Hexagonal Patch Slit-back Antenna for WiMAX Application

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Abstract— **This paper presents the simulation and measurement result of microstrip Hexagonal Patch Slit-back Antenna.It operates at 2.5GHz which is for WiMAX applications. Hexagonal patch slit-back antenna was designed and simulated using Computer Simulation Technology 2009 (CST) software. The proposed antenna was fed by quarter-wavelength transmission length for impedance matching purpose with Defected Ground Structure (DGS) at the background of the antenna. The performance of the antenna was analyzed in terms of return loss and Voltage Standing Wave Ratio (VSWR). The Hexagonal Patch Slit-back Antenna was fabricated on Fiber Reinforced (FR-4) with dielectric constant of 5.0 and thickness of 1.6mm respectively. The Hexagonal Patch Slit-back antenna was measured in the laboratory using Vector Network Analyzer (VNA).The results show the value of return loss is lower than -20 and Voltage Standing Wave Ratio (VSWR) is lower than 2.**

Keywords - hexagonal patch antenna, back slit, microstrip, CST Microwave Studio

I. INTRODUCTION

An antenna is usually defined as a structure associated with the region of transition between a guided wave or a free space or vice versa[1] and Worldwide Interoperability for Microwave Access (WiMAX) can be defined as a physical layer wireless communications technologies for outdoor broadband wireless coverage[2].Worldwide Interoperability for Microwave Access (WiMAX) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rate [3]. According to work done by Paul Piggin, it can be said that Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) is the most rapidly growing area in the modern wireless communication[4].Therefore, much effort has been paid for the design of WiMAX antenna. In order for antenna to be considered for WiMAX application, the weight and the volume of the antenna must be low and the antenna should have a wider bandwidth. Microstrip Patch Antenna is preferred in order to meet these requirements due to their compactness, inexpensive to fabricate, light in weight and can be conformable with planar and nonplanar surface. Nowadays, a great of interest has been shown in microstrip antenna due to its numerous unique and attractive features. A wide variety of shapes has been developed into the useful radiating system[5].

Work done by M.K.A Rahim, proposed a Microstrip Patch Antenna with aperture Coupler Technique at 5.8GHz but has a high value of simulated return loss which is -20.5743dB[6]. Furthermore, work done by Norfishah Ab Wahab, Zulkifli Bin Maslan, Wan Norsyafizan W. Muhamad, Norhayati Hamzah proposed a Microstrip Rectangular 4x1 Patch Array Antenna at 2.5GHz for WiMax Application. The proposed antenna was fabricated on a FR4 substrate for economic consideration. The dimensions of the proposed antenna are 34.93x25.1mm. The simulated return loss of the antenna is also high which is -20.24dB and the voltage standing wave ratio is less than 2[7].

In this paper, the design of Hexagonal Patch Slit-back Antenna is presented with the lower value of return loss. It operates at 2.5GHz which is in the range of WiMAX application. The proposed antenna was designed with Defected Ground Structure (DGS) with quarter-wavelength transmission line for impedance matching purpose. The proposed antenna was fabricated on a FR-4 substrate. The dielectric constant of FR-4 substrate is 5.0 and thickness is 1.6mm.This antenna offers a return loss of -26.49dB at 2.495GHz and VSWR at 1.099 by simulated using Computer Simulation Technology 2009 (CST) software.

Objective

The objective of this project is to design Hexagonal Patch Slit-back Antenna which consists of patch, feeder with quater-wavelength transmission line and single slit as a Defected Ground Structure (DGS).The antenna operates at frequency 2.5GHz which is in the range of frequency for WiMAX application. The antenna needs to present a good performance in terms of return loss and VSWR.

Scope of Study

The scope of this project is to design, fabricate and measured Hexagonal Patch Slit-back Antenna that has designed for WiMAX application. The antenna was designed with low value of return loss and VSWR.

