Novelty Journals

International Journal of Novel Research in Electronics and Communication
Vol. 1, Issue 1, pp: (22-29), Month: September 2014 - February 2015, Available at: www.noveltyjournals.com

An Efficient U-Slotted Patch-Antenna Array for MIMO Systems

P Sakthivel [1], C Poorana kumari [2]

[1]Asst Professor / ECE Sree Sastha College of Engineering, Chennai – 600123
[2]Asst Professor / ECE Govt. Engineering College, Bodinaikanoor, Tamilnadu

Abstract: **In this paper presents, a dual band Microstrip patch array antenna for both Multi Input Multi Output (MIMO) 4G Long-Term Evolution (LTE) and WiMax application. The Design, simulation and optimization processes are carried out with the aid of Agilent ADS momentum technique. The designed array antenna operates at 2.2 GHz and 3.6 GHz bands for 4G LTE and WiMax systems respectively. Rectangular patch antenna constructed using FR-4 substrate material with ϵ_r = 4.4 and h = 3.1 mm. U-shape slot is provided to obtain dual-band characteristics. Substrate losses are also taken into account during simulation process. The proposed array may be used as a template to form larger array in order to achieve high profile antenna system.**

Keywords: **Micro strip Antenna, U slot, MIMO, WiMax, Dual Band.**

I. INTRODUCTION

The MIMO systems are popular from the past two decades and more which is widely used in various wireless communications. It is clear from the theoretical point of view that the use of MIMO systems increases the capacity as compared to Single Input Single Output (SISO) and Single Input Multiple Output (SIMO) systems. The 4G handheld telephones, iPhone, and other new compact cellular equipments recommends the use of small scale multi-band MIMO antenna systems. This paper cover cover both the 4G LTE and the WLAN bands. The 4G cellular mobile communication standards, Long Term Evolution (LTE) and WiMAX utilizes MIMO to provide improved data rates of up to 1 Gbps .

In recent years, growth of wireless communication is very speedy. The increasing numbers of users with limited bandwidth are hard to optimize in network point of view for larger capacity and improved quality. This surge has led to the field of antenna engineering to constantly evolve and accommodate the need for wideband, low-cost, miniaturization and integration of antenna systems. A widely used antenna structure with above characteristics is Microstrip antenna. The Microstrip antennas are associated with several advantages such as low profile, versatile, conformal and low-cost. The applications on vehicle based satellite link antennas, global positioning systems (GPS), radars, cellular, telemetry, mobile handheld radios and cellular communication devices. But, these antennas are also associated with some disadvantages, such as narrow bandwidth, low gain and the excitation of surface waves.One of the main types of planar antenna is Microstrip patch antenna. They are preferred rather than other planar antennas because of their thin profile.

A patch antenna is a piece of metal mounted on a substrate of thickness with some specific dielectric constant ϵ_r. A simple rectangular patch antenna typically resonates at a single resonance frequency f_c [3]. It can be modified to resonate at multiple frequencies by providing slots [3] with different shapes on it. Several types have been reported which include mainly C, E, F and U slot shapes each one with its own effects and properties. The slot antenna performance strongly depends on the shape and position of the slot and multiple slots can be provided to obtain the desirable performance [2, 3]. The wideband antenna behavior is determined by the current along the edges of the slot that produce another resonance which combine with the resonance of the primary patch. The U-slot patch [5] antenna maintains its wideband characteristics with linear polarization when fabricated on a microwave substrate instead of an air or foam substrate well known to achieve wideband characteristics rather than multiband resonances. Later days it is found that the varying parameters of U-slot converted into a dual-band antenna. when cutting more than one U-slot on the patch, the antenna can resonate at multiple frequencies. The U-slots introduce notches [5] into the wideband of antenna, resulting multiband operation. Because of this property and due to its simple geometry, the U-slot patch antenna can be customized. U-slot dimension and its associated effect on antenna performance are analyzed in ths paper.

