Analysis of Proximity Coupled Rectangular Patch Antenna at WIMAX Frequencies

Nadirah binti Assha'ari
Faculty of Electrical Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia

Abstract— **In this study, the simulation an analysis of proximity coupled rectangular patch antenna is evaluated. Three different frequencies namely 3.5GHz, 2.5GHz and 2.3GHz have been selected since these frequencies are primarily used in WIMAX application. The performance of the antenna was evaluated by using CST software and the simulation results were described in term of return loss, VSWR, bandwidth and farfield. From the result obtained, the computed bandwidths from the three different frequencies are 4.9%, 3.96% and 3.62% respectively. The best antenna design is at 3.5GHz operating frequency which gives better performance in terms of bandwidth, antenna gain and efficiency. The specialties of proximity coupled microstrip antenna are easy to design and contribute the largest bandwidth than others.**

Keywords—multilayer, antenna, WIMAX

I.INTRODUCTION

The IEEE standard definition of terms for antenna defines the antenna as part of a transmitting or receiving system which is designed to radiate or to receive electromagnetic waves [1]. A microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate, and has a ground plane on the other side. The patch or top layer can be of any shape, but conventional shapes are generally used to simplify analysis and performance prediction [2]. The radiating patch of antenna may be square, rectangular, dipole and circular.

A part of unique and attractive properties of microstrip antennas are low in profile, light in weight, compact and conformable in structure, and easy to fabricate. In order to enhance the antenna bandwidth, the design should be done in multilayer. It consists of two main configurations which are proximity coupled microstrip antenna and aperture coupled microstrip antenna. The commercialization of the microstrip antenna should be together with the most desired application nowadays; wireless internet or WIMAX which has a variety of frequency bands including 2.3GHz, 2.5GHz, 3.3GHz, 3.5GHz and 5.8GHz.

II. DESIGN METHODOLOGY

This design deals with the simulation and analysis of multilayer proximity coupled antenna at different frequency band using the appropriate software, CST. Firstly, the possible substrate for the antenna is identified.

In this project, the substrate used was Rogers RT5880 and the selection of the substrate is essential and contributes to the performance of an antenna. First and foremost, the thinner and the lower dielectric constant of substrate should be considered to provide better efficiency and larger bandwidth [3]. The details of Rogers RT5880 are shown in Table 1:

TABLE I
ROGERS RT5880 SUBSTRATE PROPERTIES

Permittivity, ε	2.2
Permeability, μ	1
Loss Tangent	0.0001
Substrate Height, h	0.508mm

Ideally, permeability was set to one; or in other words the Rogers RT5880 substrate is the dielectric material which has no metal or magnetic properties.

The second step is the antenna design calculation. The calculation was done in order to obtain the patch, ground and substrate dimension. The same formulae as in equation (1) will be used since this study covers three designs on different frequency of WIMAX application. Starting with the width of the patch;

$$w = \frac{c}{2\,fo\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

where

c = speed of light ($3\text{x}10^8$ m/s)
f_o = operating frequency in GHz
ε_r = relative permittivity of material

For f_o = 3.5GHz and ε_r = 2.2, it yields the value of w= 33.88mm. Then, the value of effective dielectric constant, ε_{reff} is calculated based on equation (2):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{1}{2}} \tag{2}$$

where

h = substrate thickness (0.508mm)

So, the calculated value of ε_{reff} is 2.152.
By using this value, the value of length extension, ΔL is obtained as in (3):

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)}{(\varepsilon_{reff}-0.258)}\frac{\left(\frac{w}{h}+0.264\right)}{\left(\frac{w}{h}+0.8\right)} \quad (3)$$

Therefore, ΔL = 0.2673mm. Next, the value of effective length, L_{eff} is calculated using equation (4).

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

Based on the calculation above, the L_{eff} value is 29.21mm. Thus, the value of actual length, L can be determined referring to equation (5).

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

The value of the patch length is 28.67mm. Next step is to compute the ground plane dimension which also represents the substrate dimension.

