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DESIGN AND IMPLEMENTATION OF 2X2 MIMO SYSTEM FOR S-BAND APPLICATIONS

Subhasri.K[1], Srividhya.K[2]

[2]*Assistant Professor, Sri Venkateswara College Of Engineering,Sriperumbudur*

E-Mail: **Subhasrikumar27@gmail.com**

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Design and Implementation of 2x2 MIMO Systems for S-Band Applications

***Subhasri.K*[1], *Srividhya.K*[2]**
[1]*P.G.Scholar* [2]*Assistant Professor,*
Sri Venkateswara College Of Engineering, Sriperumbudur, Tamilnadu, INDIA.

E-Mail: ***subhasrikumar27@gmail.com***

ABSTRACT

A 2X2 multiple-input multiple-output (MIMO) patch antenna system is designed for S-Band operation. It uses complementary split-ring resonator placed on its ground plane for antenna miniaturization. The software used for this design is Advanced Design System. This reduces the single-element antenna size by 70%. Measured results are in good agreement with simulations. The total board size of the MIMO antenna system including the ground plane is 50x50x0.8mm^3, while the single-patch antenna element has a size of 14x18 mm^2.The antennas is fabricated and tested. The maximum measured gain for a single operating element is 0.8 dBi.

***Index Terms* —** Complementary split-ring resonator (CSRR), S-Band, MIMO antennas, Antenna miniaturization.

1.INTRODUCTION

In conventional methods, such as introducing higher modulation types or providing larger bandwidths, this is also being achieved by using multiple antenna systems. We present characteristics of microstrip patch antennas on metamaterial substrates loaded with complementary split-ring resonators (CSRRs). The proposed antenna utilizes CSRRs in the ground plane altering the effective medium parameters of the substrate. Simulation results were verified by experimental results. The experimental results confirm that the CSRR loaded patch antenna achieves size reduction and keeping the bandwidth intact as well. The design gets more challenging in the lower bands where the antenna size increases.

Multiple-Input-Multiple-Output or MIMO is one of the latest forms of smart antenna technology to improve communication performance. The concept of spatial multiplexing using MIMO was first introduced in 1993. In the commercial area, the first system was developed in 2001, where MIMO was used with orthogonal frequency-division multiple access technology (MIMO-OFDMA), which supported both diversity coding and spatial multiplexing. The introduction of MIMO technology proved to be one of the best techniques to enhance the channel capacity within the available bandwidth and power. Recently, microstrip antenna designers also employ MIMO technology, where they use two or more radiating patches in the design for transmission. In the past decade, several MIMO/ Diversity antennas have been proposed that exist in the literature, out of which a few are designed to operate in the frequency range of 3.1 to 10.6 GHz, suitable for UWB applications.

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While designing compact antennas, antenna miniaturization techniques are used that can yield low antenna bandwidth, efficiency, and gain. Similarly, in a compact design, the antenna elements are placed close to each other, resulting in high correlation between the antenna elements and therefore poor diversity performance. Thus, in the design of a MIMO antenna system, it is important to employ antenna miniaturization techniques that keep the antenna design simple and its compromise with the other antenna parameters is at a minimum.

2.LITERATURE REVIEW

Microstrip patch antenna is widely used because of its features like low cost, low profile and less design complexity [1]. In [2], a four-element compact MIMO antenna was designed to operate in the 2.48-GHz band. The antenna was made on a two-layer substrate. It was made up of a planar inverted F-antenna (PIFA) array on one layer, while a slot antenna was used on the other layer. In [3], a compact four-element antenna with isolation better than 24 dB was designed. The antenna elements were made up of quarter wavelength slot antennas.

