# *Simulation of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna for CPE WiMAX Application at 3.3 GHz*

Yusnita Rahayu
Department of Electrical Engineering, University of Riau
Pekanbaru, Indonesia
vannebula2001@yahoo.com

Rezki Ananda Gusma
Department of Electrical Engineering, University of Riau
Pekanbaru, Indonesia
tora_gusma@yahoo.com

**Abstract—** ***In this paper, Simulation of the 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna is designed for CPE WiMAX Application. This Antenna uses Aperture Coupled feed to improve bandwidth. The Proposed antenna is compared to similar design of antenna with Microstrip Line feed, to justify that the proposed antenna produces broader bandwidth. Both of Antennas are designed and simulated by using HFSS simulation software and operated in WiMAX frequency range of 3.3 GHz. The 6 Elements Aperture Coupled Feed antenna gives an impedance bandwidth of 10.53 %, this is broader than the 6 Elements Microstrip Line Feed Antenna which is only has impedance bandwidth of 6.23 %. The maximum gain is obtained 8.4327 dBi at 3.4 GHz. Details of antenna design are given and simulation results are discussed.***

***Keywords—CPE WiMAX, aperture coupled, bandwidth, gain.***

## I. INTRODUCTION

Worldwide Interoperability for Microwave Access (WiMAX) is a Broadband Wireless Access (BWA) technology which has high data transfer speed (up to 70 Mbps) and large access range (up to 50 km) [1]. In according to regulation, Ministry of Communication and Informatics of Indonesia, No. 05 /KEP/M.KOMINFO/01/2009 stated that the frequency band used for WiMAX technology is 3.3-3.4 GHz [2]. To access the WiMAX network, it is required a Customer Premise Equipment (CPE) in the subscriber station. Currently, the existing size of CPE is 20 x 20 cm. Microstrip antenna has numerous advantages that it has small size, low fabrication cost, light weight and it can be easily installed on the CPE. Microstrip antenna has very narrow bandwidth. The bandwidth can be improved by Aperture Coupled feeding technique [3]. Single layer microstrip line feed elements are typically limited to bandwidth of 2-5%. But aperture coupled antenna provides up to 10-15% of bandwidth with single layer [4].

Fig. 1 shows an overview of a microstrip patch antenna design with aperture coupled technique. In this figure two substrates; one for feed line and another for patch are formed. A slot is formed at center of ground and feed line is below the second substrate as shown in Fig. 1. These types of antennas are more popular, because of the patches and slots can be any shape and this gives the improvement in the performance of microstrip patch antennas.

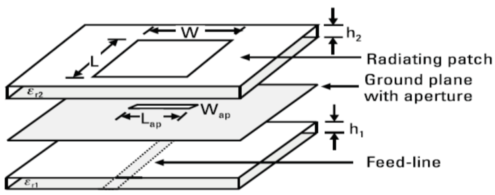



Fig. 1. Technique of Aperture Coupled Feed

In [5], this paper presents design of rectangular microstrip antenna by using aperture coupled feeding technique. The antenna operates at two bands Bandwidth-2 (BW2) and Bandwidth-3 (BW3). The impedance bandwidths of BW2 and BW3 are found to be 23.87% and 21.68%, respectively. The similar study was conducted by [6], where in antenna configuration consisted of 16 array elements. They used aperture coupled feeding for exciting array elements and obtained nearly 11% of impedance bandwidth. This study [7] presents aperture coupled stacked patch antenna using air gap variation, the measured return loss exhibit an impedance bandwidth of 35% in the frequency range of 2.9 GHz to 6.0 GHz.

This paper describes the design and simulation of rectangular microstrip patch antenna array for the CPE WiMAX which operates at 3.3 GHz band by using aperture coupled feeding technique. The simulation is developed in *Ansoft* HFSS with the specifications shown in the Table I below.

