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Design of Circularly Polarized MIMO Antenna using Defective Ground Structure for Wireless Applications

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ABSTRACT: This paper presents a compact, circularly polarized multiple input-multiple output (MIMO) antenna with wideband axial ratio bandwidth (ARBW). The designed MIMO system consists of four identical tulip-shaped radiating elements with defected ground structure. The designed MIMO antenna covers 3.34-10.70GHz ultra-wide band range with 44 dB isolation. FR4 dielectric substrate with loss tangent 0.02 of size 70.7 x 70.7 mm^2 is used for the antenna prototype. The diversity performance of this MIMO antenna system is reported in terms of gain 3.40dBi, and return loss 44.67dB. It is applicable for all ultra-wide band range high speed wireless applications, future mobile handset, microwave imaging and satellite communication.

KEYWORDS:UWB, DGS, VSWR, MIMO.

I. INTRODUCTION

In recent years, the communication system rapidly changing from wired to wireless. In a high-performance application such as spacecraft, satellite, missile, aircraft, or many commercial and government applications, mobile communication, wireless communication the high data rate antennas are required. To complete this kind of requirements and specifications like low cost and compactness, the microstrip antennas are used. [1]The capacity of a single feeding antenna is very low. To increase the capacity and working efficiency multiple-input multiple-output (MIMO) technique is used. To reduce the effect of co-channel interference, high isolation the MIMO antenna is used. To overcome the drawbacks of SISO the MIMO system is used. In SISO there is only one user can communicate at a time with low capacity but MIMO technology replaced single users with multiple users.

In wireless communication, “Multiple Input Multiple Output” that is MIMO has a very tremendous history.in 1950 the MIMO communication system was discussed when it was used in electric circuit and filter theory. Then In the 1990s, theoretical information of the communication system referred for new signal processing techniques that were developing for multiple antennas used in the communication system.in this tremendous research, the multiple input concept refers to the signals coming from the transmitting section and multiple-output term as receiving signals. In an application like mobile handset, if we place multiple antennae closely in array the radiation pattern of these multiple antennas between transmitting and receiving antennas may generate the signal distortion. When the mutual coupling is high then automatically capacity of the antennas gets reduced and also the correlation coefficient increased. To conclude the better performance of any antenna system, the multiple antennas should be suppressed.[2]Diversity techniques such as space diversity, pattern diversity, polarization diversity is traditionally used in MIMO antenna system to control the mutual coupling factor.

II. LITERATURE SURVEY

On the basis of literature surveytwo closely packed coupling element used to enhance the isolation at the same operating frequency band. The isolation of this antenna enhanced by creating an additional artificial coupling path to a neutralized coupling between the two-antenna element. This antenna design for the USB Dongle for frequency 2.4 GHz which was generally for WLAN Band. The isolation provided by this antenna was about 30 dB even though there were two parallel individual planar inverted F antenna (PIFA) in the antenna structure[3].[4]Pointed a comparative analysis of three isolation techniques to enhance the isolation in the MIMO system. These techniques include first a defected ground structure (DGS) with dumbbell shaped defect on ground, a metamaterial structure (MTM)with a spiral square shaped pattern and a neutralization line (NL). [5] This neutralization line wasn't necessary to place between the two-antenna element it can be also placed between copper ground. This antenna covers the band of 3.1-5 GHz with isolation higher than 22dB which was achieved by using the decoupling method. The neutralization line present in this antenna has two metal strips and a metal circular disc. The coupling current on the ground plane was removed by producing a decoupling current with the circular disc [6]. The addition of the neutralization line between MIMO element will degrade bandwidth and without the neutralization line, the mutual coupling becomes higher which reduced return loss.[7]**.** the history of wireless communication and mutual coupling reduction techniques explained in [8] It specified that many researchers work to enhance the channel capacity, diversity, gain, Bit Error Rate (BER) of the MIMO system but still the researcher having the opportunity to study techniques that used to improve isolation and reduced mutual coupling.[9]In this review, the history of wireless communication and several mutual coupling reduction techniques was described.This work specified some fields where the MIMO antenna used, the interesting areas are related to portable devices, wireless applications, automotive applications, handheld devices, and next-generation application i.e., 5G and beyond**.[10]** Introduced the multi-cut with a four-port common radiator using the partial stepped ground for frequency 5.2GHz of wireless application. The multi-cut rectangular antenna design was fabricated on the top side of the substrate and stepped ground design on the back of the substrate. In this design, there was no isolation technique was used rather then it provides sufficient isolation. This isolation was by introducing multiple cuts in the patch and partially stepped ground.