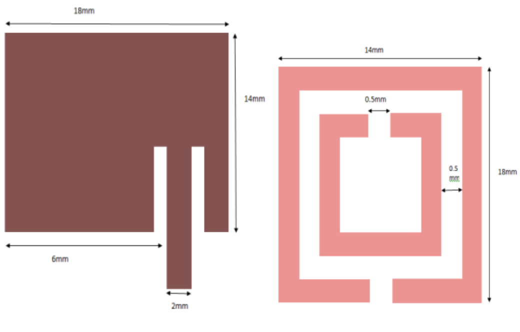
In [4], a three-element MIMO antenna was designed using three triangular patch antennas. The antenna resonated at 2.65 GHz. The antenna was characterized with high gain and wide beam characteristics. In [5], a modified printed inverted-F antenna (PIFA)-based four-element MIMO antenna was proposed. The antenna was analyzed for all MIMO antenna parameters. The operating bandwidth of the antenna was 400MHz covering the range of 2.4–2.8 GHz. In [6], a four-element four-shaped MIMO antenna system was proposed. The antenna resonates the frequency in 2.5-GHz at S-band operation. Patch antennas have been widely used due to their ease of design and fabrication. Several methods have been presented to reduce the size of patch antennas. These methods include the use of shorting posts [8], loading of reactive elements [7], Recently, complementary split-ring resonators (CSRRs), meta-material elements, have been used with patch antennas for antenna miniaturization. In all of the previous work, CSRR loaded miniaturized patch antennas were used in applications that require only a single antenna. Such patch antennas were never extended and analyzed for MIMO antenna systems. Also in many of the recently proposed MIMO antennas, most of them did not utilize patch antenna elements. Those designs that used modified patches had dimensions that were not very compact, thus making them not useful for mobile applications [9]. The rest of the paper is shown as follows.

3. DESIGN OF MIMO PATCH ANTENNA SYSTEM

The CSRR loaded patch based MIMO antenna system was first proposed. It uses the substrate of FR4 with $\varepsilon r=4.4$ and thickness t= 1.6mm. The dimension of an individual patch was 14x18 mm^2. The Underneath CSRR of each patch was 7 mm, the width of each ring *(w)* was 0.5 mm, the spacing between the two rings *(s)* was 0.5 mm and the width of slit in each ring *(d)* was 0.5 mm. The single element was simulated in ADS where its resonant frequency was found to be 2.55 GHz. Four such elements were then placed with a spacing of 12 mm to make a 4-element MIMO antenna system. Thus the total size of the antenna system was $50x50\times0.8$ mm^3.

This paper presents a novel design of a 2x2 (four-element)MIMO patch antenna system, which has highly compact patch elements. The elements of the proposed MIMO antenna system consist of four identical patch antennas loaded with CSRRs.The operating band of the proposed antenna is the S band with a resonant frequency of the antenna elements centered at 2.8 GHz. A 60% reduction in the size of the individual patch is achieved through CSRR loading, thus allowing the accommodation of the four patch antennas in an area of 50x50 mm with 10 mm spacing between them.

A 2x2 (four-element) MIMO antenna system was made using the same patch design shown in Fig.2. in an area of 50x 50 mm. The spacing between the patch antenna elements was 10 mm. The top and bottom layers of the proposed design are shown.



(a) (b)

Fig.1. A single shaped MIMO antenna system (a) top view and (b) bottom view

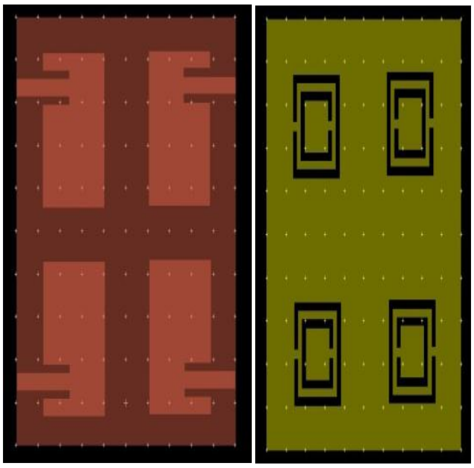
While designing compact antennas, antenna miniaturization techniques are used that can yield low antenna bandwidth, efficiency, and gain. Similarly, in a compact design, the antenna elements are placed close to each other, resulting in high correlation between the antenna elements and therefore poor diversity performance. Thus, in the design of a MIMO antenna system, it is important to employ antenna miniaturization techniques that keep the antenna design simple and its compromise with the other antenna parameters is at a minimum. The mathematical expression for calculating length, width and center frequency can be shown below,

