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DESIGN OF MICROSTRIP MIMO ANTENNA USING RT/DUROID FOR 5G BAND

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Abstract: This new era is about high speed, better Bit Error rate, better receive reception and all these needs are not able to fulfill by single patch and hence one of solution is to use MIMO antenna technique but mutual coupling is the area which requires improvement. In this paper we use RT DUROID 5880 as a substrate for the proposed antenna and we tend to reduce the problem of mutual coupling with the assistance of proposed decoupling element which reduces the mutual coupling by 34.61dB. The center frequencies of these antennas are around 37.5 GHz.

Index term: **Microstrip MIMO antenna, SISO, MIMO, decoupling element, resonator, microstrip patch antenna, RT Duroid 5880.**

I. Introduction:

In today's era communication become a crucial factor of life and thence communication system is additionally need to enhance. There is lot of work is being projected for enhancing the communication system like increasing of bandwidth, gain, channel capacity, reliability etc. In previous few years researchers are showing significant interest towards MIMO (Multiple-Input Multiple-Output). MIMO is become hot topic because with the help of MIMO the reliability, channel capacity, multipath propagation, enhanced data throughput, higher data rates and the most vital is it's wide application in Wi-Fi LAN, Bluetooth, UMTS and in next generation communication (5G).

In radio MIMO could be a methodology for multiplying the capability of a communication system using multiple transmit and receive antenna to take advantage of multipath propagation. The design of MIMO antennas are in the form of arrays (fig. 1).

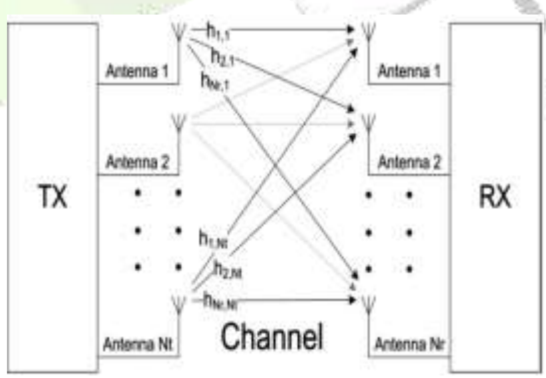


Fig.1 MIMO system

As there are so many advantages of MIMO antenna there are also having some limitations like these types of antennas are quite complex, power consumptions are high as compare to other microstrip patch antenna, these antennas are quite costly then the microstrip patch antenna and the main limitation is "Mutual Coupling" between antenna elements which cause signal interference between them and therefore the higher value of mutual coupling degrades the antenna efficiency.

For reducing the mutual coupling between microstrip MIMO antenna a number of works was presented in literature. The main methods which are used for simulation in literature for reducing the mutual coupling are Defected Ground Structure (DGS), Electronic Band Gap (EBG) Structure and resonators.

In this paper we have simulated the two cases of MIMO antenna, (SISO & MIMO). Where SISO & MIMO are stands for Single Input Single Output, Multiple Input Multiple Output respectively. The problem of mutual coupling in microstrip MIMO antenna is also resolve by using decoupling element “I Slotted resonator”. All the simulation work is done on CST 2016 software at 2.3 GHz frequency.

In the 2nd fragment the design of antennas and results has been shown. The 3rd part is the summary of this paper along with tabulation of result.

II. Antenna designs and results:

As discussed in the first section in this paper we designed the two cases of MIMO antenna i.e. SISO & MIMO. The patch antenna is prepared by the set of formulas used for calculating of width and length of microstrip patch antenna which is as follow:

Width of the patch (w) is given by

$$w = \frac{C}{2f_0\sqrt{\frac{\epsilon_r + 1}{2}}}$$

Here C is the velocity of light which is $3 \times 10^8\ m/s$, f_0 is the frequency and ϵ_r is the dielectric constant. In this paper we use RT DUROID 5880 substrate and hence the value of ϵ_r is 2.2.

The reason behind choosing the RT DUROID 5880 is the fact that as we increase permittivity of the substrate used for the patch antenna design, the size of the antenna reduces. But, bandwidth and gain of the antenna reduces with respect to the increase in the permittivity value [1]. And hence we decide to decrease the permittivity value and therefore, instead of using traditional FR-4 (permittivity = 4.4) we have used RT/duroid 5880 (permittivity = 2.2). Another fact to choose RT/Duroid is Electromagnetic wave loss in dielectric medium is related to loss tangent of that dielectric medium.