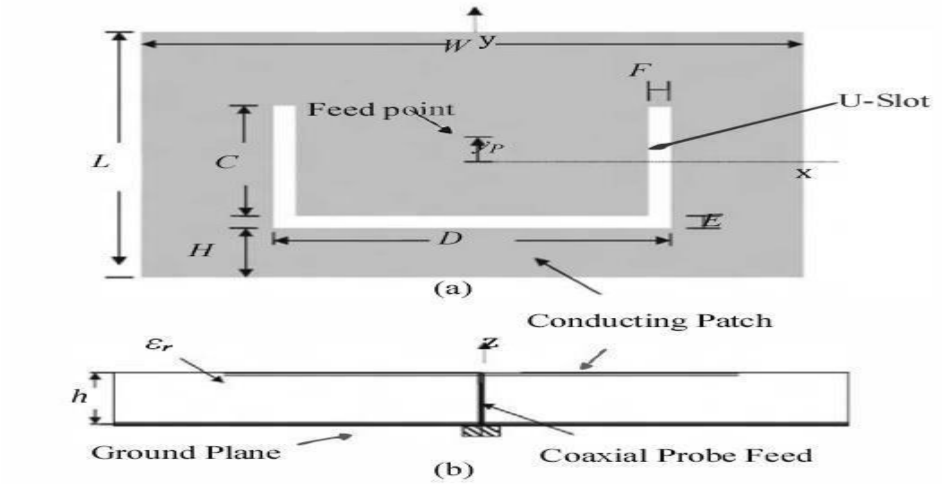

Figure 1: (a) Geometry of a rectangular U-slot micro strip patch antenna (b) Coaxial probe feeding method

The geometry of a simple rectangular Microstrip patch antenna with a U-slot is shown in Fig.1 (a), the length and width of patch antenna are represented by L and W, respectively. The U-slot has two vertical arms, each of length C, and a width of length D. The widths of horizontal and vertical slots are E and F respectively. Y_p shows the vertical distance of feed point from the center of the rectangular patch. The signal feeded by a 50 Ω coaxial probe is shown in Figure.1 (b). Inner conductor of coaxial probe is attached with patch at point P through a hole and its outer conductor is attached with the ground plane of the substrate.

II. ANTENNA DESIGN

Until, no accurate method is formulated this gives the complex relationship between U-slot patch antenna geometry and it characteristics. Most of the designs found in the research papers are based on hit and trial method which involves repeated simulations and intense parametric study [8, 9]. However, few empirical formulas, with some limitations, based on previous literature and theoretical as well as parametric analysesare available. The design rules are approximate to design a U-slot patch antenna. Then the initial design parameters can be tuned to obtain the desired antenna results. The trial and error method applied and achieved target by perodic optimization.

A. Single Antenna Element Design:

A Micro strip antenna is made up of two parallel conductors that are separated by a dielectric substrate. The lower conductor usually acts as a ground plane and the upper conductor is a patch, which is why such antennas are also called patch antennas. Substrate properties such as dielectric constant and thickness are important considerations in the design of microstrip antennas. Various substrates are available with values of dielectric constant between 2.2 and 12. Thick substrates with lower dielectric constant result in better efficiency, larger bandwidth and a larger antenna size. On the other hand, thin substrates with higher dielectric constant cause reduced efficiency, smaller bandwidths and smaller element sizes of equal importance is the method which is used to feed the antenna.

FR-4 glass epoxy [10] is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios with near zero water absorption is used as substrate (ϵ_r = 4.4 and h = 3.1 mm) to design the patch antenna. These values are carefully chosen to meet our performance and bandwidth requirement because dielectric material is

International Journal of Novel Research in Electronics and Communication
Vol. 1, Issue 1, pp: (22-29), Month: September 2014 - February 2015, Available at: www.noveltyjournals.com

crucial for determining the performance of antenna. To achieve compactness, thin substrates are required but the bandwidth of antenna decreases as height is reduced. Also higher values of ϵr the patch size can be reduced but it would also reduce the antenna bandwidth. So trade-off must be done between antenna performance and its size.

The empirical formulas in [11] are used here to obtain the initial parameters of dual band U-slot patch antenna. The inputs to these formulas are the values of ϵ_r, hand desired frequencies. To feed the antenna a coaxial probe of characteristic impedance 50 Ω is used. The coaxial probe introduces inductance to the patch which is cancelled by U-slot.

