MAT JOURNALS

Journal of Electronic Design Engineering
Volume 4 Issue 3

Design of Compact MIMO Antenna for 5G/Ultra-Wideband Communications

[1]Pankaj Kumar Singh, [2]Amit Sehgal, [3] Dinesh Kumar Singh
[1]Assistant Professor, [2,3]Associate Professor
[1, 2,3]Department of Electronics and Communication Engineering
G. L. Bajaj Institute of Technology and Management, Greater Noida, UP, India
Email:[1]*pankaj.singh@glbitm.org,*[2]*amit.sehgal@glbitm.org,*[3]*dinesh.singh@glbitm.org*
DOI:

Abstract
In this contribution, a compact 13 GHz notched band Multiple-Input Multiple-Output (MIMO) antenna is accessible for Ultra-Wide Band/broadband communication in metric linear unit wave band. The antenna structure has been designed on one substrate of FR-4 of thickness 1.6 mm.Two symmetrical microstrip patch antenna elements positioned in vertical direction to realised better diversity performance.The antenna elements are made up of a rectangular patch with microstrip feed line, operatingon the frequency of 28 GHz for Ultra-wide band applications. The result of designed structure has been computed numerical by FEM based solver HFSS v 13. Fromthe simulation results, it is clear that the proposed MIMO antenna structure covers 24.048 GHz to 37.04 GHzwith impedance bandwidth of 13 GHz (S_{11} better than -10dB) and also the isolation is found better than -20 dB in full wideband application. The gain of proposed MIMO antennadesigned structure has found approximately 2.11 dB.

Keywords: *GHz, MIMO, UWB, Gain, 5G.*

INTRODUCTION

In recent and upcoming days, the smart devices become an essential part of modern life. This is big challenge for smart devices to achieved small size, high speed data transmission, high bandwidth, broad band performance, gain, low power consumption etc.particularly at millimetre wave bands [1]. Ultra-Wideband (UWB) communications are a superb way to answer the above problems due to high records fee and relatively small radiator strength spectral density. Extremely-huge band antennas and some other conversation systems enjoy multipath fading. One of the best solutions for all issues is Multiple –Input Multiple-Output (MIMO) technology. Multiple-Input Multiple-Output (MIMO) technology combined with UWB antennas is an excellent choice for smart devices [2].

Microstrip patch antennas arethe goodpreference to accomplish abasic functional element due to reasonable symmetry of performance and also handy production especially for 5G/extremely-wide band applications. A square microstrip patch antenna has easy layout, compact and cost effective for 5G/extremely-huge Band applications [3]. The terminal impedance of microstrip patch antennas totally relies upon on physical homes of materials used, geometrical shape, size, feed region and feed types. To achieve the satisfactory geometry matching, all of the set of antenna parameters may be adjusted, at a particular resonance.A planar feed configuration of inset feed microstrip patch antenna provides a means of impedance control [1-3]. The basic limitation of microstrip patch antennas are inability to operate at high power levels of coaxial line, waveguide or even on strip line and comparatively narrow bandwidth.

The big challenges for designers are to design antenna with excessive benefit, better bandwidth and extra directional for right conversation [4]. The primary characteristics of microstrip antenna are mild weight, low cost, easy production and both compatibility to the mounting floor or much thin protrusion from the floor makes it top for numerous Wi-Fi packages.

In this communication, a very compact Multiple-Input Multiple-Output (MIMO) antenna shape is proposed for 5G/extremely-huge band programs. The proposed MIMO antenna layout shape has analysed for gain and bandwidth.

INSET FED MICROSTRIP PATCH ANTENNA

The microstrip patch antenna is designed in this kind of way that its radiation pattern maximum in normal to the patch (broadside radiator). Thicker substrate whose dielectric in lower cease of range offers better performance,larger bandwidth and loosely bounded fields for radiation into space, are major desirable components for antenna performance [6].The inset fed microstrip patch antenna isdesigned on FR4 epoxy substrate of dielectric constant 4.4 with height of 1.6 mm withpatch length 1.67 mm and patch width 3.26 mm as shown in table 1.