Loss Tangent = Dissipation factor = 1 / (Quality factor)

We should choose low loss tangent dielectric material for microstrip for achieving low loss antenna.

Loss tangent of RT/Duroid 5880 = 0.0004 while the loss tangent of FR-4=0.013-0.025

Effective width

$$W_{eff} = w + 2\Delta W$$

Here $\Delta W = 1.631 \ln\left(\frac{4}{\pi}\right)$

Length of the patch (L) is:

$$L = L_{eff} - 2\Delta L$$

The effective length $L_{eff} = \frac{C}{2f_0\sqrt{\epsilon_{reff}}}$

Here ϵ_{reff} is the effective dielectric constant which is give by

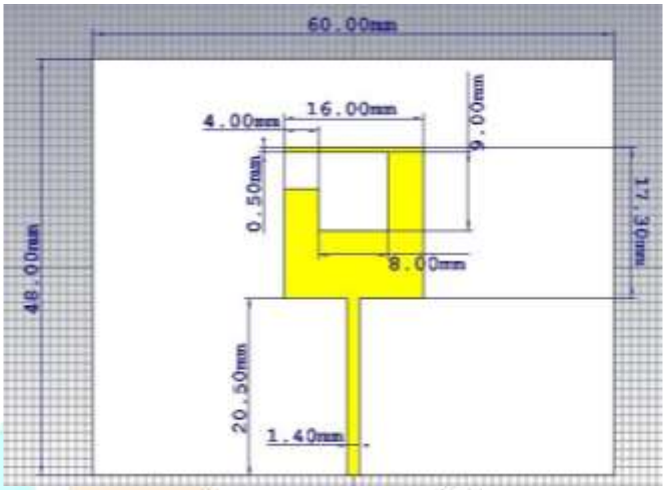
$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}}$$

Here w is width of patch and h is the height.

After successful construction of patch the next procedure is to provide feed to the antenna. Feeding is mainly used as for conversation purpose in antenna, the conversation of radio signal into electric signal or electric signal into radio signal and hence it is considered to be a part of antenna. There are primarily four kinds of feedings are utilized in microstrip patch antenna Microstrip Line Feed, Coaxial Probe Feed, Aperture Coupled Feed and Proximity Coupled Feed. Among these feedings we are using Microstrip Line Feeding for our proposed antennas. It is the simplest form of feeding and very easy to fabricate.

A. SISO antenna

The SISO (SINGLE INPUT SINGLE OUTPUT) antenna is the simplest form of MIMO antenna. It is a low profile microstrip patch antenna with less complexity and simple to manufacture and cost efficient [1]. The proposed antenna design, dimensions, hardware photograph along with graph of S-parameter is shown in fig. 2. The proposed antenna works at 37.64 GHz frequency and have return loss around -37 dB (-36.779 dB). The VSWR of the antenna is 1.029, directivity is 10.04dBi and Gain of the antenna is 9.643dB (Fig. 3)



