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MODIFIED PRINTED DIPOLE WITH REFLECTOR AND DIRECTOR

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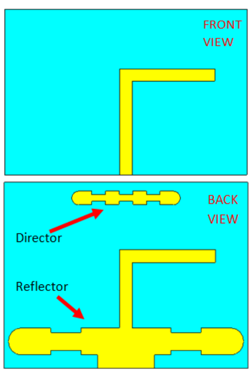
Graphical abstract



Abstract

This paper presented the design for dipole antenna at 2.4GHz for wireless local area network (WLAN) application. This design aimed to improve the antenna gains and directivity. The printed dipole with reflector and director was designed and simulated using CST Microwave Studio. In this design, a metallic reflector was added in order to increase the gain. The director was added to the structure to maximize the antenna directivity. The simulation results showed that the antenna achieved a maximum gain of 5dB for the modified design and 6dBi for the directivity. Other antenna parameters were also investigated such as bandwidth, radiation pattern, and return los.

Keywords: Dipole antenna, WLAN, reflector, and director

1.0 INTRODUCTION

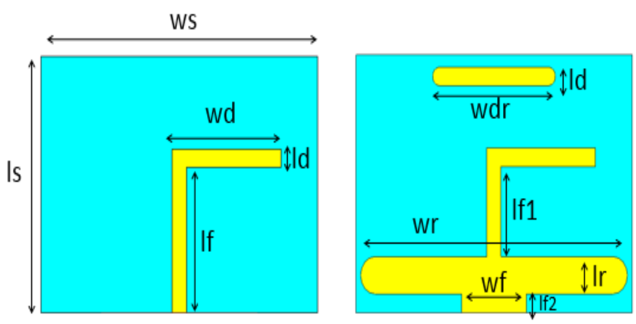
Wireless local area network (LAN) technology is widely deployed and used in organizations today. A wireless LAN is a flexible data communications system implemented as an extension to, or as an alternative to a wired network. Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility. Today, wireless LANs are becoming more widely recognized as an alternative of general-purpose connectivity for many organizations and home users. [1]-[3].

Dipole antennas have been widely used since the early days of radio. The simplicity and effectiveness of a wide range of communication needs are the reason for this and they also make dipoles worth of considerations. There is more to building and installing an effective dipole antenna system than choosing the wire and insulators. The dipole gets its name from its two halves, one on each side of its center. A dipole is a balanced antenna, meaning that the "poles" are symmetrical. They are equal in lengths and extend in the opposite directions from the feed point. In its simplest form, a dipole is an antenna made of wire and fed at its center [4].

A dipole must be electrically half-wavelength long at the operating frequency. A dipole resonance occurs at the length at which its impedance has no reactance (only resistance) on the operating frequency. The resonant impedance range is compatible with many common coaxial feed lines. However, within the limits, resonance is not necessary for a dipole to be effective. The lowest frequency at which a dipole is resonant is known as fundamental resonance. A dipole works best at and above its fundamental resonant frequency [4].

This paper presents two types of antenna designs. Design A is a basic printed dipole antenna while Design B is printed dipole with modified reflector and director. This paper shows the differences of high gain and directivity between Design A and Design B.

In order to concentrate the radiation in half-space, Design A is added with a reflector. The directivity of Design A has been improved by adding a reflector. The Design A achieves a maximum gain of 6.5dBi with a reduced bandwidth. Figure 1 shows the Design A with two arms of the dipole printed on each side of a dielectric substrate. The lengths of these arms are around $\lambda_0/4$. The distance between the arms and the connector is close to $\lambda_0/4$ [6]-[10].