III. DESIGN METHODOLOGY

A. DESIGNING OF PROPOSED ANTENNA

To design the MIMO antenna there is required to study deeply in microwave engineering field. Many research paper, books, journal[11],[12] and internet become source to give the information. In many application antennas used as wireless device for that purposed the antenna should have better isolation return loss and bandwidth. To achieved this requirement the study of various MIMO antenna is required. The theoretical dimension can help to design the antenna with approximate parameter. This parameter we can change as per our requirement.

The proposed antenna design and simulated using CST. CST MICROWAVE STUDIO is the very powerful solution and easy to handle the electromagnetic field simulation software. CST MICROWAVE STUDIO is version of CST STUDIO SUIT. It is the best featured software for the analysis of electromagnetic field travelling from antenna. The antenna can be design for lower as well as higher frequency range also.

The proposed antenna is circularly polarized the schematic view of antenna as bellow

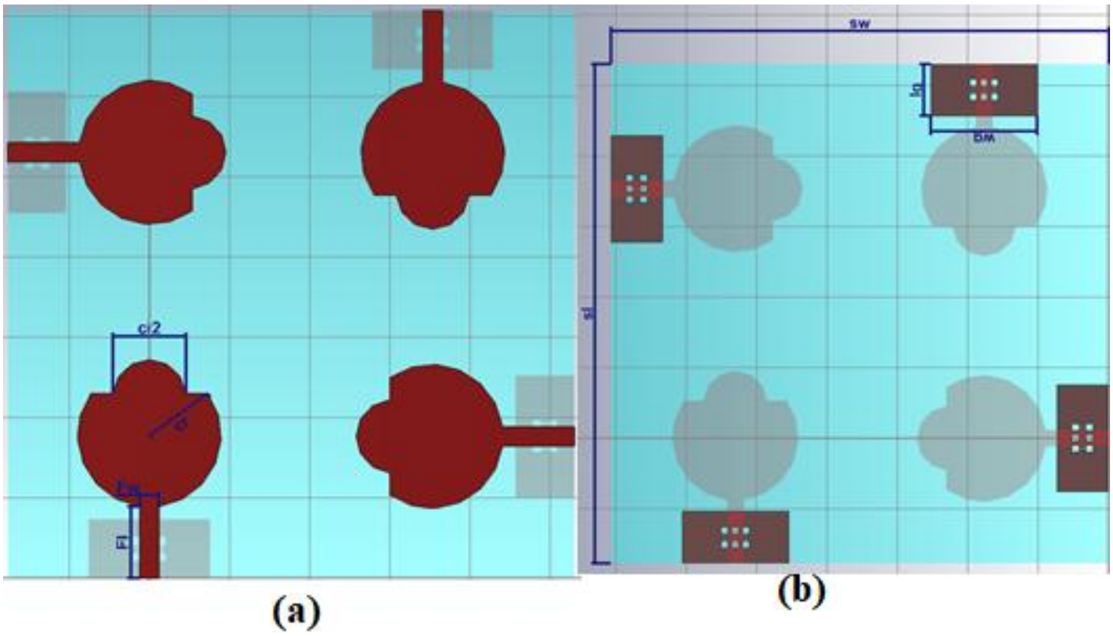

Fig. 1. The schematic view of antenna

Parameter	***sw***	***sl***	***wg***	***lg***	***fw***	***fl***	***cr***	***cr2***
Value	70.7	70.7	15	7.4	2.4	8.91	8.96	8.01

B. STEPS FOR DESIGNING ANTENNA.

1. Design specification identified by determining and calculating dimension of patch antenna
2. Defined Geometrical parameter and require material of antenna.
3. Determine antenna dimension and element spacing

4. Run the simulation
5. Check optimum result .it result are satisfied then next steps is exist otherwise we have to redesign antenna.
6. Optimized the designed antenna
7. Run the simulation
8. test the antenna

IV. SIMULATED RESULT

The proposed circularly polarized MIMO antenna system design for wireless application range 4.6-10.6 GHz frequency with dimension 70×70 mm^2. This arrangement reduced the effect of mutual coupling between two radiating elements. Partial ground with DGS provides high return loss and low mutual coupling between the radiating elements[13]. The proposed MIMO antenna system with 50 Ω ports is originated using a computer simulation tool (CST Microwave Studio 2015) version 12.0.

