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Design and implementation of MIMO antenna for Ku-band applications

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Abstract: This paper presents the designing and implementation of MIMO antenna for operation in Ku-band. The resonant frequency of antenna is 14.7 GHZ. Firstly, the single Micro-strip patch antenna were designed with the dimension of L=6.5×7.90mm2.Next,this single microstrip patch antenna is implemented in MIMO scenario with four radiating patches implemented on substrate orthogonally in such a way that to keep mutual coupling among radiating patches is less than -20db.This antenna has been simulated on Rogers RT5880 with dielectric constant of 2.2.The parameters like mutual coupling, impedance bandwidth, gain, directivity and efficiency of both the single radiating element and MIMO antenna is compared.

Keywords: MIMO, Mutual coupling, Ku-band, VSWR, Gain.

I. INTRODUCTION

Microstrip patch antenna is the center of focus, of the researchers because of light weight, compact in size and easy to fabricate, however, beside their usefulness there exist some disadvantages like narrow bandwidth, lower power handling capabilities, higher level of cross polarization radiation and low efficiency (Constantine, 2016). The MPAs consist of metallic patch and ground, and in between them a dielectric material called substrate. The dimensions of the patch affect the resonant frequency. The substrate of MPAs affect the electrical performance of the antenna, however, it is used for providing mechanical support. For antenna exciting, the feedline is used to radiate with or without direct contact. There are several methods adopted by the researcher to excite the antenna like “coaxial probe feed”, “line-feed”, inset feed etc. The careful selection of feedline is required because it affects VSWR, transmission bandwidth, losses etc. (Kumar *et al.*, 2013).

In (Ahmad *et al.*, 2017) a patch antenna with slotted ground plane is proposed which achieves a wide Impedance bandwidth of 6.12GHz, a return loss of 48.48dB and efficiency of 74.25 at center frequency. An EBG based patch antenna is presented by (Ripin *et al.*, 2012), where a smaller size antenna is shown to achieve greater performance (bandwidth) compared to its counterpart (i.e., antenna having no EBG). The Impedance bandwidth and resulting losses are the basic parameters through which one can judge the performance of the antenna. (Rameswarudu *et al.*, 2016) enhanced the impedance bandwidth by 55.19% and achieves the return loss of -45.0674 dB with the help of damaged structure of ground and slotted patch.

Due to the increased use of wireless communication, MIMO has been an interesting area of research and attracting the attention of developers/scientists for next generation developments. MIMO technology enhances the effect of multipath and channel capacity of the antenna; however, the performance is a bit degraded because of the mutual coupling.

To resolve this issue, researchers have been focusing on developing decoupling structures. However, most of them employ metamaterial or EBG structure to get low mutual coupling (Luo *et al.*, 2018). (Jiang *et al.*, 2018)proposed an antenna design with reduced coupling where they have incorporated multilayered EBG structure with antenna array for surface wave suppression.

In this paper, MIMO antenna system with orthogonal radiating elements structure for decoupling of radiating elements is proposed. First, Single microstrip patch antenna is designed for at 14.77GHz. Next, the same dimensions of the Radiating elements are transformed into MIMO scenario with four radiating patches with distance between the patches is 0.13λ, and all the patches are orthogonal for reducing the mutual coupling while keeping the design compact. Next, a comparison is performed between the performance of MIMO based antenna and single element one. The results prove that that MIMO technology not only enhances the channel capacity, but it also improves the gain, directivity, efficiency and radiation pattern.

2. DESIGN METHODOLOGY OF THE ANTENNA

Fig. 1 shows the design of patch antenna based on the rectangular Microstrip. It uses the material including Rogers “RT 5880”. This material is “0.508” mm high and it has 2.2

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dielectric constant. The patch's other dimensions (length/width) are 6.5×7.90mm.The height of radiating material is 0.035mm. The exciting of the patch is carried out via line feed with the length and width of the feedline is 1.524mm and 0.56mm respectively.