TABLE I
ARRAY ANTENNA SPECIFICATION

| Features | Required Values |
|---|---|
| Center frequency ($\lambda_0$) | 3.35 GHz |
| Array Antenna Configuration | 6 Elements Planar Array |
| Microstrip Radiator used | Rectangular Patch |
| Antenna Gain | $\geq$ 6 dB |
| Antenna impedance BW | $\geq$ 10 % |

Comparison between the proposed antenna with similar design using Microstrip Line feed is done to justify that this antenna bandwidth is broader than that one.

## II. DESIGN OVERVIEW

In this paper, two antennas design are simulated. One antenna uses aperture coupled feed and the other one uses microstrip line feed. Bandwidth of both antennas will be compared and analyzed. Materials used for antenna design are shown in the Table II and several steps used in the antenna design as following:

TABLE II
MATERIALS OF ANTENNA DESIGN

| **Parameters** | **Materials** |
|---|---|
| Input Impedance ($Z_0$) | Connector SMA 50 Ω |
| Patch | Cooper |
| Substrate | FR4 (Epoxy); $\varepsilon_r$=4.4 |
| Ground plane | Cooper |
| Radiation Box | Air |

### A. Design of Patch Dimensions

In this design, the patch used is rectangular form that has a width and a length. Equation (1)-(5) is used to calculate the width and length of patch [7].

*1) Calculation of the Patch Width (W):*

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1}{2}}} \quad (1)$$

*2) Calculation of Patch Length (L):* To determine the length of the patch ($L$) required parameter $\Delta L$ which is the length of $L$ that due to the fringing effect. The increase of length $L$ ($\Delta L$) is given by:

$$\Delta L = 0,412h\frac{\left(\varepsilon_{reff}+0,3\right)\left(\frac{W}{h}+0,264\right)}{\left(\varepsilon_{reff}-0,258\right)\left(\frac{W}{h}+0,8\right)} \quad (2)$$

$\varepsilon_{reff}$ is the effective dielectric constant is given by:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right) \quad (3)$$

Thus the patch length ($L$) is given by:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (4)$$

Where $L_{eff}$ is the effective length of the patch can be given by:

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

From that equation, the width and length of patch obtained are 27.25 mm and 21 mm, respectively. Size optimization has been done for patch length of antenna design with microstrip line feed. The optimized length is 21.5 mm instead of 21 mm. The optimized is performed to get center frequency fixed at 3.35 GHz.

### B. Design of Feed Network

Feed network is the feed line configuration of array antenna. Feed network consists of 50 Ω feed line and T-junction. The T-junction used has an impedance of 70.71 Ω and 86.6 Ω.

*1) Calculation of the 50 Ω feed line Width ($W_f$):* Feed line used in this design has an impedance of 50 Ω. The width of the 50 Ω feed line is given by equation (6) and (7) [8]:

$$B = \frac{60\times\varepsilon_r^2}{Z_0\times\sqrt{\varepsilon_r}} \quad (6)$$

$$W = \frac{2h}{\pi}\left\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1)+0,39-\frac{0,61}{\varepsilon_r}\right]\right\} \quad (7)$$

From the equation, the feed line width is obtained 3.06 mm.

*2) Calculation of the T-Junction:* This paper uses the T-junction as a power divider [10]. T-junction used has an impedance of 70.71 Ω and 86.6 Ω. The width of 70.71 Ω is given by equation (6) and (7). From the equation, the feed line is 1.6 mm. To calculate the length of the feed line of 70.71 Ω is calculated by the equation (8) to (10):

$$l = \frac{\lambda_o}{4\sqrt{\varepsilon_{eff}}} \quad (8)$$

Where $\varepsilon_{eff}$ is an effective dielectric constant calculated by the equation:

$$\frac{W}{h} = \frac{2h}{\pi}\left\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1)+0,39-\frac{0,61}{\varepsilon_r}\right]\right\} \quad (9)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\left(\frac{1}{\mathrm{W/h}}\right)}}\right) \quad (10)$$

From the calculation, the length of the 70.71 Ω feed is obtained 12.57 mm. In addition, T-Junction 86.6 Ω is also used for 3 branching points. By using the same equations, the width and length of 86.6 Ω are obtained 0.98 mm and 12.77 mm, respectively.

