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Design Of Miniaturized, Two Elements 6-Band Mimo Antenna With Patch Isolator

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Abstract: Use of MIMO (Multiple input multiple output) for advance wireless communication is trending since last couple of decades. Multiband systems, such as WiFi (Wireless Fidelity), Bluetooth, or BLE (Bluetooth Low Energy) are referred as the way of advanced communication technology. These communication technologies are operating at a commonly used ISM frequency band, 2.4GHz. This frequency band is unlicensed and free to use. In this article, designed MIMO antenna can be used at 2.51GHz, 4.15 GHz, 6.04 GHz, 2.36 GHz, 3.68 GHz and 5.47GHz frequencies. This MIMO antenna is designed by using multiple patches on single ground plane, separated by Isolator. Improvement in VSWR, Directivity and Gain can be achieved by using microstrip patch antenna. Return loss of Designed MIMO is below -10dB and VSWR is in between 1 to 2. Isolator is used to reduce mutual coupling between the patches of MIMO antenna.

Index Terms: Microstrip Patch Antenna, Isolator, MIMO, Multiband Antennas,

1 INTRODUCTION

Multiple input multiple outputs has several advantages over the conventional SISO (Single input single output) transmit receive method. In terms of channel capacity, SISO faces bottleneck issues which highly degrade the performance of the communication system. MIMO means use of multiple antennas at transmitter for transmission and multiple antennas at receiver for reception of electromagnetic waves. MIMO increases channel capacity as number of elements in MIMO increases. MIMO enhances the bandwidth of communication. It improves the directivity, Gain and Antenna efficiency since it does not require additional transmit power. The ratio of maximum radiation intensity of the subject antenna to the radiation intensity of an isotropic or reference antenna, radiating the same total power is called the directivity and Antenna Efficiency is the ratio of the radiated power of the antenna to the input power accepted by the antenna. The term antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. To maintain VSWR in between 1:2, the approximate value of impedance of a transmission line, must equals the approximate value of the impedance of a transmitter antenna, or vice versa, it is termed as Impedance matching. Impedance matching is necessary between the antenna and the circuitry. The impedance of the antenna, the transmission line, and the circuitry should match so that maximum power transfer takes place between the antenna and the receiver or the transmitter.

2 REVIEW OF LITERATURE

The 4 element Multiple Input Multiple output (MIMO) Microstrip Patch Antenna that has 4 ports, been designed and implemented in [1], The proposed antenna consists of four ports with all the four patches operates at LTE and WLAN frequencies 1.8GHz, 2.8GHz, 3.3 GHz. The antenna is fabricated on an inexpensive FR4 material of a dielectric constant of $\varepsilon = 4.4$, with thickness of substrate that is 1.6 mm and the thickness of patch is 0.035 mm.

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From practical results of [2], it is concluded that the increase in the number of patches on the substrate, data rate and radiation pattern get increased. The Proposed design is of 3 bands which is resonating at three frequencies and that are 1.8GHz, 2.8GHz and 3.3GHz and it gives VSWR in the range of 1 to 2 and the values of S Parameters which are less than -10 dB. Kartiki Gaikwad et. al. [3], demonstrated, two element slotted patch antenna for two different applications that is Wi-Fi (wireless fidelity) and LTE (long term evolution) which operates on the frequency 2.4GHz and 2.6GHz. Comparison of various methodologies of antenna design and different software tools used for simulation is done to propose powerful techniques to proceed in the field of Microstrip Patch Antenna design for implementation of MIMO systems. Antenna system with high data rate, high gain, wider bandwidth, improved signal quality, higher spectral efficiency, reduced mutual coupling, low cost and small size is the need of today's wireless communication engineering. Hence, overall objectives of this article is to summarize and study different shapes of MIMO antennas and compare different parameters of various designs of antenna such as Mutual coupling, Resonating Frequency, VSWR, Bandwidth, Data rate, Efficiency, Gain and Return Loss [4]. Multiple input multiple output (MIMO) antennas are great candidates to be utilized in multiband applications. They are capable of supporting high data rate, decreasing multiple fading, increasing channel capacity and improving the reliability of the communication system [5]. Due to decisive aspect of coupling between the MIMO antenna elements, increasing the isolation of close elements is necessary. On the other hand, the compactness is another aspect of the design as well as radiation efficiency and envelope correlation [6]. In recent years, telecommunication researchers increase the isolation of multiband MIMO antennas elements by various techniques. Liao et al. have used inverted F-antenna and a folded slot to miniaturize a dual-band MIMO antenna and decrease the coupling elements [7]. In [8], transmission line decoupling technique has been utilized to increase the isolation of the elements.