(a) (b)

Figure 1 Design A, (a) Front view, and (b) Back view

2.0 ANTENNA DESIGN

Figure2 shows the design structure for Design B. The Design B was composed of a dipole, a reflector and a director as shown in Figure 2. The two arms of the dipole were printed on each side of FR4 substrate with thickness of 1.6 mm, permittivity of 4.4, and copper thickness of 0.035mm. The calculation for the patch dimension was calculated according to the formula below:

Width of the patch, *ws* was calculated by:

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

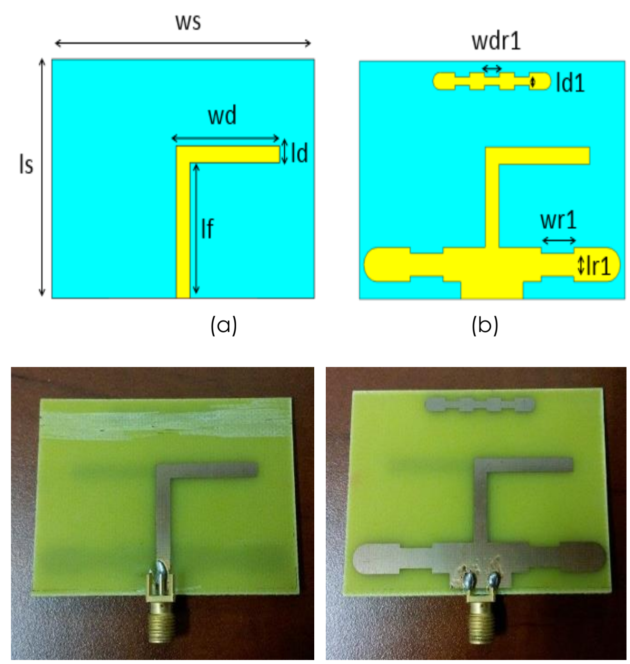
Where the speed of light, *c* is 3×10^8 meter per second. The resonant frequency is known as f_o and the dielectric constant is ε_r.

The length of the patch, *ls* is calculated by:

$$ls = \frac{c}{2fo\sqrt{\varepsilon_{eff}}} - 2\Delta \tag{2}$$

Where the effective dielectric constant is known as ε_{eff} and the length extension is Δ.

Based on the mathematical calculation, the width and length of the patch were calculated as *ws*=41.5mm and *ls*=58.5mm. Other parameters were defined by using parametric studies. The parametric studies were carried out by CST MWS to understand the main dimensions of the proposed antenna. The parametric studies also influenced the performance of the antenna. Then the optimization was done to obtain the best performance of the antenna at 2.4GHz. Other details of dimension are shown in Table 1.



(c) (d)

Figure 2 Design B, (a) Front view, (b) Back view, (c) Front view of Prototype, and (d) Back view of Prototype

Table 1 Dimension of the Design A and Design B

Parameter	Dimension (mm)	
	Design A	**Design B**
h	1.6	1.6
t	0.035	0.035
ls	58.5	58.5
ld	3	3
lf	29	29
lr	6	6
lf1	14.5	14.5
lf2	3	3
lr1	-	4
ld1	-	1.5
ws	41.5	41.5
wd	23.5	23.5
wdr	34	23.5
wf	13.7	13.7
wr	51	56.5
wr1	-	7.2
wdr1	-	3.28

Table 1 shows the design parameter dimension of Design A and Design B. The length and distance between each arms, and the connector were around quarter-wavelength *(λ/4)*. *λ/4* is the wavelength in free space corresponding to a resonant frequency of 2.4GHz. The gain of this structure was enhanced by adding a metallic reflector. The reflector has to be longer than the length of the two arms of the dipole in order to reflect the radiated power in the front direction ($\theta = 0°$). The director has to be shorter than the length of the two arms of the dipole in order to reflect the radiated power in the reverse direction ($\theta = 180°$).

3.0 RESULTS AND DISCUSSION

3.1 Return Loss

Figure 2 shows the result of the reflection coefficient for Design A and Design B. Both designs was simulated and measured in the range of frequency between 1GHz and 4GHz.

