

Design of a Rectangular Spiral Antenna for Wi-Fi Application

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Abstract— This paper highlights the design, simulation, analysis and fabrication of a coaxial-fed rectangular spiral microstrip antenna (RSMA) for Wi-Fi application. The centre frequency is 2.45 GHz and the bandwidth is 22 MHz. The radiation pattern of this RSMA illustrated an omni-directional pattern with voltage standing wave ratio of less than two (2), return loss of less than -10 dB, the line impedance of 50 Ω and gain of 5 dBi. All the design and simulation of this RSMA were carried by using a commercial 3-D electromagnetic simulator. The prototype was fabricated on FR 4 substrate with 4.9 dielectric constant and 1.54 mm of thickness. Vector network analyzer ZVA40 was used to measure all the parameters of this RSMA. The 2D radiation pattern was obtained by using antenna training system ED3200. It was observed that the simulated and measured values of the parameters of the RSMA were quite close with each other.

Keywords- rectangular spiral antenna, Wi-Fi, microstrip,

I. INTRODUCTION

Wi-Fi networks use radio technologies. A person with a Wi-Fi enabled device such as a PC, cell phone or PDA can access to the internet when in proximity of an access point. The region covered by one or several access points is called a hotspot. Hotspot can range from a single room to many square miles of overlapping hotspots [1].

One of the important components in Wi-Fi application is an antenna. The characteristics needed for a Wi-Fi antenna is an omni-directional antenna with circular polarization [2]. Spiral antennas were introduced in 1950s by Edwin Turner [3] who demonstrated experimentally that an Archimedean spiral resulted in constant input impedance and circular polarization over a wide range of frequencies [4]. Figure 1 shows some of the spiral antennas that are used in broadband applications [1]-[4].

The rectangular spiral antenna was chosen for this work due to the circular polarization characteristic and the frequency independent characteristics at a relatively small size for Wi-Fi applications. Furthermore, this type of antenna can avoid the use of different antenna for different services [1] since an excessive number of access points in one area can

prevent the access due to the interference with other access points. This rectangular antenna was an improvement of [1] in term of the pattern and the feeding technique and differ from typical circular Archimedean antenna [5]-[7]. The prototype was fabricated on FR4 substrate with 4.9 dielectric constant and 1.524 mm of thickness. The centre frequency was 2.45 GHz and the bandwidth was 22 MHz. The antenna was fed by using coaxial cable at the centre.

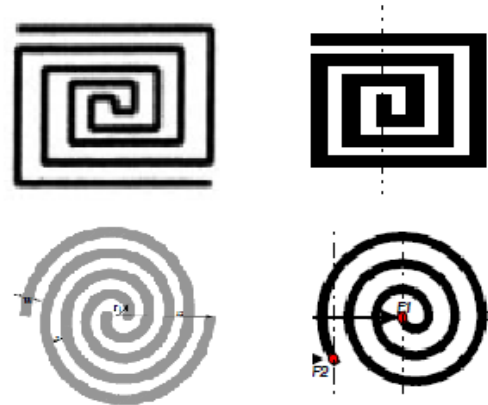


Figure.1. Variety of spiral antenna for broadband application [1] – [4].

II. METHODOLOGY

The design and simulation of this RSMA was carried out using a 3D electromagnetic simulator with the specifications as in Table 1 and the substrate properties as indicated by Table 2 respectively.

TABLE 1. SPECIFICATION OF THE ANTENNA

Center frequency (fc)	2.4 GHz
Bandwidth (BW)	22 MHz
Gain	5 dBi
Radiation pattern	Omni-directional
Voltage standing wave ratio (VSWR)	≤ 2
Return loss (S_{11})	≤ -10 dB
Line impedance (Z_0)	50 Ω

TABLE 2. SUBSTRATE PROPERTIES

Properties	FR-4
Dielectric constant , ϵ_r	4.9
Mue	1
El. Tand	0.025
Thickness(mm), h	1.54
Metal Thickness (mm), T	0.03
Resistivity	1 rel Au

A. Design Procedure

The coordinate system of the RSMA are shown in Figure 2. The geometry of the slot was generated by $dn = 2(n-1) dl$, ($n=2,3,\dots,10$) where $2dl (=ab)$ and n denotes the length of the first turn of the single arm rectangular spiral slot respectively. It was assumed that the slot width, W was very narrow compared with the wavelength, λ_o at the resonance frequency f_o [8].

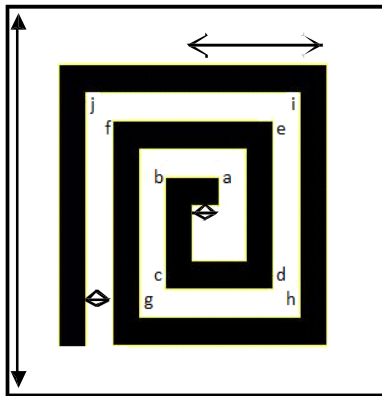


Figure 2. Geometry of Archimedean spiral antenna

The dimension of the RSMA is as shown by Table 3.

TABLE 3. DIMENSION OF RSMA

Number of turn, N	3-turn
Outer radius, r1	2.27 cm
Inner radius, W	0.379 cm
Space, S	0.379 cm
Length, L	6 cm

B. Feeder network

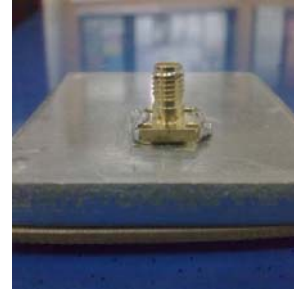


Figure 3a. Coaxial feed for the antenna

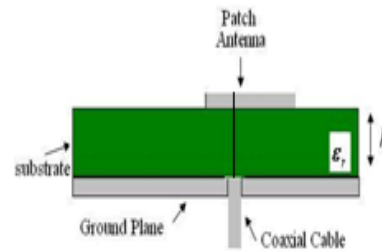


Figure 3b. Cross-section view of coaxial feed

There are many methods that can be adopted to feed the antenna and can be classified into two categories; contacting and non-contacting. The four most popular approaches are the microstrip line, coaxial probe, aperture coupling and proximity coupling [9]. This work adopted the coaxial feed as illustrated by Fig. 3. The inner conductor of the probe extends through the dielectric at a point whereby the impedance matched the input impedance and then soldered to the radiating patch, while the outer conductor is connected to the ground plane. The input impedance Z_o of the antenna is also affected by the inner and outer radius of the coaxial feed, the distance between the lines s , the dielectric constant, ϵ_r and also the thickness t_{su} of the substrate. The disadvantage of this feeding technique will result in an increase in probe length that makes the input impedance more inductive leading to the matching problems [10].

C. CAD Simulation

Simulation of RSMA inclusive of the coaxial feed was carried out. The inner radius, W of the RSMA was varied to obtain the optimum performance as to meet the specification. The dimensions of the antenna was kept constant at 6 cm x 6 cm. The best width, W for this antenna to perform as a Wi-Fi antenna was 3.79 mm. Figure 4 shows the simulated 3-D RSMA while Figure 5, Figure 6 and Figure 7 illustrated the simulation results for the various parameters of the antenna; return loss, S_{11} , voltage standing wave ratio, VSWR, line impedance, Z_o , and radiation pattern respectively.

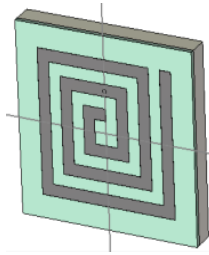


Figure 4: Simulated 3D RSMA

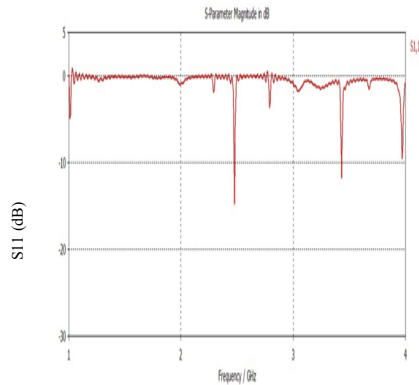


Fig. 5a Return Loss showing all the harmonics

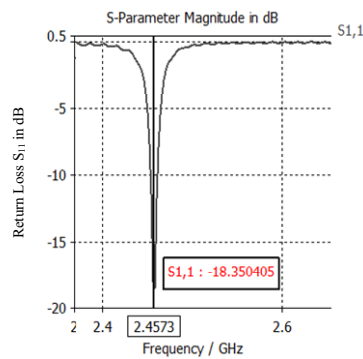


Figure 5b: Return loss, S_{11} at center frequency

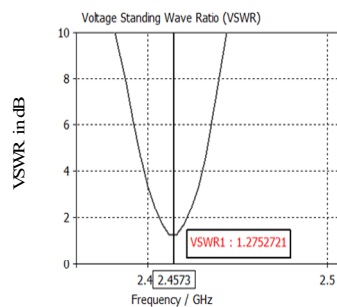


Figure 6: Voltage standing wave ratio, VSWR

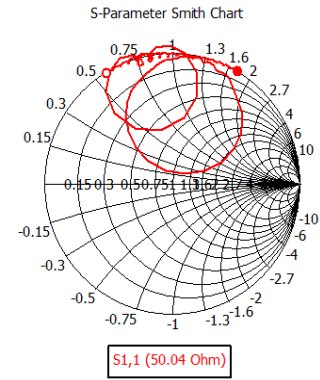


Figure 7. Line impedance, Z_o

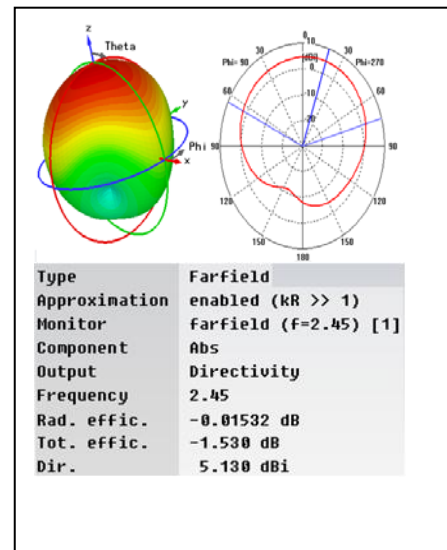


Figure 8. 3-D Radiation pattern

The parameters for the simulated antenna were tabulated in Table 4.

TABLE 4. COMPARISON ON SIMULATED VALUES AND SPECIFICATIONS

Parameter	Specification	Simulated
fc	2.4 GHz	2.45 GHz
BW	22 MHz	22 MHz
Gain	5 dBi	5.103 dBi
Radiation pattern	Omni-directional	Omni-directional
VSWR	≤ 2	1.275
S_{11}	≤ -10 dB	-18.350 dB
Z_o	50 Ω	50.04 Ω

The antenna fulfills the required values of parameters to act as a Wi-Fi antenna. Then, fabrication of the prototype RSMA was carried out prior to analysis and measurement of the RSMA.

III. RESULTS AND DISCUSSIONS

The fabrication of the prototype has been achieved on *FR4* substrate with $\epsilon_r = 4.9$ and $h = 1.54 \text{ mm}$. The prototype of the antenna is shown in Figure 8 with the dimensions of $W = S = 3.79 \text{ mm}$ and $L = 6 \text{ cm}$. Measurements of the S_{11} , VSWR and Z_o were carried out by using a vector network analyzer, *ZVA 40* while the 2-D radiation pattern was obtained by using an antenna training system, ED3200. Standard calibration [6] procedure was used prior to the measurement.

Analysis of the measured and simulated values for S_{11} , VSWR, Z_o and radiation pattern were carried out, and as illustrated by Figures 10, 11, 12 and 13 respectively. All the values obtained met the specifications.

The value of the return loss, S_{11} was -19.47 dB at 2.37 GHz . This value was good since it was lower than -10 dB and it showed close agreement between measured and simulated values as indicated by Fig. 10.

The measured value for VSWR was 1.24 where VSWR for the ideal antenna is unity. The low value of VSWR indicated that the antenna has low value of reflected power. The measured and simulated VSWR values were comparable as illustrated by Fig. 11.



Figure 9. Fabricated RSMA

There were slight discrepancies between the simulated and measured values of the parameter of the RSMA. The use of coaxial feeding techniques caused the input impedance to be inductive as indicated by Fig. 12 and vary slightly in values from the simulated value. However, the values were quite close with each other. The radiation pattern of the antenna was omni-directional as depicted by Fig. 8 and Fig. 13 which obeyed the requirement to act as a Wi-Fi antenna.

The discrepancies might be due to the parasitic losses and the value of *FR4* dielectric constant that was used during fabrication process. The *FR4* dielectric constant may vary from 4.4 to 4.9. Other factors that caused the errors were the effects of connectors, soldering patch and air gap that introduced between the substrate and the ground. The discrepancy of dimension during fabrication also contributed to the error.

