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Aperture Coupled Stacked Microstrip Antenna Array

Ayushi Agarwal, Amanpreet Kaur*

Department of ECE, Thapar University, Patiala, India

*Email: amanpreet.kaur@thapar.edu

ABSTRACT

This paper presents a novel design of stacked microstrip antenna array for MIMO systems. An aperture coupled feeding technique with rectangular slots has been used to ensure equal coupling to each radiating slots. The antenna system is a layered structure consisting of two driven patches and two parasitic patches. The proposed antenna uses FR4 substrate with dielectric constant 4.4 and height 1.57 mm. The designed structure covers A BROAD wireless band from 5.59 GHz to 5.86 GHz with impedance bandwidth of 270 MHz. Antenna shows gain of 6.828dBi and CORE;ETOION COEFF of 0.35. These characteristics make this antenna suitable for wireless MIMO communications. To deploy the antenna in MIMO system S_{11}, diversity gain, envelope correlation coefficient (ECC) and capacity analysis is also carried out.

Keywords: Stacked, aperture coupled, MIMO, S_{11}, diversity gain, ECC, capacity, CST MWS'14, MATLAB r'11.

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1. INTRODUCTION

Antenna is one of the most vital components of any wireless communication system. They behave as transducers and convert the data embedded on a high frequency carrier signal from electrical to electromagnetic waves and discharge those in free air for transmission and vice versa for reception [1]. Since mirostrip antennas have advantage over the other types of antenna of being small in size, ease of fabrication, conformability to planar and non-planar surfaces, and ease of integration with RF front end circuits,These are preferred choices for most of the wireless applications. The basic configuration of microstrip antenna consists of a metallic patch printed on a thin ground dielectric substrate. The radiating element and the feedlines are photo etched on the dielectric substrate [1]. The microstrip patch is designed so that by excitation beneath the patch its pattern maximum is normalto the plane of the antenna.

Apart from the advantages provided by the microstrip antenna, one disadvantage to be overcome is low bandwidth. Thus to provide greater bandwidth to support a good data rate, there are different techniques available like U-slot technique [2], probe-feeding, slit loading etc. in this paper bandwidth was improved by stacking parasitic patches over the driven patches. With stacking, aperture coupling is used to further improve the performanceof the antenna array system [2, 3].

With the increasing demand of data rate in wireless communication field, it is necessary to design small as well as efficient transmitters and receivers.The feed network in aperture coupling makes little influence on radiating elements and is suitable as feed points of antenna array [4]. Another advantage of it is the elimination of the probe penetrating through the substrate layer [5].

In the aperture coupler adjusting the size of the aperture can control the impedance of the array system [4, 5].

The system, in which the multiple antennas are employed at the input and the output, is known as multiple inputmultiple output (MIMO) system. Multiple antennas increase the capacity proportionally [6].

The current work focuses on for employing antenna in MIMO system by using an array of MSA to designed and simulated for parameters like diversity gain, and ECC. In context to the same, in this paper the design for an aperture coupled antenna is described and simulated results for the S_{11}, radiation pattern, ECC, diversity gain, and capacity of the antenna array system are presented.

The paper is organised as follows section II gives the brief about the MIMO system model. Section III describes the antenna geometry and specifications. Next sections are dedicated to the discussion of the simulated results and the conclusions.

2. SYSTEM MODEL

This array system is designed to deploy at the receiver side. A single input multiple output system is considered. The channel is assumed to be quasi-static Raleigh flat fading between the transmitter and the receiver. We also assume that the transmit antenna has no state information of the channel i.e. CSI and only the receiver knows about the actual realization of the channel. Thus, uniform power allocation among the transmitter is reasonable and deployed.

Diagrammatically system can be represented as:

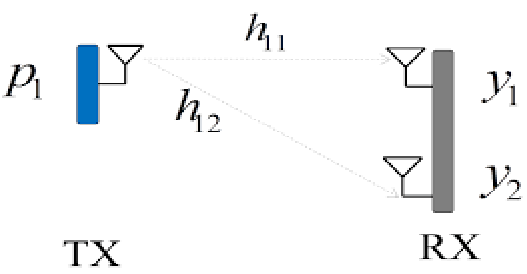

Fig.1. 1X2 System Model

For a narrowband MIMO channel, when CSI is not known at the transmitter, the capacity is given by [7]:

$$C = E\left[log_2 det\left(I_{nr} + \rho\frac{HH^+}{N}\right)\right] \quad (1)$$