3 METHODOLOGY

Microstrip Patch antenna is one of the most popular types of printed antenna. It plays a very significant role in today's world of wireless communication systems. Microstrip antennae are very simple in construction using a conventional microstrip fabrication technique. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate (FR4) that has a ground plane (Cu) on the other side as shown in Fig. 1. The patch is generally made up of a conducting material such as copper or gold and can take any possible shape like rectangular, circular, triangular, elliptical or some other common shape. The radiating patch and the feed lines are usually photo-etched on the dielectric substrate.

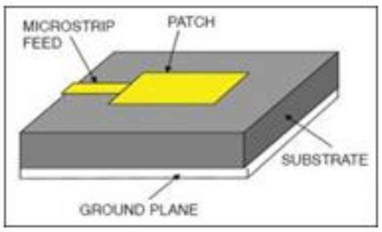

Fig. 1. Microstrip Patch antenna.

4 DESIGN STEPS

1	Resonating Frequency	$F_r =$	2.4 $\times 10^9$	Hz
2	Permittivity	$\varepsilon_r =$	50	
3	Speed of Light	C =	3 $\times 10^8$	m/s
4	Substrate Height	h =	1.6 $\times 10^{-3}$	m
5	Calculation of W (Width of Patch 2)	W =	$\frac{C}{2F_r\sqrt{(\varepsilon_r+1)/2}}$	
		W =	12.38	mm
6	Calculation of ε_{reff}	$\varepsilon_{reff} =$	40.84	
7	Calculation of L (Length of Patch 2)	$L_{eff} =$	$\frac{C}{2F_r\sqrt{\varepsilon_{reff}}}$	
		$L_{eff} =$	9.78	mm
	and	$\Delta L =$	$0.412 \times h \frac{(\varepsilon_{reff}+0.3)(W/h+0.264)}{(\varepsilon_{reff}-0.258)(W/h+0.8)}$	
		$\Delta L =$	0.63	mm
		L =	Leff - 2 ΔL	
		L =	8.53	mm
8	Calculation of Lg (Length of Ground)	Lg =	2 x L	
		Lg =	23.13	mm
9	Calculation of Wg (Width of Ground)	Wg =	2 x W	
		Wg =	33.00	mm
10	Calculation of Fi (Length of Fed Line)	Fi =	$\frac{6h}{2}$	
		Fi =	4.8	Mm
11	The Gap between the patch and the inset feed (Gpf) is usually 1mm			
		Gpf =	1	mm

From above example, for resonating at 2.51GHz, 4.15 GHz, 6.04 GHz, 2.36 GHz, 3.68 GHz and 5.47GHz frequencies, dimensions of Patch-I and Patch-II are decided as shown in Table-1.

TABLE 1

DIMENSIONS OF MICROSTRIP PATCH

Sr. No.	*Dimension*	*Length (mm)*
1	*Width of Ground Plane*	*19*
2	*Length of Ground Plane*	*4.5*
3	*Thickness of Ground Plane*	*0.035*
4	*Width of Substrate*	*19*
5	*Length of Substrate*	*27*
6	*Thickness of Substrate*	*1.6*
7	*Width of Patch*	*19*
9	*Length of Patch*	*18.3*
10	*Thickness of Patch*	*0.035*
11	*Width of feedline*	*3.08*
12	*Length of feedline*	*5.2*

Other dimensions of the Microstrip patch are mentioned in Fig.2. The increase in the number of patches on the substrate, data rate and radiation pattern get increased. The Proposed design is of 6 bands which is resonating at six frequencies and that are 2.51GHz, 4.15 GHz, 6.04 GHz, 2.36 GHz, 3.68 GHz and 5.47GHz, and it gives VSWR in the range of 1 to 2 and the values of S Parameters which are less than -10 dB. Two microstrip patches are used to resonate at selected bands of frequencies. FR4 material is used as dielectric substrate between ground plane and the patches.

