

Compact Design of 1x2 MIMO Microstrip Patch Antenna with Corners Trimmed for Vehicle-to-Vehicle Communication

Ko Ko Zaw, Hla Myo Tun*, Ei Ei Khin, Thandar Oo, Devasis Pradhan

Abstract—This paper mainly focuses on the compact design of circularly polarized microstrip patch antenna for vehicle-to-vehicle communication. The charging time of electric vehicle is longer waiting time than compared to traditional gasoline-based vehicles. The charging is done at the public charging stations. When the vehicles need charging while driving, they communicate with Dedicated Short Range Communications (DSRC) band to send the information to the nearest vehicles and receive information from the charging station. Moreover, the DSRC band is used in many application areas such as Intelligent Transportation System (ITS), Electronic Toll Collection (ETC), Collision Avoidance, and connected vehicles. The vehicle-to-vehicle communication system needs to achieve higher data rates multimedia. These requirements cannot be supported by using single microstrip patch antenna. However, some research challenges have been in MIMO antenna such as antenna miniaturization, decoupling, and isolation between the antennas. The research solution for the problem statement in this study is emphasized on the corner trimmed is added in the rectangular patch and ground plane to make the current part longer and the impedance matching better, and to get low ECC. After that, the mutual coupling can be reduced by adding suitable separation between two radiating patches. S_{12} and S_{21} are less than -20dB from 5.81 GHz to 5.930 GHz . So, the proposed antenna design is very appropriate for car-to-car ($5.85\text{--}5.925\text{ GHz}$) communication. The measurement result of the proposed antenna is valid because the desired values such as minimum $S_{11} \leq -10\text{ dB}$, $\text{VSWR} \leq 2$, and $\text{ECC} < 0.3$ are obtained for V2V communication in both simulation and measurement results.

Index Terms— ECC, MIMO, Patch Antenna, Trimmed Corners, Vehicle-to-Vehicle

I. INTRODUCTION

TODAY the wireless communication is widely used in vehicular communication system. In a wireless communication system, the free space is used as the communication channel instead of wires and cables. So, the transmitter needs to be converted from the electrical signals to the EM signals for propagation through free space and then the receiver needs to be converted back the EM signals into electrical signals. The antenna which converts electrical signals to EM signals and vice versa at the transmitter and receiver side respectively. So, the antenna is a necessary component in a wireless communication. Nowadays, the wireless devices are

becoming more and more popular and compact and increasing in number of applications in a single device. So, the antenna design needs to compact in size, light in weight, lower in cost and supports multiple frequency band operation. The microstrip patch antenna can be solved all the above-mentioned and needed. It can be mounted directly on devices. Moreover, these microstrip patch antennas have many advantages such as low power consumption, ease of fabrication, low cost, and ease of manufacturing them in bulk as well as low power consumption. So, the microstrip patch antennas are highly suitable for applications like WLAN, WiMAX, satellite communication, vehicle to vehicle communication and so on. Due to this patch antenna occupy a special place in satellites, mobile phones, vehicles and so on [1].

Vehicle to vehicle or car to car communication is a new approach of technology that allows vehicles to communicate with each other based on the new standard IEEE 802.11p for WAVE. It designates to IEEE 802.11 the basic products marketed as Wi-Fi. It is required to support ITS, in the permitted ITS band of 5.9 GHz . IEEE 802.11p standard has 7 channels of 10 MHz bandwidth in the 5.9 GHz band, this 10 MHz channel width is obtained from 75 MHz spectrum divide into seven intervals, range from 5.85 GHz to 5.925 GHz . A microstrip patch antenna configuration can be divided into three layers of sandwich structure, the first layer is the antenna patch, the second layer is the patch layer which consist of a dielectric substrate and the third layer is the ground plane. The conductor of the patch is usually made of copper and sometimes can be replaced by any conductive material which is dependent on antenna application. The shape of the radiating patch can be into various shapes such as square, circular, rectangular elliptical or other irregular shapes. However, most commonly used shapes are square, rectangular and circular [2].

