A MIMO Antenna Based On Cooperative Diversity for Improved Envelope Correlation Coefficient

Dr.Vaishali S .Dabhade[1] Neha R. Jadhav[2]

[1,2]JSPM's Bhivrabai Sawant Polytechnic, Wagholi, Pune, Maharashtra, India

Abstract— Multiple-Input Multiple-Output systems are important for increasing the capacity in wireless channels. In MIMO system more than one antenna is used at both the transmitter and receiver sides. Compared to the usual wireless systems, the main advantages of the MIMO systems are thehigher system capacity, improved bit rates, more link reliability, and coverage area is wider. The emerging new services in wireless applications have created a great motivation to use the MIMO systems to complete the demands needed for these applications. The MIMO systems can be used with other new techniques to get the benefits by using a higher spectral efficiency. Co-operative diversity is a cooperative multiple antenna technique for increasing total network channel capacities for any given set of bandwidths In the proposed system modified 2x2 multi input multi output triangular microstrip patch antenna is designed and analyzed.

Keywords: MIMO Antenna, Cooperative Diversity

I. INTRODUCTION

One of the effective ways of improving reliability and increasing the channel capacity is using multi-element antennas, such as multiple-input multiple-output (MIMO) antenna systems. It makes use of multiple antennas at both the transmitter and receiver to exploit the spatial channel for increasing the capacity. It is one of several forms of smart antenna technology. The basic properties that are used to describe the performance of an antenna include impedance and VSWR (Voltage Standing Wave Ratio), amplitude radiation patterns, 3 dB beam width, directivity, gain, polarization, and finally, bandwidth. Antenna arrays suffer from fairly high level of mutual coupling between antenna elements due to surface waves. This becomes worse with increase in frequency, dielectric constant, and substrate thickness. High antenna coupling (or low isolation) would cause signal loss, so increasing the signal correlation between the channels. Also the antenna radiation efficiency decreases due to the loss of the power dissipated in the coupled antenna port. To defeat this problem in MIMO a newly developed technique known as multi-user cooperative diversity is used. This allows a single antenna user to achieve transmit diversity benefits by sharing their resources through a virtual transmit and receive antenna array.

II. COOPERATIVE DIVERSITY IN MIMO

A MIMO system with N number of transmitting and receiving antennas is shown in figure 1.The basic idea of this system is to transmit various data streams using different antennas at the same carrier frequency and without additional power.

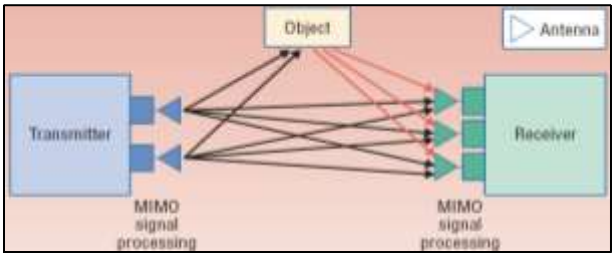

Fig. 1: MIMO system using cooperative communication

As depicted in Figure 1, the transmitter is transmitting data to the receiver, while the object (another user) is also hearing the transmission. The object also process and forward this message to the receiver, where both of the received signals are combined. As both copies of the signals are transmitted through independent paths, this results into cooperative communication. In this proposed work, we propose a 2x2 tapered triangular MIMO antenna based on cooperative diversity that achieves high isolation using stub element. The designed antenna shows reduction in mutual coupling and return loss.