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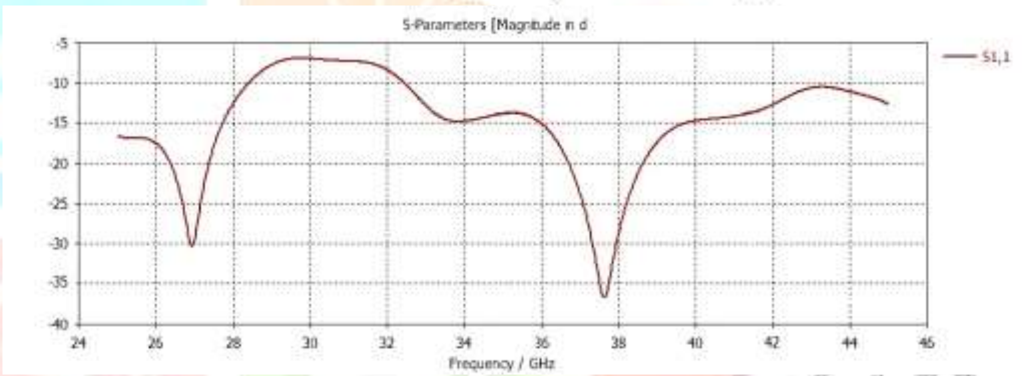
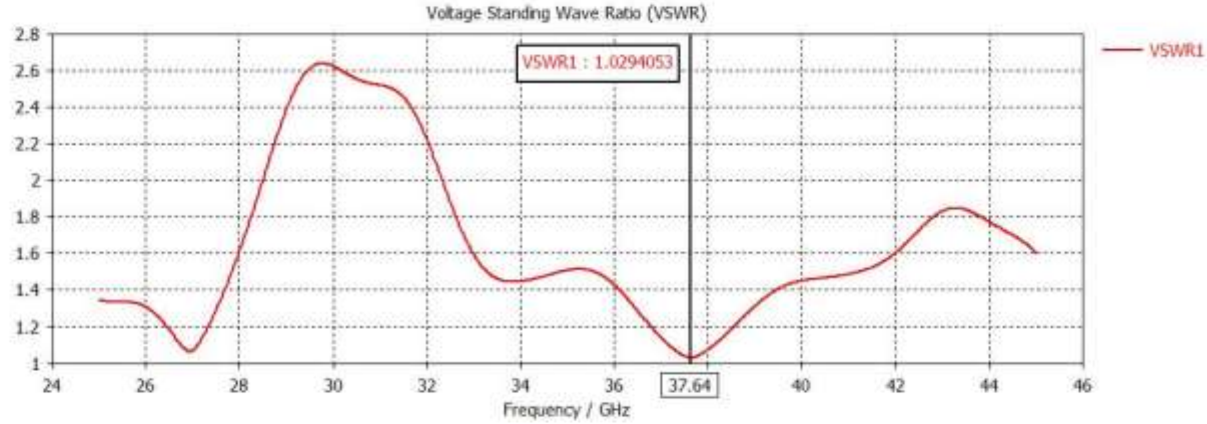


(b)

Fig.2 antenna 1

(a) Design dimensions of proposed SISO antenna

(b) Result (graph of S- parameter)



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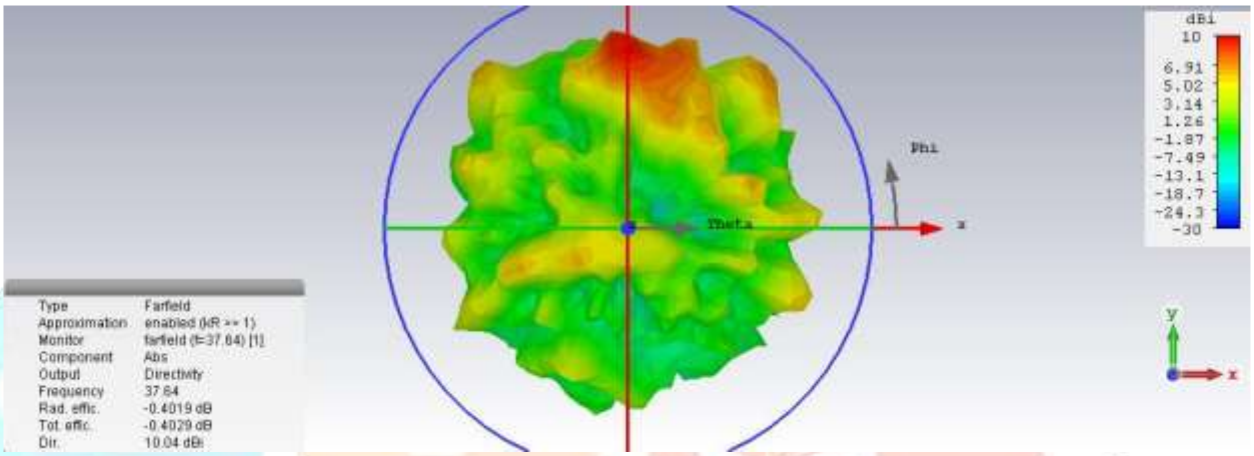