Substrate Width

$$W_g = 6h + w \quad (6)$$

Substrate Length

$$L_g = 6h + L \quad (7)$$

$\therefore$ L_g = 31.72mm while W_g = 36.92mm. Both substrates use the same value since both are using the Rogers RT5880 substrate.

All the equations above were used to calculate the initial value of the antenna dimensions with respect to 3.5GHz operating frequency and also Rogers RT5880 permittivity as well as its thickness. The same procedures applied to the 2.3GHz and 2.5GHz operating frequency while considering the other parameters are constant. The calculated result was tabulated as shown in Table II & Table III:

TABLE II
DIMENSIONS OF 2.3GHz ANTENNA

Patch Width, W	51.55mm
Patch Length, L	43.75mm
Substrate Width, W_g	54.98mm
Substrate Length, L_g	46.8mm

TABLE III
DIMENSIONS OF 2.5GHz ANTENNA

Patch Width, W	47.43mm
Patch Length, L	40.24mm
Substrate Width, W_g	50.48mm
Substrate Length, L_g	43.29mm

Transmission line or feeder width and length were obtained using Line Calc. Additionally, the patch, ground plane and feeder itself are build by Perfect Electric Conductor (PEC). All the simulations were done using CST Microwave Studio and lots of effort has been put on in order to obtain the appropriate result in term of return loss, VSWR, bandwidth and farfield characteristics.

The Figure 1 below indicates the configuration of the proximity coupled antenna design:

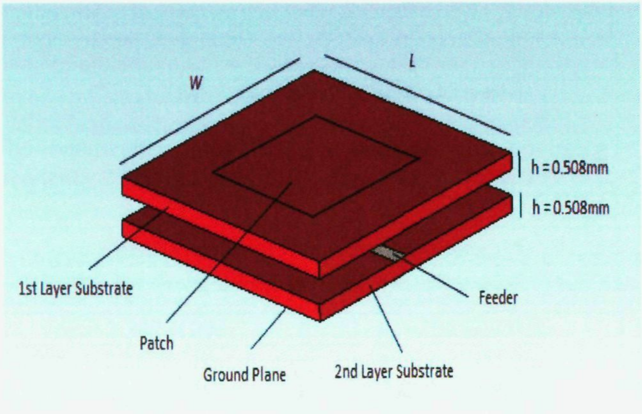

Fig. 1: Configuration of proximity coupled antenna

III. RESULTS AND DISCUSSIONS

The design on three WIMAX frequency band gives the appropriate results which; return loss are less than -20dB as shown in Figure 2. This condition need to be met since it affects the performance of the antenna which means it represents the quantity of the reflection wave [4].For this design, it only permits a very small amount of reflection power and it can be considered as a good antenna.

Theoretically, the value of VSWR is identical to 1. In this design, all the VSWR value is approximate to 1 as shown in Figure 3 and it signify that there is a little mismatch and signal reflection occurs between the antenna and the transmission line with respect to all of operating frequencies.