TABLE I. INITIAL DIMENSION OF SINGLE U-SLOT PATCH ANTENNA (UNIT: mm)

W	L	C	D	E	F	H	Y_P
38.3	24.3	11.5	24	1.8	1.8	14	0

W – Width in mm

L – Length in mm

C – Slot Side Lenth in mm

D – Slot Bottom Lenth in mm

E – Slot Side Width in mm

F – Slot Bottom Width in mm

H – Thickness of plate

Y_p – Feed Height from slot reference in mm

B. Tuning:

Tuning involves varying the initially obtained dimensions of U-slot and rectangular patch to make antenna resonate at desired frequencies. Several tuning technique that have been suggested. It is not increasing the substrate height beyond a certain range. Some easy tuning steps to achieve dual-band operation involve altering the dimensions of single U-slot and moving the feed position vertically and horizontally from its center position. Parametric study [9] summarizes the relationship between each U-slot dimension and its associated effect on antenna performance. The antenna dimensions obtained after necessary tuning on single antenna elements are shown below in Table II.

TABLE II. TUNED DIMENSIONS OF SINGLE U-SLOT PATCH ANTENNA (UNIT: mm)

W	L	C	D	E	F	H	Y_P
39	25	10	18	2	2	7	2

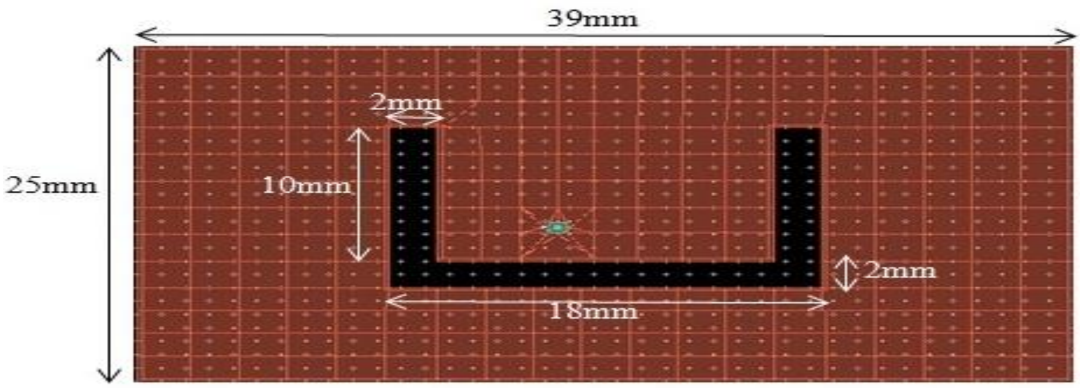

Figure 2: Single element dual-band U-slot rectangular patch antenna

III. SIMULATION & RESULTS

The simulation result Fig.2 shows the optimized single element dual-band patch element. The antenna fed by a port having characteristic impedance of 50 Ω. Reflection coefficient S_{11} or return loss plot of single element is shown in Fig. 3. S_{11} at 2.2 GHz and 3.6 GHz is -20.58 dB and -27.84 dB respectively. These values of S_{11} suggest that the antenna has good impedance matching at two different frequencies.