$$Width\ W = \frac{c}{2f0}\sqrt{\frac{2}{\epsilon r+1}} \qquad (1)$$

$$Length\ L = Leff - 2L \qquad (2)$$

$$Center\ Freq\ fc = \frac{c}{2L\sqrt{\epsilon r}} \qquad (3)$$

We can add it for different shapes for DGS substrate. The different shapes of DGS shapes with their corresponding isolation and frequencies were shown in tabular column. The DGS (Defected Ground Structure) may come in a variety of geometries and sizes, depending upon their mode of application, as well as the frequency of operation. Some of the shapes and their frequency and isolation such as CSRR, dumb-bell, concentric ring, H and cross shape can be shown in table1.



(a) (b)

Fig.2.A 2x2 MIMO antenna system (a) top view and (b) bottom view

A CSRR etched out underneath a patch antenna actually changes the characteristics of antenna cavity, and thus its resonance frequency is shifted. Since a CSRR is an anisotropic element, its orientation has a profound effect on the resonant frequency of the antenna apart from its dimensions. For different shapes of DGS substrate, we compare the results with various enhancements like bandwidth, isolation, gain and directivity. The main aim is to enhance the isolation.

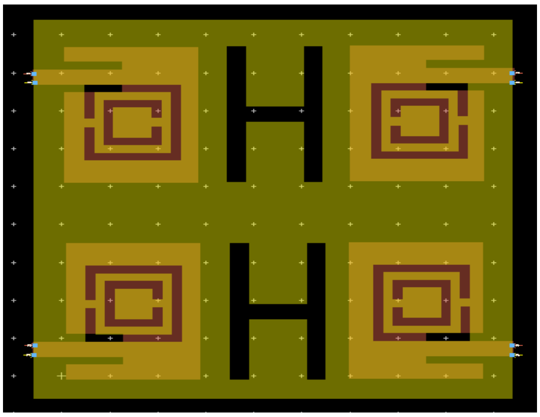


Fig.3.complete design for center etched H-shaped DGS substrate.

The simulation result for center etched H-shaped DGS substrate has resonated the frequency at 2.806GHZ at S-band applications and the result can be shown in fig.5.Tabular column for different shapes of DGS substrate can be shown in table1.

DIFFERENT SHAPES	FREQUENCY (GHz)	ISOLATION (dB)
CSRR	2.586	9.5
Dumb bell	2.665	7.4
H-shape	2.806	14.46
Concentric Ring	2.704	10.98
Cross-shape	2.330	10.89

Table 1: Different shapes of DGS substrate with isolation and their frequencies.

4. ANTENNA DESIGN AND RESULTS

The proposed antennas described in the previous section were first designed and tuned in HFSS. They were then fabricated. The scattering S- parameters of the MIMO antennas were measured using the Agilent network analyzer. The two dimensional gain measurements of the MIMO antennas were carried out at an outdoor antenna test facility.

The 3D-pattern for MIMO patch antenna system can be shown in fig.4. The simulated results can be discussed in section 1V.Calculating and optimizing the both patch, inner and outer to get the required resonant frequency, which as radiating element. The length of inner rectangular ring and both of small rectangular patches has been optimized to control the bandwidth of microstrip antenna.

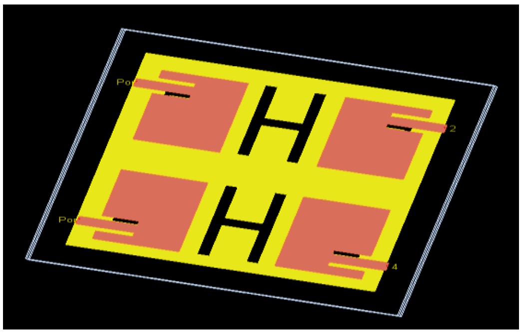


Fig.4.3D pattern for 2x2 MIMO antenna

A steps involved in designing a substrate can be shown in table. Connect a pin at the feed point of the antenna as shown below. Go to the EM setup window and click on Substrate and click on new to accept the 1.6 mm FR4 and is ghown in figure.