II. METHODOLOGY

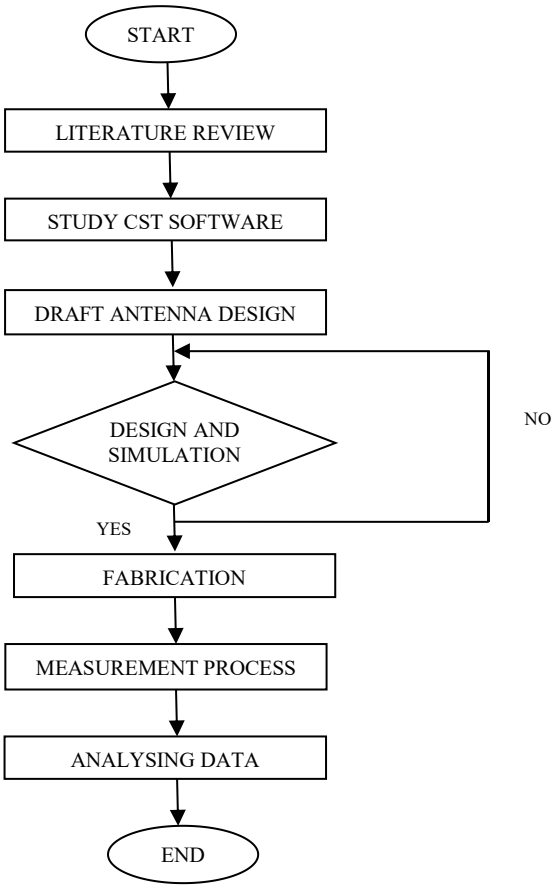

Figure 1: Flowchart of Hexagonal Patch Antenna Design

This project starts with the literature review which analyzed the topic chosen continues with study about CST software. The information about the project was getting from the internet, journal, reference books, magazine and published work. After collecting the data, it is necessary to study about it to make sure that this project will meet its specification. At this stage, the critical points of current knowledge including substantive findings as well as theoretical and methodological contributions about design Hexagonal Patch Slit-back Antenna for WiMAX Application needs to review. Antenna design should be drafted to get the permission by supervisor to proceed with the title chosen. After get the permission from the supervisor, the project has been continued with the design process. The antenna needs to design until it meets the specification needed for the simulation process. If the antenna does not meet the specifications required, the design process should be repeated. In this project, the simulation part is done when the graph of simulation drop at the operating frequency which is 2.5GHz, return loss and VSWR is lower than -20dB and 2.0 and line impedance is 50 Ohm. After designing process, the fabrication process was done and continued with the measured process which is measured the antenna in the laboratory. In this project, the antenna was measured using Vector Network Analyzer (VNA). This process was ended with analyzing the data.

III. ANTENNA DESIGN

The first step in designing an antenna is to choose an appropriate substrate which is needed for mechanical support of the antenna metallization. Therefore, the substrate needs to consist of dielectric material, which may affect the electrical performance of the antenna, circuits, and transmission line. It is not easy to find a substrate that will satisfy the electrical and mechanical requirement. The best substrate is RT Duroid 5870 since it has a lower electrical loss, but it is not used as a substrate in this project since the cost of using RT Duroid 5870 is too high. FR4 was chosen to replaced RT Duroid since it cheaper and widely used for low-frequency and digital board [8]. Besides low cost, it is available and ease of the fabrication process.

The antenna analysis has been done by using CST Microwave Studio(CST) tools. The geometry of this antenna is a patch in hexagonal shape, combine with the small feeder and big feeder with the single slit at the background. Performance evaluation on the hexagonal patch antenna is successfully conducted and the specifications are listed in Table 1.

TABLE I. DESIGN SPECIFICATION FOR HEXAGONAL PATCH ANTENNA

Center Frequency,fo	2.5 GHz
Substrate	FR-4
Dielectric Constant	5.0
Substrate Height	1.6mm
Copper Thickness	0.035 mm

A. Patch Antenna Design

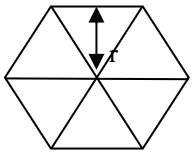

Figure 2: Structure Diagram of the Patch Antenna

A microstrip patch antenna consists of a conducting patch of any geometry on one side of a dielectric substrate with a ground plane on the other side. The shape of a patch is the main parameter which affects the bandwidth of the antenna and electrical characteristics such as directivity and gain. In this project, the hexagonal shape was chosen as a patch in order to design a new shape of the antenna. Figure 2 shows the structure diagram of patch antenna design that have been design in this project where r stands for the radius of the hexagonal. The radius of hexagonal, that has been design is 17mm.According to Garg Bhartia Bahl Ittipiboon in Microstrip Antenna Design Handbook, basic microstrip patch antenna shapes that are commonly used in practice are square, disk, rectangle, ellipse, equilateral triangle and ring while the other possible geometries for microstrip patch antenna are disk with slot, semi disk, disk sector, elliptical ring, semi ring, ring

sector, pentagon, hexagonal with inner circle, eccentric circular ring, H-Shape, U-shape, L-shape, rectangular ring, rectangular with inner circle, right angled isosceles triangle, cross junction- shape and trapezoidal[8]. Therefore, this antenna becomes a new shape of the antenna since hexagonal shape without the inner circle is not listed in the other possible shape of the antenna.