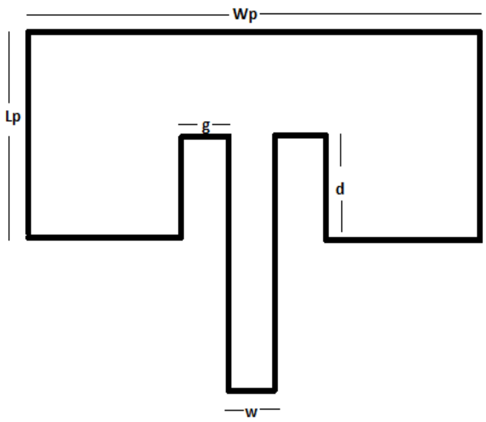

Fig: 1. *Inset fed microstrip antenna*

Table: 1.*Physical dimensions of antenna*

Resonance frequency (GHz)	28
Dielectric constant (ε_{eff})	4.4
Patch length L_p (mm)	1.67
Patch width W_p(mm)	3.26
Inset Feed position d(mm)	0.42
Width of fed line W (mm)	1

DESIGN PROCEDURE

The design procedure used is applicable forantenna that works on or above 28 GHz i.e. in the range 5G/Ultra-Wide band applications. The design techniques applicable to any frequency ranges which can be selected according to the designer's wish[6-8]. For simple single element antenna, the S_{11} parameter should be lower than -10 dB. In case of two elements polarization diversity antennas, S_{11} and S_{22} should be lower than -10 dB and the coupling parameters S_{21} and S_{12} should be lower than -15 dB [9].

Step 1: Width calculation:

The width of microstrip patch antenna can be calculated with the following relation:

$$W = \frac{c}{2f_a\sqrt{\frac{(E_r+1)}{2}}} \quad (1)$$

Step 2: Calculation of effective dielectric (E_{reff})

The effective dielectric constant can be calculated by the following relation given bellow:

$$E_{reff} = \frac{E_r+1}{2} + \frac{E_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \quad (2)$$

Step 3: Calculation of the effective length Effective (L_{eff}): The effective length can be calculated from the following relation as follows

$$L_{eff} = \frac{c}{2f_a\sqrt{E_{reff}}} \quad (3)$$

Step 4: Calculation of lengthextension (**Δ**L)

$$\Delta L = \frac{0.412h(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}+0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Step 5: Calculation of actual length of patch (L):

The actual length of patch can be calculated by the following equation

$$L = L_{eff} - 2\,\Delta L \quad (5)$$

DESIGN OF PROPOSED MIMO ANTENNA

Basic elements of MIMO antenna is designed on FR-4 substrate of size 13 mm x 13 mm x 1.6 mmand patch of size 1.67 mm x 3.26 mm to operate at 28 GHz frequency.

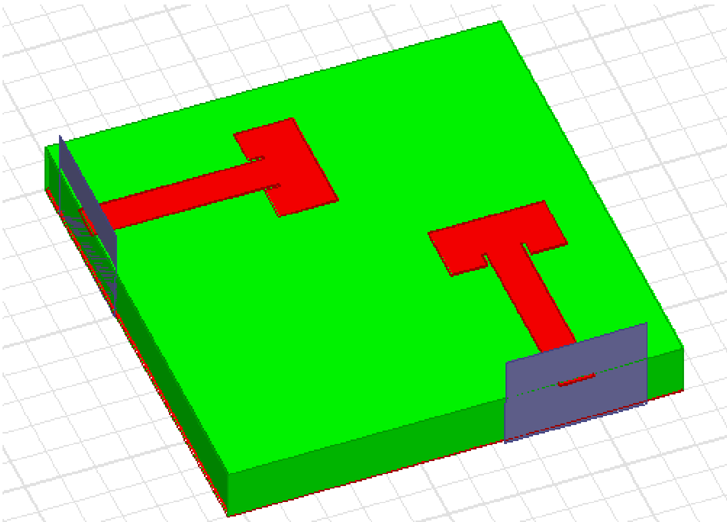

Fig: 2. *Proposed MIMO antenna*

RESULTS AND DISCUSSION

S-Parameter

The S_{11} parametershows that the MIMO antenna resonates at 27.96 GHz and offer bandwidth of approximately 13 GHz, from 24.04 GHz to 37.04 GHz, which is more suitable for wideband application in millimetre wave band.

The coupling parameter S_{21} of proposed MIMO antenna is better than -18 dB at frequency band 32.30 GHz to 34.90 GHz but better than -20 dBon remaining operating band of 24.04GHz to 32.25 GHz. The S_{22} parameter is also show the approximately same result as S_{11}. The S_{11}, S_{21} and S_{22} parameters of proposed MIMO antenna are shown in Fig 3, Fig 4 and Fig 5,respectively.