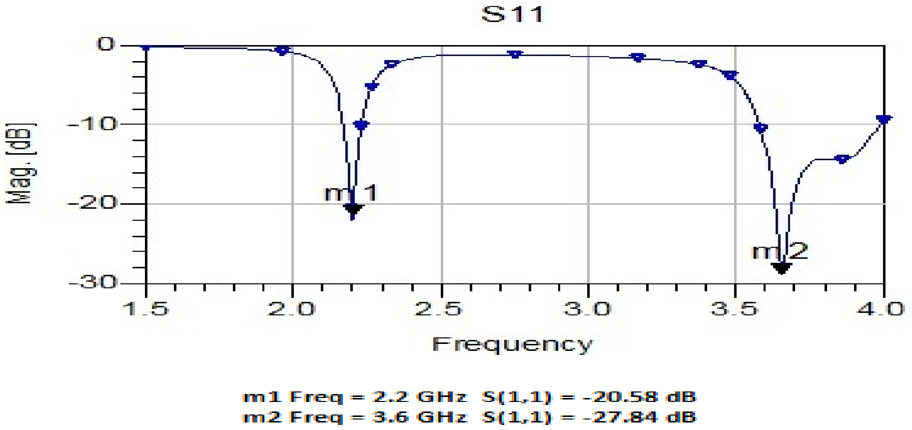

Figure 3: Single element patch antenna reflection coefficient - S_{11}

The Gain at 2.2 GHz is 3 dB with efficiency of 46% and at 3.6 GHz the gain is 1 dB Fig. 5 shows the current distribution over the surface of U-slot patch element. The radiating edges are clearly identified. The current distribution shows that there are two radiations; one at the edges of rectangular patch and other around the vertical arms of the U-slot. This confirms the basic theory of U-slot patch antenna that insertion of slot causes disturbance to current and triggers another radiation. The antenna resonates at 2.2 GHz on the edges and at 3.6 GHz around arms of U-slot.

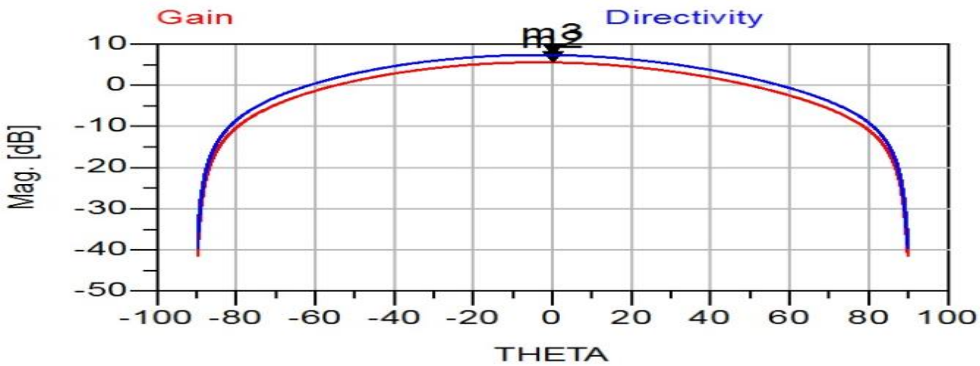

Figure 4: Single element antenna gain and directivity at 2.2 GHz

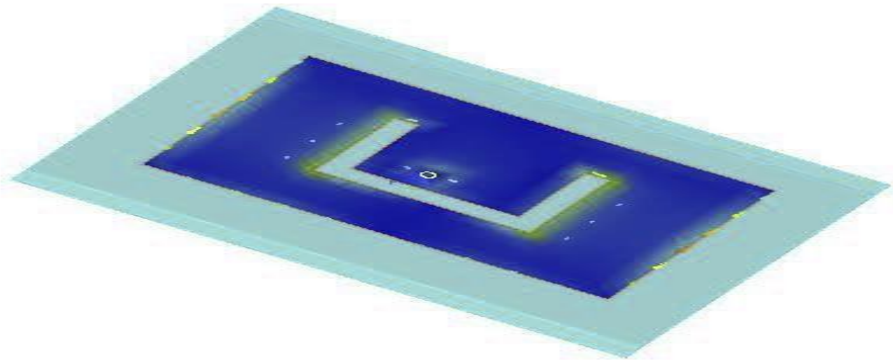

Figure 5: Surface current distribution on U-slot patch antenna

International Journal of Novel Research in Electronics and Communication
Vol. 1, Issue 1, pp: (22-29), Month: September 2014 - February 2015, Available at: www.noveltyjournals.com

