
600×300	6	-24.25	7.60

order to minimize the losses caused by the spurious noise of the engines. The results are simulated using the software ANSYS HFSS by assuming the aluminium (Al) plate as the vehicle roof. Considering these limitations, the proposed antenna is placed at the center of the roof (Al plate) to get better performance. For instance, the top surface (where antenna is placed) of the Al plate is assumed at 3 mm from the Earth's surface. However, the size of the vehicle influences the antenna performance. This is because when the antenna is mounted on the roof of the vehicle, the roof acts as an extended ground plane of the antenna. Since the ground plane dimension has influence on the antenna parameters (return loss, gain, and radiation pattern), they change as the roof size changes. Table 4 shows the antenna performance influenced by the size of the vehicle. From the table below it can be seen that whatever the size of the vehicle roof is, the frequency of operation of the antenna lies within the vehicular communication band. The return loss and gain of the antenna change with a change in the roof size. The electromagnetic waves radiated by the antenna get influenced by the vehicle body. This also results in the change of antenna parameters when it is mounted on the vehicle. Other reasons for the change in return loss are due to the presence of the obstacles around the antenna, influence of the nearby antennas, and the interference from the nearby sources.

5. CONCLUSION

An omnidirectional microstrip antenna is proposed. The proposed antenna resonates in the V2V band (5.85 GHz $\sim$ 5.925 GHz). The gain of the proposed antenna is obtained as 5.6 dB after optimization. It is compared with the existing works in the literature and found to be high. VSWR of the antenna is nearly equal to 1, and a good matching is achieved with the transmission line. Moreover, the fabricated antenna is measured. The deviation between simulation and measurement is appropriate considering the measurement environment and the difference in fabrication. However, tendencies of the two curves are basically the same. The effect of the vehicle roof on the antenna is also discussed in this paper.

REFERENCES

1. Std 802.11p — 2010, IEEE standard for information technology — telecommunication and information exchange between systems — local and metropolitan area networks — specific requirements, Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, Amendment 6: wireless access in vehicular environments, 2010.
2. Mondal, T., S. Maity, and R. Ghatak, "Compact circularly polarized wide-beam width fern-fractal-shaped micro strip antenna for vehicular communication," *IEEE Transactions on Vehicular Technology*, Vol. 67, No. 6, 5126–5134, June 2018.
3. Madhav, B. T. P., T. Anilkumar, and S. K. Kotamraju, "Transparent and conformal wheel shaped fractal antenna for vehicular communication applications," *Int. J. Electron. Commun. (AEU)*, Vol. 91, 1–10, Elsevier Publications, August 2016.
4. Hao, H., J. Li, D. Huang, and W. Luo, "Design of hexagon micro strip antenna for vehicle-to-vehicle communication," *The Journal of China Universities of Posts and Telecommunications*, Vol. 23, No. 4, 69–76, August 2016.
5. Liu, A., Y. Lu, and L. Huang, "Low-profile patch antennas with enhanced horizontal omni-directional gain for DSRC applications," *IET Microwaves, Antennas & Propagation*, Vol. 12, No. 2, 246–253, 2018.
6. Rafi, Gh. Z., M. Mohajer, A. Malarky, P. Mousavi, and S. Safavi-Naeini, "Low-profile integrated microstrip antenna for GPS-DSRC application," *IEEE Antennas and Wireless Propagation Letters*, Vol. 8, 44–48, 2009.
7. Lamsalli, M., A. El Hamichi, M. Boussouis, N. A. Touhami, and T.-E. Elhamadi, "Genetic algorithm optimization for microstrip patch antenna miniaturization," *Progress In Electromagnetics Research Letters*, Vol. 60, 113–120, 2016.
8. Nema, A., D. K. Raghuvanshi, and P. Raghuvanshi, "Loss reduction in microstrip antenna using different methods," *International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)*, Vol. IV, No. IX, 56–60, September 2015.
9. Rahanandeh, M., A. S. Noor Amin, M. Hosseinzadeh, P. Rezai, and M. Sadegh, "A compact elliptical slot antenna for covering Bluetooth/WiMAX WLAN/ITu," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 857–860, 2012.
10. Chaudhari, A. R., "Effect of wide slots on bandwidth & gain of broadband micro strip antenna," *International Journal of Engineering Technology Science and Research IJETSR*, Vol. 4, No. 4, 395–399, April 2017.
11. Li, P., J. Liang, and X. Chen, "Study of printed elliptical/circular slot antennas for ultra wideband applications," *IEEE Transactions on Antennas and Propagation*, Vol. 54, No. 6, 1670–1675, July 2006.

12. Naik, D. A., P. K. Padiyar, V. N. Virnodkar, and Y. Muttu, "Design and analysis of micro strip patch antenna and comparison between arrays," *International Journal for Innovative Research in Science and Technology*, Vol. 3, No. 12, 119–124, May 2017.
13. Nguyen, M. T., B. Kim, H. Choo, and I. Park, "Effect of ground plane size on a square micro strip patch antenna designed on a low permittivity substrate with an air gap," *2010 International Workshop on Antenna Technology (iWAT)*, IEEE, Lisbon, Portugal, March 1–3, 2010.
14. Chen, H.-M., Y.-F. Lin, C.-H. Chen, C.-Y. Pan, and Y.-S. Cai, "Miniature folded patch GPS antenna for vehicle communication devices," *IEEE Transactions on Antennas and Propagation*, Vol. 63, No. 5, 1891–1898, May 2015.
15. Cseh, C., "Architecture of the Dedicated Short-Range Communications (DSRC) protocol," *Proc. 48th IEEE Veh. Technol. Conf.*, Vol. 3, 2095–2099, Ottawa, ON, Canada, May 21, 1998.
16. Koch, N., "New advances in vehicular technology and automotive engineering," *Antennas for Automobiles*, Joao Carmo (eds.), 191–206, Altran GmbH & Co. KG, Germany, 2012.
17. Kaul, S., K. Ramachandran, P. Shankar, S. Oh, M. Gruteser, I. Seskar, and T. Nadeem, "Effect of antenna placement and diversity on vehicular network communications," *2007 4th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks*, IEEE, San Diego, CA, USA, June 18–21, 2007.