### *C. Design of Aperture Slot*

Design of aperture slot is only used by antenna using aperture coupled feed. The width and length of the slot aperture determined by using Equation (11) and (12) [9].

$$L_a = 0,2\lambda_0 = 0,2 \times 89,55 = 18 \text{ mm} \quad (11)$$

$$W_a = 0,1L_a = 0,1 \times 18 = 1,8 \text{ mm} \quad (12)$$

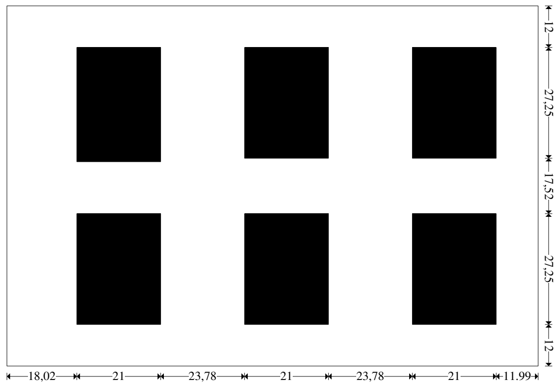
From the calculation, the slot width ($W_a$) and length ($L_a$) are 1.8 mm and 18 mm. Size optimization has been done for slot aperture length. The optimized length is 20.3 mm instead of 18 mm. The optimized is performed to get center frequency fixed at 3.35 GHz. Table III is antenna dimensions after optimization.

TABLE III
ANTENNA DIMENSIONS AFTER OPTIMIZATION

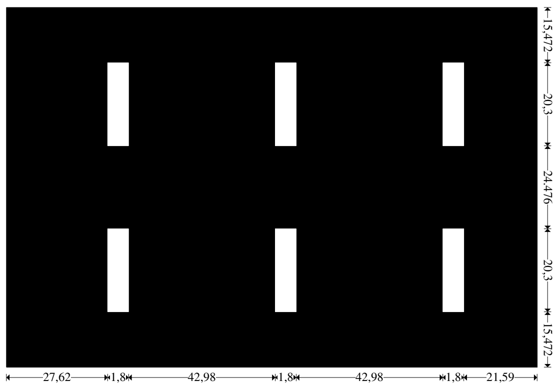
| **Dimensions** | **Values** | | |
|---|---|---|---|
| | **Parameters** | **Aperture Coupled Feed** | **Microstrip Line Feed** |
| Substrat FR-4 (epoxy) | Length ($L_s$) | 140.57 mm | 140.57 mm |
| | Width ($W_s$) | 96.02 mm | 96.02 mm |
| Patch | Length ($L_p$) | 21 mm | 21.5 mm |
| | Width ($W_p$) | 27.25 mm | 27.25 mm |
| Ground Plane | Length ($l_g$) | 140.57 mm | 140.57 mm |
| | Width ($w_g$) | 96.02 mm | 96.02 mm |
| 50 Ω Feed Line | Length ($L_{50}$) | 20 mm | 5 mm |
| | Width ($W_{50}$) | 3.06 mm | 3.06 mm |
| T-Junction (86.6 Ω) | Length ( $L_{86.6}$) | 12.77 mm | 12.77 mm |
| | Width ( $W_{86.6}$) | 0.98 mm | 0.98 mm |
| T-Junction (70.71 Ω) | Length ( $L_{70.71}$) | 12.57 mm | 12.57 mm |
| | Width ( $W_{70.71}$) | 1.6 mm | 1.6 mm |
| Aperture Slot | Length ($L_a$) | 20.3 mm | - |
| | Width ($W_a$) | 1.8 mm | - |