B. Ground Plane Design

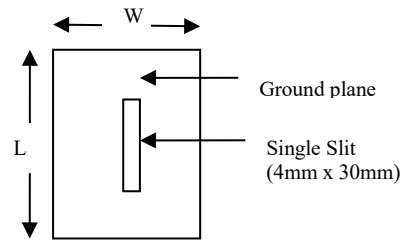

Figure 3:Structure Diagram of the Ground Plane

Figure 3 shows the ground plane design of this antenna where W stands for width and L stands for length. The width of the ground is 54 mm and the length of ground is 80 mm respectively. In this project, ground plane has been design by the same dimension of the substrate. The performance of the antenna has been decrease by adjusting the ground to small dimension than the substrate. This antenna will show the best result when a single slit is added at the background as a Defected Ground Structure(DGS) of the proposed antenna.

C. Microstrip feedline design

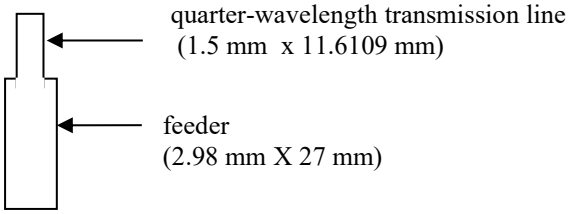

Figure 4:Structure Diagram of microstrip feedline

Figure 4 shows the microstrip feedline design of this antenna. This antenna is fed by a quarter-wavelength transmission line. Quater-wavelength transmission line has been added between feeder and patch antenna to increase the performance of the antenna. Without quarter-wavelength transmission line, it is difficult to make this antenna to meet its specification. The size of feeder is 2.98 mm x 27 mm and the size of the quarter-wavelength transmission line is 1.5mm x 11.6109 mm respectively.

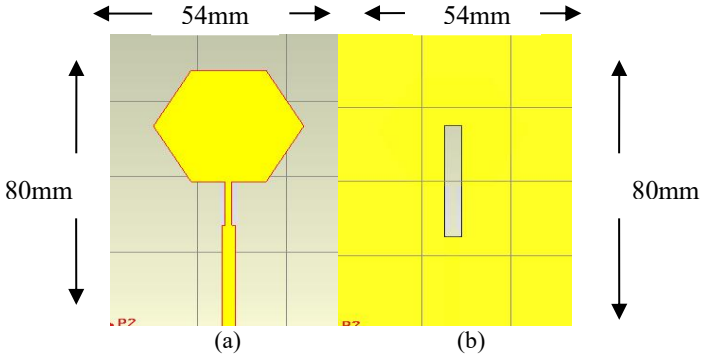

Figure 5: Antenna Geometry. (a) front view (b)back view

TABLE II. OVERALL DIMENSIONS FOR HEXAGONAL PATCH SLIT-BACK ANTENNA

GEOMETRY	SIZE
Hexagonal Patch	Radius= 17 mm
Feeder	2.98mm X 27 mm
Single Slit	4mm X 30 mm
Transmission line	1.5 mm X 11.6109 mm

Figure 5 shows the full design of this antenna and the overall dimensions are listed in Table 2.

IV. SIMULATION RESULT

A. Return Loss Simulation

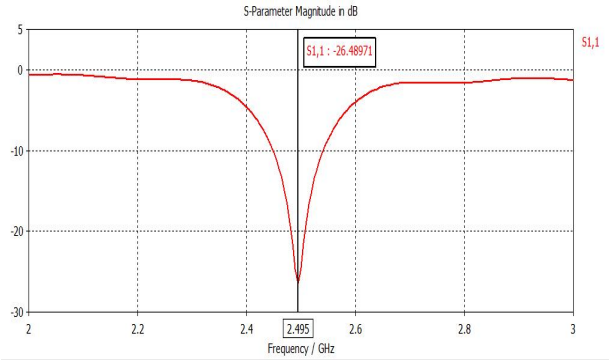

Figure 6 .Return Loss of Hexagonal Patch Slit-back Antenna

Return loss is a parameter that indicates the amount of power that is lost to the load and does not return as a reflection. Figure 6 shows the simulated return loss of Hexagonal Patch Slit-back Antenna at operating frequency 2.495GHz,the return loss value is -26.49dB.