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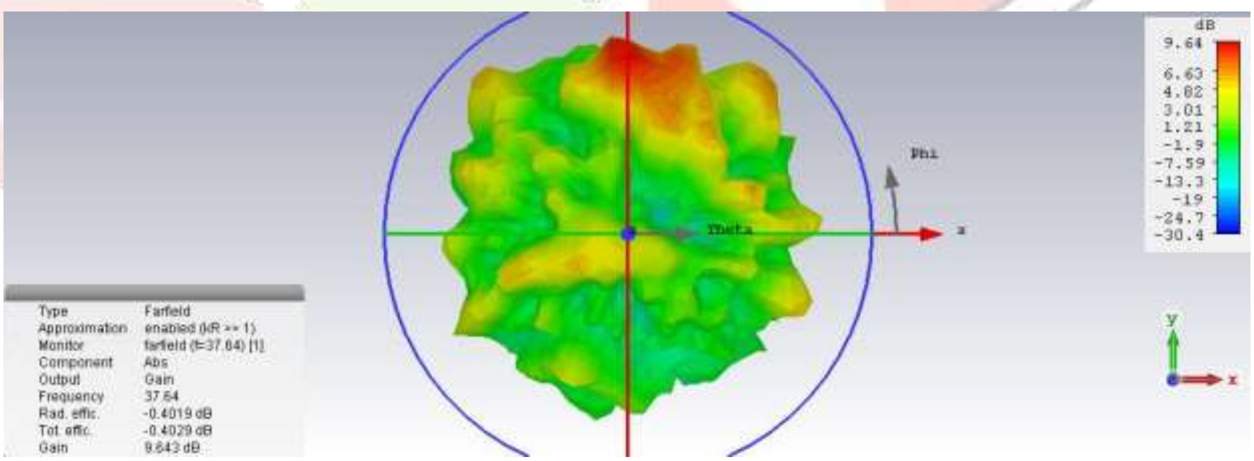


(c)

Fig. 3 Other results of antenna 1
(a) VSWR
(b) Directivity
(c) Gain

The SISO antenna is most commonly used in radio, GSM and CDMA systems. But as the technology upgraded the recruitment of the higher data rate, better Bit Error Rates are required which does not fulfilled by the SISO system.

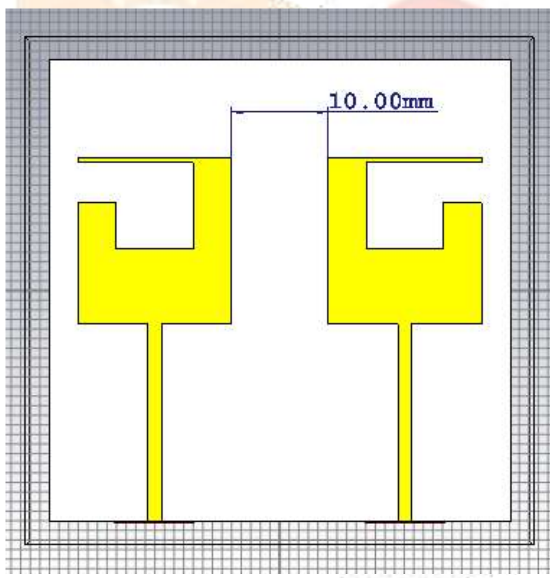
B. MIMO antenna

The Multiple Inputs Multiple Outputs antenna has more than one transmitting and receiving channels. This antenna works on multipath propagation phenomena due to which the probability of receive reception increased. It also increases the data throughput and has very low Bit Error Rate as compare to the SISO antenna. This is the reason why it is most usually used in next generation communication system. As MIMO antenna is having upper hand as compare to the other microstrip patch antennas it has some disadvantages also like as there are multiple channels the design of MIMO antenna becomes more complex as well as it also increase the overall cost of the antenna. One major problem with the MIMO antenna is Mutual Coupling. As the MIMO antenna has multiple channels which are placed closely to each other and having multiple inputs as well it is the main reason for mutual coupling between antenna channels. This mutual coupling is the main reason for reduction in gain and distorted beam pattern.

In past few years some work was proposed to reduce this Mutual Coupling by using DGS, EBG structure or by the use of resonators. DGS and EBG structures placed within the ground plane offer undesirable back radiation. By the employment of these techniques mutual coupling has been reduced significantly at the cost of some sophisticated structure at the ground plane and it suffers from radiation pattern degradation [2]. The DGS and EBG structures are more complicated structures and optimum deigns are more complicated to realize [3] and hence in this paper we uses “I slotted resonator for reducing the mutual coupling” as a decoupling element.

The basic concept for reducing the Mutual Coupling is the presence of one or more decoupling elements or networks. The decoupling components are situated between neighboring channels of MIMO antenna. These decoupling components alleviate the mutual coupling problem between closely spaced antenna elements [4]. This decoupling element resists the signal going straightforwardly from component to component. Here we should note that the inserted decoupling element does not degrade the antenna’s radiation pattern, return loss, gain.

In this paper we proposed a type of antenna which is a two channel two ports MIMO antenna. Fig. 4 is the two channel two ports MIMO antenna where fig. 4 is the proposed MIMO antenna design without decoupling element (I slotted resonator). The VSWR of the antenna 2 is 1.021, directivity is 8.963 dBi and the gain of the antenna is 8.584 dB (Fig. 5).