III. DESIGN STEPS

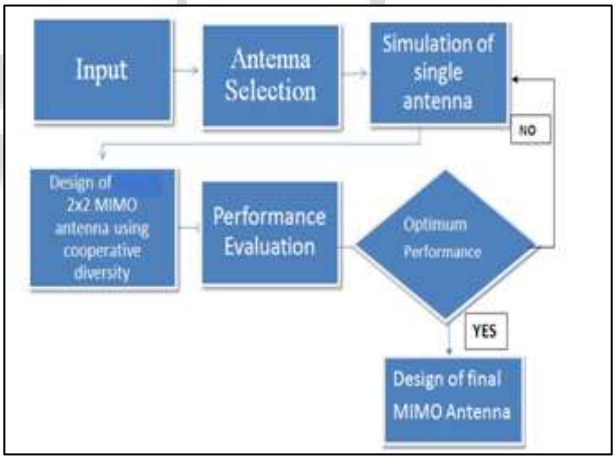

Fig. 2: Design Steps of MIMO Antenna

Figure 2 shows the design steps for design of MIMO antenna. First an input i.e. dimensions, frequency, voltage is given to HFSS. Then the shape and type of antenna is selected. The next step is to simulate the single antenna of desired shape. Using this single antenna 2x2 MIMO i.e.4 antenna elements are designed in cooperative communication. The next step is to evaluate the performance of the simulated antenna design.If the designer satisfies with the output parameters given by HFSS then only he or she may go for actual fabrication of the respective microstrip patch antenna otherwise designer has to modify certain inputs to achieve best output performance.

IV. ANTENNA GEOMETRY AND DESIGN

For design of antenna, the type is chosen and the input parameters are given. Due to number of advantages microstrip patch antenna is chosen.

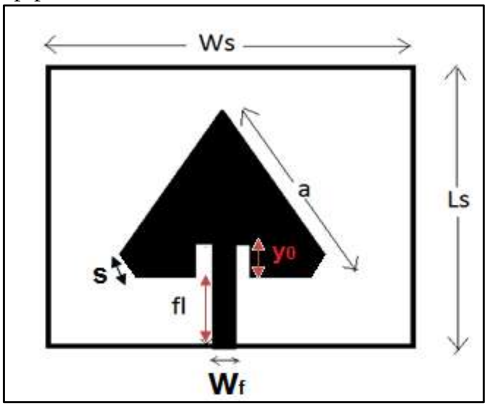

Fig. 3: Antenna geometry

Input Parameters-

- Freq (GHz) =2.4Ghz
- Material=FR4 modified

Output Parameters

First Calculate Lamba (λ)

Lambda (λ)=C0/f=$3x10^8/2.4x10^9$=125mm

λ =125mm

Step 1: Calculation of side length of triangle (a)-

The first fundamental resonant frequency of antenna is given by

$$fr = \frac{2c}{3a\sqrt{\varepsilon_r}}$$

$$a = \frac{2c}{3\,fr\sqrt{\varepsilon_r}}$$

Where εr=4.4, c=$3*10^8$m/s^2 and fr=$2.4*10^9$

We get a=39mm

Step 2: Calculation of feed point

For this feed would be given L/4 distance.

Feed point (y0)=28/4=7mm

y0=7mm

Step 3: Calculation of feed width(Wf)

Feed width calculate by using

$$Z= \frac{377}{\sqrt{er}(w/t+2)}$$

Where

er = dielectric constant = 4.4

W = width of feed line = ?

t= thickness of substrate=1.6 mm

Z = 50 ohm

We get Wf=2.84mm

Step 4: Calculation of Feed length(Fl)

The Length of quarter-wave transformer is,

Feed Length (Fl)=λ/4*sqrt (4.4) = 14.5 mm

Fl=14.5mm

Step 5: Calculation of Slot length(S)

The Slot Length is given by,

Slot Length (S)=0.05*λ

S = 6.5 mm

Step 6: Calculation of Substrate dimension-

For this design this substrate dimension would be

Ls=a+2*6h=28+2*6*1.6=58mm

Ws=a+2*6h=38+2*6*1.6=58mm

After calculation of all parameters, the next step is simulation of a single antenna. Then using this single antenna,a 2 x 2 MIMO is simulated. The antennas are arranged such that they exhibit cooperative diversity. As in figure 4,two antenna elements are for the transmitters (port 2 and port 4) and two elements for the receivers (port 1 and port 3).Antenna element 2 will transmit to 4, then 2 and 4 both will transmit to 1 and element 3.Thus cooperative diversity is achieved. After simulation the performance is checked by measuring the return loss. VSWR, isolation. If the performance obtained is optimum, then the final step is fabrication of the MIMO antenna. The proposed MIMO antenna is printed on FR4-Epoxy substrate. The antenna consists of four elements perpendicular to each other to form the 2 x 2 MIMO configuration.