The first result shows the graph of s parameters which specified the S_{11} as reflection coefficient and S_{11} as transmission coefficient. This are the important parameter to explain the transmission between two microstrip line that is two radiating elements[14]. The return loss is generated because of the low impedance matching between two antennas. The return loss of proposed antenna is -44.677dB as in fig.2.

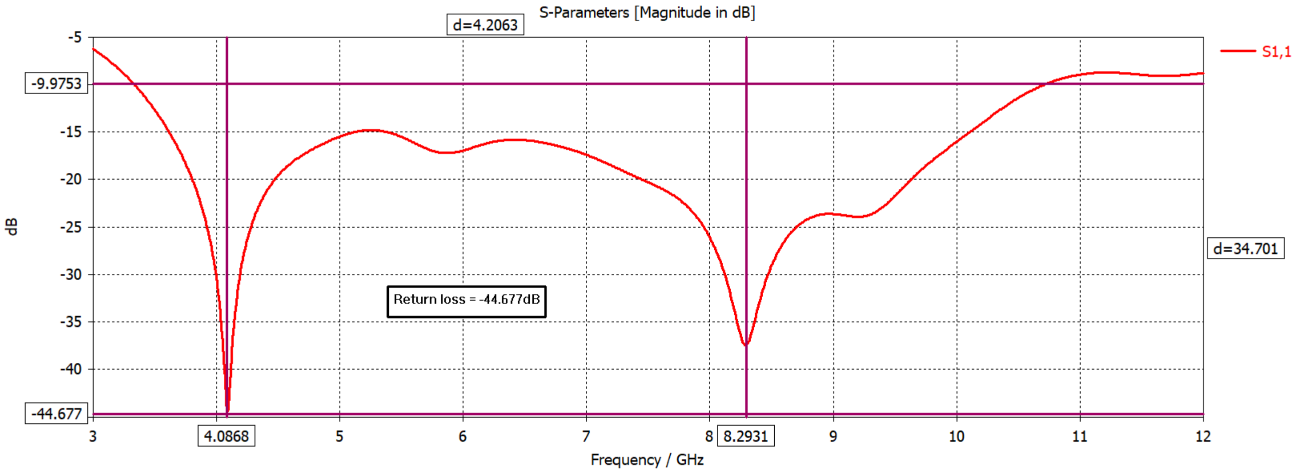

Fig. 2. Simulated result of S_{11} parameter of the proposed antenna with return loss

A. *ISOLATION*

Another fundamental parameter of antenna is isolation which is used to specify the transmission coefficient. Isolation state the mutual coupling between two radiating elements[15]. Isolation is calculated using S_{12} scattering parameter. In the proposed antenna there is the use of defected ground structure and circular polarization hence the evaluated isolation is up to -42.61dB. The graphical representation of isolation is shown in fig.3.