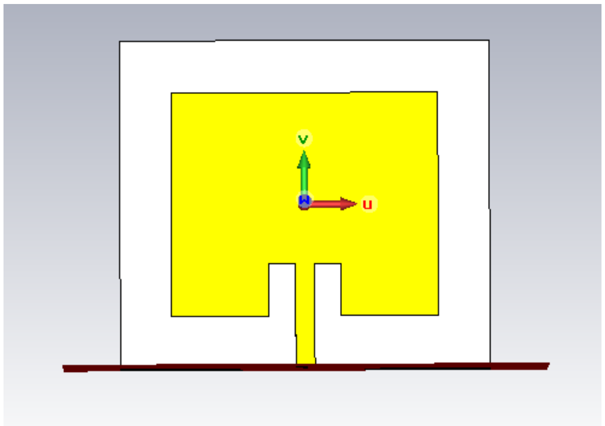


Fig.1.Single patch antenna

After getting the Dimension of single radiating element of antenna we move on toward more complex design terminologies which is MIMO antenna structure. In proposed MIMO antenna structure, there are four radiating elements with their own excitation ports. Firstly, the patches are placed parallel to each other as shown in (Fig. 2a).The radiating patches are then placed orthogonal for suppressing the mutual coupling as depicted in (Fig. 2b), and compare the performance of two different design with each other.

3. RESULTS AND DISCUSSIONS

A. *MUTUAL COUPLING*

The energy radiated by one antenna radiating element is absorbed by the other antenna element is termed as mutual coupling. The MIMO technology is adversely affected by the mutual coupling. It also introduces power loss when the radiating elements are close to each other and hence degrades the outage capacity of the MIMO system.

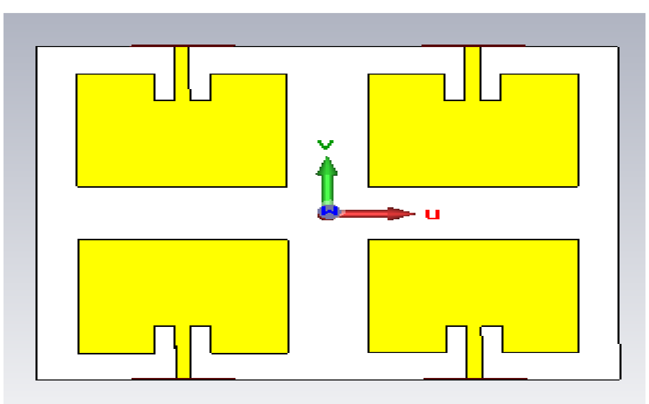


Fig. 2a. parallel alignment of patches

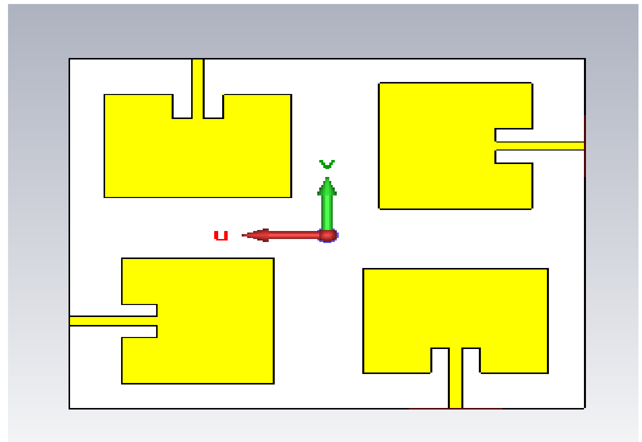


Fig. 2b. Orthogonal alignment of patches

The mutual coupling of the two different MIMO design are shown in (Fig.3a) and (Fig.3b) respectively. In the design shown in (Fig.3a) has isolation starts from -17.75 dB and goes upto -34.75 which is not satisfactory in case of KU-band. Now, in comparison the design shown in (Fig.3b) in which radiating patches are orthogonal to each other has scattering matrix values starting from -28.28 dB to -46.05 dB in the entire operating region (13-17 GHz).

