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4-Port MIMO Antenna Simulation and Analysis for 5G Portable Applications

Latane Pravin[1]
Research Scholar, SGVU, Jaipur, India.

Dr. Paresh Jain[2]
Assistant Professor, SGVU Jaipur, India.

Dr. Omkar. S. Lamba [3]
Professor, SGVU Jaipur, India.

Dr. Om Prakash Sharma [4]
Professor, SGVU Jaipur, India.

ABSTRACT: In this paper we design and simulate a 4 port MIMO rectangular microstrip patch antenna operating at a frequency range of 3.3 GHz for 5G application. MIMO channel with four spatial streams should be capable of four times the capacity of the SISO channel. IEEE 802.11n (WLAN) standard is designed to support MIMO configurations with as many as four spatial streams. At the highest data rate, bursts using a 64 QAM modulation scheme with a 5/6 channel code rate. A single Dielectric Resonator antenna (DRA) is designed first. The dielectric resonator shape is square with a height of 19.868 mm, width of 15.482 mm. This antenna is designated to operate at 3.3 GHz. The input impedance is near 50 Ω, using FR4 (ε_r = 4.8) and height (h) of 1.6 mm. HFSS software is used initially simulate and obtain the exact position of the DRA for any 5G application. The performance of antenna is studied in terms of parameter like, Gain, Reflection Coefficient, VSWR, Impedance & Bandwidth of antenna. The 4 Port microstrip antenna array has been designed by using the FR4 board at operating frequency 3.3 GHz ISM band.

KEYWORDS: Microstrip Patch Antenna, Gain of antenna, Reflection Coefficient of antenna, VSWR of antenna, 5G, MIMO.

I. INTRODUCTION

Microstrip antenna elements radiate efficiently as deviced on microstrip printed circuit boards. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. The patch is generally made of conducting material such as copper or gold and can take any possible shape [1].

The structure of Rectangular Microstrip Patch Antenna is as shown in fig.1. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that t << λo (where *t* is the patch thickness). The height *h* of the dielectric substrate is usually $0.003\lambda o \leq h \leq 0.05\lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$ [1, 2].

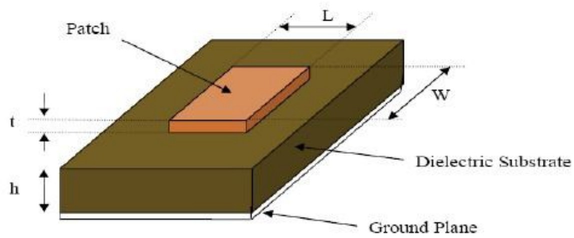

Fig.1: Structure of Rectangular Microstrip Patch Antenna

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Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance [1-3]. In this paper we simulate a 2 port MIMO rectangular microstrip patch antenna working at a frequency range of 2 to 2.1 GHz, the coaxial feeding technique is used as a feed for antenna, and simulation is done by using Finite element based HFSS software.

II. RELATED WORK

In [4] a microstrip patch antenna is designed for a wireless communication application, which is operating at a frequency of 2.4 GHz. In this paper an antenna is designed having substrate material as Styrofoam (εr=1.03) & height of substrate is 12 mm. An outdoor gain of 11 dB is obtained by using this design. A probe feed antenna design is presented in [5]; this antenna is working at a frequency of 2.21GHz & 4.45 GHz. The substrate material is RT Duroid (εr=2.2) & height of substrate is 1.6 mm. Another antenna with same substrate material is present in [6] here height of substrate is 3.2 mm & antenna is working at a frequency of 2.36 GHz. An antenna for operate in S band is deigned in [7], here the substrate material is FR4 (εr=4.4) & height of substrate is 1.6 mm. This design is working at a frequency of 3.3 GHz.

A stripline fed antenna is present in [8], which is working at a frequency of 2.4 GHz. Different Technique used for enhancement of bandwidth of antenna are present in [9] [10]. Yasin Kabiri et al. [11] have presented 4 element, IFA, MIMO antenna, Specifications of antenna are 2.11 GHz with bandwidth set to 100 MHz. The Dielectric Substrate used for fabrication is FR4 and Application of antenna is massive MIMO antenna for the 5G system.