## III. DESCRIPTION OF ANTENNA GEOMETRY

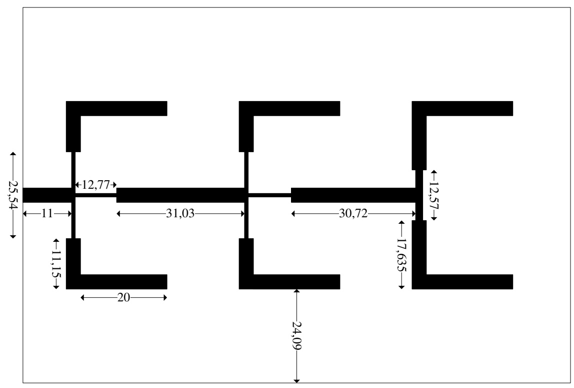
Fig. 2 shows geometry of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna. This antenna is designed using two FR-4 (epoxy) substrates having 1.6 mm thickness (h) and 4.4 dielectric constant ($\varepsilon_r$). The gap between the substrate-1 and substrate-2 is 3 mm. Radiating elements (patch) are etched on the top surface of the substrate-1. Usually in array configuration, spacing between two radiating elements is kept at a distance $\lambda_o/2$. The network feed is etched below the substrate-2 as shown in Fig. 2 (c) having thickness (h) and dielectric constant ($\varepsilon_r$) as that of substrate-1. The network feed consists the 50 Ω feed line and T-Junction. The 50 Ω feed line has the length of 20 mm after it was optimized. The aperture slots are place on the top surface, as shown in Fig. 2 (b), which is the ground plane of the substrate-2 exactly at the below center of the radiating elements. The aperture slot has 20.3 mm x 1.8 mm size after it was optimized. The substrate-2 is placed below the substrate-1 that forms aperture coupled feed. The radiating elements are placed on the top surface of substrate-1 shown in Fig. 2 (a) energizes through coupling slots. The SMA connector is used at the tip of 50 Ω feed line for feeding the microwave power.




(a) Top view of substrate-1




(b) Top view of substrate-2




(c) Bottom view of substrate-2

Fig. 2. Geometry of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna

Fig. 3 shows geometry of 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna. This antenna only designed using one substrate. The radiating elements and network feed are etched on the top surface of the substrate. The ground plane is place below of the substrate. The spacing between two radiating elements and network feed are used same with antenna using aperture coupled feed. But the 50 Ω feed line has the length of 5 mm and then length of radiating element is 21.5 mm after it was optimized.

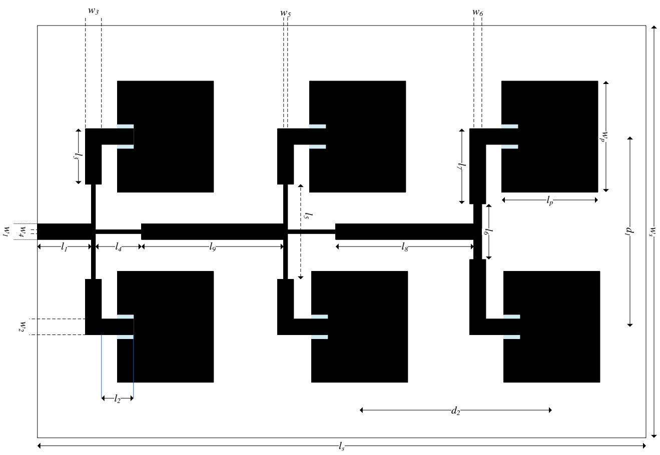


Fig. 3. Geometry of 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna

## IV. SIMULATION RESULT

The antenna design is modeled by using Ansoft HFSS software. The solution setup is 3.35 GHz and frequency sweep of 3.1 until 3.6 GHz with step size 10 MHz and the setting boundaries is Perf E and Radiation. Fig. 4 shows the complete antenna validation.