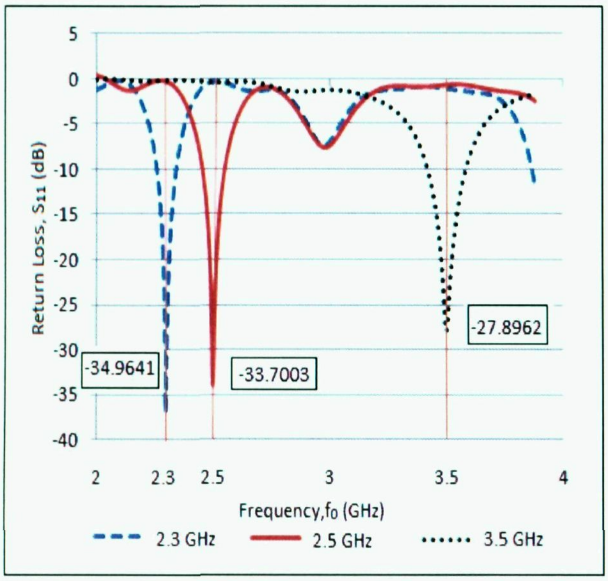

Fig. 2: Combination of return loss graphs

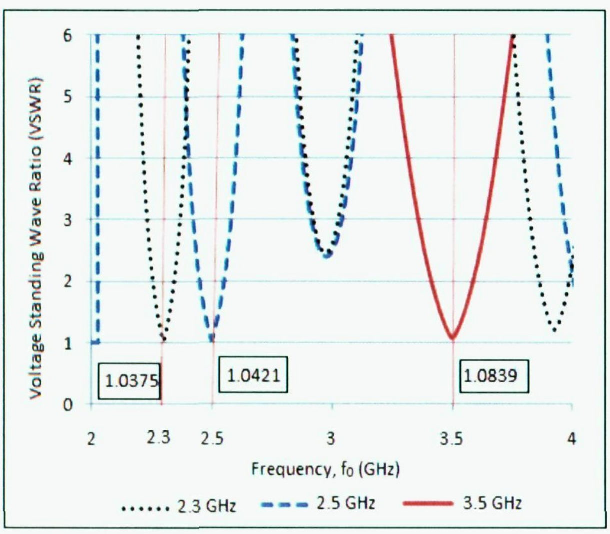

Fig. 3: Combination of VSWR graphs

Bandwidth criterion is important for WIMAX application; larger bandwidth contributes to more users [5]. The bandwidth of the antenna is normally defined as the satisfactory voltage standing wave ratio (VSWR) value over the frequency range [6]. The value of bandwidth computed based on equation (8).

$$\% BW = \frac{(f_H - f_L)}{f_o} \times 100\,\% \qquad (8)$$

For 3.5GHz, the f_H = 3.5819GHz and f_L = 3.4101GHz.So, the bandwidth value of this antenna with respect to its operating frequency is 4.9%. This figure indicates that the design is applicable for WIMAX since it supports a good bandwidth.

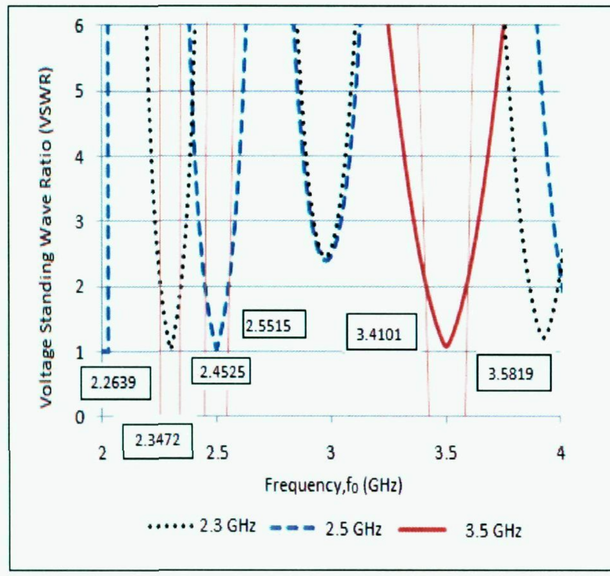

Fig. 4: Combination of bandwidth graphs

The bandwidth value for the antenna with operating frequency 2.3GHz and 2.5GHz are shown in Table IV:

TABLE IV
BANDWIDTH VALUE AT 2.3GHz AND 2.5GHz

Antenna Design at 2.3GHz	Antenna Design at 2.5GHz
f_H = 2.3472GHz	f_H = 2.5515GHz
f_L = 2.2639GHz	f_L = 2.4525GHz
$\%BW$ = 3.62%	$\%BW$ = 3.96%

From the computed results, it clearly shown that the bandwidth of antenna with operating frequency 3.5GHz has a bigger bandwidth compared to the designed antenna at 2.3GHz and 2.5GHz. The computed values for those three frequencies still suit the requirement of WIMAX application.

