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COMPARISON BETWEEN SPATIAL AND POLARIZATION DIVERSITY TECHNIQUES IN2X1 MIMO ANTENNA FOR VEHICULAR COMMUNICATION

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Abstract - In recent times, the use of wireless communications and especially vehicular communication networks has been growing. This networks that use the IEEE 802.11p standard have a greater capacity for data transport as well as a higher communication speed. To achieve these requirements, MIMO systems present a satisfactory resolution. This paper proposes the design of hexagonal ring 2x1 MIMO antenna to operate within the full range of 75MHz DSRC band with the center frequency at 5.9GHz. In this work, MIMO antenna designs that focus on spatial and polarization diversity, and its impact on performance. The use of ring reduces the overall area of the patch considerably at 5.9GHz.Thestructures were simulated in free space (S-parameter, radiation diagrams, correlation coefficient).The simulations were carried out based on the FEKO software environments. According to the simulation results, the proposed hexagonal ring MIMO antenna could be utilized in vehicular communication network.

Keywords - Vehicular Communication Network, Hexagonal Ring MIMO Antenna, DSRC Band, Spatial Diversity, Polarization Diversity, FEKO.

I. INTRODUCTION

In most recent years, there exists an increasing tendency of road accident in Myanmar. According to the road crashes data, the road accident rate in Myanmar increases from 8568 cases in 2011 to 9339 cases in 2012 [1]. There are several aspects that add to those increases such as the absence of proper road facilities and the human error factor. As the amount of car and motor in the road increases, this upsetting trend is forecast to continue in upcoming years. One of the determinations to reduce the amount of road accident is done by installing the intelligent transportation system. Vehicular communication network is required for intelligent transportation system [2].Most of the vehicular communication equipment like Side View Camera Model [3], Shadow or Edge Features Detector [4] that have been proposed over time for vehicular safety, show performance limitations in the presence of fog, mist and bad weather. Solid State Infrared Detectors [5] are high on cost. Apart from that, mechanically controlled devices like Dynamic Angling Side View Mirror [6] has high response time and is more disposed to constant wear and tear.

Vehicular communication between infrastructure and vehicles is based on the roadside units with a dedicated short range communication (DSRC) and mostly omnidirectional data link. The roadside units (RSU) are installed in cities on standing traffic lights of appropriate junctions or under bridges in the situation of highways. The typical mounting height of the roadside unit is between two and six meters. In Europe, DSRC operates at 5.9GHz, using 75MHz band [5.85 5.925GHz] with 7 channels 10MHz each [8].The idea behind this standard was that it would be able to provide a much betterperformance and to increase the link's speed.

As such, in order to be ableto carry very high data rates, 802.11p has utilized MIMO systems. For each transmitter/receiver pair ofantennas added to the system, the average capacityof a MIMO Rayleigh fading channel increases linearly. Using different strategies such as spatial multiplexing, different types ofdiversity (time, frequency, space) and the required information coding, these goals can be achieved. In order to achieve these goals, to obtain an effective MIMO system, it is necessaryto have enough uncorrelated antennas at the beginning and end of the link. In addition to the conventional antenna parameters, such as gain, radiationpattern and reflection coefficients, new parametersand aspects have to be considered in the design ofMIMO systems, such as the mutual coupling andcorrelation between antennas. Facing these challenges, printed antennas are assumed to be the bestchoice for MIMO systems, due to its low-cost, easyfabrication and small dimensions.

Traditionallyuncorrelated signals can be achieved by spatial diversity i.e. placing the antennas sufficient distance apart. Analyticalstudies have shown that for minimal correlation, a half wavelength distance between antennas is required. Other waysof reducing the correlation between received signals are pattern and polarization diversity which utilize orthogonalpatterns and orthogonal polarizations as a means to create uncorrelated channels. Antennas with orthogonal radiationpatterns pick up signals at different directions and since the fading signals coming from different directions in a multipathenvironment are independent, good MIMO performance can be achieved.

In this work, spatial and polarization diversity method are used to compare the performance of the communication.The rest of the paper is organized based on the different sections. Section II presents the state of art of designconsideration for specific purposesMIMO antenna. Section III mentions the simulation of proposed antenna design. Finally, the conclusion of the research works have been pointed out in Section V.