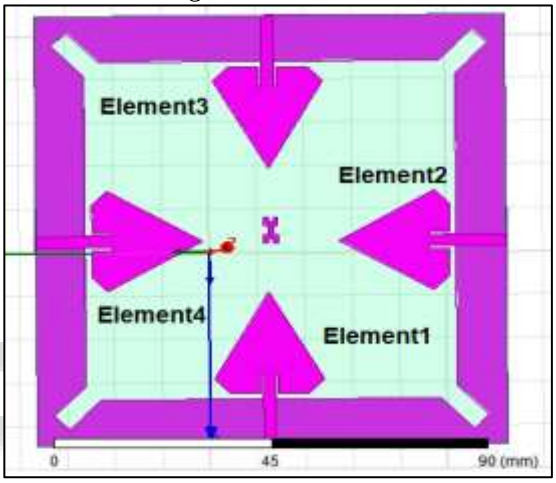

Fig. 4: 2x2 MIMO Antenna

V. RESULTS AND DISCUSSIONS

Before fabrication of the 2x2 multi input multi output antenna, it was simulated and tested.The simulation results are checked using HFSS.The Vector network analyzer (VNA) is used to measure the antenna parameters of the fabricated antenna.Fig 5 shows Vector Network Analyzer (VNA)-Agilent technologies N9923A (300 Khz– 6 GHz). A fast, reliable and well secured device that gives the best solution for network visibility.

Fig. 5: Vector Network analyser

The diversity performance of the MIMO antenna depends on cross-correlation among the signals delivered from each antenna element. The cross-correlation of signals is characterized by envelope correlation coefficient 'ρ'. The envelope correlation coefficient is the important parameter for judging the diversity performance of antenna. Correlation coefficient is calculated using S parameters. For a two port antenna system, using uniform multipath environment, the correlation coefficient (ECC) is given by,

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

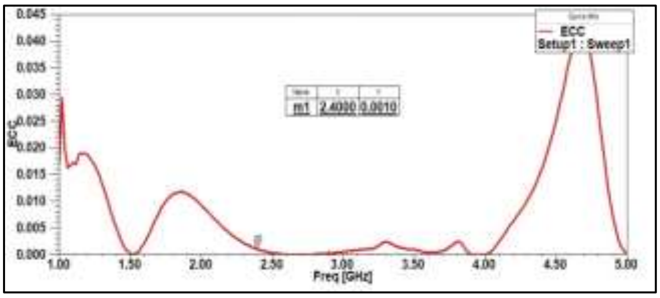

Fig. 6: Envelope correlation coefficient of 2x2 MIMO antenna

The mutual coupling causes the correlation coefficient between each antenna element to increase under some conditions. For figure 6, we have vertical polarization, this induce a mutual coupling effect that reduces the correlation between antenna elements. The correlation coefficient between element 1 &element 3 = 0.001 and between 2 and other two elements (1 and 3) = 0.002. These values are adequate to fulfill the requirements for MIMO systems

Another important parameter for MIMO antenna performance is its diversity gain (DG). The diversity gain of the MIMO antenna can be calculated using the following relation.

$$DG = 10\sqrt{1-(ECC)^2}$$

It is noted from that the proposed MIMO antenna has high diversity gain (DG > 9.0 dB) for the entire bandwidth.

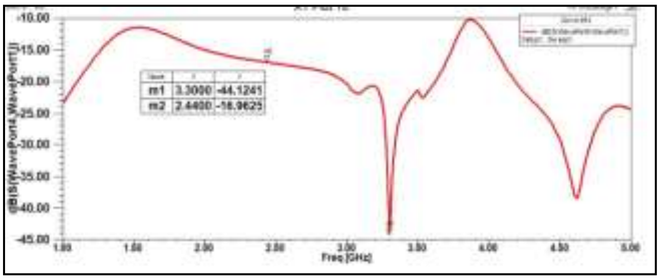

Fig. 7: Isolation for a 2x2 MIMO antenna with stub

Fig. 7 shows the isolation for the final 2x2 multi input multi output antenna. With the addition of stub, the value is increased upto -44 as seen in above graph.

Fig. 8: Mutual coupling of 2x2 MIMO

Fig.8 shows the mutual coupling of -45.57 dB at 3 GHz and -38 dB at 2.4 GHz for the fabricated 2x2 MIMO antenna. Thus a good improvement in isolation is obtained. The simulated and measured results are nearly equal.