A part of that, another criterion need to be considered in this design is the input impedance. Input impedance indicates how accurate the transmission line or feeder matches with the patch antenna. Basically, the input impedance should be 50Ω at the resonant frequency. Besides, resonant resistance should be equal or slightly greater than feed line impedance [7]. The results in Figure 5 below show that this design experienced impedance mismatch since the value for input impedance, Z_{11} are greater than 50Ω. One factor that may contribute to this condition is unsuitable feed location.

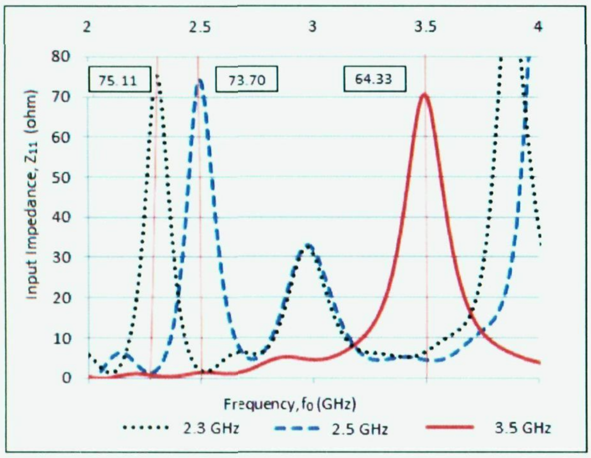

Fig. 5: Combination of input impedance graphs

The farfield was discussed in term of antenna gain. It takes into account losses of the antenna due to Ohmic resistance [7]. The loss incurred by the antenna is defined in terms of efficiency; normally in total efficiency and it also affected by the impedance matching characteristic. Figure 6, 7 and 8 show the antenna farfield at frequency 3.5GHz, 2.5GHz and 2.3GHz respectively. For the result at 3.5GHz, the gain of the antenna is 7.041 dB while the total efficiency is 72.40%.

Moreover, the gain of the designed antenna at 2.5GHz is 5.995 dB while the total efficiency of the antenna is 67.31%. A part of that, the gain and the total efficiency at 2.3GHz is 5.727 dB and 65.31% respectively. All values are satisfying and each gain obtained is in the expected range for microstrip patch antenna; 3 dB to 15 dB. The farfield radiates in the positive z-direction and thus, indicate that it functions in a proper way and transmitting a certain amount of current through its patch. Red color indicates that the antenna radiate a signal at the maximum output while blue color refers to the minimum output.