The monopole microstrip patch antenna is a patch antenna which has defected ground plane in some case. The monopole is used as a resonant antenna. The main advantage of the monopole antenna is the omnidirectional pattern in the horizontal plane [3]. According to this reason, microstrip patch monopole is used in car-to-car communication. Because the receiver monopole microstrip patch antenna can receive all signals from any direction in the horizontal (Azimuth) plane.

This paper is constructed as follows. In section II, the antenna geometry is focused. In section III, the parameter study for the proposed antenna is described. In sections IV and V, the simulation and measurement results of the research work is presented. In sections VI and VII, the discussion and conclusion of the research work are

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discussed, respectively.

II. ANTENNA GEOMETRY

In this section, the calculation of antenna design and the proposed antenna are discussed. In the reference antenna, a rectangular patch is fed by using a microstrip line feed technique. The omni-directional radiation pattern can be got by using the partial ground plane on substrate. The microstrip line feed is designed to match a 50 Ω characteristic impedance [4]. The dimension of antenna is calculated by using following equations [5-8].

$$W = \frac{1}{2f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_0}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right], \frac{W}{h} > 1 \quad (2)$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{\text{reff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{\text{reff}} - 0.258) \left(\frac{W}{h} - 0.8 \right)} \quad (3)$$

$$L_{\text{eff}} = L + 2\Delta L \quad (4)$$

$$L = \frac{1}{2f_r \sqrt{\epsilon_{\text{reff}}} \sqrt{\mu_0 \epsilon_0}} - 2\Delta L \quad (5)$$

$$= \frac{v_0}{2f_r \sqrt{\epsilon_{\text{reff}}}} - 2\Delta L \quad (6)$$

$$W_g = 6h + W \quad (7)$$

$$L_g = 6h + L \quad (8)$$

After the calculation, it is necessary to adjust the parameters to get the resonant frequency. In [9], the antennas should be placed at a distance higher than $\lambda/4$ to avoid high coupling in MIMO antenna. In [10-12], the distance between the neighboring antenna elements has to be larger than 0.5λ , which is contrary to compact designs. The proposed antenna is made up of a FR4 substrate and fed by a fifty-ohm SMA connector. The dimension of antenna is 28.5 mm $\times$ 77 mm $\times$ 1.6 mm. The corner trimmed length and separation between two radiating patches is 2mm and $d_{\text{min}} = 21.3$ mm, respectively. The dimension obtained after parameter adjustment of the proposed antenna is shown in Table I. The top view and bottom view of the proposed antenna are shown in Fig 1.

TABLE I.

DIMENSION OF 1X2 MIMO MICROSTRIP PATCH ANTENNA

Sr. No	Parameters	Values (mm)
1.	Width of Patch	17.2
2.	Length of Patch	18.8
3.	Width of Feed Line	3.3
4.	Length of Feed Line	9.3
5.	Width of Ground Plane	28.5
6.	Length of Ground Plane	7.35

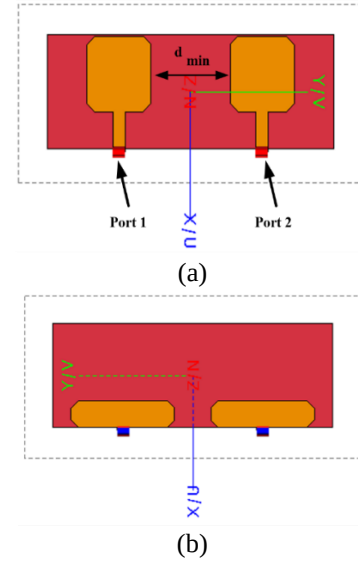
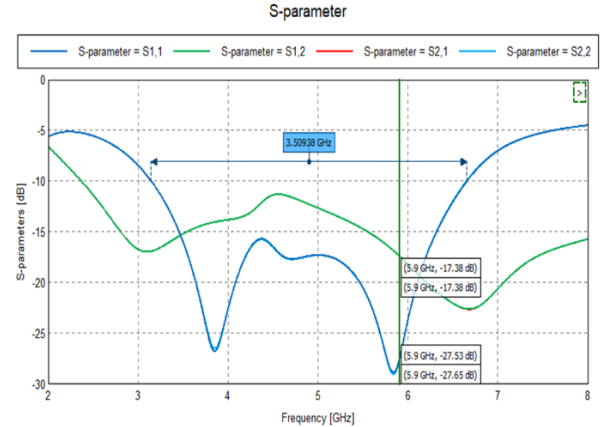