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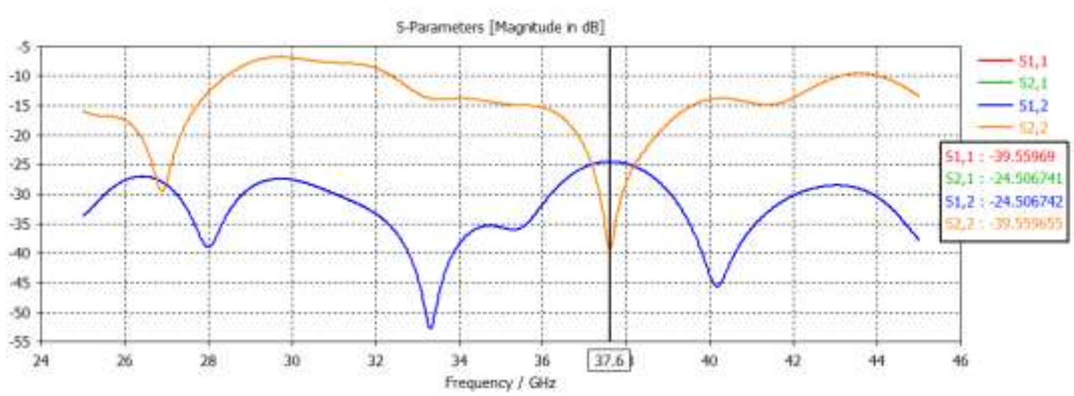
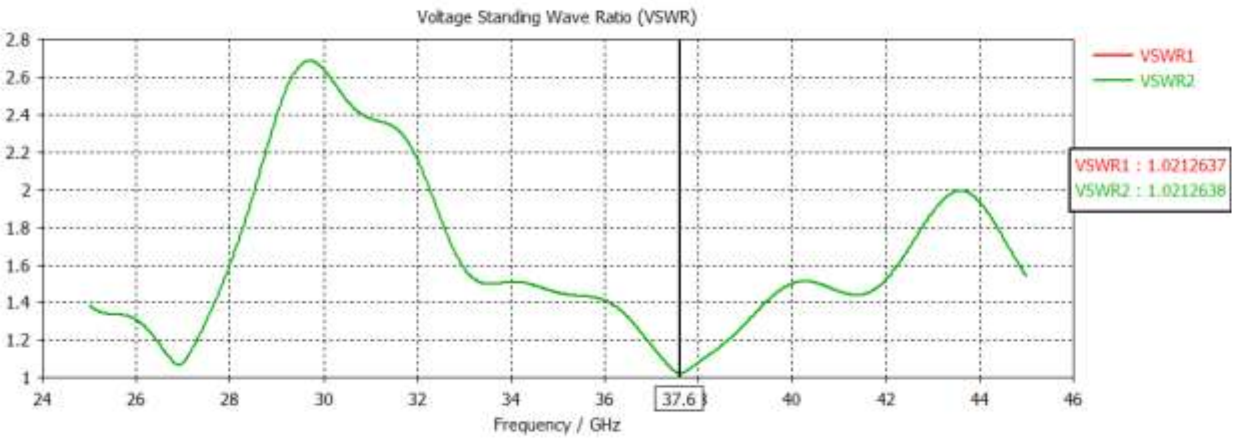


(b)

Fig.4 antenna 2

(a) Design dimensions of proposed MIMO antenna (without resonator)

(b) Result (graph of S- parameter)