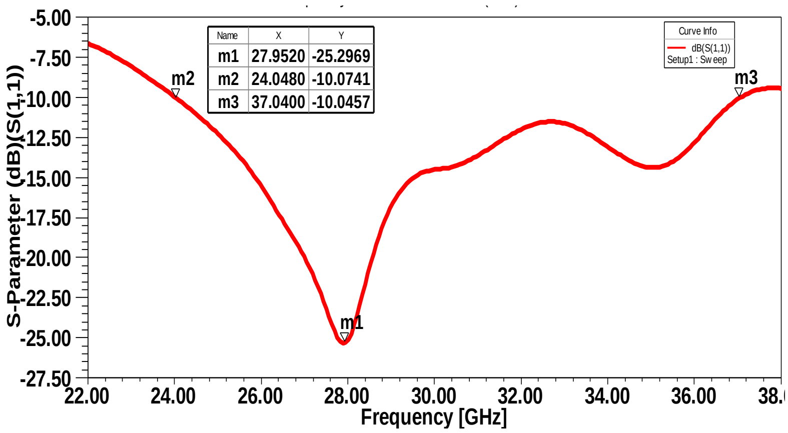

Fig: 3. *S_{11} Parameter of proposed MIMO antenna*

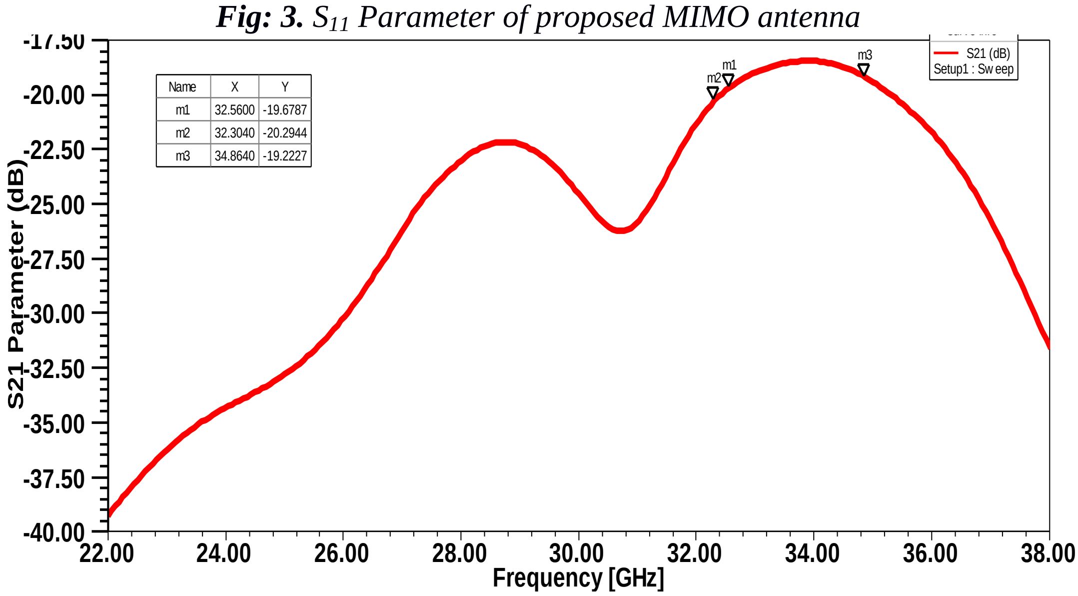

Fig: 4.The S_{21} Parameter of proposed MIMO antenna

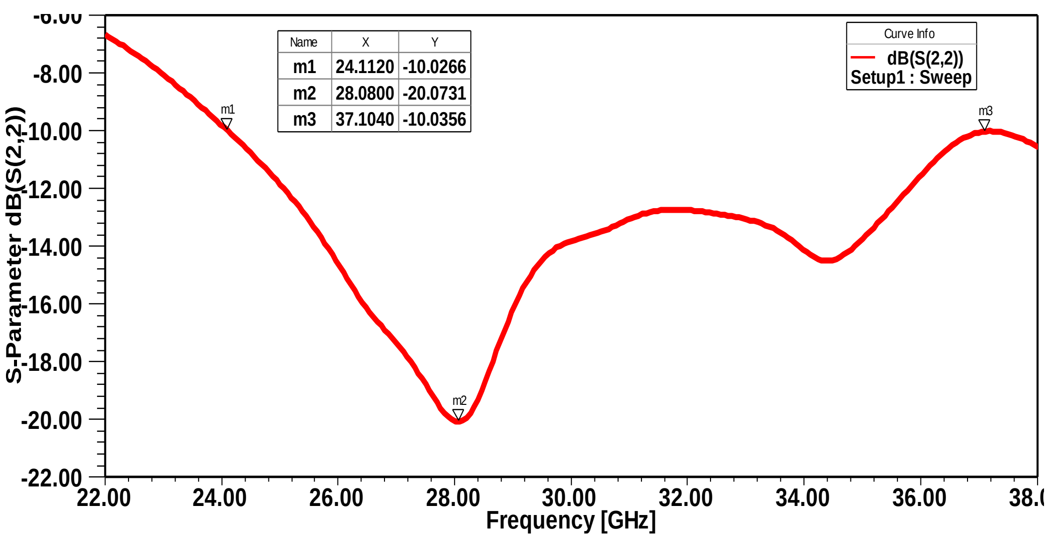

Fig: 5.The S_{22} Parameter of proposed MIMO antenna

Radiation Pattern

The radiation pattern of proposed MIMO antenna is shown in fig .7 and fig.8 at theta equal to 0^0 and 90^0respectively.

