2017 2nd International Conference on Communication Systems, Computing and IT Applications (CSCITA)

A dual band omni-directional antenna for WAVE and Wi-Fi

Ani Taggu*, Bikram Patir†, Utpal Bhattacharjee‡

Rajiv Gandhi University, Doimukh, India
*ani.taggu@rgu.ac.in †bikrampatir15@gmail.com ‡utpal.bhattacharjee@rgu.ac.in

***Abstract*—Vehicles of today are increasingly being networked via various available networking technologies. IEEE 802.11p advocates Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication via Wireless Access in Vehicular Environments (WAVE) between vehicles in the frequency range of 5.9 GHz. Also, IEEE 802.11j proposes the usage of 4.9 GHz frequency range for Wi-Fi. This paper proposes a dual band antenna that is capable of operating in both the WAVE and Wi-Fi bands. This proposed antenna is expected to be simple, easy-to-produce and inexpensive; it can be a cost-effective alternative to use of multiple directional antennas for vehicles. The choice of microstrip patch antenna technology with defected ground structure (DGS) was driven by cost considerations and ease of bulk manufacturing. This omni-directional antenna is expected to be fitted in a central location in the vehicle to avoid requirement of two or more directional antennas. The proposed antenna is characterized by popular antenna design software Ansoft HFSS.**

***Index Terms*—Antenna, Wi-Fi, Microstrip antenna, Defected Ground Structures, DGS, Dedicated Short Range Communication System, WAVE, VANET, V2V, V2I**

I. Introduction

Modern vehicles are expected to be smart and connected via Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) using networking technologies like Wi-Fi or WAVE. However, to enable low-end vehicles to join this network of vehicles, inexpensive and small antennas are required to cater to various reasonable needs of vehicular communication. A small car fitted with an omni-directional antenna with sufficient power will obviate the need for two or more directional antennas. The cost of antenna system to be fitted to inexpensive vehicles is another obvious constraint. The antenna also needs to be easily mountable and mechanically robust on rigid surfaces like roof or body of a vehicle.

As vehicles with extensive communication are expected to be deployed in near future, the area of antenna design for vehicles is a growing research area [1]. Many of the microstrip antennas are designed by modifying the basic rectangular, hexagonal or circular microstrip antennas [1][2].

To meet the requirements of low-cost and miniaturized antenna, microstrip patch antenna is a good fit. A microstrip antenna is simple and inexpensive as it can be mass produced using printed circuit technology. This type of antenna is lightweight, mechanically robust and can support multiple resonant frequencies [3].

In this paper, a microstrip line fed patch antenna have been proposed and designed using Ansoft HFSS software and characterized by evaluating relevant antenna parameters. The simulation was done by taking FR-4 substrate with the dimensions $(25 \times 38 \times 1.6)$ mm^3. The antenna parameters being investigated include reflection coefficient, VSWR, peak gain and radiation pattern. The proposed microstrip line fed patch antenna resonates at frequencies of 4.91 GHz and 5.9 GHz. Thus, this antenna will enable communication at multiple bands — the standard WAVE frequency band of 5.9 GHz and Wi-Fi range of 4.91 GHz.

So, the proposed dual-band antenna enables V2V and V2I communication using WAVE, in addition to enabling communication using the Wi-Fi band. This antenna can be mass produced easily, is inexpensive, lightweight and also easily mountable and mechanically robust.

The remainder of this paper is organized as follows: Section II contains a brief review of some of the related work. Section III describes the design of the proposed antenna. Section IV describes the performance of the antenna in detail. Section V endeavors to identify the future directions. Finally, Section VI concludes this paper.

II. Related Work

Microstrip antennas has been an active area of research for years [4][5][6]. In particular, Mono band microstrip antennas with very good parametric values can be routinely achieved – theoretical and practical design guidelines are lucidly explained in [3][6] and others.

To improve the performance of microstrip antennas, many techniques like photonic bandgap structures (PBG) [7] and compact microstrip resonant cell (CMRC) techniques have been proposed [8].

Many recent works have focused on the technique of Defected Ground Structures (DGS) for the purpose of harmonic suppression and reduction of antenna sizes [9][10][11]. DGS is a simple or a complicated shape etched on the ground-plane of an antenna – thus, a defect is introduced causing changes in current distribution the ground plane. Using this ‘defect’, harmonic suppression of unwanted harmonics or size reduction can be achieved. Various kinds of shapes have been used in DGS – from simple shapes like square or circular to cross-shaped or hairpin [11].