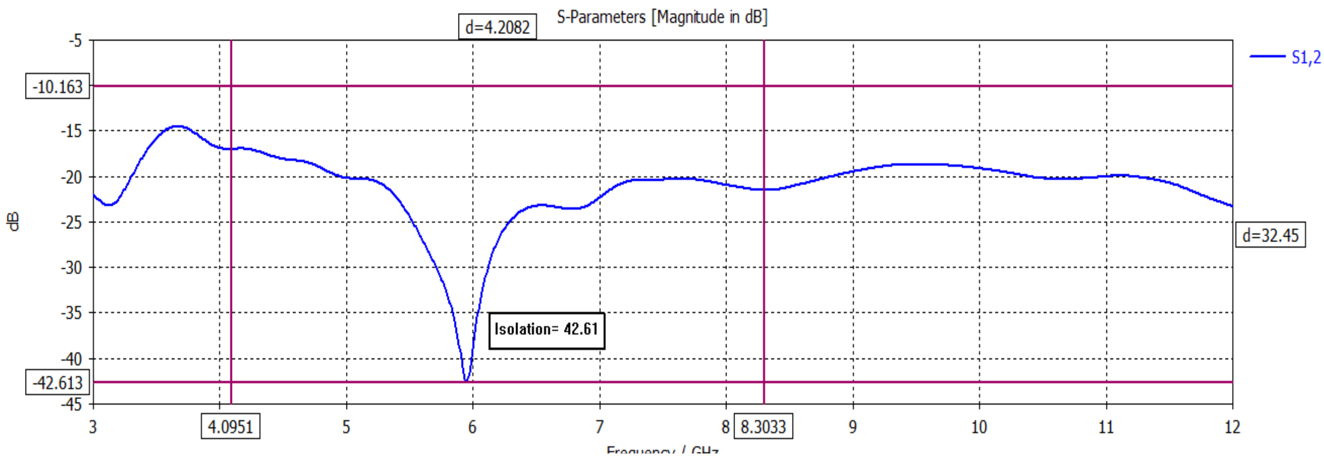

Fig. 3. Simulated S_{12} parameter with isolation

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B. GAIN

The Gain of the antenna specifies the overall performance of the antenna. It is the key fundamental parameter that defines the radiation of power rate from one transmitting antenna to the receiving antenna. The gain is specified in dB and dBi. The unit dBi stands for the gain of an isotropic antenna. While the gain is nothing but the comparison of the practical antenna with the isotropic ideal antenna[16]. The overall gain of this antenna is 2.69dBi. Gain of designed antenna is shown in fig.4.

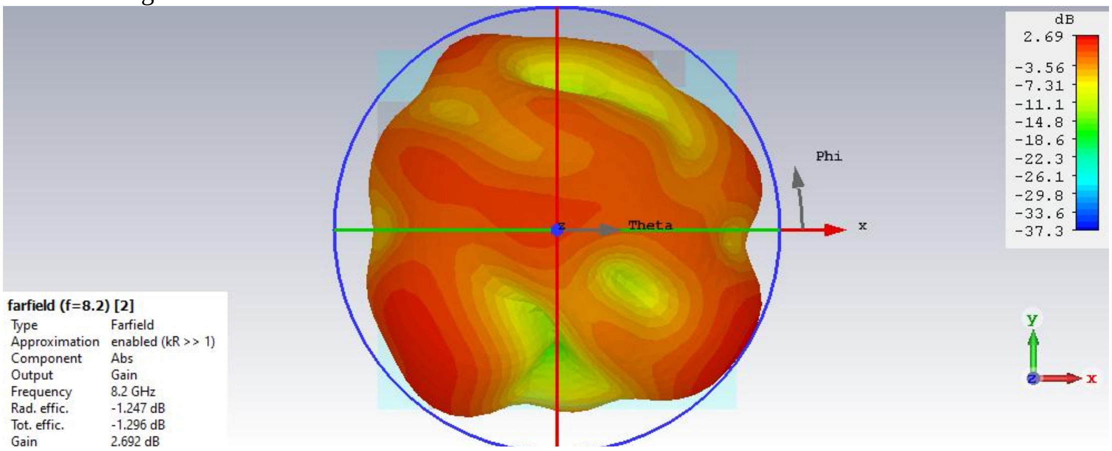

Fig 4. Gain of port 1 of the proposed antenna

C. FAR FILLED RADIATION PATTERN

The far-field characteristics of the proposed design explore the normal condition of electromagnetic radiation. In this far-field region, the field distribution from an antenna does not depend on the distance from an antenna. The H field and E field radiation pattern of proposed antenna shows in fig.5& fig.6. These matrices perform a dominant role while testing a MIMO antenna in wireless environments. This parameter shows the channel correlation while the channel is correlated or not. It is responsible for better channel capacity.

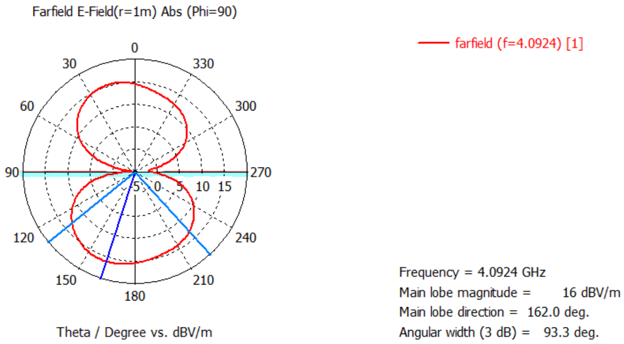

Fig. 5. E-field pattern of port 1 of proposed antenna.