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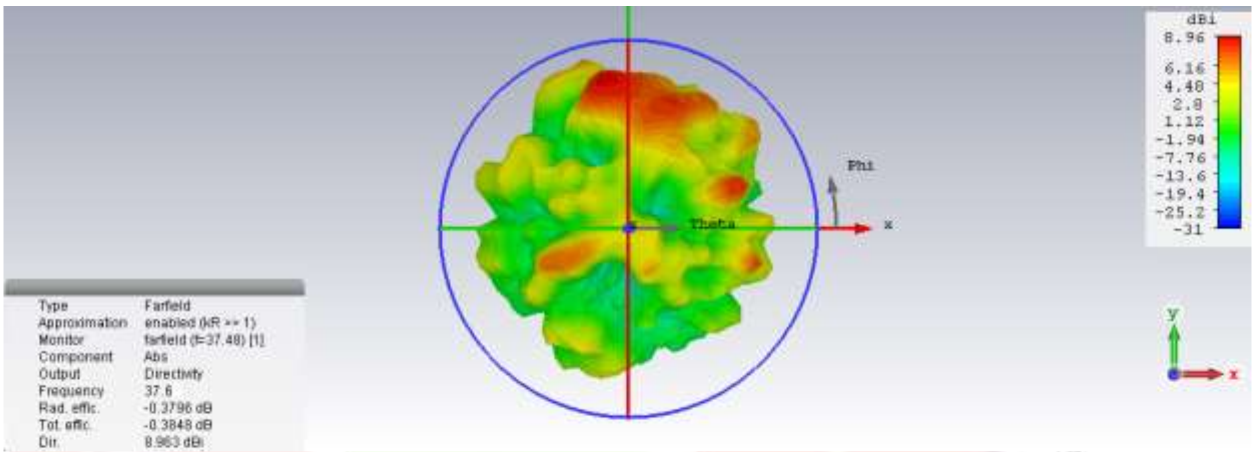

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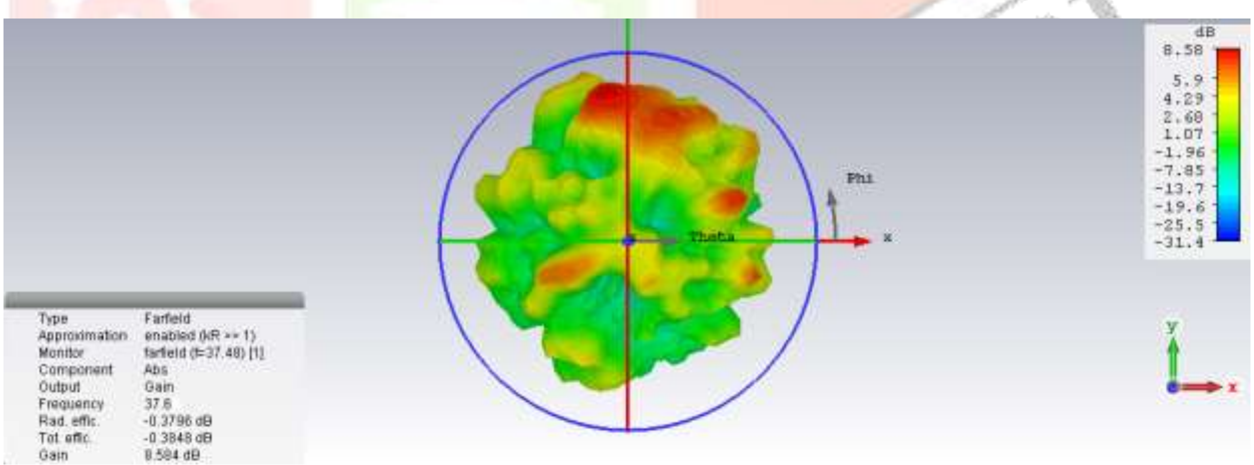


(c)

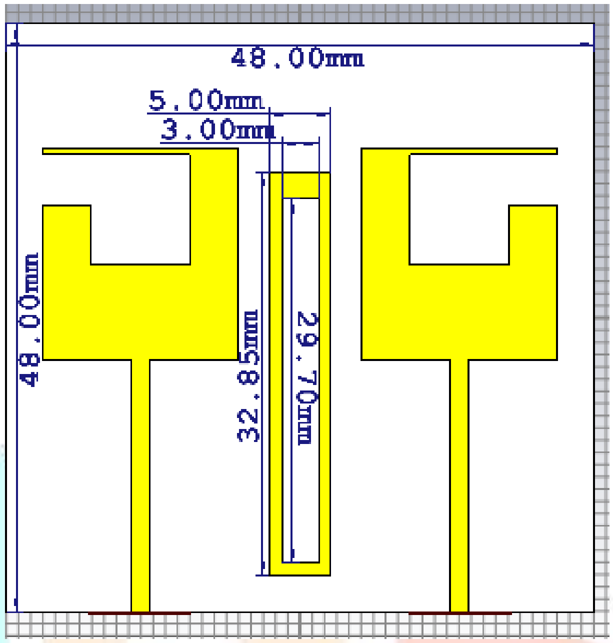
Fig. 5 Other results of antenna 2

(a) VSWR

(b) Directivity

(c) Gain

But fig. 6 is the proposed MIMO antenna with decoupling element (I slotted resonator). From fig. 4's S-parameter graph it is clearly seen that due to the problem of mutual coupling only one port is working properly but at the same time the other port is not working and hence to reduce this mutual coupling problem a decoupling element named as I slotted resonator is proposed in this paper which is placed between the closely spaced antenna channels (fig. 6). After the use of decoupling element the mutual coupling reduced by 34.61 dB. The VSWR of the antenna 3 is 1.006, directivity is 9.905 dBi and the gain of the antenna is 9.484 dB (Fig. 7).