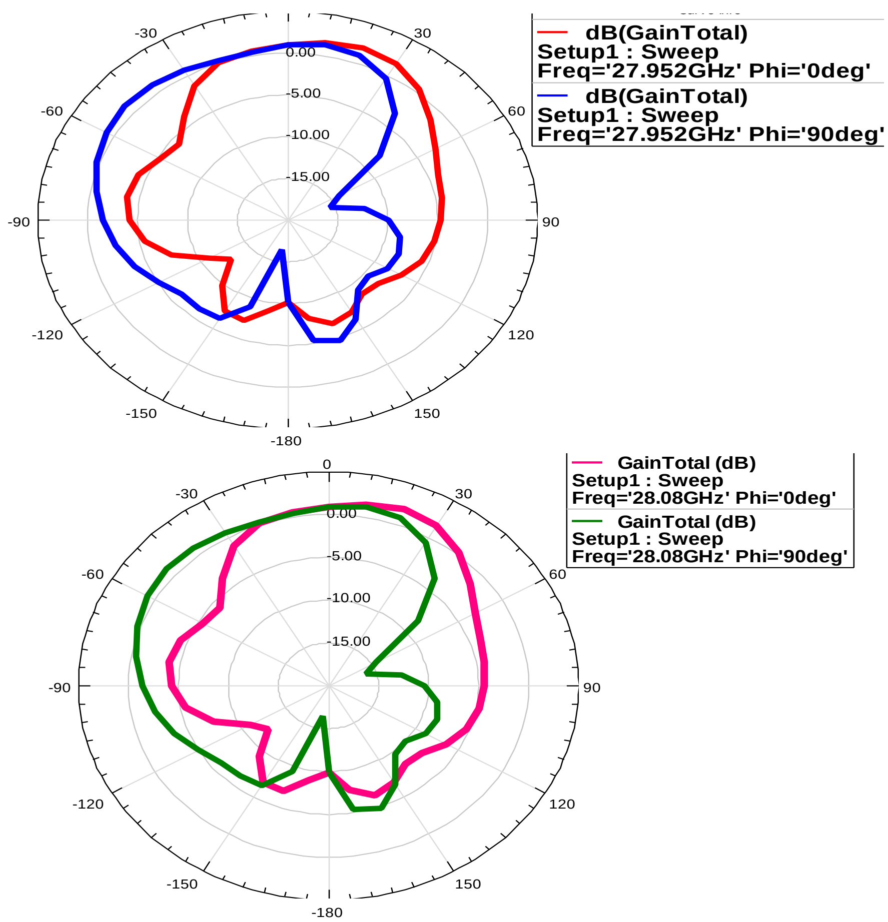

***Fig: 6.** The Radiation pattern of proposed MIMO antenna*

Directivity

The directivity of proposed MIMO antenna is shown at theta equal to 0^0 and 90^0shown in fig.7.

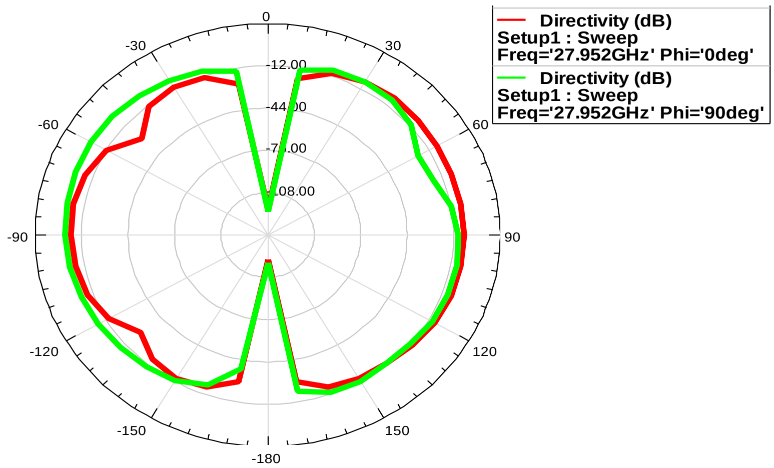

***Fig: 7.** Directivity of proposed MIMO antenna*

Gain

The total gain of proposed MIMO antenna is approximately 2.11 dB at 27.96 GHz as shown in Fig 8.