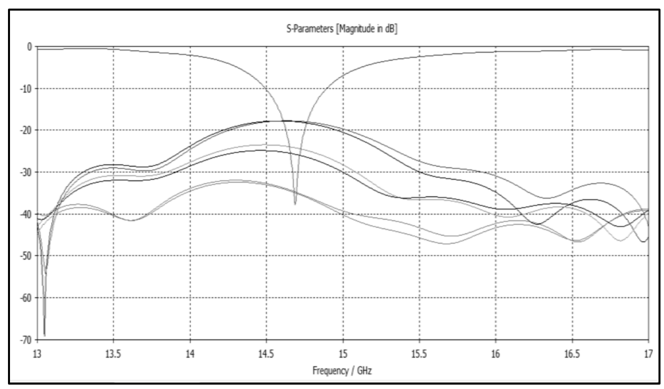


Fig.3a. Mutual coupling of parallel alignment

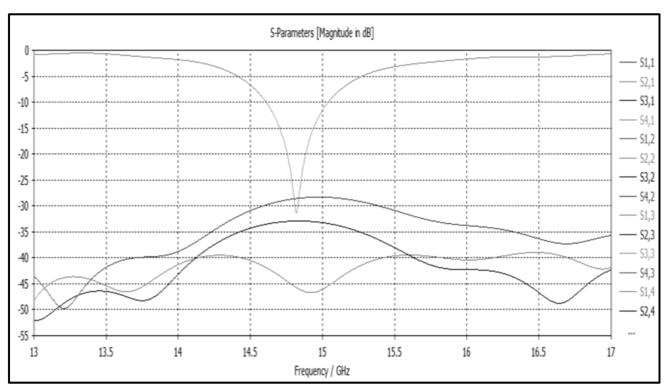


Fig.3b. Mutual coupling of orthogonal alignment

A. VOLTAGE STANDING WAVE RATIO

The standing wave pattern is developed because of the input signal reflection which is caused by the difference of the transmission line and antenna's input impedance. The VSWR ranges from 0 to ∞. The antenna having perfectly matched has VSWR equal to one. In single patch antenna the VSWR has equal to 1.07 at resonating frequency and in proposed MIMO design the ratio of 1.05 has been achieved as shown in **(Fig.4).**

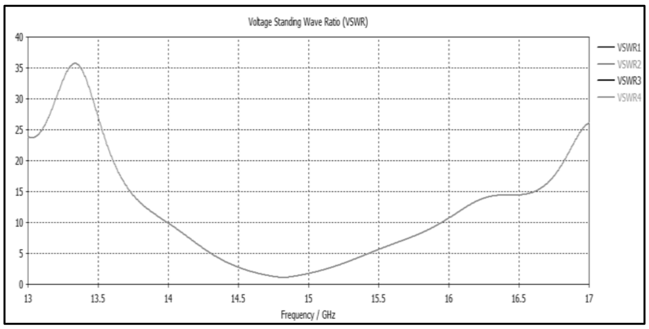
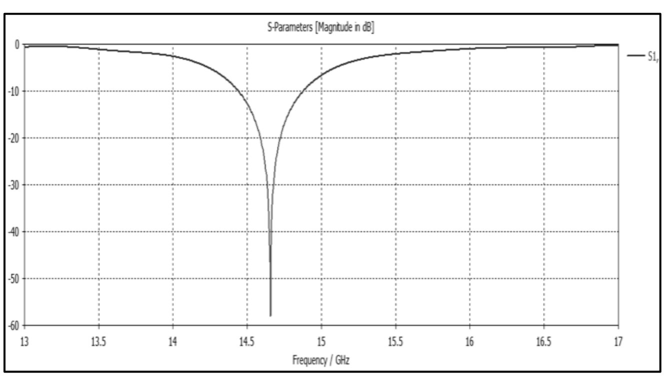


Fig.4. Voltage Standing Wave Ratio

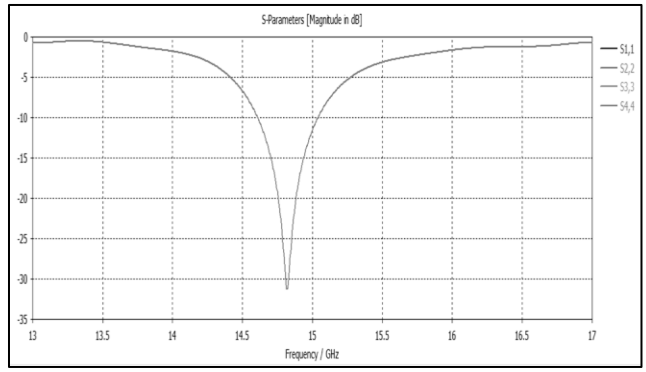
B. REFLECTION COEFFICIENT

Reflection coefficient relates to the power reflected by the antenna. This happens because of the mismatch between the transmission line and antenna. If the antenna and transmission line are properly matched, the reflection coefficient is minimum in the resonating range of antenna.