M. Waqas et al. [12] used a compacted design of 4 × 4 Massive Multiple Input Multiple Output (mMIMO) antennas that will be used for future 39 GHz millimeter-wave (mm-Wave) effective communications required for 5th Generation (5G) networks. It is covering a bandwidth of around 1.43 GHz. Peak gain obtained in the required band is 6.38 dB. Moreover, the results of the Envelope Correlation Coefficient (ECC), Diversity Gain (DG), and the Mean Effective Gain (MEG) have also been discussed. J. Zhou and M. Yang [13] designed based on shared U-shaped patch, a six-port antenna with frequency and radiation pattern diversity is investigated in this paper. Furthermore, the port isolation in the two operating bandwidth is better than 21.7 dB and 18.5 dB, which also indicates that the designed six port antenna can be applied for 5G. Muhannad Y. Muhsin et al. [14] uses compact low-profile four and eight elements Multi-Input Multi-Output (MIMO) antenna arrays are presented for 5G smartphone devices. The proposed antenna systems can operate at two wide bands with triple resonance frequencies that cover the extended Personal Communication Purposes (PCS) n25 band

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and other related applications, the mobile china's band, and the LTE Band-46.

III. GEOMETRY OF ANTENNA

After studying various antenna geometry and their performance in section II related work, we are preparing a design as shown in Fig.2 for simulation. The dimension of substrate is 38 mm * 27.3 mm, the thickness of substrate is 1.6 mm. The material used for substrate is FR4 having dielectric constant 4.4 & loss tangent of 0.02. The patch is rectangular shape with modified edges; the size of single patch is 33 mm * 2.8 mm. The antenna uses coaxial feeding technique. The position of feed point is on YZ plain of substrate.

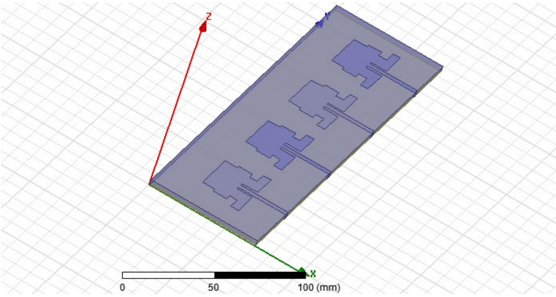

Fig.2 Geometry of 4 port MIMO Rectangular Patch Antenna

IV. SIMULATION RESULTS

The simulation of above design is being done using HFSS software. The above given dimensions are used to simulate the structure. The operating frequency of this design is 3.3 GHz and the obtained return loss is -33.81 dB. Fig.3, indicate a plot of reflection coefficient (S11, S22, S33, S44) vs frequency, which indicate that, for port 1 antenna start working at a frequency of 3.03 GHz (marker m3) & stop working at a frequency of 3.09 GHz (marker m4). The centre frequency of antenna is at 3.3 GHz (marker m1) and the bandwidth is 60 MHz. similarly for port 2 antenna start working at a frequency of 3.09 GHz (marker m4) & stop working at a frequency of 3.15 GHz (marker m5). The centre frequency of antenna is at 3.12 GHz (marker m2), for port 3 antenna start working at a frequency of 3.03 GHz (marker m3) & stop working at a frequency of 3.09 GHz (marker m4). The centre frequency of antenna is at 3.3 GHz (marker m2), similarly for port 4 antenna start working at a frequency of 3.09 GHz (marker m4) & stop working at a frequency of 3.15 GHz (marker m6). The centre frequency of antenna is at 3.12 GHz (marker m2) and the bandwidth is 60 MHz.

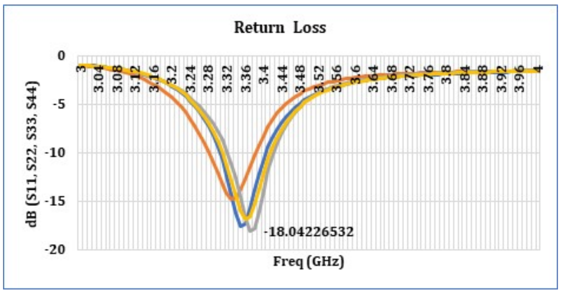

Fig.3. Return Loss of 4 port MIMO antenna using FR4 material

Fig.4 indicates a 3D radiation pattern of antenna, which also indicates total gain of antenna. The total obtained gain of antenna when using FR4 as a substrate material is 21.32 dB.