Where ρ is the average SNR at receiver and H is the $N_t X N_r$ channel matrix. Given by:

$$H = [h_{11}\ h_{12}]$$

$N=\min(N_t,N_r)$. N_t and N_r are the number of transmitting and receiving antennas respectively. More often each element of H is taken to be i.i.d complex Gaussian distributed random variable signifying that each pair of transmitters and receivers experiences independent fading. But, this is not true in practical situations. Because of spacing and mutual coupling between the elements, independent fading is not a valid assumption. This kind of system is acceptable in many applications of C-band MIMO system like WLAN, WIFI. To allow the antenna to be easily embedded inside the devices used for communication, a MSA is a good choice. The proposed antenna array for such systems is discussed in the next sections.

3. ANTENNA GEOMETRY AND SPECIFICATION

The basic design of the proposed structure is an array of two antennaswith stacked patches and fed using aperture coupling feeding technique.The antenna array consists of three layers as shown in figure 2. The length and width of ground plane and substrate is 7.6cm X 3.6cm. All the parametric details of the antenna are mentioned in table 1 for reference.

On the top and middle layers array of two rectangular patches is photoetched. The array of top patches act as radiating patches. Both the patches are excited respectively with two feedlines that are energised with the separate ports 1 and 2 as shown in figure 2. The dimensions of the patches were optimised so that all the four patches resonate at a centre frequency of 5.8 GHz. Values of the various parameters are calculated using transmission line equations [1]. All the calculated parameters are presented in table 2. The overall dimension of the antenna is 7.6 X 3.6 X 4.78 cm^3.

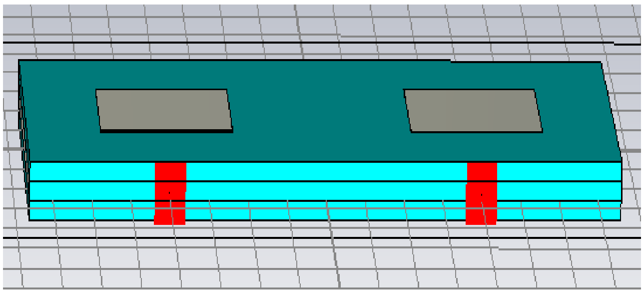

Fig.2. Side View of the Proposed Antenna Array

Two rectangular shaped defected ground slots (DGS) are etched on the ground plane for back radiation reduction [2], which is sandwiched between the lower and middle substrate. The antenna is fed using aperture coupling feed method in which the feedline is etched on the lower part of the lowest substrate.The next section presents the simulated results of the antenna in terms of its bandwidth gain, diversity gain, radiation pattern and correlation coefficient.

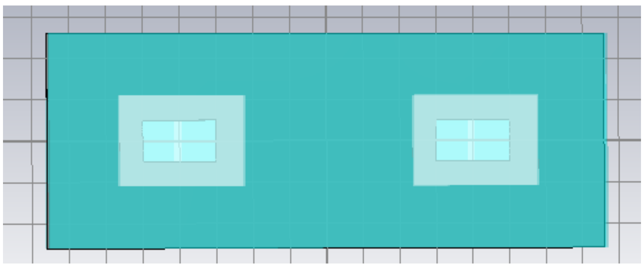

Fig.3. Front View of the Ground-plane

TABLE 1: Patch Antenna Specifications

Parameter	Value
Substrate Material	FR4
Dielectric constant	4.4
Loss Tangent	0.009
Substrate Thickness	1.57mm

Substrate Width	76 mm
Substrate Length	36 mm
Lower patches width	17 mm
Lower patches length	11 mm
Upper patches width	17 mm
Upper patches length	11 mm
Aperture width	12 mm
Aperture length	5 mm
Feedline Length	20 mm
Feedline width	2 mm

4. RESULTS AND DISCUSSIONS

All the simulations related to antenna array designs were carried out using CST MWS'14. All the four patches were optimized for the desired results. The results are presented in this section.

4.1. S_{11}(dB):

The S_{11} graph of an antenna represents its impedance bandwidth with respect to a return loss of less than -10dB. Figure 4 shows the return loss of a stacked antenna.It covers an impedance bandwidth of 132.4 MHz around 5.8GHz with S_{11} of -15dB.