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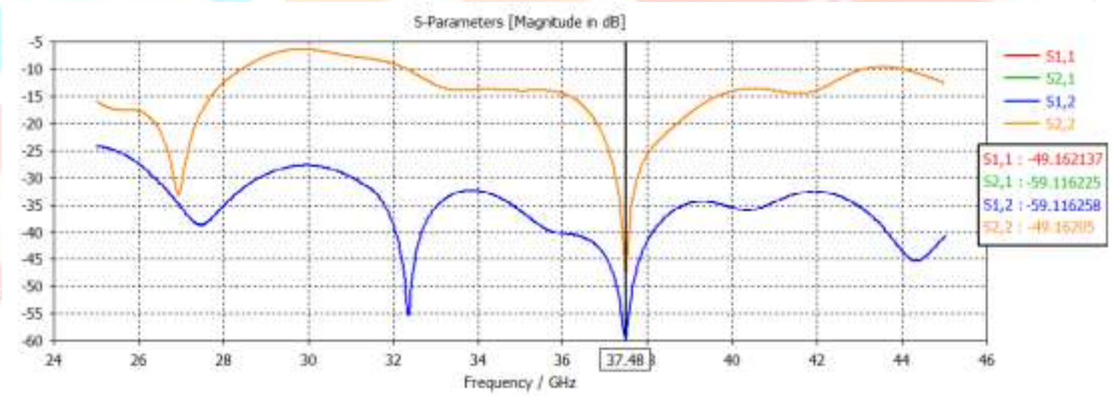
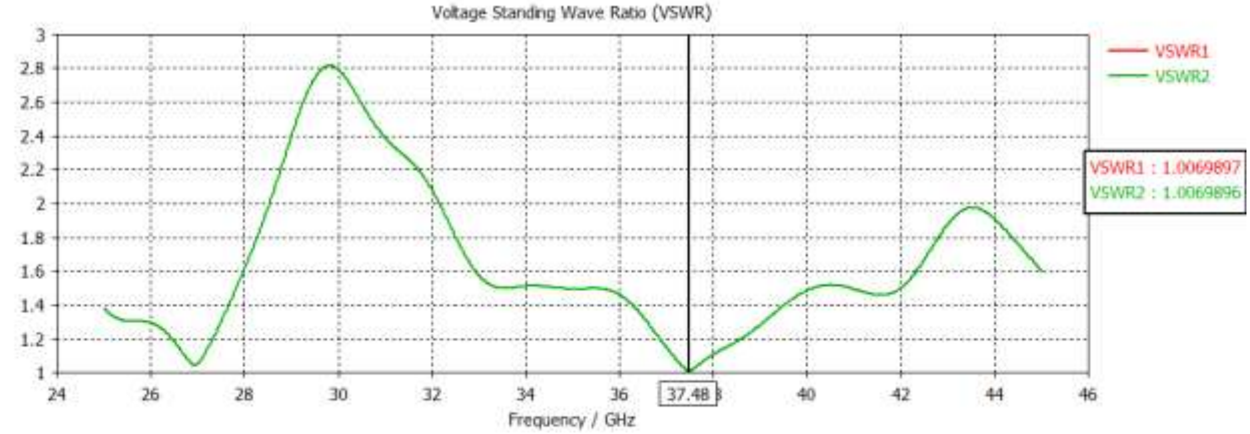


(b)

Fig.6 antenna 3

(a) Design dimensions of proposed MIMO antenna (with resonator)

(b) Result (graph of S- parameter)