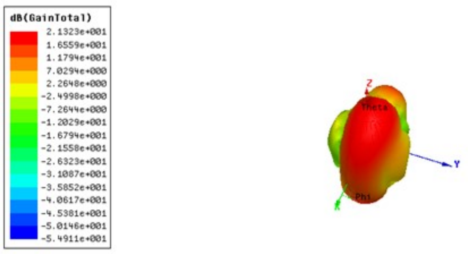

Fig.4. Total Gain of 4 port MIMO antenna

The gain of antenna is increasing when we go away from antenna. A 2D radiation pattern of antenna, which indicates a unidirectional radiation pattern, having a major lobe & back lobe is shown in Fig.5. The maximum value of gain is 18.21dB, at

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angle (θ) of 0 degree, indicated by marker m1.

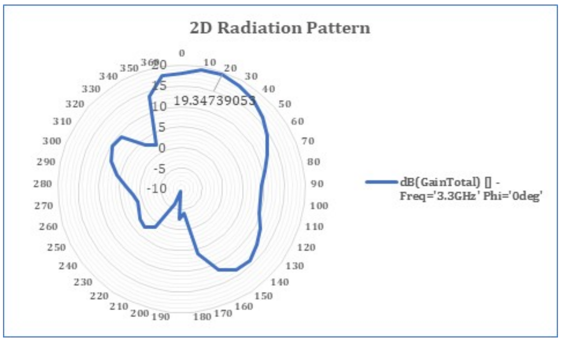

Fig.5. 2D radiation pattern of 4 port MIMO antenna

The graph of impedance vs frequency is shown in fig.6, which indicates that, at a frequency of 3.3 GHz the value of impedance of antenna is 41.51Ω, so that it is easy to connect this antenna with a 50Ω transmission line.

The incident power for 4 port MIMO is 1W each, the radiation efficiency of antenna is

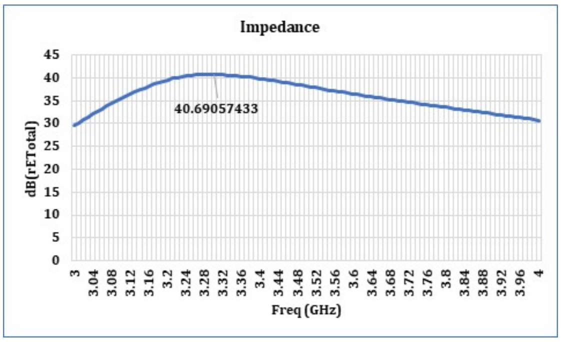

Fig.6. Graph of Impedance Vs frequency

26.22%. On the other hand, the FBRs under each port excitation are over 13.49 dB within the frequency band of interest, showing low backward radiations. Front to Back Ration is calculated by subtracting gain in dB at φ= 0deg, θ= 0deg (shown by marker m1) and φ= 0deg, θ= 180deg (shown by marker m2).

Table 2: State of the art Comparison

Survey of Research Variable for 2 Port MIMO Microstrip Patch Antenna Array for 5G Application									
Reference No	Frequency (GHz)	Gain (dBi)	Bandwidth (%)	Isolation (dB)	Radiation Efficiency	Front to Back Ratio (FBR) (dB)	Diversity Analysis		
							Mean Efficient gain (MEG)	Envelope Correlation Coefficient (ECC)	Diversity Gain (EDG) (dB)
[11]	25.2 GHz	8.732 dB	15.60%	15 dB	78.30%	-	4.07 Identical to all 8 Port)	0.03	15.8 dB
[13]	37 GHz	5.1 dBi	1.43GHz	23 dB	88%	-	3.01dB same for all 16 port	0.014	9.99 dB
[14]	4.73-5.02 GHz	5.38dBi	14.60%	21.7 dB	84.80%	-	Same for all 6 port	< 0.25	9.9 dB
This Work	**3.3 GHz**	**18.21dB**	**60 MHz**	**18.21dB**	**26.22%**	**13.49 dB**	**Same for all 2 port**	**< 0.5**	-

V. CONCLUSION

In this paper a 4 port MIMO antenna rectangular microstrip patch antenna is being proposed & simulated using HFSS software. It is being observed that the antenna is having bandwidth of 60MHz, the radiation efficiency of antenna is 26.22% and total Gain obtained at this frequency is 18.21dB. The VSWR of antenna is 1. The antenna having impedance of 41.51Ω, due to this it is easy to connect a 50Ω transmission line to antenna, without generating impedance mismatch losses. ECC values are well below 0.5 in the desired frequency bands, which ensures good diversity performance.

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The diversity gain in the frequency bands is almost 10dB. The Mean Effective Gain curves are almost the same that signifies the independent and identical polarization diversity. It is believed the proposed antenna is a promising candidate for application to modern 5G wireless communication systems.

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