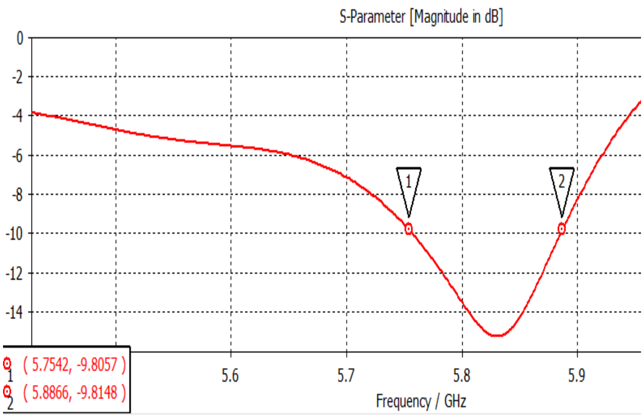

Fig.4. S_{11} of Single Antenna Element

Various antenna parameters were optimized for the desired results. The iterations done on the driven patch are shown in figure 5.

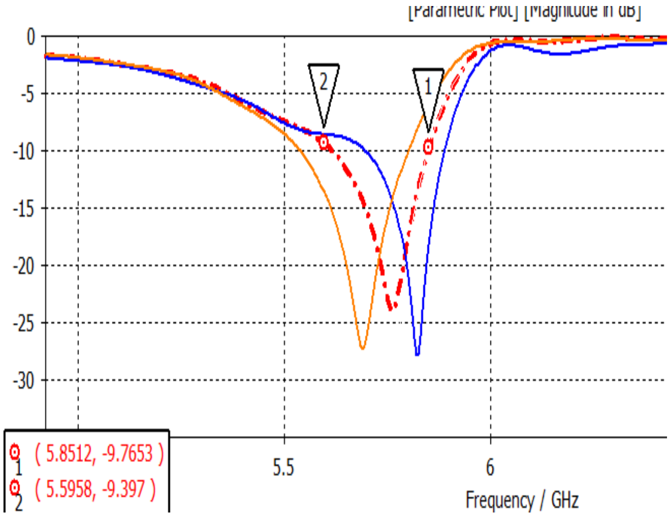

Fig.5. S_{11} of Various Iterations done on the Driven Patch

When the patches were optimised the slot was iterated. The results of iterating the slot is given in figure 6.

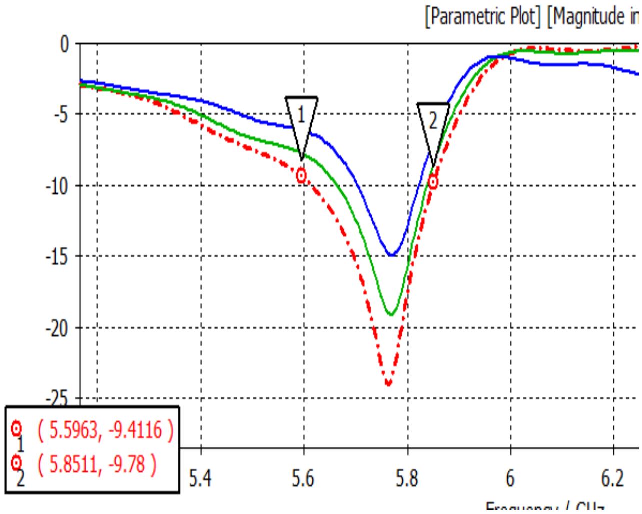

Fig.6. S_{11} of Various Iterations done on the Aperture

The figure 7 represents the plot of simulated array's S11 on the Y-axis with the frequency on the X-axis. The antenna resonates at 5.8 GHz with the S11 of -29 dB covering the frequency range of WLAN. Due to the presence of many elements when their resonances are close they produce a larger bandwidth. The structure shows an impedance bandwidth of 270 MHz. Bandwidth and capacity is related to each other according Shannon theorem. As antenna array is offering greater bandwidth, hence supports a greater capacity.