The return loss of both single patch and proposed MIMO antenna are shown in **(Fig.5a) and (Fig.5b).** The impedance bandwidth of both single patch and MIMO antenna is 3.18% and 2.92%.



(a)



(b)

Fig. 5. Reflection coefficient
(a) Single patch (b) MIMO

C. Efficiency

Efficiency is the ratio of the power radiated into the space to the total power supplied to the antenna is known as the total efficiency. **(Fig.6)** depicts the total efficiency and radiated efficiency of our proposed approach (antenna).Antenna efficiency ranges between 0 and 1.

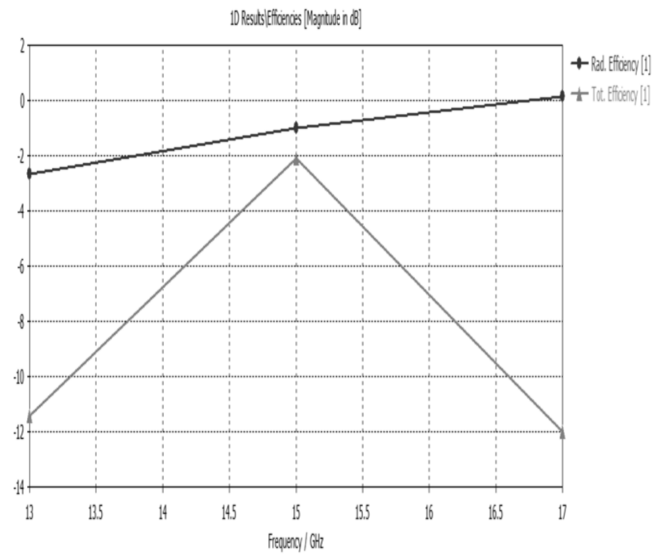


Fig.6. Efficiency comparison

D. Radiation pattern

The strength of radio waves from antenna is represented by the Radiation pattern. Figure 7 depicts the radiation pattern of the two approaches, i.e., the signal patch antenna and the proposed one at various frequencies.

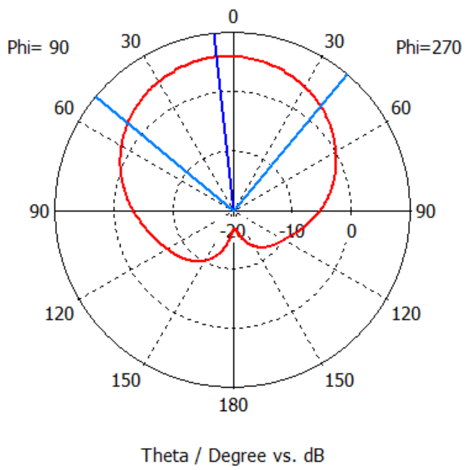


Fig.7a.The Radiation Pattern of single patch Antenna at various frequencies

Fig. 7a shows the radiation pattern of single radiating element antenna at 15GHz frequency, with angular width of 90 degree.

The Radiation Pattern at 15 GHz of MIMO antenna are shown in Fig.7b, with angular width of 90.1 and side lobe level is -15.2.