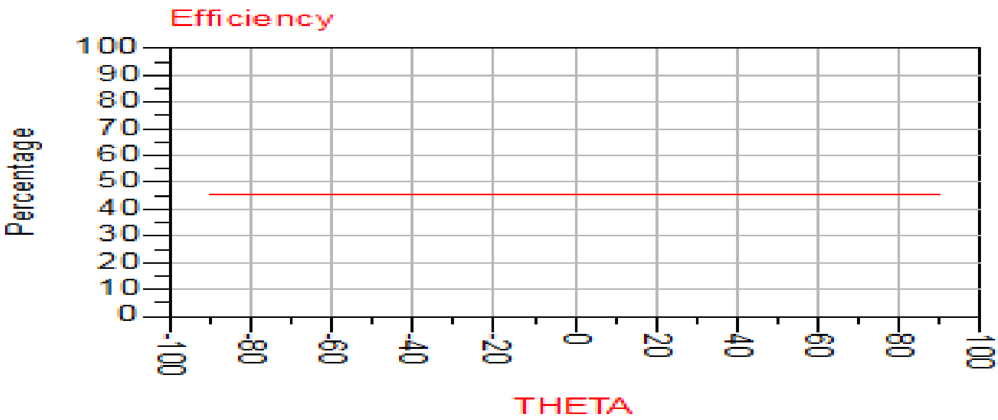

Figure 6: Antenna efficiency at 2.2 GHz

After achieving the desirable properties of single element U-slot patch antenna, an array of 3x 3 is simulated for improving the gain of antenna. Each element is fed by a separate port and edge-to-edge separation between elements is l0 mm. The theoretical and analytical studies about the effect of inter-element distance on the capacity of MIMO systems are presented in [12]. Studies for maximum efficiency can be obtained at an inter-element distance of 0.4 or above. However, good results have been reported at a separation of 10mm [14].

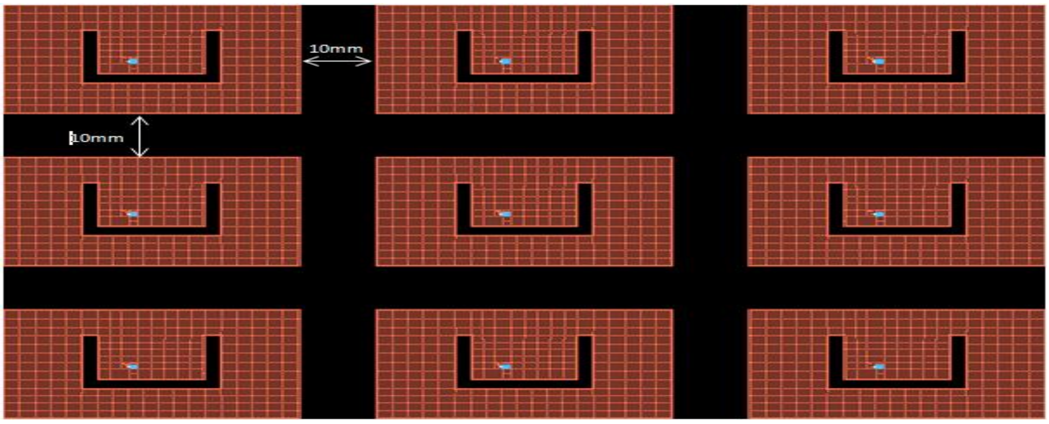

Figure 7: Dual-band 3x3 U-slot rectangular patch antenna array

The reflection coefficients S_{11} – S_{99} for the 3x3 rectangular patch antenna arrays are shown in Fig. 8. S_{11} through S_{99} refer to the return loss of nine U-slot rectangular patch antenna elements modelled in 3x3 array formation. It is observed that each of the patch elements has different reflection coefficient values cantered at 2.2 GHz and 3.6 GHz.