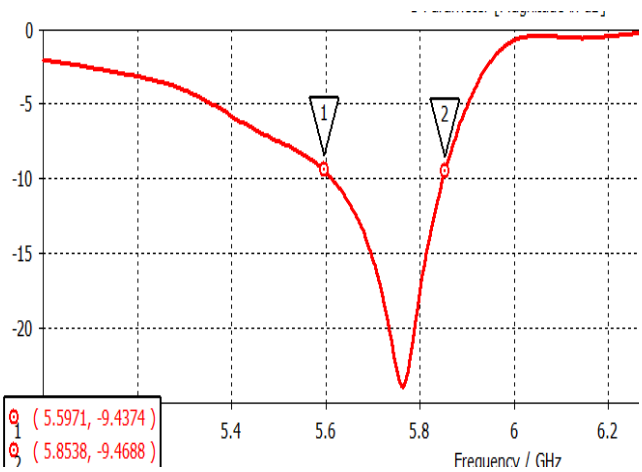

Fig.7. S_{11} of Stacked Antenna Array

When the two ports are excited simultaneously the energy from one port is transferred to other port, the parameter representing this value is known as transmission coefficient. When then power is transfer from port to port 2 the parameter is S_{21}. For any MIMO system array this value should be less than -15 dB that shows an ECC less than 0.5. Figure 8 shows the graph of S_{21} of the proposed antenna array. The antenna has S_{21} of -24 Db with desirable ECC.

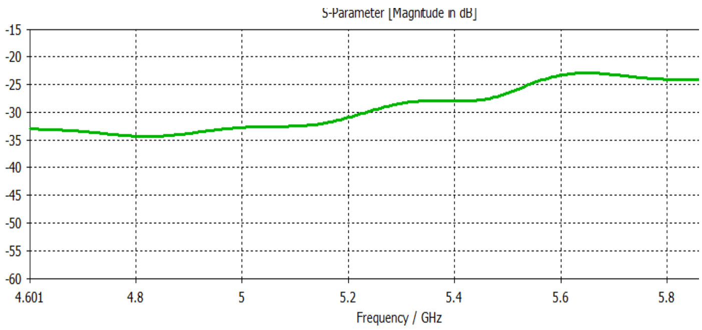

Fig.8. S_{21} of Stacked Antenna Array

4.2. Radiation Pattern:

The antenna structure uses two feedlines to excite the patches simultaneously. When the antenna is energised it radiates and the 3D plot of the radiation characteristics can be inferred as the radiation pattern. A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. Fig 9 shows the gain of 6.8dBi at port 1. And from graph 10 it can be inferred that proposed antenna shows the gain of 6.8 dBi from exciting port 2.

4.3. Envelope Correlation Coefficient:

In a MIMO antenna array system envelope correlation coefficient (ECC) represents the influence of different propagation paths of the RF signals reaching the antenna elements. When antennas are oriented with less than half wavelength distance between them then mutual coupling takes place which affect the envelope correlation coefficient [13].

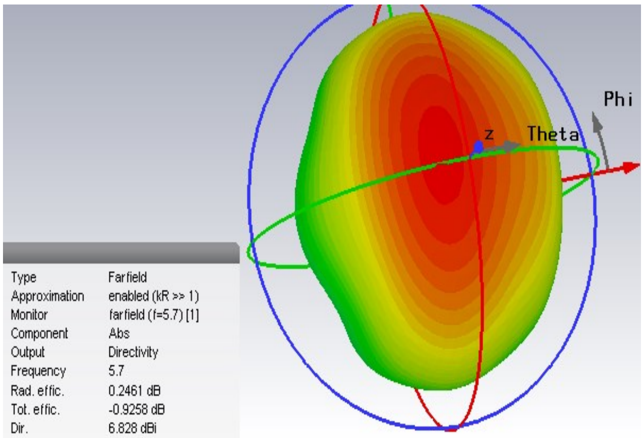

Fig.9. Radiation Pattern at Excitation 1

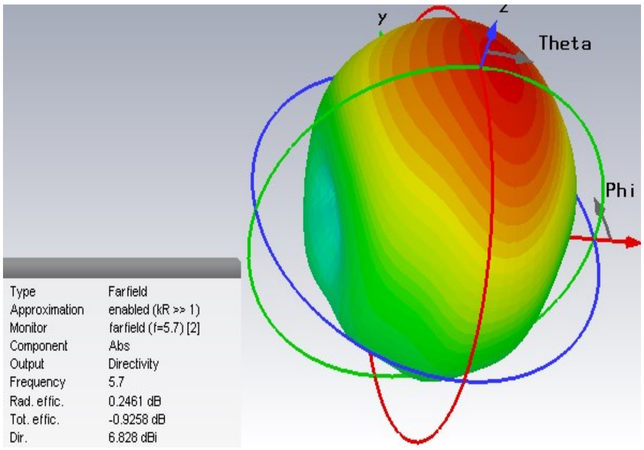

Fig.10. Radiation Pattern at Excitation 2

The approximated value of this coefficient is based on a simple closed-form equation and also varies from 0 to 1. Quite ideal performance for MIMO applications is attained when this parameter approximates to zero. For the proposed structure the approximate value is 0.035. For the desirable result this value should be less than 0.4 in any MIMO system.