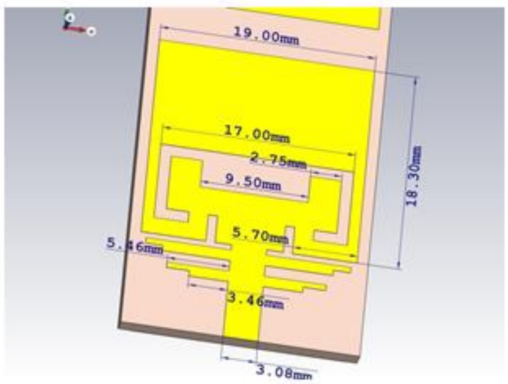

Fig. 2. Dimensions of Patch

Dielectric constant of FR4 is 4.4 and thickness of FR4 is 1.6 mm. Proposed MIMO antenna for six different bands of frequencies with isolator for mutual coupling separation is shown in figure 3.

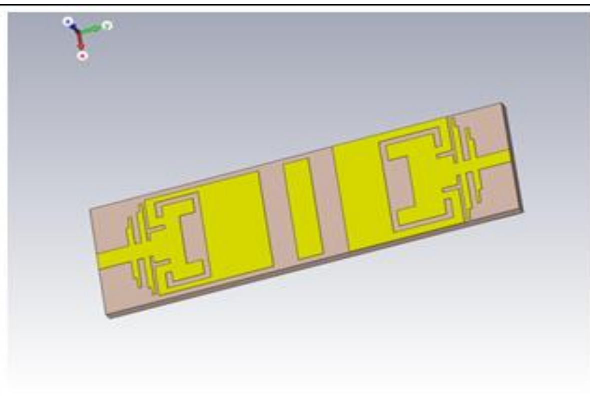

Fig. 3. Two Elements 6-Band MIMO antenna with

5 RESULTS AND DISCUSSIONS:

5.1 S-PARAMETER:

Microstrip antenna patch-I design resonates at 2.51GHz, 4.15GHz and 6.04GHz. At those three resonating frequencies, values of S-Parameters are -21.19dB, -21.58dB and -16.06dB respectively. Simulation result of 6-Band MIMO antenna with Patch Isolator is shown in Fig. 4.

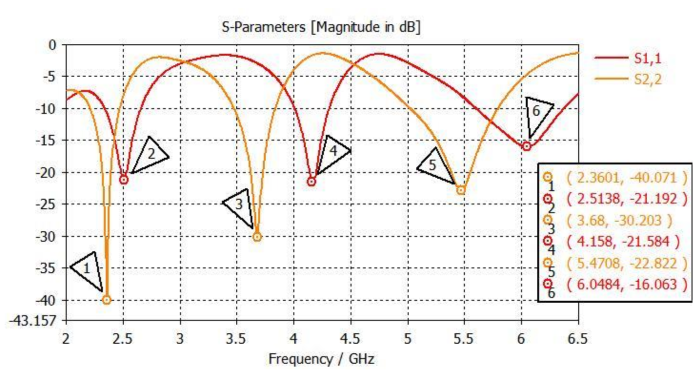

Fig. 4. *S-Parameters of Two Elements, 6-Band MIMO antenna*

Patch-2 resonates at 2.36GHz, 3.68GHz and 5.47GHz. At those three resonating frequencies, values of S-Parameters are -40.07dB, -30.20dB and -22.82dB respectively as shown in Table: 2.

Table: 2.
S-Parameters of Two Elements

MIMO	*Frequency (GHz)*	*S- Parameter (dB)*
Patch-1	*2.51*	*-21.19*
	4.15	*-21.58*
	6.04	*-16.06*
Patch-2	*2.36*	*-40.07*
	3.68	*-30.20*
	5.47	*-22.82*

5.2 BANDWIDTH ENHANCEMENT:

Bandwidth of antenna is calculated below -10dB line of S-Parameter plot. Each patch resonates at three different frequencies with three wide frequency bands. Microstrip antenna patch-I design resonates at 2.51GHz (2.3443 to 2.6582 GHz, Bandwidth: 314Mhz), 4.15GHz (4.0092-4.3092GHz, Bandwidth: 300Mhz) and 6.04GHz(5.5941-6.3687GHz, Bandwidth: 775Mhz) as shown in Fig.5.