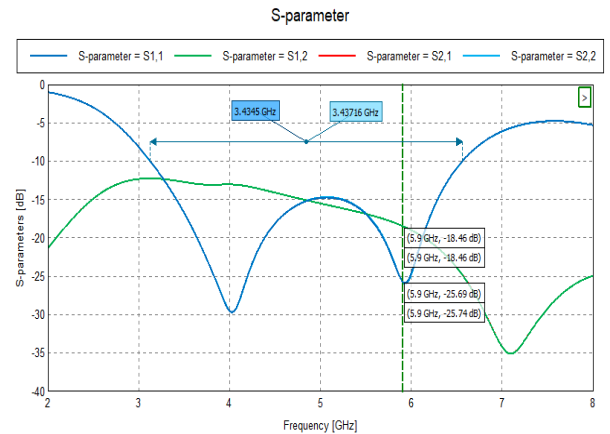
Fig. 1. 2D View of Proposed Antenna (a) Top View, (b) Bottom View

III. PARAMETER STUDY

In this research work, the reflection coefficient is studied when various separation between two radiation patches is changed such as 11.3 mm, and 21.3 mm, respectively. Changing the separation between antenna is affected on the value of S12 and S21. According to the result, when the d_{min} is 11.3 mm, the S11 and S22 are -27.53 dB and -27.65 dB at 5.9 GHz. The bandwidth is 3.51 GHz. The S12 and S21 are -17.38 at 5.9 GHz.