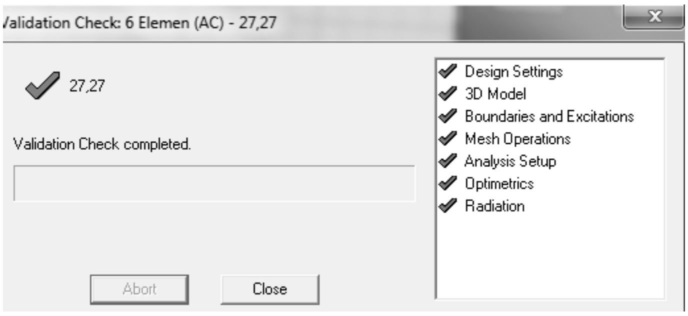



Fig. 4. Validation Check

The variation of return loss versus frequency of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna is shown in Fig. 5. In this graph shows what the antenna operates at 3.3-3.4 GHz frequency. Value of the VSWR at 3.3 GHz, 3.35 GHz and 3.4 GHz are 1.2045, 1.1076 and 1.2457, respectively. The variation of return loss versus frequency of 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna is shown in Fig. 6 for comparison. Value of the VSWR at 3.3 GHz, 3.35 GHz and 3.4 GHz are 1.3430, 1.0515, and 1.3857, respectively.

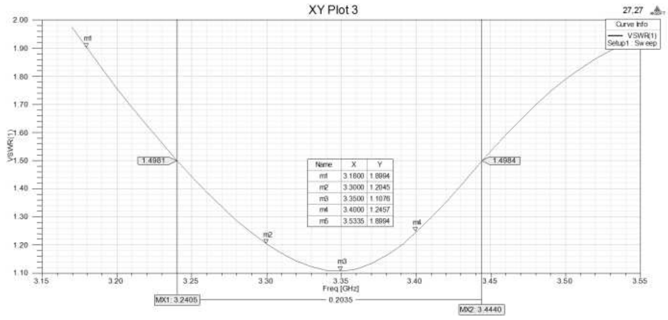



Fig. 5. VSWR graph of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna

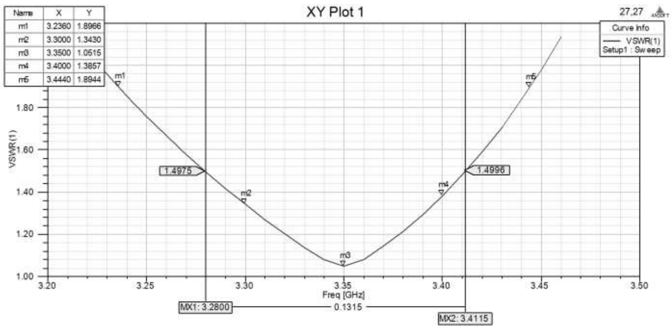



Fig. 6. Geometry of 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna

From Fig. 5 and 6, the impedance bandwidth is calculated using the following formula [11]:

$$Bandwidth = \frac{f_2 - f_1}{f_c} \times 100\ \% \qquad (13)$$

Where, $f_2$ and $f_1$ are higher and lower cut-off frequency of the band respectively, when its return loss reaches ≤ -10.16 dB (VSWR ≤ 1.9) and $f_c$ is the center frequency of this band. Comparison of bandwidth between antenna using aperture coupled feed with antenna using microstrip line feed is given in Table IV.

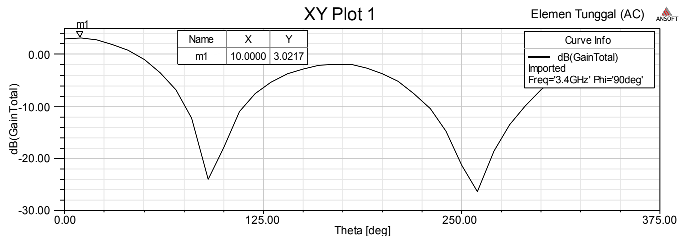
TABLE IV
COMPARISON OF ANTENNA BANDWIDTH

| Antenna | Lower Frequeny (GHz) | Higher Frequeny (GHz) | Center Frequeny (GHz) | Bandwidth | |
|---|---|---|---|---|---|
| | | | | MHz | % |
| 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna | 3.236 | 3.444 | 3.34 | 208 | 6.23 |
| 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna | 3.18 | 3.5335 | 3.3568 | 353.5 | 10.53 |

In Table IV shows the 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna having an impedance bandwidth of 208 MHz (6.23 %). And then the 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna gives broader impedance bandwidth (10.53%) when compared to antenna using microstrip line feed. The 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna achieves bandwidth of 10% which is usually bandwidth obtained single element antenna using aperture coupled feed.