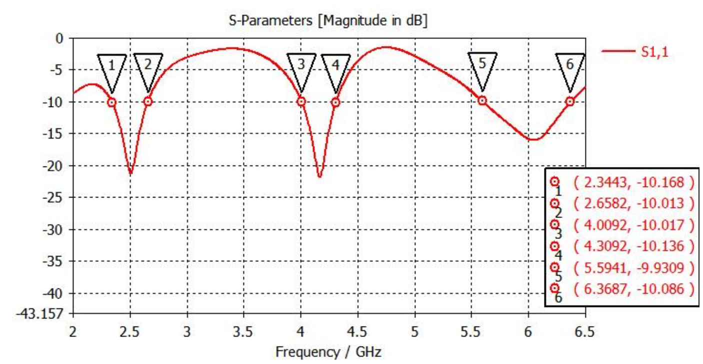

Fig.5. *Bandwidth of Patch-1.*

Patch-2 resonates at 2.36GHz(2.2158-2.4733GHz, Bandwidth: 257Mhz), 3.68GHz (3.4757-3.8411GHz, Bandwidth: 365Mhz) and 5.47GHz (5.0213-5.7872GHz, Bandwidth: 765Mhz) as shown in Fig.6.

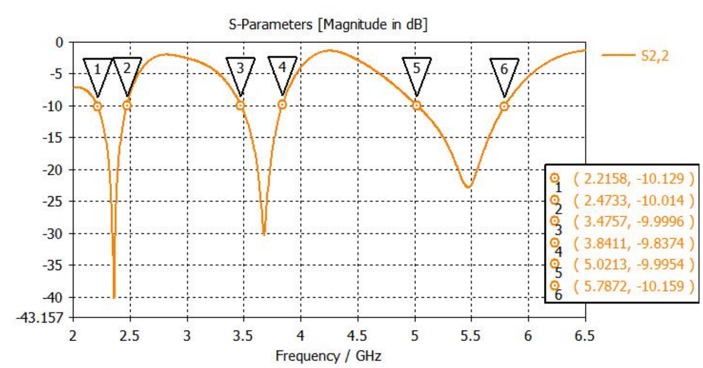

Fig.6. *Bandwidth of Patch-2.*

5.3REFERENCE IMPEDANCE:

If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back in the form of reflected/standing waves.

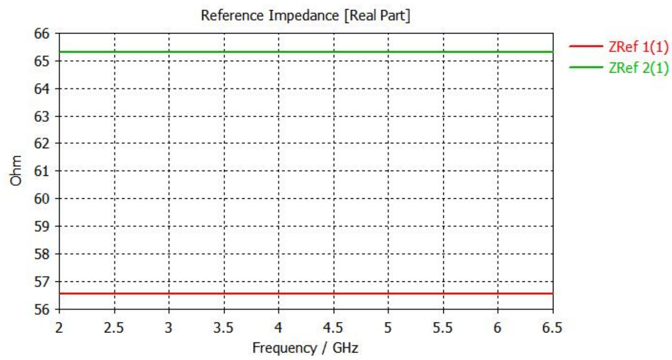

***Fig. 7**. Reference impedance (Zref) of Patch-1 and Patch-2*

To match 50Ω transmission line impedance, Impedance of Patch is made 50Ω by selecting 3.08mm width of feedline. Fig.7. Shows simulated values of reference impedance (Zref) of Patch-1 and Patch-2.

5.4 VOLTAGE STANDING WAVES RATIO (VSWR):

The ratio of the maximum voltage to the minimum voltage in a standing wave is known as Voltage Standing Wave Ratio. If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back in the form of reflected/standing waves. The term, which indicates the impedance mismatch is VSWR. VSWR stands for Voltage Standing Wave Ratio. It is also called as SWR. The higher the impedance mismatch, the higher will be the value of VSWR. Antenna to resonate efficient must have VSWR value in the range 1-2. The simulated MIMO antenna for six different frequencies is having VSWR between 1 and 2 as shown in Fig. 8. and Fig. 9.