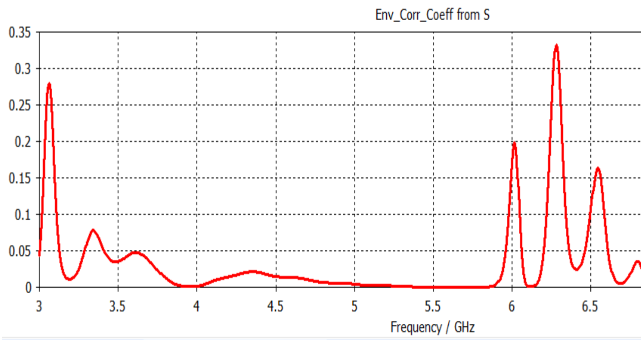

Fig.11. Envelope Correlation Coefficient

For two antenna elements equation of ECC can be written as [14]:

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

4.4. Diversity Gain:

In a MIMO system, diversity gain gives gain of transmitted signals that is attained by employing multiple antennas at transmitter and/or receiver, with respect to single antennas at both the ends. Figure 12 shows the diversity gain achieved in the proposed array.

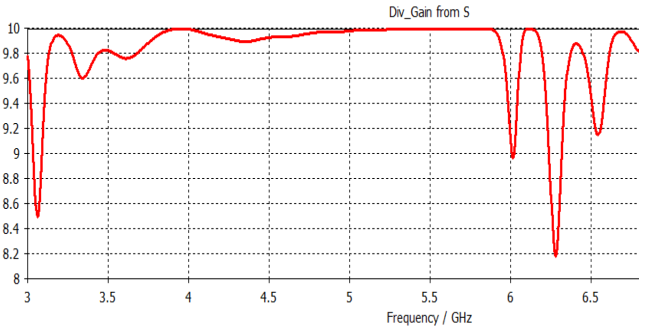

Fig.12. Diversity Gain

5. Capacity of the Proposed Antenna Array System

5.1. Capacity vs Power:

Increase in the signal power infers splitting the signal level into large number of levels while ensuring low probability of error. Hence increase signal power will lead to more capacity. Figure 13 shows the plot of capacity vs power. Equation (3) is used for plotting the graph.

$$C = B.^{*} \log_2\left(1 + \frac{P}{N_o{}^{*}B}\right) \quad (3)$$

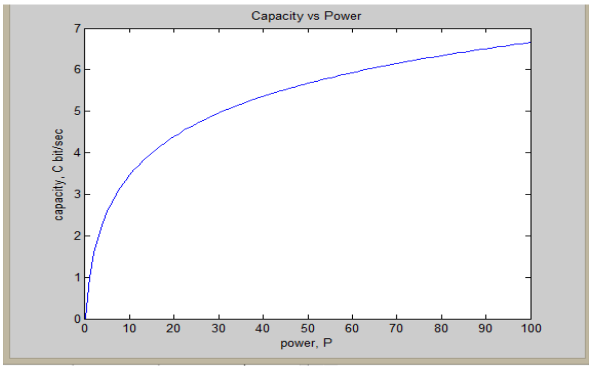

Fig.13. Capacity vs Power

From the graph it can be inferred that capacity is exponentially increasing with the increase in power. As an ideal case scenario in this case noise and bandwidth were taken to be fixed. The graph was then plotted for capacity VS power (dBm). But the power cannot be increased beyond certain limits.

B. Capacity vs Bandwidth:

As discussed above power cannot be increased indefinitely so the next quantity that can be worked upon is bandwidth. The figure 14 shows the graph of capacity VS bandwidth. Graph shows that firstly there is an exponential increase in capacity, after a limit the increase is linear. More bandwidth means more number of transmissions per second, hence increase in the capacity. Maximum achievable capacity by increasing bandwidth is 1.44 times the P/N_o value.