(a) $d_{\text{min}} = 11.3$ mm



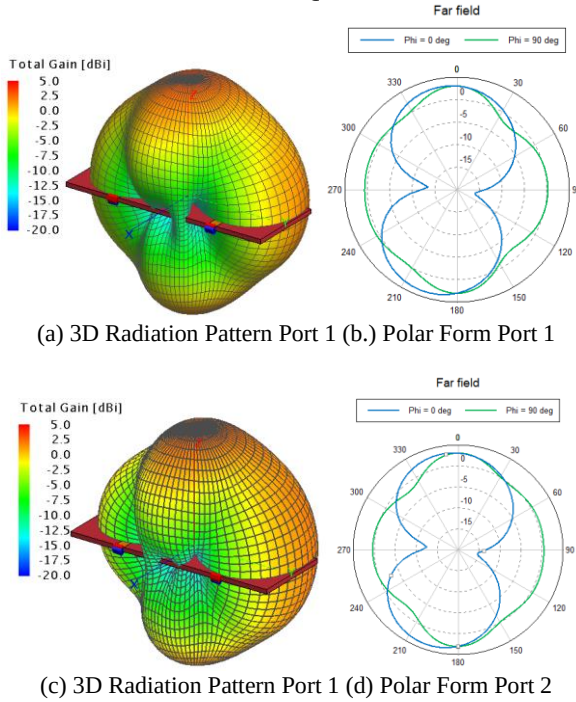
(b) $d_{\text{min}} = 21.3$ mm

Fig.2. Comparison of S-Parameters for Proposed Antenna

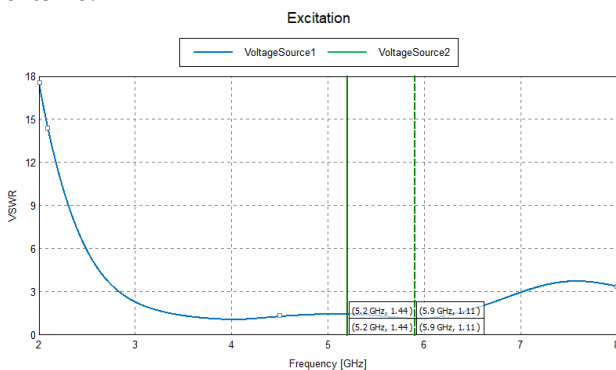
When the $d_{\min}$ is 21.3 mm, the S_{11} and S_{22} are -25.69 dB and -25.74 dB at 5.9 GHz. The bandwidth is 3.43 GHz. The S_{12} and S_{21} are -1846 dB at 5.9 GHz. In this dimension, the S_{12} and S_{21} are more isolated than $d_{\min} = 11.3$ mm. The simulation results of various separations between antenna are shown in Fig 2 (a.) and (b).

IV. SIMULATION RESULTS

Firstly, the simulation results of two ports MIMO antenna are discussed. According to the result, When the $d_{\min}$ is 21.3 mm, the realized gain of antenna is 3.03 dBi.

**Fig. 3.** Radiation Pattern of Proposed Antenna.

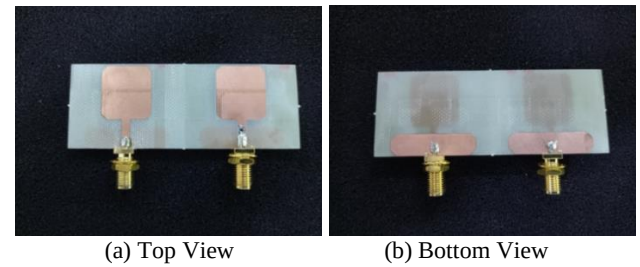
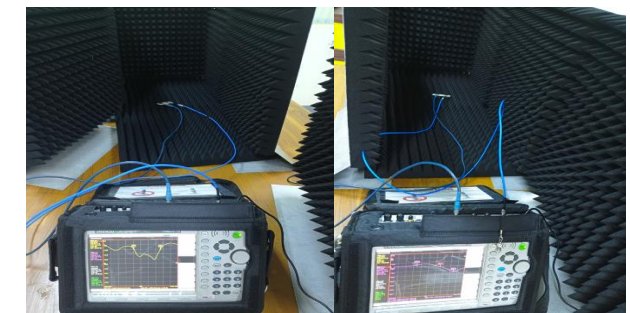
The maximum total gain of the antenna is 5 dBi at port 1 and port 2. In port 1, beamwidth of the antenna is 70.09 degree in $\phi = 0$ degree and 56.13 degree in $\phi = 90$ degree at 5.9 GHz. In port 2, beamwidth of the antenna is 70.2937 degree in $\phi = 0$ degree and 54.24 degree in $\phi = 90$ degree at 5.9 GHz. The directional radiation pattern of proposed antenna is shown in Fig 3. In this design, the radiation pattern is omni-directional pattern. Omni-directional refers to the notion of existing in every direction. For all direction can be covered with only one antenna.

**Fig. 4.** VSWR of Proposed Antenna

When the current is flow in patch 1, the current is not flow in patch 2. So, the current is isolated between two radiating patches. The polarization of the antenna is linear polarization. So, the proposed antenna design is very appropriate for car-to-car (5.85-5.925 GHz) communication. The antenna has a compact geometry and can be fabricated easily and at a low cost. VSWR of the proposed antenna is 1.11. This means that the antenna design matches between antenna and feed. VSWR of the proposed antenna is shown in Fig 4.