B. *Voltage Standing Wave Ratio(VSWR)*

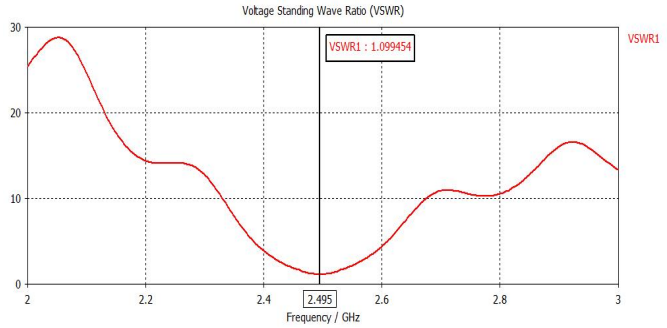

Figure 7:Simulation of VSWR of Hexagonal Patch Slit-back Antenna

Voltage Standing Wave Ratio(VSWR) can be defined as the ratio of maximum voltage to the minimum voltage in a transmission line. Figure 7 shows the simulated Voltage Standing Wave Ratio(VSWR) of Hexagonal Patch Slit-back Antenna at operating frequency 2.495GHz,the VSWR value is 1.099454. Basically, the value of VSWR used to indicate on how good the impedance is match. The lower value is better since the impedance is matched. The impedance is perfectly matched when VSWR is equal to 1.

C. *Radiation Pattern*

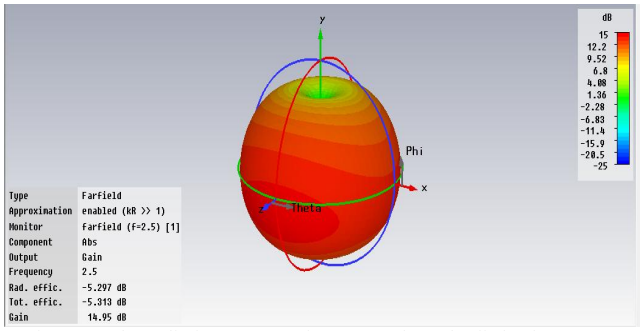

Figure 8: The radiation pattern of Hexagonal Patch Slit-back Antenna

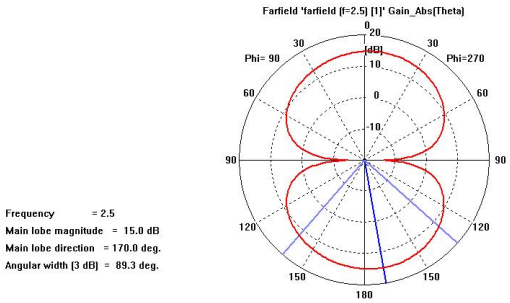

Figure 9: The simulated radiation pattern of Hexagonal Patch Slit-back Antenna

Radiation pattern can be defined as a graphical description of the relative field strength transmit or receive by the antenna. The directivity or gain of an antenna is a measure of concentration of the radiated power in a particular direction. Figure 8 and Figure 9 shows the simulated radiation pattern of Hexagonal Patch Slit-back Antenna with directivity of 20.25dB and gain of 14.95dBi.

V. EXPERIMENTAL RESULT

The antenna was fabricated on Fiber Reinforced (FR-4) with dielectric constant of 5.0 and thickness of 1.6mm.Figure 10 shows the hardware design of Hexagonal Patch Slit-back Antenna.

(a) (b)

Figure 10: Hardware Design. (a) front view (b)back view

The fabricated antenna was measured by using 2VA 4G-Vector Network Analyzer(VNA) 10MGHz-40 GHz at Microwave Technology Center(MTC) laboratory. The VNA was re-calibrated before starts the measurement to enhance the accuracy.