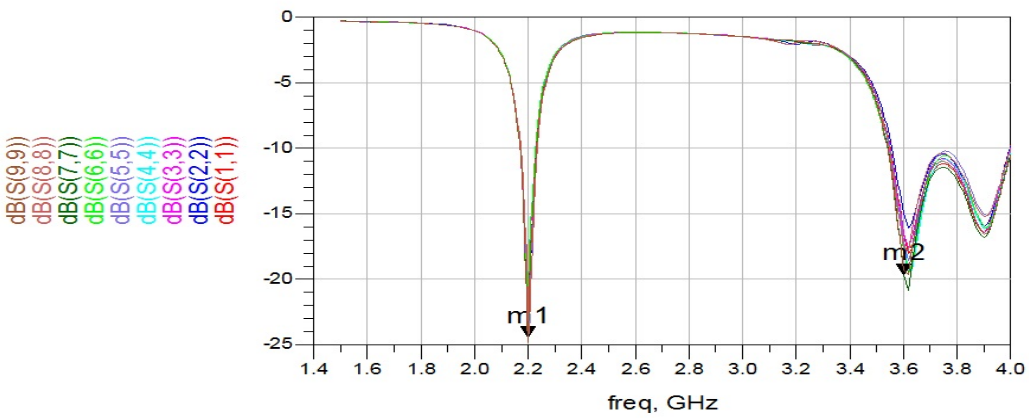

Figure 8: 3x3 U-slot rectangular patch antenna array reflection coefficients – S_{11}

International Journal of Novel Research in Electronics and Communication
Vol. 1, Issue 1, pp: (22-29), Month: September 2014 - February 2015, Available at: www.noveltyjournals.com

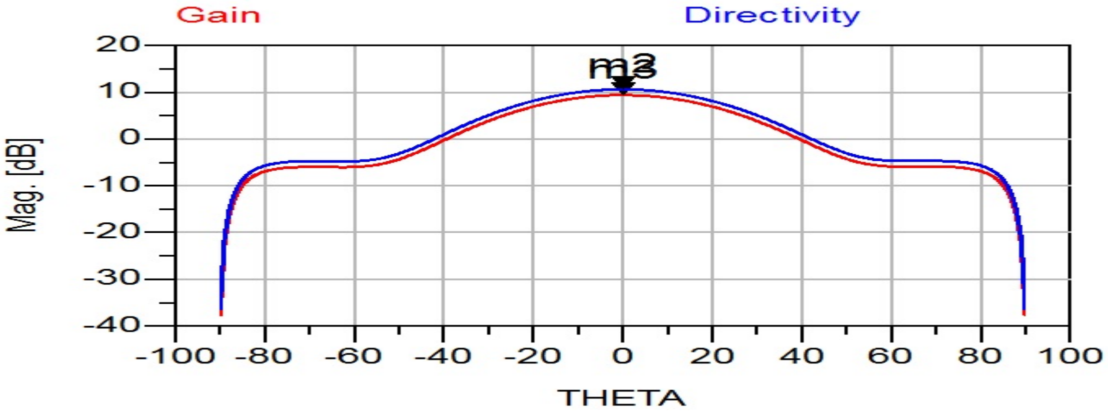

Figure 9a: 3x3 U-slot rectangular patch antenna array gain and directivity at 2.2 GHz

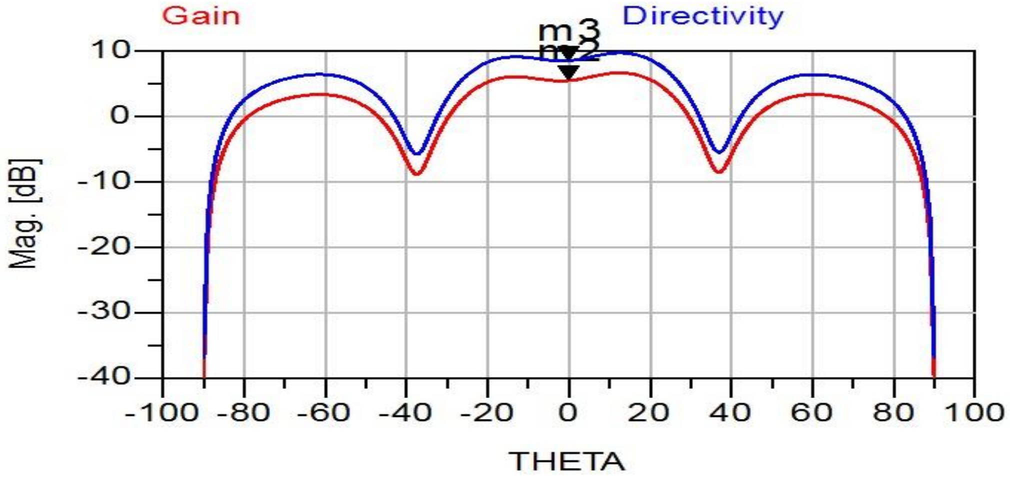

Figure 9b: 3x3 U-slot rectangular patch antenna array gain and directivity at 2.2 GHz