V. MEASUREMENT RESULTS

In this section, measurement result of proposed antenna is discussed. The design is fabricated on FR4 substrate by using mini mini-drilling machine. According to the measurement result, the bandwidth of antenna is 2.16 GHz from 4.43 GHz to 6.590 GHz in S_{11} and 2.4 GHz from 4.01 GHz to 6.410 GHz in S_{22} . S_{12} and S_{21} are less than -20 dB from 5.810 GHz to 5.930 GHz. This means that the MIMO antenna decoupling and isolation between radiating patches. The fabricated antenna is shown in Fig 5. The reflection coefficient and VSWR are measured by using VNA master in anechoic chamber. Measurement of fabricated antenna is shown in Fig 6 and 7. The S_{11} , S_{12} , S_{21} , and S_{22} of fabricated antenna on Anritsu VNA master (MS2038C) screen is shown in Fig 8.

**Fig. 5.** Fabricated 1x2 MIMO Microstrip Patch Antenna.**Fig. 6.** Measurement Setup

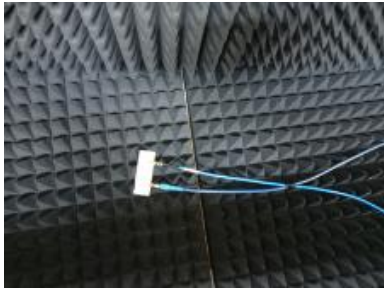
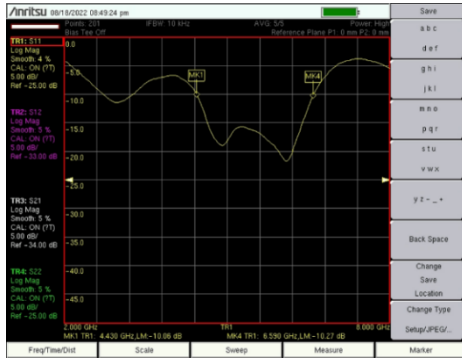
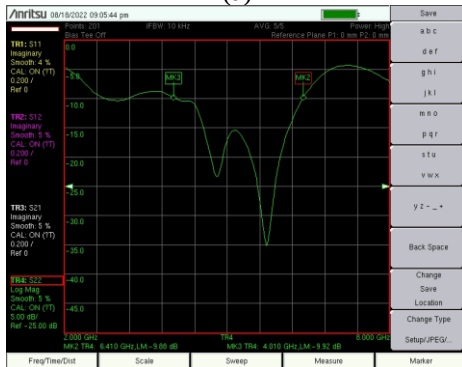


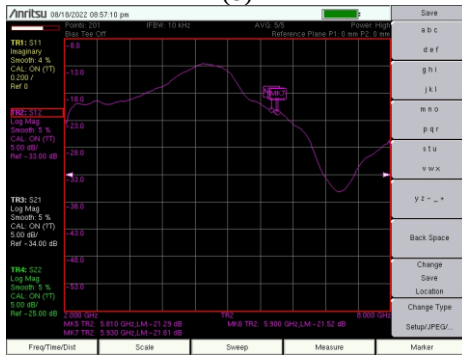
Fig. 7. Measurement of 1x2 MIMO Microstrip Patch Antenna



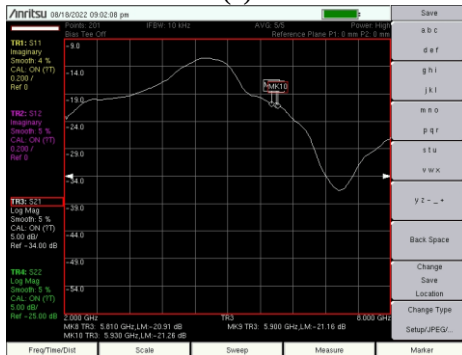
(a)



(b)



(c)

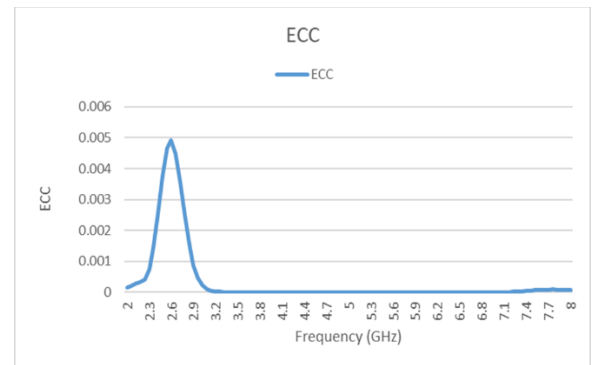


(d)