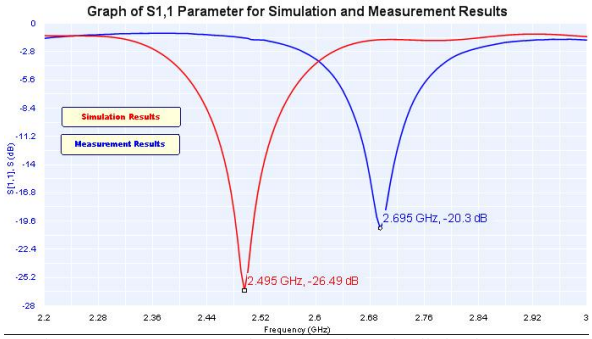

Figure 11 .Return Loss of Hexagonal Patch Slit-back Antenna

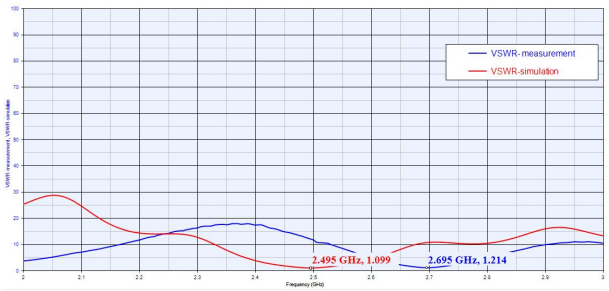

Figure 11 .VSWR of Hexagonal Patch Slit-back Antenna

Figure 11 shows the S1,1 of Hexagonal Patch Slit-back Antenna for simulation and measurement and Figure 12 shows the Voltage Standing Wave Ratio(VSWR) for simulation and measurement.S1,1 contains information about operating frequency and return loss of the antenna. Return loss can be defined as a ratio of the power reflected back from the line to the power transmitted into the line. The simulation result gives

return loss -26.49dB at operating frequency of 2.495GHz which is the best result after optimization while the measurement result gives return loss -20.3dB at operating frequency of 2.695GHz. The simulation result gives the VSWR 1.09 at operating frequency of 2.495 and the simulation result gives the VSWR 1.214 at operating frequency of 2.695. The shifted of the operating frequency, return loss and VSWR of the measurement results maybe because of there are errors in the fabrication process that contributes some flaws to the hardware. Besides that the influence of coaxial cable that is connected to the antenna during the measurement process was the major factor to the differences of the result because this factor was not will affect the simulation result.The measured operating frequency has shifted about 8.016% from the simulated operating frequency while the measured return loss has shifted about 23.37% from the simulated return loss.

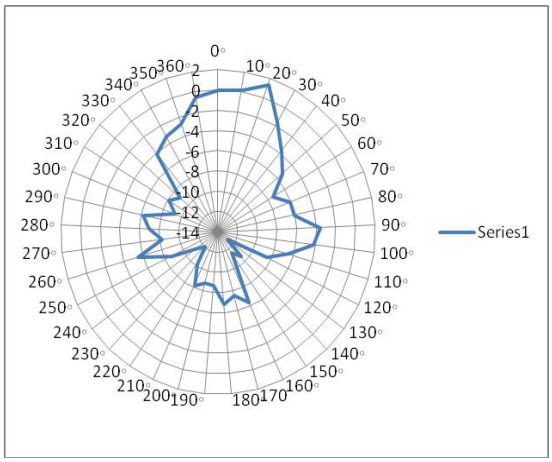

Figure 12 .Measured Radiation Pattern of Hexagonal Patch Slit-back Antenna

Figure 12 shows the measured radiation pattern of Hexagonal Patch Slit-back Antenna. The measurement result shows that the proposed antenna has a omnidirectional radiation pattern. The result of measured radiation pattern is quite different compared to the simulation result. This is because of the noise floor from the equipment and the measurement process is done in open space where it supposed to be done in a chamber to decrease the effect of noise.

VI. CONCLUSION

A Hexagonal Patch Slit-back Antenna have been design, fabricated and measured. The performance has measured and it shows that Hexagonal Patch Slit-back Antenna performed a good performance. Overall, the performance of Hexagonal Patch Slit-back Antenna meets the desired requirements in terms of return loss and VSWR. A Hexagonal Patch Slit-back Antenna have been successfully design with low value of return loss and VSWR. .The simulation return loss is -26.49dB at operating frequency 2.495Ghz. However, the measured frequency has been shifted about 8.016%,the return loss is increased about 23.37% and the VSWR is increased about 10.46% from the simulated value. Although the value of measurement is changing but the value is still under condition which is return loss is lower than -10dB and VSWR is lower than 2.Lastly,it can be said that the objectives of this project are successfully achieved.

VII. RECOMMENDATION

Future work includes to design this antenna by using RT/Duroid 5870 because it has a lower value of dielectric constant. Lower value of dielectric constant will provide better efficiency, wider bandwidth and lower electrical loss.

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