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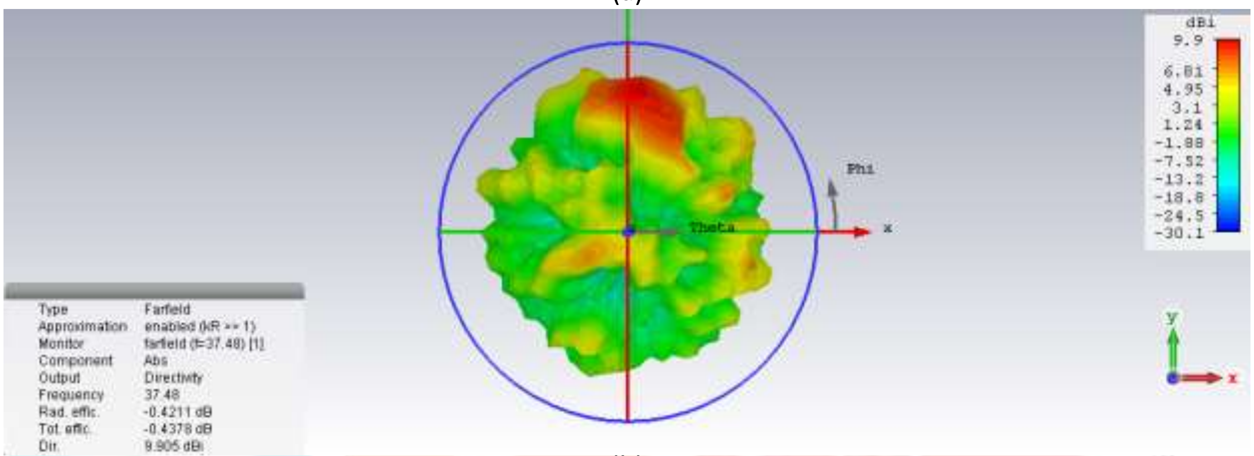

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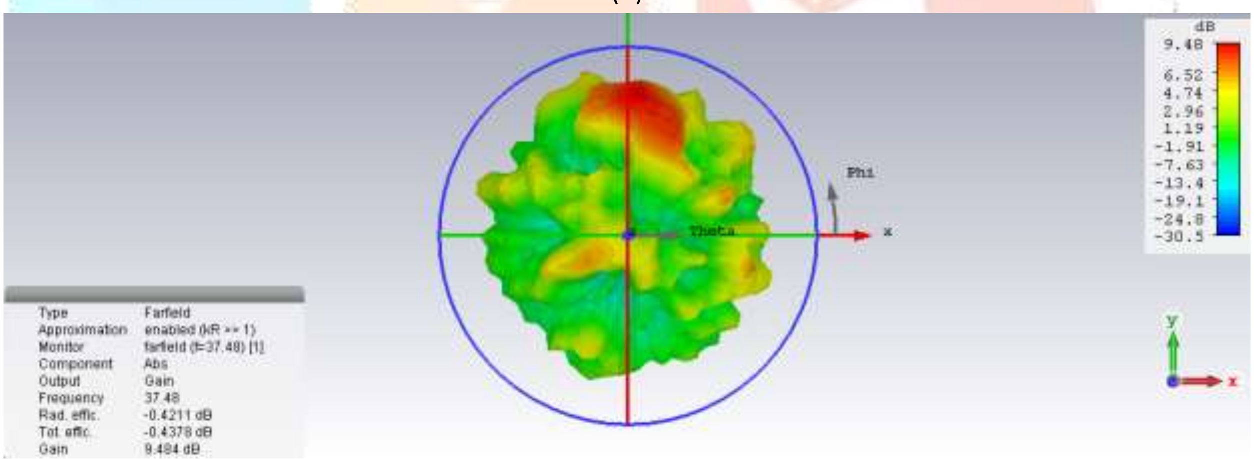

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Fig. 7 Other results of antenna 3

(a) VSWR

(b) Directivity

(c) Gain

III. Conclusion:

As mentioned in the previous section the problem of mutual coupling and its reduction with the help of decoupling element is proposed. The mutual coupling is reduced by 34.61dB after using decoupling element in antenna 3. The other results like VSWR, Directivity and Gain are also improved of antenna 3 as compare to antenna 2. In this section we tabulated all the results.

S. No.	Parameters	Antenna 1	Antenna 2	Antenna 3
1	Center frequency	37.64 GHz	37.6	37.48
2	S-Parameter	-36.799 dB	$S_{1,1} = -39.559$	$S_{1,1} = -49.162$
			$S_{1,2} = -24.506$	$S_{1,2} = -59.116$
3	VSWR	1.029	1.021	1.006
4	Directivity	10.04 dBi	8.963 dBi	9.905 dBi
5	Gain	9.643 dB	8.584 dB	9.484 dB

IV. References:

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