DGS is a periodic structure similar to PBG – but PBG suffers from some issues. Realizing PBG for a sufficiently thin substrate is problematic; also, it is difficult to realize

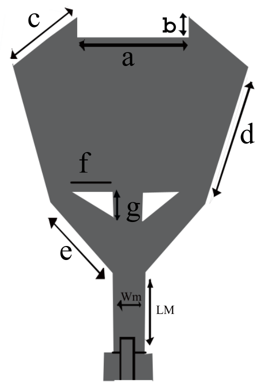

Fig. 1. Top View: Radiating Patch

many holes in the substrate [10]. In contrast, DGS is far easier to realize – etching some shapes in ground plane provides performance that is comparable to PBS. Thus, DGS has become a well-accepted technique to improve performance of an antenna. In this paper, DGS was chosen for ground plane design.

III. Antenna Design

A. Materials Used

FR-4 substrate material with dielectric constant (ϵ_r) 4.4 and loss tangent of 0.02 was chosen – its dielectric constant is in the lower end of the prescribed range $2.2 \leq \epsilon_r \leq 12$ [3]. This substrate enjoys good efficiency and a comparatively larger bandwidth.

The patch and the ground plane, made of copper, is to be photo-etched to the FR-4 substrate.

The feeding-method chosen is microstrip feed line, primarily due to its simplicity. The cladding material used for the feed line is ULTRALAM® 2000. The feeding port is a 50Ω coaxial SMA connector.

B. Antenna Geometry

The FR-4 substrate has the dimensions ($L \times W \times H$)= $38 \times 25 \times 1.6$ mm^3.

The feed line of the proposed antenna is $L_m = 13$ mm by $W_m = 2.4$ mm in size with the coaxial feed connector. This feed line connects to the octagonal radiating patch which has the dimensions as described below.

1) Radiating Patch Design: The radiating patch is a modified octagonal shaped antenna which is fed by the microstrip line feed as shown in Fig. 1.

The patch was designed by initially considering a basic octagonal shape. After multiple iterations, the final parameters of the radiating patch were determined. The final parameters of the patch are shown in the table I.

2) Ground Plane Design: The ground plane is a simple structure. The overall dimensions are the same as the substrate i.e. 25mm × 38mm.

TABLE I
Radiating Patch Parameters

Patch Parameter	Specification
L_m	13 mm
W_m	2.4 mm
a	7 mm
b	2 mm
c	10 mm
d	12 mm
e	8.5 mm
f	4 mm
g	2 mm

TABLE II
DGS based Ground Plane

Ground Plane Parameter	Specification
Dimension ($L \times W$)	38×25mm^2
p	11 mm
q	5 mm
r	2 mm
s	2 mm
g	6 mm
w	9 mm

Initially, a classic ground plane was assumed in the design. Then, using a number of iterations, 'defects' in the form of slots are introduced in the ground plane. The primary purpose of these defects i.e. Defected Ground Structures (DGS) is for harmonic suppression and to reduce the antenna sizes.

Since DGS are physical defects that are introduced in the ground plane, a large number of simulation iterations were needed to identify the efficacy of the defects so introduced.

After satisfactory results were obtained, the final dimensions for the slotted ground plane is given in Table II.