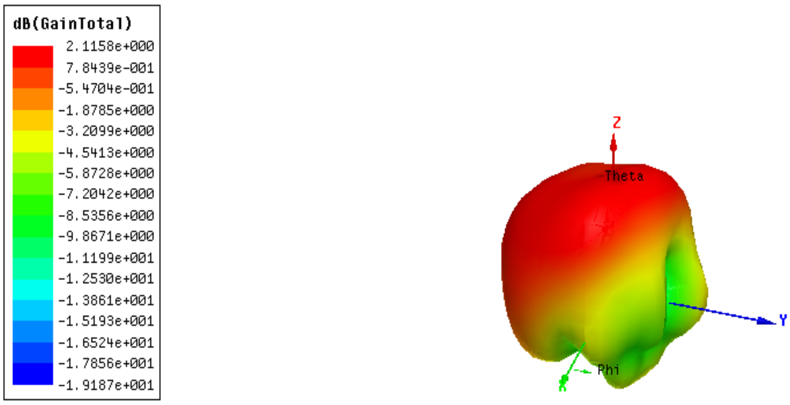

Fig: 8. *3-D Gain of proposed MIMO antenna*

The envelope correlation coefficient ρ of the MIMO antenna is given by

$$\rho = \frac{|S_{11} * S_{12} + S_{21} * S_{22}|^2}{(1-(|S_{11}|^2+|S_{21}|^2)^2)(1-(|S_{12}|^2+|S_{22}|^2))} \quad (6)$$

For $S_{11} = S_{22}$ = -10 dB and $S_{12} = S_{21}$ = -15 dB the envelope correlation coefficient ρ is 0.0167.
From the S_{11} and S_{21}parameterof proposed MIMO antenna, it is evident that the proposed MIMO antenna offer good isolation in operating band which is better than -20 dB.

CONCLUSION

In this contribution MIMO antenna with rectangular patch is proposed. The proposed MIMO antenna structure has showngood isolation better than -20 dB in operating band and offer gain of 2.11 dB. The proposed antenna is suitable for UWB/broadband applications in millimetre wave band for 5G. However, the physical antenna design for 5G/Ultra-wide band communications is a massive mission to the designers due to reduced dimensions imposed through the huge frequencies at millimetre waveband.

REFERENCE

1. W. Roh et al., “Millimeter-Wave as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results,” IEEE Comm. Magazine, pp. 106-113, Feb. 2014.
2. C. Liang et al., “Compact printed MIMO antenna with 6.1 GHz Notched Band for Ultra-wideband applications”, Progress in Electromagnetics research letter, vol. 76, pp-77-83, 2018.
3. X. P. Chen et al., “Low-cost high gain planar antenna array for 60 GHz band applications,” IEEE Trans. Antenna and Propagation, vol. 58, no. 6, pp. 2126-2129, June 2010.
4. T. Samaras, et al., “A note on the impedance variation with feed position of a rectangular microstrip antenna,” IEEE Antenna and Propagation Magazine, Vol. 46, pp. 90-92,April 2004.
5. R. Mailloux, et al., "Microstrip array technology," Antennas andPropagation, IEEE Transactions on, vol. 29, pp. 25-37, 1981.
6. M. T. I. Huque, et al., "Design and Simulation of a Low-cost and HighGain Microstrip Patch Antenna Arrays for the X-band Applications," inInternational Conference on Network Communication and Computer – ICNCC 2011, New Delhi, India., March 21-23, 2011.
7. D.M.Pozar, “A Microstrip Antenna Aperture Coupled to a Microstrip Line” Electronic Letters,vol.21,pp.49-50,January 1985.
8. Minhaz G. Vayada, Mohammed G. Vayada, Arti Patel,”Design & simulation of Rectangular Shaped

Patch Antenna Used for ISM band using HFSS" IJARCET,vol.4, issue 4,April 2015.
9. Wang, A., F. Zhenghe, and K.-M. Luk, "Pattern and polarization diversity antenna with high isolation for portable wireless devices," *IEEE Antennas Wireless Propag. Letters,* Vol. 8, 209–211,2009
10. Constantine A.Balanis's book of "Antenna Theory" third edition, Analysis and design.

Cite this article as:

