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Investigation of Meander Slots To Microstrip Patch Patch Antenna

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Abstract— **Microstrip slotted meander line antenna with a diverse number of meander slots is presented for 2.4 GHz of Wireless Local Area Network (WLAN) application. The proposed antenna comprises a rectangular microstrip patch element embedded with several numbers of meander slots in many positions. The parametric study is performed to investigate the characteristic of these microstrip patch antennas with different numbers of meandered slots. Many designs of slotted meander line antenna are produced and they are analyzed based on the number of slotted meander line used. Antenna with 7 slotted meander lines has the most size reduction of approximately 23% of the original size. This study is an early investigation in designing the RF energy harvesting to support green technology and sustainable development particularly for Wireless Sensor Network (WSN) as well as Radio Frequency Identification (RFID) applications.**

Keywords— ***Slotted meander line antenna, microstrip patch, return loss, bandwidth, CST Studio Suite 2010.***

I. INTRODUCTION

Energy harvesting or energy scavenging is basically a conversion process of the ambient energy into electrical energy. In recent years, there has been a growing interest in the deployment of wireless sensor networks (WSN) that are used in applications such as in structural monitoring, habitat monitoring, healthcare systems and precision agriculture [1].

An energy harvesting system consists of two main subsystems which is receiving antenna and rectification circuitry. An efficient antenna is required to transfer wireless power efficiently. The antenna captures the RF signals from the ambient, and subsequently the rectifier circuit will extract the power from those signals and converts them into DC voltage.

Microstrip antennas have the attractive features of low profile, small size, low cost, and conformability to mounting hosts which makes them excellent candidates for satisfying this design consideration. [2]. However, microstrip antennas inherently have certain drawbacks to be given attention such as narrow bandwidth [3]. Therefore, bandwidth enhancement is usually demanded for practical applications. Nowadays, to meet miniaturization requirements of mobile units, smaller size of the antenna is usually required for applications in mobile communication systems. Thus, size reduction and bandwidth enhancement are major design considerations for practical applications of microstrip antennas [4].

The meander line antenna is one type of the microstrip antennas. Meander line technology allows designing an antenna with a small size and provides wideband performance [5]. Having the advantage to miniaturize antenna like other proposed methods [6] [7] [8], slotted meander line antenna is chosen because it is able to reduce the size of the antenna. It is smaller and very flexible to be shifted or relocated [9][10]. The performance of the slotted meander line antenna depends on various factors such as the position of meander slots and number of turns of the meander line. This includes the number of meander slot existed in particular antenna.

II. ANTENNA DESIGN

The geometry for the slotted meander line antenna consists of 3 layers [11] which are patch (Layer 1), dielectric substrate (Layer 2) and ground plane (Layer 3) as shown in Fig. 1. The antenna was simulated on an FR4 substrate with dielectric constant of 4.4 and a thickness of 1.6 mm. While the upper and the bottom layer of the patch and ground plane used material from the copper annealed with thickness of 0.035 mm. The ground also consists of SMA connecter which is used as an RF connector to connect the 50 Ω coaxial cable and the 50 Ω microstrip lines on a board. Coaxial probe was chosen as the feed because it can be placed at any location and the impedance match will depend on its location on the patch [12]. The geometry of the microstrip patch antenna is shown in Fig. 1. The basis of the antenna structure is chosen to be a rectangular patch element with the dimensions of width Wp and length Lp.

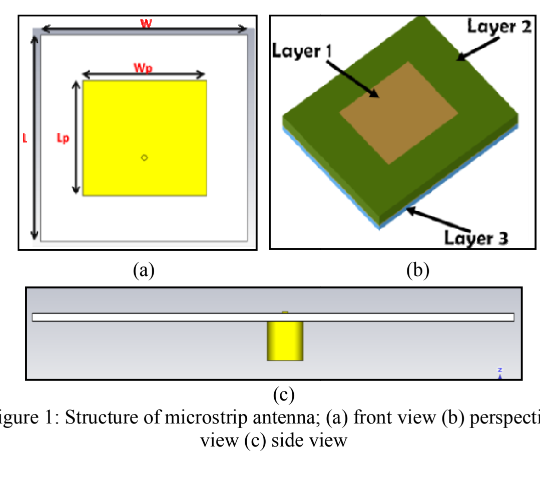


Figure 1: Structure of microstrip antenna; (a) front view (b) perspective view (c) side view

Patch length and width are calculated by using the transmission line model.

Formula for patch width [13][14] is given by

$$W = \frac{1}{2f(\sqrt{\varepsilon_0 \mu_0})}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

And length is given by;

$$L = \frac{1}{2f(\sqrt{\varepsilon_{eff}})} - 2\Delta L \quad (2)$$

The parametric study method is used to obtain the best dimension of microstrip patch antenna to achieve 2.4GHz operation.

Fig. 2 below shows the parameters of the meander slot that will be used in all designs of slotted meander line antennas. Basically it consists of the width of horizontal length W_H, length of horizontal line L_H, width of vertical line W_V, length of vertical line L_V and the number of turns, N.

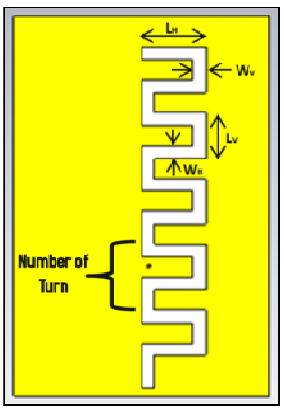


Figure 2: Design parameter of slotted meander line antenna

For all designed structure, the width of the horizontal line, W_H is fixed to 1mm. The antennas are categorized based on the number of slots attached to the microstrip antenna.

i) Slotted Meander Line Antenna – 6 slots

Fig. 3 shows the slotted meander line antenna with 6 slots. Two meander slots each are located at the right, left and top of the probe feed.

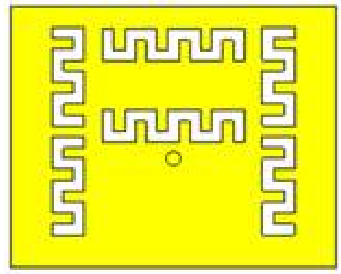


Figure 3: Structure of 6 meander slot antenna

ii) Slotted Meander Line Antenna – 7 slots

Fig. 4 shows the slotted meander line antenna with 7 slots. All of the meandered slots have the same number of turns, N = 2. Four of them are located at the corners of the antenna while remaining 3 meander line slots are located at the top, right and left of the probe feed.

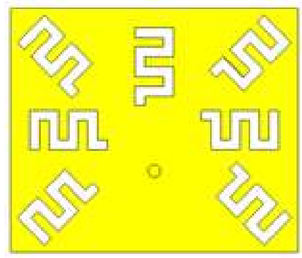


Figure 4: Structure of 7 meander slot antenna

III. Experimental Results And Analysis

Fig. 5 shows the simulation result of frequency response, return loss and bandwidth of the rectangular microstrip patch antenna.

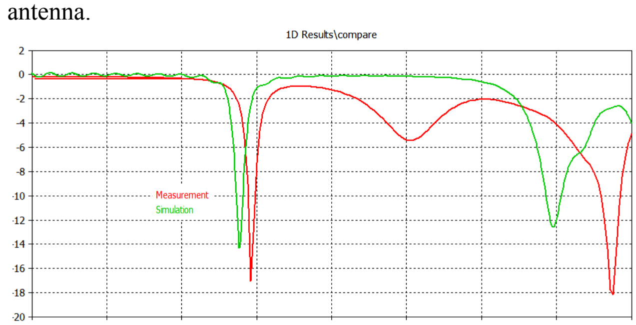


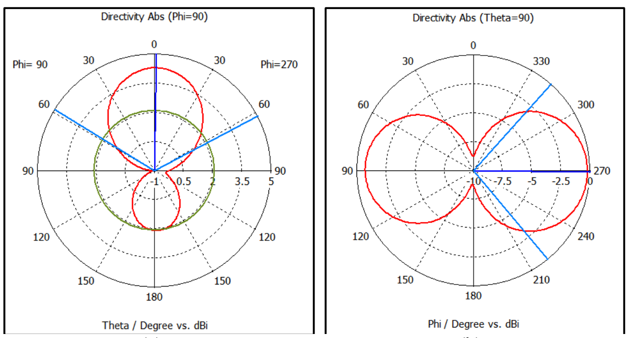
Figure 5: Simulated and measured return loss of the rectangular microstrip patch antenna

The simulation return loss at 2.4 GHz is at -14.33 dB, which meets the requirement of the design which is less than -10 dB (90% of power fed is absorbed). Table 1 shows the data of simulation and measurement result for rectangular microstrip patch antenna.

TABLE I. SIMULATION AND MEASUREMENT RESULT OF RECTANGULAR MICROSTRIP PATCH ANTENNA

	Freq.	R. Loss	Bandwidth	Gain
Sim.	2.4 GHz	-14.33 dB	42.68 MHz	4.23 dB
Mea.	2.46 GHz	-17.05 dB	48.08 MHz	2.67 dB

The simulation bandwidth produced is satisfactory and sufficient to cover the 2.4 GHz span of RFID applications. This 10 dB bandwidth ranges from 2.4424 GHz to 2.4905 GHz which is practically adequate. The measurement result shows that the resonant frequency shifted to the left to 2.46 GHz displaying return loss of -17.05 dB which is better than the simulation return loss. The radiation pattern of this antenna is shown in Fig. 6 and Fig. 7.



(a) (b)

Figure 6: Simulated radiation pattern of rectangular microstrip patch antenna at (a) H-field (b) E-field.

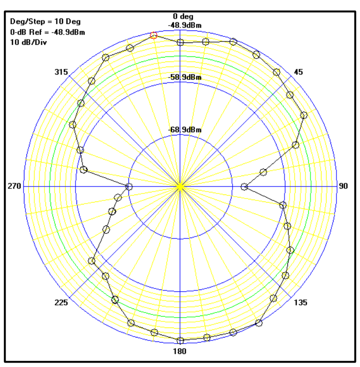


Figure 7: Measurement radiation pattern of rectangular microstrip patch antenna

i) Result Analysis of 6 Meander Slots Antenna

From the return loss graph shown in Fig. 8 below, the 6 meander slot antenna has a good return loss with -16.52 dB. The additional number of slotted meander lines on the antenna improved the return loss and also the bandwidth.

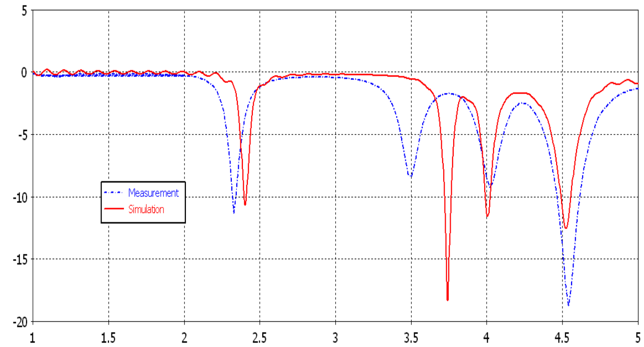


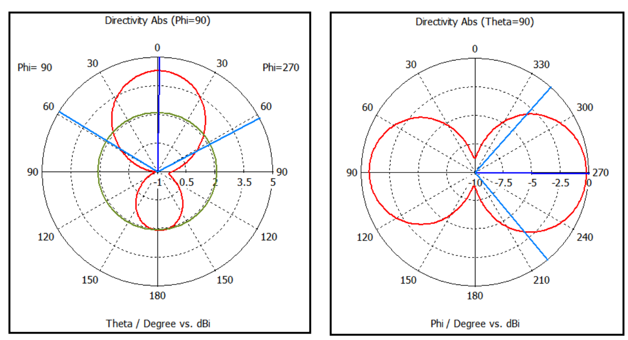
Figure 8: Simulated and measured return loss of 6 meander slot antenna

The measurement result shows that this antenna only able to get a slightly lower than -10 dB return loss. It managed to achieve -11.52 dB. The antenna obtained a higher gain compared to 7 meander slot antenna. Table 2 shows the comparison of simulation and measurement result for 6 meander slot antenna.

TABLE II. SIMULATION AND MEASUREMENT RESULT OF 6 MEANDER SLOTS ANTENNA

	Frequency	Return Loss	Bandwidth	Gain
Sim.	2.41 GHz	-16.52 dB	43.01 MHz	3.65 dB
Mea.	2.32 GHz	-11.52 dB	28.27 MHz	1.69 dB

The simulated radiation pattern is as presented in Fig. 9 below. The simulated HPBW for E-field is 120.7º at 2.4 GHz while the HPBW for H-field is 98.9º at 2.4 GHz. The measured radiation pattern is shown in Fig. 10.



(a) (b)

Figure 9: Simulated radiation pattern of 6 meander slot antenna at (a) H-field (b) E-field

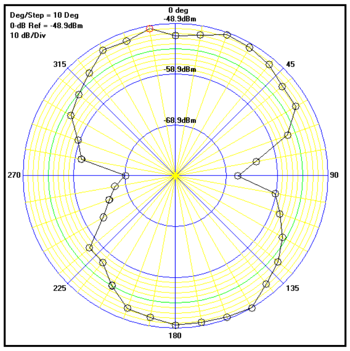


Figure 10: Measured radiation pattern of 6 slot meander line antenna

ii) Result Analysis of 7 Meander Slots Antenna

From the return loss graph shown in Fig. 11 below, the 7 meander slot antenna achieved a return loss of -19.42 dB. The position of the slotted meander lines at the corners of the antenna improved the return loss as well as the bandwidth.

For measured results, this antenna is only able to get a slightly lower than -10 dB return loss. It managed to achieve -14.35 dB of return loss. One of the disadvantages of this antenna is its low gain compared to 6 meandered slot antenna.

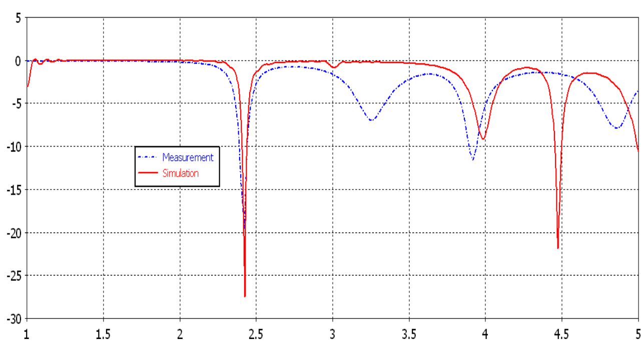


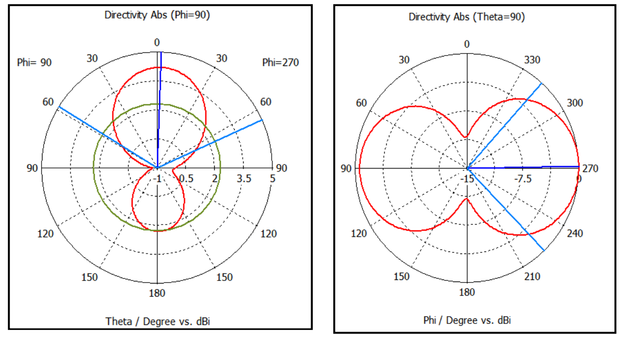
Figure 11: Simulated and measured return loss of 7 meander slot antenna

Table 3 shows the comparison of simulation and measurement result for 7 meandered slot antenna.

TABLE III. SIMULATION AND MEASUREMENT RESULT OF 7 MEANDER SLOTS ANTENNA

	Freq.	Return Loss	Bandwidth	Gain
Sim.	2.40 GHz	-19.42 dB	32.08 MHz	-0.76 dB
Mea.	2.41 GHz	-14.35 dB	33.27 MHz	-1.28 dB

The simulated radiation pattern is as presented in Fig. 12. The simulated HPBW for E-field is 123.8º at 2.4 GHz while the HPBW for H-field is 94.4º at 2.4 GHz. As for measurement radiation pattern, it is shown in Fig. 13.



(a) (b)

Figure 12: Simulated radiation pattern of 7 meander slot antenna at (a) H-field (b) E-field

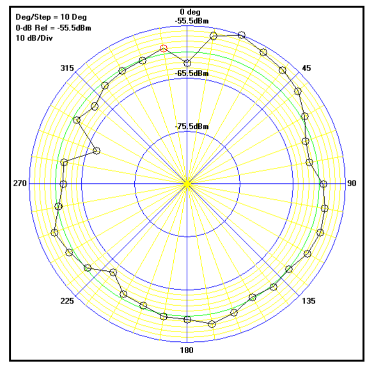


Figure 13: Measured radiation pattern of 7 meander slot antenna

A comparison of return loss has been made between simulation and measurement. For this purpose, the data obtained from the measurement process has been exported into the CST Microwave software in order to get a better picture of the comparison.

As for the measured radiation pattern, antenna with 7 meandered slots shows an omnidirectional radiation pattern rather than the bidirectional pattern in simulation.

The comparison of simulation and measurement results for both antennas has been converted into table form for a better picture. Table 5 below shows the detailed comparison.

TABLE IV. RESULT COMPARISON OF 6 MEANDER SLOTS AND 7 MEANDER SLOTS ANTENNA

	6 Meander Slots Antenna		7 Meander Slots Antenna	
	Sim.	Mea.	Sim.	Mea.
Freq. (GHz)	2.41	2.32	2.40	2.42
$RL_{2.4GHz}$ (dB)	-14.54	-11.52	-19.42	-14.35
BW (MHz)	43.0	10.3	32.1	52.3
Gain (dB)	3.65	1.69	-0.76	-1.28

The gain of 7 meander slot antenna is negative which means that the antenna gain at particular direction is less than the isotropic antenna. It happened due to the mismatch loss where the antenna has a low efficiency. The meander slot position also is one of the factors that affect the antenna gain. Meanwhile, the measured gain is also negative in accordance with the simulation result and due to the losses influenced by the distance, cables and connectors.

IV. CONCLUSION

In this paper, the effect of meander slots on a microstrip patch antenna is investigated. Two slotted meander line antennas with different number of slots has been designed, simulated and fabricated. 7 meander slot antenna obtained better performance than the 6 meander slot antenna in terms of return loss, bandwidth and resonant frequency. However, 6 meander slot antenna has a better simulated and measured gain. Further works can be done to explore the designed antenna for RF energy harvesting applications.

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