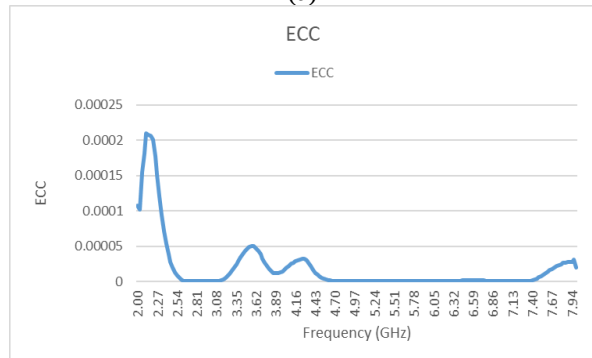
Fig. 8. Measurement of S12 and S21 for Proposed Antenna (a) Measurement (s11), (b) Measurement (s22), (c) Measurement (s12), (d) Measurement (s21)

VI. DISCUSSIONS

Envelope Correlation Coefficient (ECC) determines how independent two antennas' radiation patterns are. When one antenna is horizontally polarized, and the other is vertically polarized, the two antennas would have a correlation of zero. Similarly, when one antenna only radiated energy towards the sky, and the other only radiated energy towards the ground, these antennas would also have an ECC of zero. It turns out 0.5 is “OK”, higher than 0.5 is considered “Bad”, and 0.3 or less is considered “good” for MIMO applications. In ECC graph, the maximum value of ECC is under 0.003. This means that the proposed MIMO antenna is low coupling and high isolation between two ports in DSRC band. The simulated and measured ECC of proposed antenna is shown in Fig. 9.



(a)



(b)

Fig. 9. Envelope Correlation Coefficient (ECC) (a) Simulated, (b) Measurement

After measurement, the bandwidth of proposed antenna is changed from 3.43 GHz to 2.16 GHz and 2.4 GHz, respectively. But the results are still valid for car-to-car (5.85-5.925 GHz) communication because the desired values such as minimum $S_{11} \leq -10$ dB, and $VSWR \leq 2$, and $ECC < 0.3$ are obtained.

VII. CONCLUSION

The proposed antenna has been simulated over different parametric studies by using FEKO software. The dimension of antenna is 28.5 mm × 77 mm × 1.6 mm. When the d_{min} is 21.3 mm, the S11 and S22 are -25.69 dB and -25.74 dB at 5.9 GHz. The bandwidth is 3.43 GHz. The S12 and S21 are -18.46 dB at 5.9 GHz. ECC is less than 0.005. This means that the proposed MIMO antenna is low coupling and high isolation between two ports in DSRC band. The polarization of antenna is linear polarization. So, the proposed antenna design is very appropriate for car-to-

car (5.85-5.925 GHz) communication. In measurement results, the bandwidth of the antenna is 2.16 GHz from 4.43 GHz to 6.590 GHz in S11 and 2.4 GHz from 4.01 GHz to 6.410 GHz in S22. S12 and S21 are less than -20 dB from 5.810 GHz to 5.930 GHz. ECC is less than 0.0002. This means that the MIMO antenna decoupling and high isolation between two ports. So, the proposed antenna design is very appropriate for car-to-car (5.85-5.925 GHz) communication. The proposed antenna has a compact geometry and can be fabricated easily and at a low cost. The discrepancy between them was probably due to the fabricated imperfections and the loss of the feeding cable and connectors. In the future, a compact-size MIMO antenna will be developed by contributing such new approaches that are making low coupling and high isolation in other applications and folded patches for antenna miniaturization and enhancing bandwidth and gain because the proposed antenna is wide bandwidth.

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