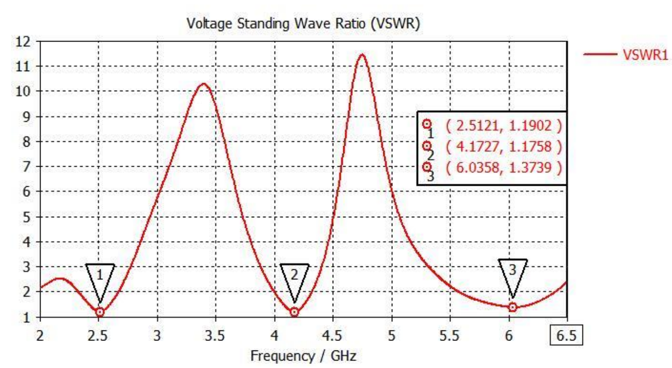

***Fig. 8**. VSWR of Patch-1*

Microstrip Patch-1 is designed to radiate at 2.5GHz, 4.17 GHz and 6.06GHz. VSWR value of patch-1 at those frequencies is 1.19, 1.17, and 1.37 respectively

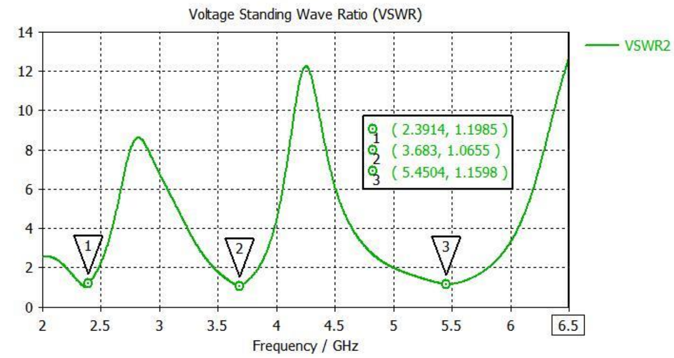

***Fig. 9**. VSWR of Patch-2*

Microstrip Patch-2 is designed to radiate at 2.4GHz, 3.68 GHz and 5.45GHz. VSWR value of patch-2 at those frequencies is 1.19,1.06 and 1.15 respectively

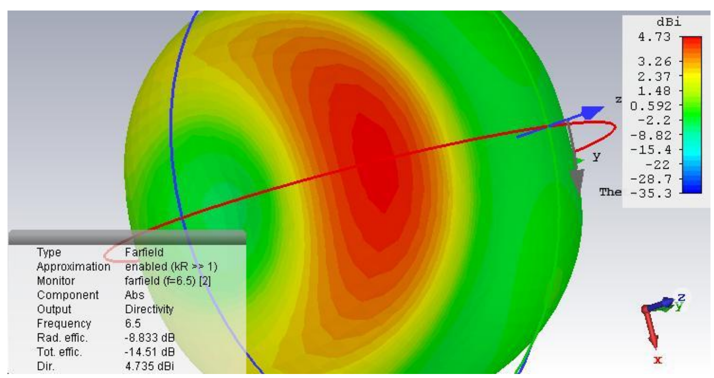

***Fig.10** Radiation Pattern of Designed 6-Band MIMO antenna*

Fig.10 shows radiation pattern of 6-Band MIMO antenna. At 6.5 GHz frequency, above radiation pattern is observed and total directivity obtained is 4.735dBi

6 CONCLUSIONS

Simulation results show that, it is possible to design an MIMO antenna with Patch Isolator to resonate at 6 different frequencies (2.51GHz, 4.15 GHz, 6.04 GHz, 2.36 GHz, 3.68 GHz and 5.47GHz). S- Parameter at those frequencies are less than -10dB and VSWR is lower than 1.2. Average bandwidth obtained at all the 6-Bands of operating frequency is 300MHz. This MIMO antenna is designed by using multiple patches on single ground plane, separated by Isolator. Isolator is used to reduce mutual coupling between the patches of MIMO antenna.

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