Comparison Table Simulated Vs Measured Results

Sr.No	Antenna	Freq range (GHz)	Mutual Coupling (dB)	BW (MHz)
1.	Simulated 2x2 MIMO	1.52-3.37	-44.12	1800
2.	Measured 2x2 MIMO	1.65-3.23	-45.57	1670

VI. CONCLUSION

In this work, a new configuration of the parasitic fractal stub for miniaturization with reduced mutual coupling and improved envelope correlation coefficient has been introduced. A simple compact wideband modified triangular shaped MIMO for wireless applications is presented. This MIMO antenna uses cooperative communication which gives envelope correlation coefficientof 0.002 and diversity gain greater than 9 dB. Also mutual coupling is significantly reduced.This research work is about adding a parasitic element, stub which is placed between MIMOantennas to improve the isolation between the four ports and use of diversity for improvedenvelope correlation coefficient.Results show that envelope correlation coefficientis improved with added fractal parasitic element stub due to reduced mutual coupling.

REFERENCES

[1] Mahinthan V, Mark Jon W , Xuemin Shen, "Performance analysis and power allocation for M-QAM cooperative diversity systems," in Wireless Communications, IEEETransactions on ,vol.9, no.3, pp.1237,1247, March 2010
[2] JagadeeshBabuK , Sri Rama Krishna K ,Pratap Reddy L, "A review on the design of MIMO antennas for upcoming 4G communications"in International Journal of AppliedEngineering Research,Dindigul,vol-1,2011.
[3] Mohammad S.Sharawi, YanalS.Faouri, Sheikh S.Iqbal, "Design and Fabrication of a Dual Electrically Small MIMO Antenna System for 4G Terminals," in Proceeding of the 6thGerman Microwave Conference, March 2011.

[4] Del Coso A, Spagnolini U, Ibars C, "Cooperative distributed MIMO channels in wirelesssensor networks" in Selected Areas in Communications, IEEE Journal on vol.25, no.2pp.402, 414, February 2007.
[5] Weiqian Weng, Yuan xin Xu, Kuang Wang, "Channel Estimation in Correlated ChannelFor802.11n System," in Networking, Sensing and Control, 2008, IEEE InternationalConference on vol., no., pp.519,522, 6-8 April 2008.
[6] Alishir Moradi Kordaliv and, Tharek A. Rahman Mohsin Khalily, "Common Elements Wideband MIMO Antenna System for WiFi/LTE Access-Point Applications", IEEE Antennas and Wireless Propagation Letters, Vol.13, 2014.
[7] Torabi M, Haccoun D, Ajib W, "BER Performance Analysis of Multiuser Diversity with Antenna Selection in MRC MIMO Systems" in Global Telecommunications Conference, 2009. (GLOBECOM 2009) IEEE, vol., no., pp.1,6, Nov. 30 2009-Dec. 4 2009.
[8] Bhatti R.A,Jung-Hwan Choi, Seong-Ook Park, "Quad-Band MIMO Antenna Array for Portable. Wireless Communications Terminals" in Antennas and Wireless Propagation, Letters, IEEE , vol.8, no., pp.129,132, 2009
[9] M.Cabedo, E.Antonino, M.Ferrando, V.M.Rodrigo, A.vila, J.M.Molina, L.Juan, "Compact planner antennas with multiple ports for MIMO and diversity applications," in ISSN 1889-8297/waves/2010.
[10] Cheng Yang, Yuan Yao,Junsheng Yu, Xiaodong Chen, "Novel Compact Multiband MIMO Antenna for Mobile Terminal," Hindawi Publishing Corporation, International Journal of Antennas and Propagation volume 2012.
[11] Ssorin V, Artemenko A, Sevastyanovn A, Maslennikov R, "Compact bandwidthoptimized two element MIMO antenna system for 2.5 – 2.7 GHz band" in Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference on , vol., no., pp.319,323, 11-15 April 2011.
[12] Min Seok Han, Jaehoon Choi, " Multiband MIMO Antenna with a Band Stop Matching Circuit for Next Generation Mobile Applications" in PIERS Proceedings Moscow, Russia, August, 2009.