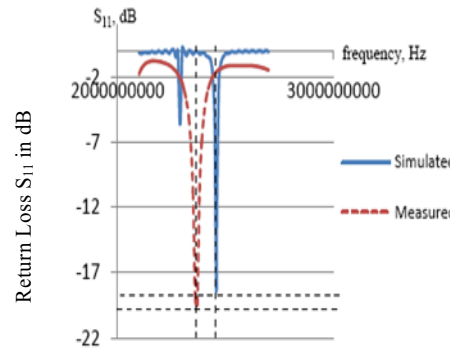


Figure 10. Measured and simulated values of S_{11}

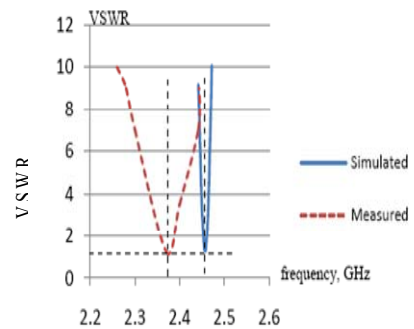


Figure 11. Measured and simulated values of VSWR

(a) Simulated : S_{11} (30.09 nH)
(b) Measured : $M1$ 2.366000 GHz
41.807 Ω
j5.6612 Ω
380.81 pF

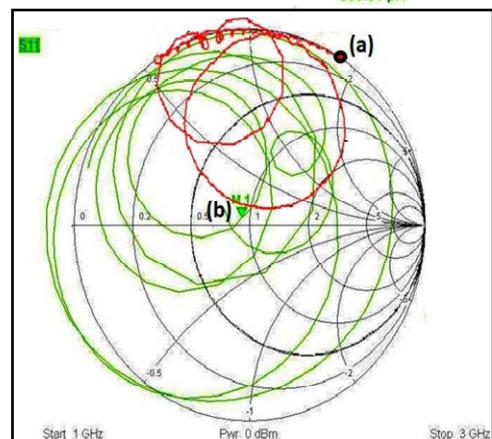


Figure 12. Measured and simulated values of Z_o

IV. CONCLUSION

This paper has presented the design, simulation and the prototype of RSMA, fabricated on *FR4* substrates with 4.9 dielectric constant and 1.54 mm thickness. The results show that the simulated and measured values were quite close with each other. The relationship between f_c and W is inversely proportional. The improvement from [1] has been achieved as the size is reduced to 6 cm x 6 cm. The bottom coaxial fed provide space for other device to mount on the substrate which can further reduced the overall size of a Wi-Fi.

V. RECOMMENDATION

The performances of this antenna can be further upgraded. The use of substrate of lower value of the dielectric constant can further reduced the size of the antenna [11]. In future the number of turn can be increased to obtain better performance of a Wi-Fi antenna.

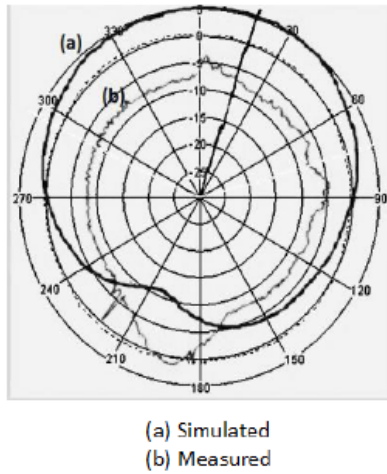


Figure 13. 2- D Radiation pattern

The measured value of Z_0 was 41.81 Ω which slightly differs from the simulated value of 50.04 Ω . Figure 13 highlights the omni-directional radiation pattern of this antenna.

All the measured, simulated and specification values of the parameters of the prototype RSMA were summarized by Table 5.

TABLE 5. COMPARISON BETWEEN SIMULATED AND MEASURED OF VALUES OF PARAMETERS OF RSMA

Parameter	Measured	Simulated	Specification
fc (GHz)	2.37	2.457	2.4
Radiation Pattern	Omni-directional	Omni-directional	Omni-directional
VSWR	1.24	1.278	≤ 2
S11 (dB)	-19.47	-18.287	≤ 10
Z_0 (Ω)	41.81	50.04	50

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