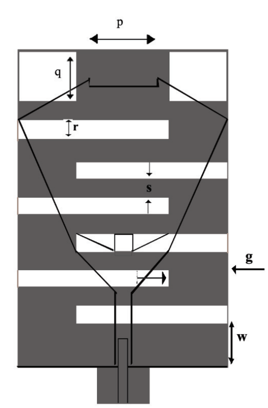

Fig. 2. Bottom View: Ground Plane with DGS

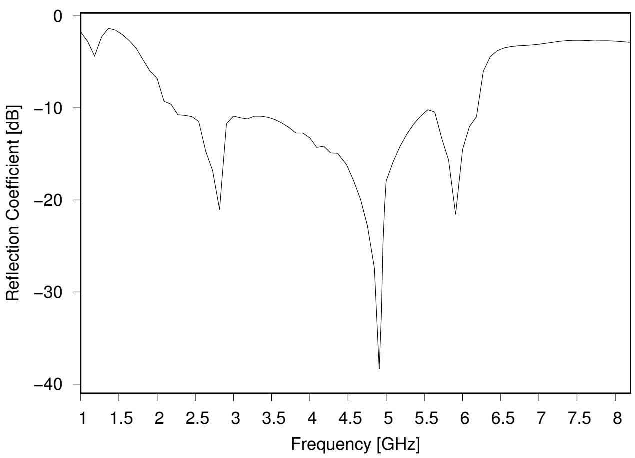

Fig. 3. Reflection coefficient S11 of Patch Antenna

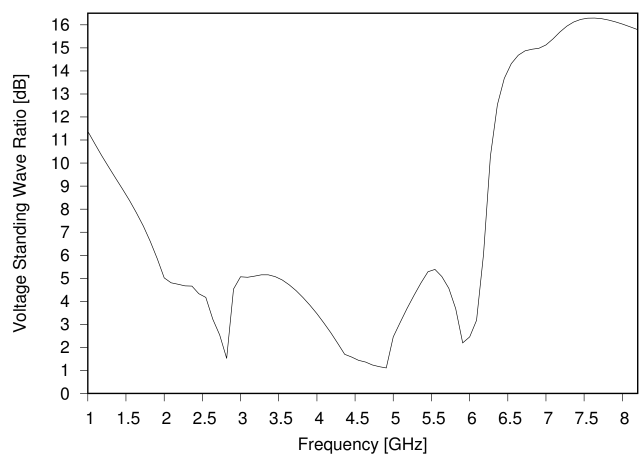

Fig. 4. VSWR of Patch Antenna

TABLE III
SIMULATED PEAK GAIN AT DIFFERENT RESONANT FREQUENCIES

Resonant Frequency	Simulated Peak Gain
2.81 GHz	0.6 dBi
4.91 GHz	3.4 dBi
5.9 GHz	4.26 dBi

IV. RESULTS

In this section, the simulation results obtained for the proposed antenna with respect to relevant parameters are discussed.

A. Reflection Coefficient

The S11 simulated reflection coefficient for the proposed antenna is shown in the Fig. 3.

At resonant frequencies, the return loss has been observed to be -38.36 dB for 4.91 GHz and -21.56 dB for 5.9 GHz.

It is also observed that there is another resonant frequency 2.81 GHz with a return loss of -20.90 dB. However, this frequency band is ignored since the corresponding peak gain is too low.

The corresponding Peak Gains for different resonant frequencies are given in the table III.

B. VSWR

Usually, the Voltage Standing Wave Ratio should be in the range 1.0 – 2.0.

The VSWR was computed using the well-known equation (1) where Γ represents the reflection coefficient.

$$\text{VSWR} = \frac{(1 + |\Gamma|)}{1 - |\Gamma|} \tag{1}$$

The VSWR so obtained is plotted in Fig. 4. It is clearly seen that at resonant frequencies, the values of VSWR are in the acceptable range.

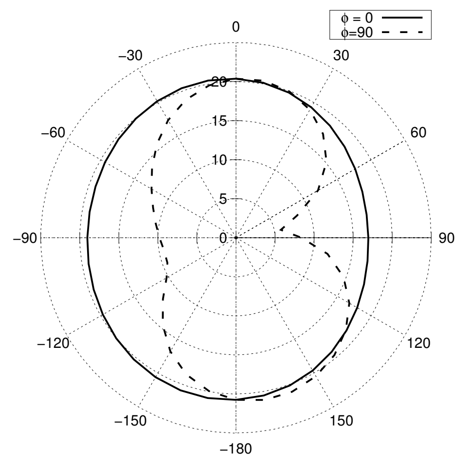

Fig. 5. Radiation Patterns at 4.91 GHz

C. Radiation Patterns

The radiation patterns for the resonant frequency 4.91 GHz is computed for two planes i.e. $\phi = 0°$ and $\phi = 90°$ as can be seen in Fig. 5. The radiation patterns at 4.91 GHz clearly show the non-directional pattern in both the planes.

Then the radiation patterns for the resonant frequency range of 5.9 GHz were obtained for the $\phi = 0°$ and $\phi = 90°$ planes as seen in Fig. 6. These radiation patterns also clearly illustrate the essentially omni-directional nature of the antenna at 5.9 GHz resonant frequency.