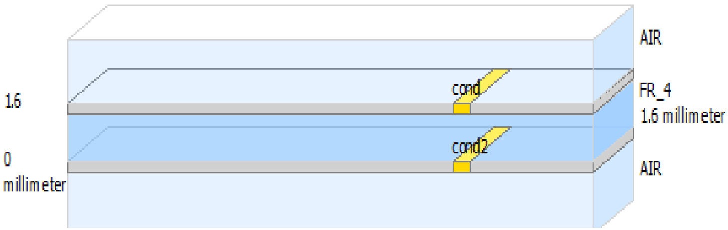


Fig.5.A substrate of 2x2 MIMO antenna system.

A 2x2 (four-element) multiple-input multiple-output (MIMO) patch antenna system is designed and fabricated for S-band operation. It uses complementary split-ring resonator (CSRR) loading on its ground plane for antenna miniaturization. The single-patch antenna element has a size of 14x18 mm^2. The antenna is fabricated and tested. The Efficiency for the antenna design is reduced to be 60%. Fig.6. shows the simulation result of MIMO antenna system by generating the frequency at 2.806GHz.

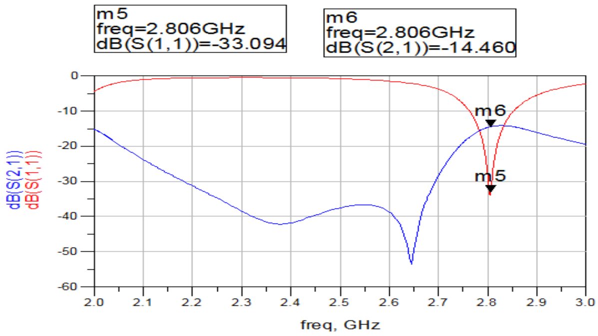


Fig.5.Simulated result for H-shaped DGS substrate.

The gain obtained for this MIMO antenna system is 0.347dBi and the directivity can be displayed as 3.46dBi.The efficiency optimized for a single antenna element is 60%.The antenna parameters for gain, directivity and the received parameters for this design can be shown in figure.The results can be analyzed and compared with different shapes of DGS substrates

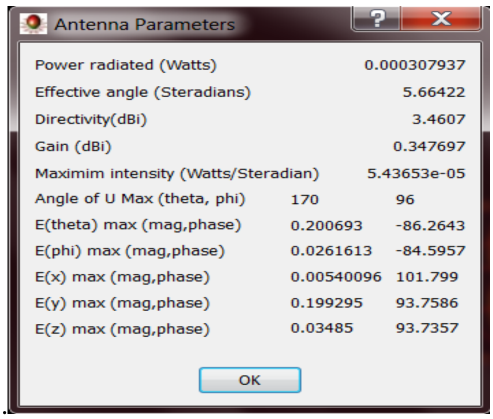


Fig. 7.Antenna parameters of 2x2 MIMO system

5. CONCLUSION

All the simulation results show that the microstrip array antenna performs better than the single patch antenna. The radiation pattern of the microstrip array antenna is better than the single patch. These simulations lead to the conclusion that the number of patches in an array is directly proportional to the efficiency of the antenna. If we increase the number of elements in the array, the radiation pattern will improve further. The technique was simple and easy to implement. It increased the isolation without any major effect on any other parameter of the antenna. Thus, the proposed technique can be implemented for any MIMO antenna system based on the CSRR loaded patches. Another important conclusion that was deduced from all the experiments that were made during the design of this antenna was that impedance matching is very important. Efficient results were only obtained when the impedance of the system was perfectly matched to 50 Ω.

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