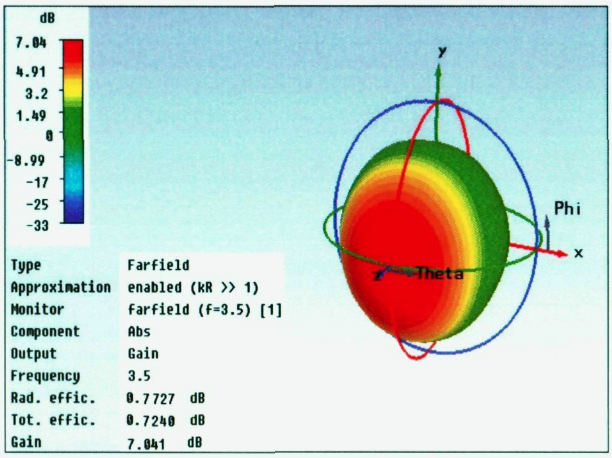

Fig. 6: Antenna farfield at 3.5GHz

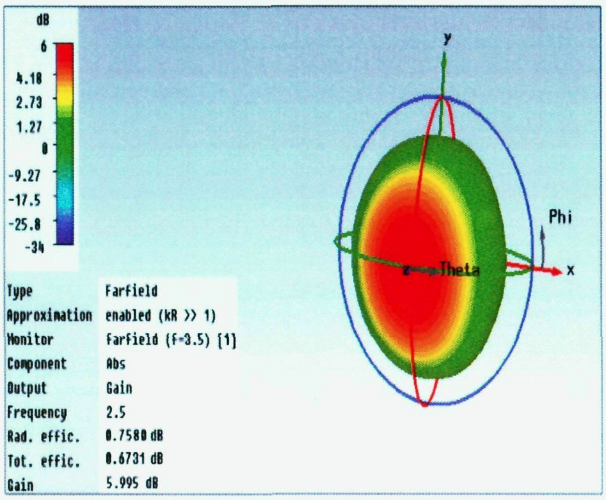

Fig. 7: Antenna farfield at 2.5GHz

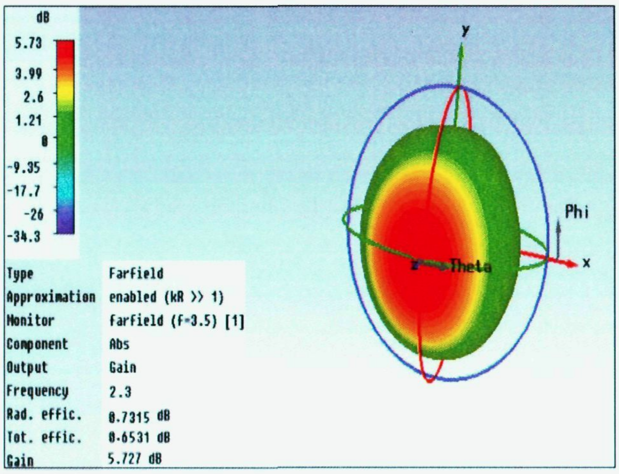

Fig. 8: Antenna farfield at 2.3GHz

IV. CONCLUSION

A design of multilayer proximity coupled antenna with three different operating frequencies has been done successfully. The results are typically similar to the desired and expectations done before. The expected value of return loss and VSWR are achieved; S_{11} less than -20dB and VSWR less than 1.5. In addition, the computed bandwidths for the three different frequencies; 3.5GHz, 2.5GHz and 2.3GHz are 4.9%, 3.96% and 3.62% respectively.

V. FUTURE DEVELOPMENT

This paper discussed on the analysis of three different frequencies in wireless communication network. In line with the aim of the next generation as getting higher speed networks services, it is recommended to apply more techniques in enhancing the bandwidth of the antenna. One solution is using the multilayer antenna. Besides, bandwidth enhancement via non-contact feedings methods can also be achieved by using aperture coupling [8]. Furthermore, the design can be implement by using different substrate, feeding method and other structure of patch as well.

ACKNOWLEDGEMENT

The author would like to thanks Robi'atun Adayiah binti Awang and Ahmad Asari bin Sulaiman for their supervision, guidance and supports for this project. Thanks also to Maizatun Muhamad for her ideas and valuable opinions towards the successful of this project.

REFERENCES

[1] "IEEE standard definitions of terms for antennas," *IEEE Std 145-1983*, 1983.
[2] Zaiki Awang, "*RF Monograph*", Faculty of Electrical Engineering, Universiti Teknologi Mara, 2007.
[3] G.A. Deschamps, "Microstrip Microwave Antenna,"Presented at the Third USAF Symposium on Antennas, 1953.
[4] D. M. Pozar, "Microstrip Antennas," *Proc. IEEE*, Vol. 80, No.1, pp.79- 81, January 1992.
[5]Rod Watnerhouse, "*Printed Antennas for Wireless Communications*", John Wiley & Sons, Ltd, 1807.
[6] Rashid A. Saeed and Sabira Khatun, "Design of Microstrip Antenna for WLAN", Malaysia, *Journal of Applied Science 5(1)*: 47-51, 2005.
[7] Z.Awang, *Microwave Engineering for Wireless Communication*: Prentice Hall, 2006.
[8] Croq, F., Kossiavas, G., Papiernik, A., "Stacked resonators for bandwidth enhancement: A comparison of two feeding technique"*IEE Proceedings on Microwave, Antenna and Propagation, Part H, Vol. 1404, Aug 1993*, pp. 303-308.