II. ANTENNA DESIGN CONSIDERATION

A. Printed Monopole Antenna

Electromagnetically printed antennas are settled to provide every wideband impedance characteristics. Many parameters optimize the impedance bandwidth of this antenna which has to be studied. These antennas are built up for modern wideband wireless applications like mobilephones or Wireless LAN, Bluetooth, UWB and RFID technologies.

In [9, 10] two different antennas were designed inorder to operate at 2.45 GHz frequency (ISM Band),on a FR4 substrate suitable for Body-Centric and wireless communications, fed by a micro strip Line.Circular Disc Monopole (CDM) with a a CPW feeding (using FR4 substr

- ate, as well) with 50 Ohm impedance matched with the coaxial cable and two notches cut on the circular disk patch
- ate, (used to increase the reflection coefficient at lower fre
- quencies), as it shows [11], reveals to be an interestingsolution for UWB applications.

A dual-band transparent antenna for ISM applications is studied in [12]. The antenna design consists of a circular radiating patch fed with a 50 OhmCPW feeding and uses a transparent thin film material (AgHT-4) as substrate, with an overall size of 60 x60 x 2.075mm3. Depend on the above literature survey, this paper presented novel design of printed hexagonal ring monopole fed by micro strip line is proposed and investigated based on our previous studies. In this paper, the HRMA is approved as a basic antenna element in the MIMO system since our intention is to reduce the total surface area of the metallic parts of the antenna and good isolation. This is done by removingthe metallization from the antenna’s center since most of the surface current was concentrated alongthe edges of the hexagon structure.

B. MIMO Antenna Solution

In [8], several reflections concerning MIMO antenna design are established in order to optimize aspects such as array configuration, radiation pattern,type of polarization and mutual coupling. Thispaper suggests di fferent ideas and solutions for MIMO systems such as Antenna array configuration and reconfigurable antennas. Antenna array or phased array system consist on a set of patch antennas with unlike layouts. The array topology is decided in order to maximize capacity and minimize error rate. In MIMO arrays,the correlation between the multiple signals mustbe as least as possible to counteract the development of degradation in channel capacity. Gain enhancementcan be achieved by using several diversity strategies:

- Spatial Diversity:diversity elements are spaced with optimum distance to increase the number of channels in the link. In this technique,the smaller the distance, the more the mutualcoupling between antennas, which result in areduction of the channel capacity.
- Polarization Diversity: elements in the array are fed with differently polarized signals.
- Pattern Diversity: the signals with di efferent angles are given to each one of the antenna present in the array.

MIMO arrays can be suitable for UWB applications, as it is reported on [13]. The author proposes a UWB MIMO antenna, with a bandwidth from 3.1 to 10.6 GHz, composed by two planar-monopole (PM) elements with 50 Ohm micro strip-fed placed perpendicularly to each other, in order to provide good isolation between the two input ports.

For better matching at high frequencies of the ground plane. To increase isolation and impedance bandwidth, two long ground stubs were introduced, placed in parallel with the respective PM. In [14] an antenna has been designed for 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHzWiMAX applications that consists of two back-to-back monopole antennas, using a strategy to reduce the mutual coupling between two ports at the lower frequency band, introducing a T-shapedstub, where two rectangular slots are cut from the ground. A different approach is made in [15], whereas compact micro strip patch antenna with four ports has been designed and implemented. In [16] a directional shorted four-port patch antenna is led, fed with vertical probes which can operate either in dual linear and circular polarization modes in order to increase system capacity. The same concept is introduced on [17] structured with two printed F antennas on the top layer ofa FR4 PCB with a rectangular ground plane underneath and a pair of quarter wavelength slot antennas inserted diagonally on the back side of the PCB. From the literature survey, it is found that all these techniques have the problems of requiring additional structures to reduce mutual couplingand size of antenna. In this work 2x1 MIMO antenna is designed by using spatial and polarization diversity method to show the correlation performance.

III. DESIGN AND SIMULATIONS

The design method started by choosing the materials used as well as the feeding technique. Then the operating frequencies and the patch shape were chosen. Finally, the component's length was optimizedin order to obtain the resonance at the intended frequencies, and there was also a readjustment of theantenna's overall size, to make it as small as possible. Firstly, a model of the simulated referenceelement will be presented as well as an explanationof the choices made in its construction. Then thesimulated 2x1 MIMO structures are presented. Initially,two element structures are shown utilizing spatial diversity techniques among various types of diversity. All the presented models simulated by FEKO software.