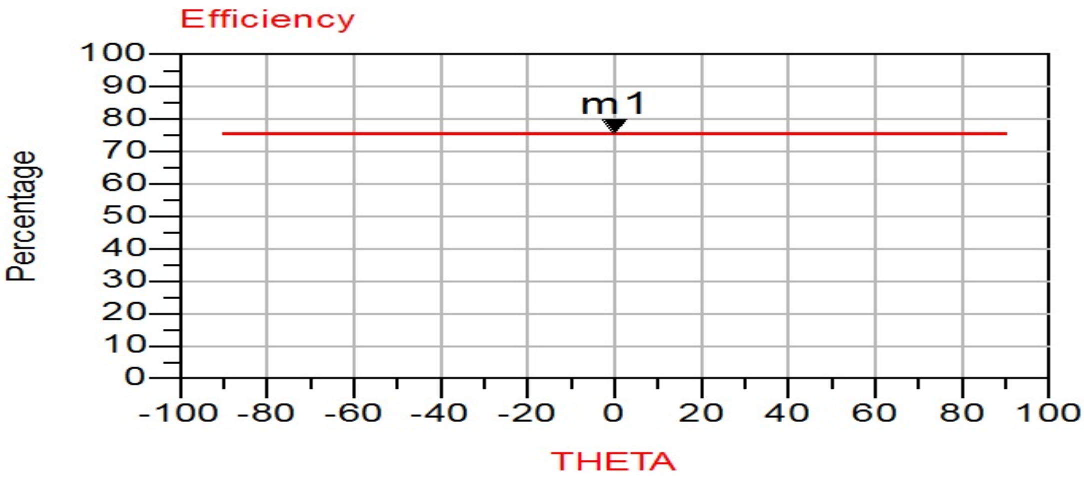

Figure 10: 3x3 U-slot rectangular patch antenna array efficiency at 2.2 GHz

The gain and directivity of 3 x 3 patch antenna array which is around 9.4 dB at 2.2 GHz and 5.51 dB at 3.6GHz respectively. Fig.9 and Fig.10 also indicates the beam of the array is narrower than that of single element which suggests that smart antenna beam forming operations. The signal phase at each of the four input ports. The antenna efficiency is 75.6 % at 2.2 GHz and 50 % at 3.6GHz as shown in Fig. 10 and Fig. 11 respectively. It is important to mention that in dual-band antennas.

International Journal of Novel Research in Electronics and Communication
Vol. 1, Issue 1, pp: (22-29), Month: September 2014 - February 2015, Available at: www.noveltyjournals.com