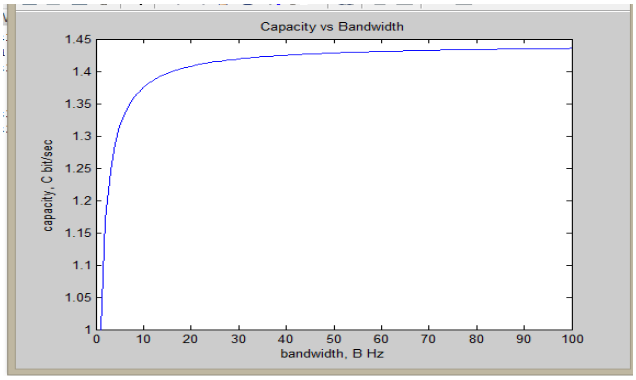

Fig.14. Capacity vs Bandwidth

6. CONCLUSION

A stacked antenna array is designed and simulated using CST MWS. To ensure its usage in MIMO system, capacity of the array system is also evaluated using MATLAB r'11. The array was designed using an aperture coupling feed. The proposed structure can be used for WLAN wireless application from 5.59 to 5.86 GHz. Antenna offers a bandwidth of 270 MHz The dimensions of the patch, and length and width of the aperture was optimized for the desired results. The compact size of the array makes it desirable for wireless receiver circuits. Antenna has a gain of 6.828 dBi making it suitable for indoor wireless applications

REFERENCES

[1] C.A. Balanis, *Antenna Theory: Analysis and Design*, 2nd ed. United States of America, John Wiley&Sons Inc., 1997.

[2] R.S Kushwaha, D.K Srivastava, S. Dhupkariya, J.P saini and K. Prasad, 'Slot loaded Electromagnetically Coupled Microstrip Line Fed Microstrip Patch Antenna for Wideband Applications',*IEEE Conference on Communications and Signal Processing (ICCSP),* 2013, 1082-1086.

[3] Serra, A.A.; Nepa, P.; Manara, G.; Tribellini, G. and Cioci, S.: 'A wideband dual-polarized stacked patch antenna'. *IEEE Antennas Wireless Propag. Letter*, 6 (2007), 141–143.

[4] Grag, R.; Bhartia, P.; Bahl, I. and Ittipiboon, A.*: Microstrip Antenna Design Handbook*. Artech House, 2001.

[5] I. Park and R. Mittra, 'Aperture-coupled small microstrip antenna', *Electron. Lett.,* vol. 32, pp.1741 - 1742 , 1996.

[6] Alper Ocalan, AsumanSavascihabes, Ibrahim Gorgec, OzgurErtug and ErdemYazgan: 'Compact Space-Multimode Diversity Stacked Circular Microstrip Antenna Array for 802.11n MIMO-OFDM WLANs', *Loughborough Antennas and Propagation Conference,* November 16-17 2009.

[7] Xingjin Lin, Ming Luo, Yang Yang, Kama Huang 'High Gain Aperture Coupled Antenna Array', *IEEE,* 2012.
[8] H. Alias, M.T. Ali, S. Subahir, N. Ya'acob and M.A. Sulaiman, 'Aperture Coupled Microstrip Antenna Array Integrated with DGS and Parasitic Elements', *IEEE Symposium on Wireless Technology and Applications (ISWTA),*September 22-25,2013.
[9] Daniele Pinchera, Fulvio Schettino, 'A Dual-Polarized Parasitic Patch Antenna for MIMO Systems', *39th EuropeanMicrowave Conference*, 2009.
[10] Hassan Elesawy, W. Swelam, AbdalmonemFouda, Ismail M. Hafez, 'Design of Microstrip Array Antenna for Wireless Communication Application', *IOSR Journal of Engineering (IOSRJEN)*, Vol. 3, Issue 12, December, 2013.
[11] Eduardo Rodriguez A, EzdeenElghannai, Roberto G. Rojas and Roberto Bustamante, 'Design and Evaluation of an Antenna Array forMIMO Systems and Handset Wireless Applications', *IEEE,* 2015.
[12] Chandan Kumar Ghosh, Susanta Kumar Parui, 'Design of Triple Frequency Compact Microstrip Patch Antenna Array for MIMO Application', *IEEE,* 2009.
[13] Matilde Sanchez-Fernandez, Eva Rajo-Iglesias, Oscar Quevedo-Teruel, M. Luz Pablo-Gonzalez. 2008 Spectral Efficiency in MIMO Systems Using Space and Pattern Diversities Under Compactness Constraints. *IEEE T* 1637-1645.
[14] R. G. Vaughan and J. B. Andersen, "Antenna Diversity in Mobile Communications," *IEEE Transactions on Vehicular Technology*, Vol. 36, 1987, pp. 149-172.
[15] R. G. Vaughan, "Signals in Mobile Communications," *IEEE Transactions on Vehicular Technology*, Vol. 35, 1986, pp. 133-145.