A. Reference Element

The basic element that was designed in order to build the proposed MIMO system is presented in figure 1. To obtain the corresponding designeddimensions, several parameters such as the strip line techniques andthe ground plane had to be adjusted. In orderto tune the frequencies for the required application and increase the resonance on these frequencies (5.9GHz), multiple parameter sweepswere made.

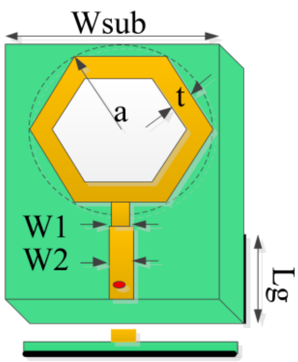


Fig 1. Design of Hexagonal Ring Monopole Antenna

The element is composed by a hexagonal ring monopole antenna that ensures resonance on the desired frequencies. Micro strip patch antennas consist of very thin metallicstrip placed on ground plane where the thickness of the metallic strip is restricted by t << λ_0 and the height is restricted by $0.0003\,\lambda_0 \leqslant h \leqslant 0.05\,\lambda_0$.There are numerous substrates that can be used for the design of micrrostrip

TABLE I: Optimize Parameters of Monopole Antennas

Parameters	Dimensions (mm)
Wsub x L_{sub}	10x13
Wg	10
Lg	5.2
a	3.8
t	1.6
W1	1.6
W2	2

and their dielectric constants are usually in the range of $2.2 \leqslant \varepsilon_r \leqslant 12$ [16]. According to the restricted and easily find in Myanmar market, 1.6mm thick FR4-epoxy substrate, with a permittivity of 4.4 and loss tangent 0.018 are chosen to obtain optimal design.To describe and analyses an antenna's behavior as well as its operating band, the reflection coefficient is most commonly used. The absolute value of this parameter relates to antenna impedance matching and is defined by the ratio between the reflected power, Pr, to the antenna's incident power,Pi

$$|S_{11}| = 10\log_{10}\frac{P_r}{P_i}$$

(1)

To determine the operating band of an antenna there is one condition that must be satisfied.

$$|S_{11}| \le 10$$
$$P_r \le P_i \times 0.1$$

(2)

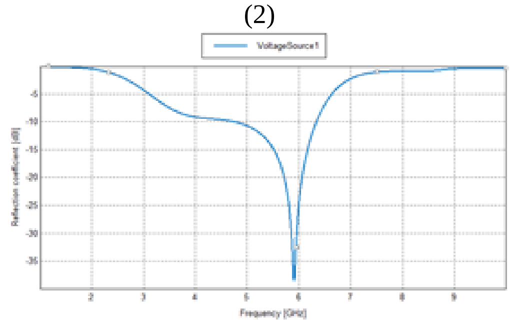
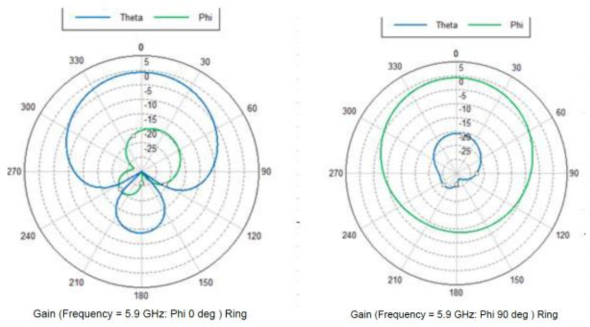


Fig 2. S-parameter for the reference element

Observing figure 2, it can be concluded that the described element has resonant frequency band at 5.9 GHz (DSRC Band operations), being described as a single -band antenna.The design of the structure was made using the FEKO software, where were also carried out all the simulations of this work.



(a) (b)

Fig3. Radiation pattern for 5.9GHz of the reference element in different planes

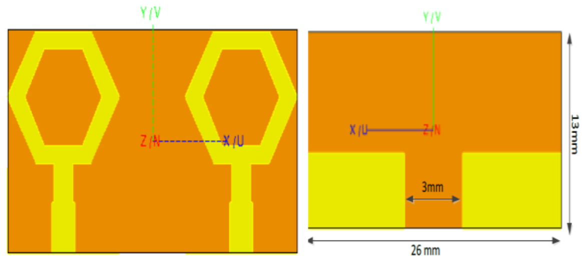
In figure 3, a polar representation of the radiation pattern of the element of reference at 5.9 GHz is shown. Acccording to the radiation pattern result, this type of anten
is Omni-directional radiation pattern.