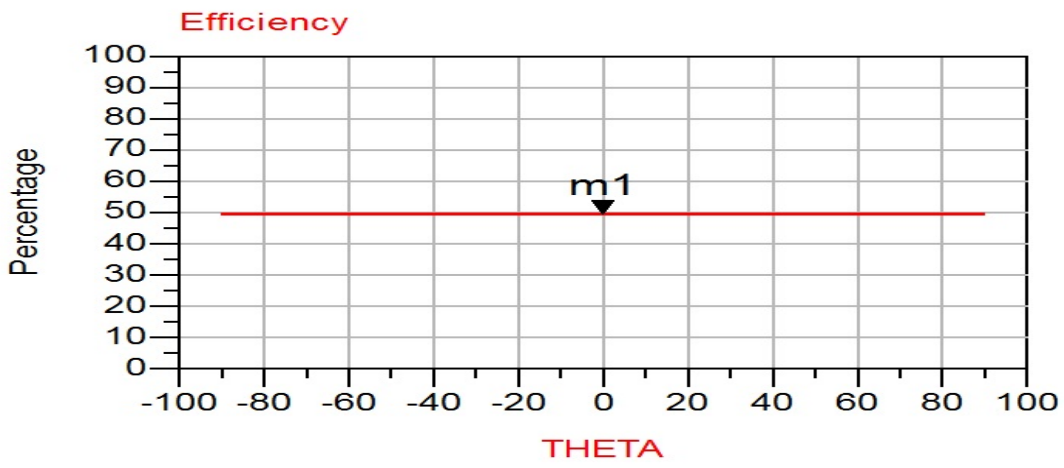

Figure 11: 3x3 U-slot rectangular patch antenna array efficiency at 3.6 GHz

IV. CONCLUSION

A 3 x 3 dual-band U-slot micro strip patch antenna array for 4G- LTE and Wi Max application system presented. The improved results were obtained in reflection coefficients and array gain. The software that there would not be large deviations between the results of simulated outputs and design outcomes. The U-slot patch antenna array fabrication can also performed using the same FR-4 substrate to compare antenna results, which is subject to future work.

REFERENCES

[1] Muhsin Ali and Bilal A. Khawaja, "Dual Band Micro strip Patch Antenna Array for Next Generation Wireless Sensor Network Applications" International conference on Sensor Network Security Technology and Privacy Communication System (SNS & PCS), 2013.

[2] Constantine A. Balanis, Antenna Theory, Analysis and Design, Third Edition, John Wiley & Sons, Inc. 2005.

[3] Y. X. Guo, K. M. Luk, K. F. Lee and Y. L. Chow, "Double U-slot rectangular patch antenna," Electronics Letters, vol. 34, pp. 1805-1806, Sept.1995.

[4] T. Huynh, K. F. Lee, "Single-layer single-patch wideband microstrip antenna," Electronics Letters, vol. 31, pp. 1310-1312, Aug. 1995.

[5] K. F. Tong, K. M. Luk, K. F. Lee and R. Q. Lee, "A broad-band U-slot rectangular patch antenna on a microwave substrate," IEEE Trans. Antennas Propag., vol. 48, pp. 954-960, Jun. 2000.

[6] K. F. Lee, K. N. Luk, K. M. Mak and S. L. D. Yang, "On the use of U- slots in the design of dual-and triple-band patch antennas," IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 645-747, Dec. 2005.

[7] K. F. Lee, K. M. Suk, T. Mang and S. Yand, "Dual and triple band stacked patch antennas with U-slots," Proceedings of Fourth Europen Conference on Antennas and Propagation (EuCAP), Barcelona, Spain, 2010, pp. 1-5.

[8] Advanced Design System, 2008 Momentum Software Manual, Agilent Technologies, CA: Palo Alto, 2005.

[9] N. Hasan, et al. "Design and simulation based studies of a dual band U- Slot patch antenna for WLAN application," Proceedings of 15th Intl. Conf. on Advanced Communications Technology (ICACT2012), Pyeongchang, Koera, 2012, pp. 997-1001.

[10] Material characteristics., http://en.wikipedia.org/wiki/FR-4

[11] S. Weigand, G. H. Huff, K. H. Pan, J. T. Bernhard, "Analysis and design of broad-band single layer rectangular U-slot mirostrip patch antennas," IEEE Transactions on Antennas and Propagation, vol. 51, no. 3, March 2003.

[12] V. Natarajan, E. Chettiar, D. Chatterjee, "Performance of two empirical techniques for optimized design of wideband, U-slot antennas using commercial CAD tools," IEEE antennas and propagation and URSI/USNC symposium digest, vol. 3, Monterey, California, June 2004.

[13] Abouda, A. A. and S. G. H"" aggman, "Effect of mutual coupling capacity of MIMO wireless channels in high SNR scenario," Progress In Electromagnetic Research, PIER 65, 27-40.

[14] S. Pan, S. Durrani and M.E. Bialkowski, "MIMO capacity for spatial channel model scenarios,"8th Australian Communications Theory Workshop (AusCTW'07), Adelaide, Australia, Feb 2007.

[15] K. J.Babu, K.R. Krishna and L. P. Reddy, "A multi slot patch antenna for 4G MIMO communications," International Journal of Future Generation Communication and Networking, vol. 4, no. 2, June 2011.

[16] M.S.c. Thesis, "Design of a compact micro strip patch antenna for use in wireless / cellular devices," pp. 44, The Florida State University, 2004.