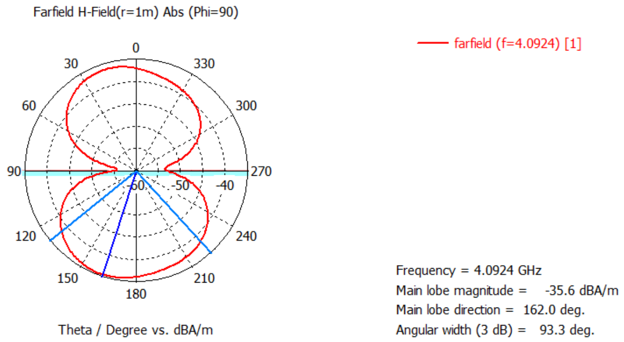

Fig. 6. H-field pattern of port 1 of proposed antenna.

D. VOLTAGE STANDING WAVE RATIO

When the power of antenna is not acceptable at another point then it may be reflected back and crate some standing wave that is the reflection coefficient which then names as Voltage Standing Wave Ratio (VSWR).

If we talk about mathematical expression the then the ratio of maximum and minimum voltage present in the transmission line during communication. Although it is also related to the power of the antenna. So, the formula as below:

$$s = \frac{V_{max}}{V_{mim}} = \frac{I_{max}}{I_{min}} = \frac{|V_{forw}| + |V_{refl}|}{|V_{forw}| - |V_{refl}|} = \frac{\sqrt{P_{forw}} + \sqrt{P_{refl}}}{\sqrt{P_{forw}} - \sqrt{P_{refl}}}$$

VSWR is closely related to the reflection coefficient of the antenna. Then in terms reflection coefficient calculated as a ratio with an amplitude of both reflected wave V_{ref} to incident wave V_{forw} :

$$\Gamma = \frac{V_{refl}}{V_{forw}}$$

So the VSWR is:

$$VSWR = \frac{1 + |\tau|}{1 - |\tau|}$$

The VSWR of the designed antenna is shown in fig.6 which is 1.01.

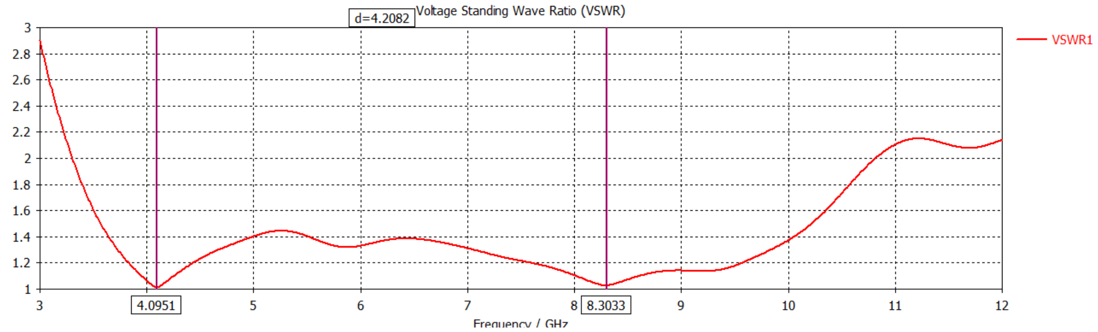

Fig. 7. VSWR of proposed antenna

V. CONCLUSION

A circularly polarized 2x2 MIMO antenna is designed with defected ground structure for UWB range 4.6zHz to 10.6GHz range which shows 7.5GHz bandwidth. A parametric analysis has also been performed to achieve the optimal performance of the designed MIMO antenna. The proposed antenna has demonstrated a high impedance bandwidth and a peak gain of 2.69dBi. This MIMO antenna can be extended to four, eight, or in an array with proper dimension. The designed antenna can be used on a practical basis in the application of microwave imaging and future mobile handset application.

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