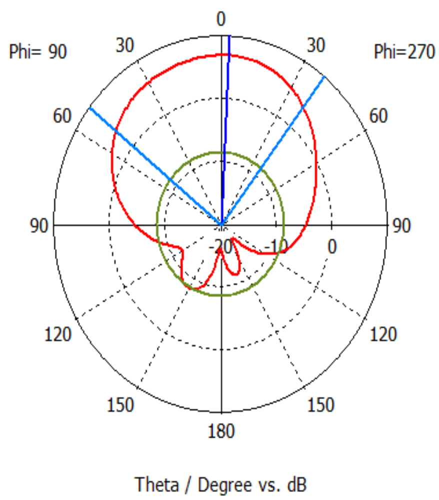


Fig.7b. Radiation pattern at 15 GHz

The Radiation pattern at 13 GHz of the proposed antenna are depicted in (Fig. 7c), the angular width of 95.3 ad ide lobe level of -15dB.

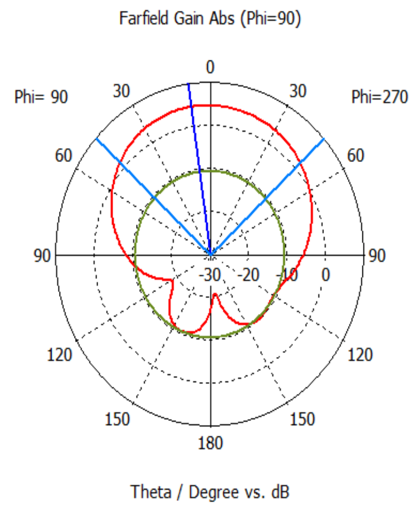


Fig. 7c. Radiation pattern at 13 GHz

The Radiation Pattern at 17 GHz with angular width of 89.7 degree and side lobe level of -9.7 dB are shown below in (fig.7d)

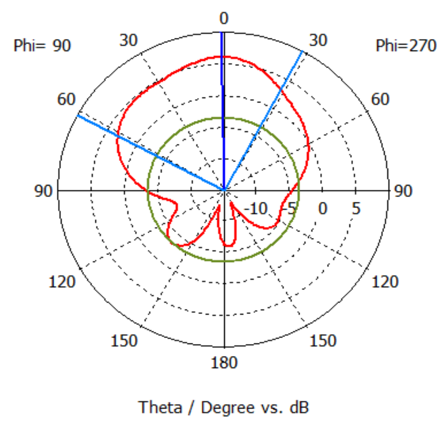


Fig.7d. Radiation Pattern at 17 GHz

E. Antenna Gain

Antenna gain indicates how much power is transmitted in a specific direction as compared to isotropic antenna. In a specific direction antenna gain specifies how strong the signal can be transmitted and received by the antenna. The gain of the proposed and reference single patch antenna is shown in below table. The graph of the gain versus frequency are shown in **(Fig.8).**

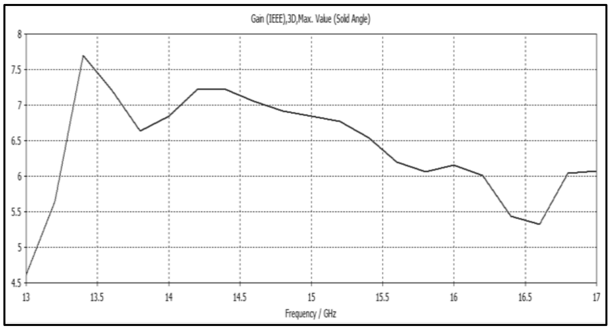


Fig.8. Gain of the proposed antenna

The Gain of single antenna and proposed MIMO antenna are shown **(Table.2)**

Table.2. Gain of proposed and single patch antennas

Frequency(GHZ)	Single Patch Gain(dB)	MIMO Gain(dB)
13	4.7	4.66
15	5.93	6.85
17	7.039	6.07

4. CONCLUSION

In this paper, MIMO antenna for Ku-band application is successfully designed. The dimensions of the proposed antenna are 19.09×21.88mm2 with good isolation in between the patches ranging from -28 dB upto -45.7dB. The Radiating patches are placed orthogonal to each other so that to minimize the mutual coupling among them. The impedance bandwidth of the proposed antenna is 3.18%. Moreover, the gain of 6.85dB is achieved at center frequency of 14.82 GHz and directivity of 7.43dB. The proposed antenna achieved an improvement of 1.07dB in the gain. Due to these improvement in characteristics, the proposed design of MIMO antenna would be a good choice for the wireless communication in future.

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