B. Two-element antennas

Significant SNR improvement and added gain is expected when using diversity systems, which areevaluated by three main parameters: correlation coefficient, diversity gain and antenna efficiency. Onthis paper, only correlation coefficient will be presented and discussed.

$$\rho_e = \frac{\left|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}\right|^2}{\left(1-\left(\left|S_{11}\right|^2 + \left|S_{21}\right|^2\right)\right)\left(1-\left(\left|S_{22}\right|^2 + \left|S_{12}\right|^2\right)\right)} \quad (3)$$

2x1 MIMO configurations are a basic additionof two referenced elements spaced by a substrate layer of 3mm. It is important to note that, inevery 2-element antenna that will be proposed inthis section, "port 1" refers to the element displayedon the left and "port 2" the other one. Figure 4 refers to a structure that is composedby two reference elements displayed parallel to eachother (spatial diversity).

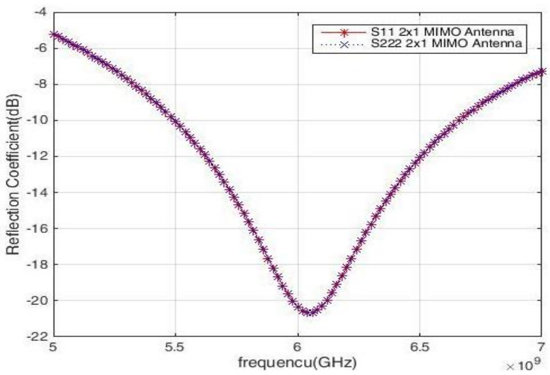


(a) Top View (b) Bottom View

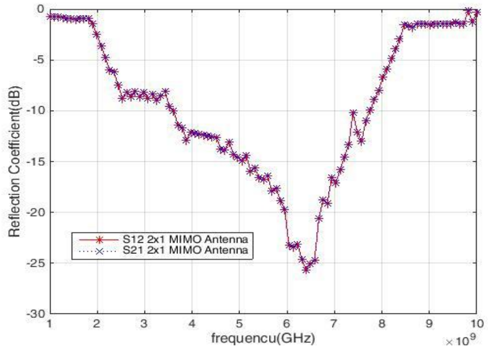
Fig 4. Geometry design of 2x1 MIMO antenna

Observing the S-parameter present in figures 5, it is noted that some mutual coupling between ports 1 and 2 is present, especially of the resonant frequencies (it’s concluded because curvesS11 and S22 overlap on S12 and S21).

However, the resonance at the higher frequency has registered a shift for lower frequencies (approximately 5.9GHz), which can be possible due to the mutual coupling registered. The correlation coefficient between ports shows satisfactory results, despite showing a peak very close to 6 GHz. Spatial diversity technique was first investigated for MIMO antennas with low correlation between multiple antenna elements, and achieved using EMCP(electromagnetic coupled patch antenna) and the meandering patch method.



(a)



(b)

Fig 5. Simulated results for 2x1 MIMO antenna (a) S-parameters (b) Isolation

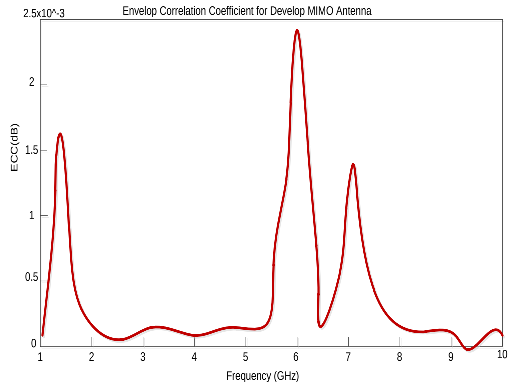


Fig 6. Ports correlation coefficient for 2x1 MIMO antenna

For MIMO applications, spatial correlation is one of the key factors that influences system performance. If antenna spacing is insufficient or the scattering environment does not provide completely uncorrelated channels. MIMO systems where multipath fading is only partially correlated could use polarization diversity to provide a higher diversity gain.