Fig. 7 shows the gain of each antenna. In Fig. 7 (a), gain of 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna is 8.4327 dBi. This gain has achieved the required specification ( ≥ 6 dBi).


(a) 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna




(b) 6 Elements Microstrip Line Feed Planar Array Rectangular Microstrip Patch Antenna

Fig. 7. Gain of Antennas

This antenna gain is higher when compare to the 6 Elements Microstrip Line Feed Antenna which is only has gain of 3.0217 dBi as shown in Fig. 7 (b). Aperture coupled antenna is able to decrease surface wave. This improves the gain.

## V. CONCLUSION

Simulation 6 Elements Aperture Coupled Feed Planar Array Rectangular Microstrip Patch Antenna operating at 3.3 to 3.4 GHz completed. This microstrip antenna has an impedance bandwidth of 353.5 MHz (10.53%). This antenna has broader bandwidth than antenna using microstrip line feed (6.23%). The 6 elements aperture coupled feed antenna has a gain of 8.4327 dBi. This antenna has compact in size of about 15 x 10 cm and suitable on the CPE WiMAX device.

## V. REFERENCE

[1] Gaurav Jindal & Vinay Grover, “Voice and Video over the WiMAX”, International Journal for Computer Application and Research (IJCAR, ISSN: 2320 –5067), Vol. Special Issue 1, pp. 18-25, February 2013.

[2] Minister of Communication and Information, 2009. Decision of the Minister of Communication and Information Number: 05/KEP/M.KOMINFO/01/2009 About Determination of Radio Frequency Band Blocks and Wireless Broadband Service Zones On the 3.3 GHz Radio Frequency Band for Existing Radio Frequency Band Users for Wireless Broadband Service Requirement. [Online]. Available: Http :// publikasi.kominfo.go.id/handle/54323613/61.

[3] Kaur Manpreet, Kaur Amanpreet & Khanna Rajesh, A Microstrip Patch Antenna with Aperture Coupler Technique At 5.8 GHz & 2 GHz, International Journal of Modern Engineering Research (IJMER), Vol. 03, Issue. 01, PP. 587-594 Jan-Feb 2013.

[4] Chakraborty S, Gupta B & Poddar D R, Development of Closed form design formulae for aperture coupled microstrip antenna, JSci Ind Res (India), 64 (2005) 482.

[5] B. Suryakanth & S. N. Mulgi, “Design and Development of Aperture Coupled Rectangular Microstrip Antenna for Dual Band” Operation International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE, ISSN: 2278-8875), Vol. 2, PP. 3607-3613, Agustus 2013.

[6] Nwalozie G.C, Okorogu V.N, Okafor A.C & Oweh V.E, “Simulation Implementation of Microstrip Antenna Array for 1.8 GHz Band With 10 dB Gain”, International Journal of Emerging Technology and Advanced Engineering (IJETAE), Vol. 02, Issue 12, December 2012.

[7] Rajesh Kumar Vishwakarma & Sanjay Tiwari, “Aperture Coupled Stacked Patch Antenna for Dual Band”, International Journal of Electronics and Computer Science Engineering (IJECSE, ISSN: 2277-1956), Vol. 01, No. 03, PP. 933-939, 2012.

[8] James J. R., Hall P. S., eds. “Handbook of Microstrip Antenas“. Vol. I and II. Peter Pergrinus. IEEE. 1989.

[9] Rambe, Ali Hanafi, Design of 4 Elements Planar Array Rectangular Microstrip Patch Antenna for WiMAX CPE Applications, Graduate Thesis, University of Indonesia, Indonesia: 2008.

[10] David M. Pozar, *Microwave Engineering,* John Willey and Sons, 1997.

[11] Mulgi S. N, Pushpanjali G. M, Konda R. B, Satnoor S. K & Hunagund P. V, “Broadband Aperture Coupled Equilateral Triangular Microstrip Array Antenna”, Indian Journal of Radio & Space Physics, Vol. 38, PP. 174-179, Juni 2009.