V. FUTURE DIRECTIONS

Although the performance of the proposed antenna has been confirmed to be acceptable, the proposed antenna suffers from the following limitations:

1) *Extra resonant Frequency*: The design could not erase the extra resonant frequency at 2.8 GHz range as can be seen in Fig. 3 and Fig. 4.
2) *Imprecise Dual band operation*: From Fig. 3, it can be observed that the return loss does not increase above -10 dB clearly beyond the first resonant frequency of 4.91

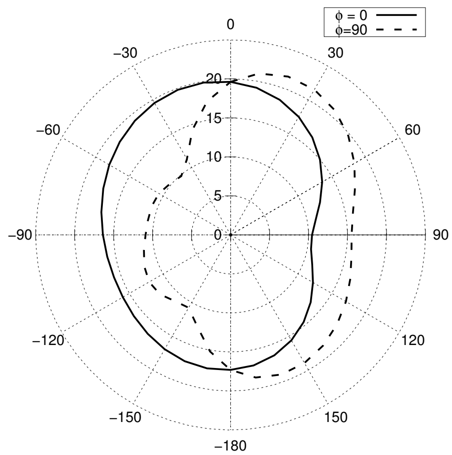

Fig. 6. Radiation Patterns at 5.9 GHz

GHz and then drop below -10 dB at the second resonant frequency as ideally expected of an antenna operating precisely in dual bands.

3) *Slightly High VSWR at 5.9 GHz*: From Fig. 4, we can observe that the VSWR is slightly higher than the required 2.0. Also, the radiation is slightly asymmetrical at 5.9 GHz.

The above limitations mean that other techniques should be investigated for further refinement of the proposed antenna.

VI. Conclusion

This paper describes the design of a simple microstrip line fed patch antenna. Various relevant parameters for this antenna were evaluated like reflection loss, VSWR, Peak Gain and radiation patterns.

The antenna resonates at the frequencies of Wi-Fi band (4.91 GHz) and WAVE (5.9 GHz) as intended and has satisfactory performance in terms of gain and low reflection losses. Thus, the proposed antenna has been found to be suitable for use as omni-directional antenna for the purpose of vehicular communications.

References

[1] R. Leelaratne and R. Langley, "Multiband pifa vehicle telematics antennas," *IEEE Transactions on Vehicular Technology*, vol. 54, no. 2, pp. 477–485, March 2005.

[2] B. Mazumdar, U. Chakraborty, A. Bhowmik, and S. Chowdhury, "Design of compact printed antenna for wimax & wlan applications," in *2nd International Conference on Computer, Communication, Control and Information Technology (C3IT-2012)*, vol. 4, February 2012, pp. 87–91.

[3] C. A. Balanis, *Antenna Theory: Analysis and Design*. Wiley-Interscience, 2005.

[4] K. Carver and J. Mink, "Microstrip antenna technology," *IEEE Transactions on Antennas and Propagation*, vol. 29, no. 1, pp. 2–24, Jan 1981.

[5] N. P. Agrawall, G. Kumar, and K. P. Ray, "Wide-band planar monopole antennas," *IEEE Transactions on Antennas and Propagation*, vol. 46, no. 2, pp. 294–295, Feb 1998.

[6] J. James, P. S. Hall, and C. Wood, *Microstrip Antenna Theory and Design*. Institution of Engineering and Technology, 1981.

[7] F. Yang and Y. Samii, *Electromagnetic Band Gap Structures in Antenna Engineering*. Cambridge University Press, 2008.

[8] Y. J. Sung and Y. S. Kim, "An improved design of microstrip patch antennas using photonic bandgap structure," *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 5, pp. 1799–1804, May 2005.

[9] J.-S. Lim, J.-S. Park, Y.-T. Lee, D. Ahn, and S. Nam, "Application of defected ground structure in reducing the size of amplifiers," *IEEE Microwave and Wireless Components Letters*, vol. 12, no. 7, pp. 261–263, July 2002.

[10] L. H. Weng, Y.-C. Guo, X.-W. Shi, and X.-Q. Chen, "An overview on defected ground structure," *Progress In Electromagnetics Research B*, vol. 7, pp. 173–189, 2008.

[11] A. K. Arya, M. Kartikeyan, and A. Patnaik, "Defected ground structure in the perspective of microstrip antennas: a review," *Frequenz*, vol. 64, no. 5-6, pp. 79–84, 2010.