Figure 8 illustrates a two-element MIMO antennausing polarization diversity. The element on theleft is placed vertically, while the other is placedhorizontally, according to the standpoint presented in Figure 7 (the elements are placed orthogonally,resulting in polarization diversity). Comparing theresults obtained with the structure previously investigated, it is concluded that mutual coupling hasdecreased, as well as the peaks of the correlation coefficient (approximately 1.3, Figure 9).

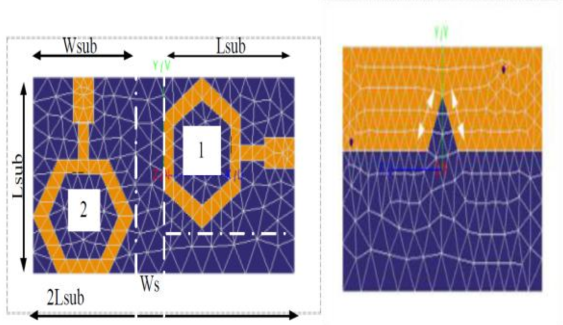
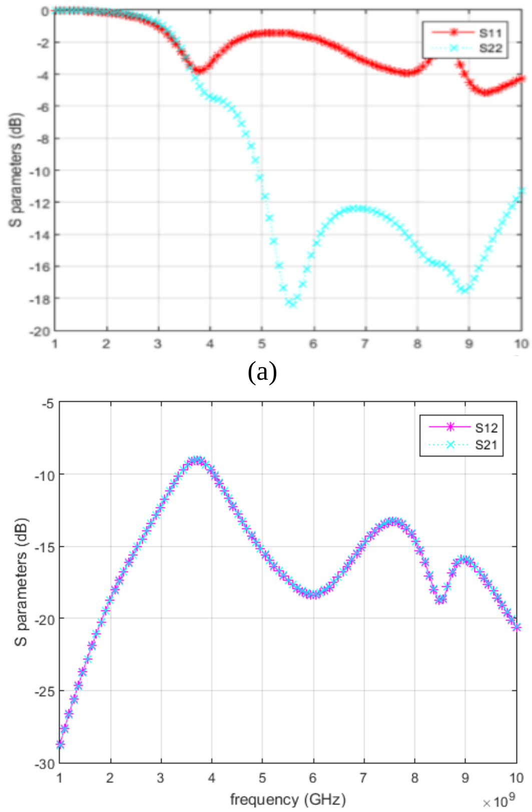


Fig 7. Ports correlation coefficient for 2x1 MIMO antenna



(a)

(b)

Fig 8. Simulated results for 2x1 MIMO antenna (a) S-parameters (b) Isolation

The results regarding theS-parameter are good as is shown in Figure 7.Correlation coefficient plot also shows reasonablevalues. Looking at the S-parameter results, signalsperform to be perfectly decoupled. However, overallresults are not better than those presented in figure 9. Analyzing the discussed structures, the one that turns out to be the best solution for vehicular applications is the antenna simulated and presented.

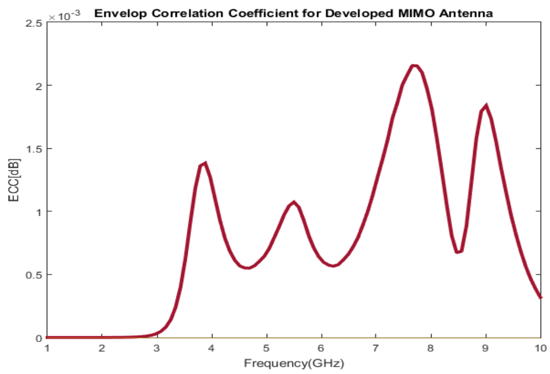


Fig 9. Ports correlation coefficient for 2x1 MIMO antenna

IV. CONCLUSION

Base on the two designs, we can conclude that two techniques of spatial and polarization diversity are the common choice for MIMO array systems. The simulation result of first element is satisfied for intelligent transportation system. And then, the other two designs is also satisfied for vehicular communication. Although spatial diversity method is more satisfied return loss and isolation, diversity method is the best ports correlation coefficient for 2x1 MIMO antenna design. Therefore, all three design could be proved the utilizing of the special purposes for vehicular communication network application.

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