The minimum reflection coefficient of -22.3159dB was found at frequency 2.3GHz for simulation result of Design A. For Design B of simulation result, the minimum reflection coefficient of -28.358dB was found at frequency 2.4GHz. Meanwhile, the minimum reflection coefficient of -30.252dB was found at frequency 2.47GHz for Design B measurement result. Thus, the best value of reflection coefficient is Design B for measurement result is -30.252dB with a frequency of 2.47GHz.

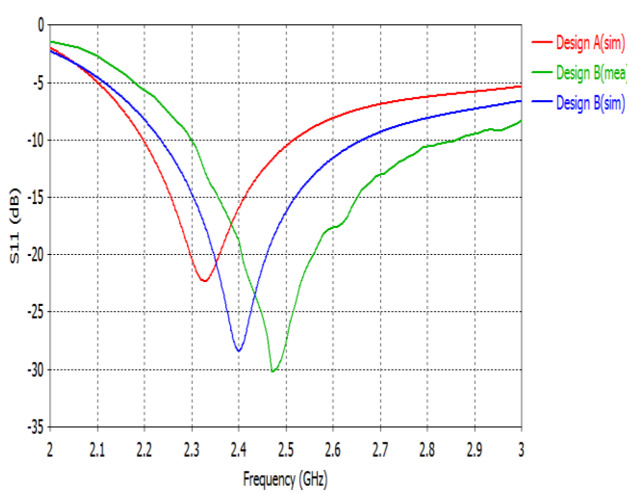


Figure 3 The reflection coefficient for Design A (simulation) and Design B (simulation and measurement).

3.2 Gain and Directivity

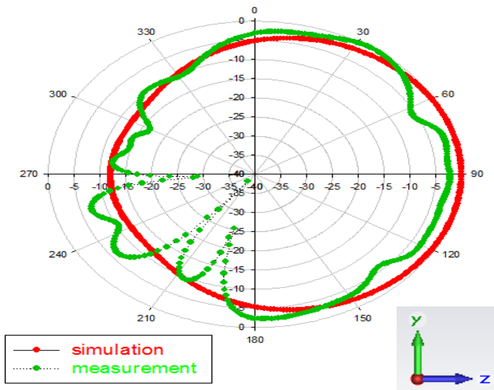
Table 2 shows the antenna performance for Design A and Design B. The simulation results showed the differences of Design A and Design B such as frequency, gain, directivity, polarization, efficiency, and bandwidth. Design B achieved higher gain which was 5.040dB compared to the Design A. The directivity of Design B was 6.123dBi meanwhile the directivity of Design A was 6.085dBi. The efficiency of Design B is higher than Design A which was 82%. The bandwidth for Design B was much broader than Design A. The bandwidth for Design B was 428MHz from frequency 2.2456GHz to 2.6743GHz. Design B in measurement result shows that the frequency achieved at 2.47GHz. The gain is -6.033dB much lower compared to Design A in simulation result and Design B in simulation result. Other details of antenna performance are shown in Table 2.

Table 2 Antenna Performance

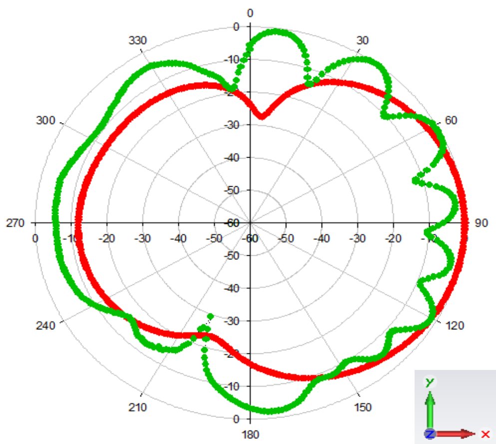
	Design A (simulation)	Design B (simulation)	Design B (measurement)
Frequency	2.32GHz	2.4GHz	2.47GHz
Gain	4.875dB	5.040dB	-6.033dB
Directivity	6.085dBi	6.123dBi	-
Polarization	Horizontal	Horizontal	-
Efficiency	80%	82%	-
Bandwidth	325MHz	428MHz	512 MHz

3.3 Radiation Pattern

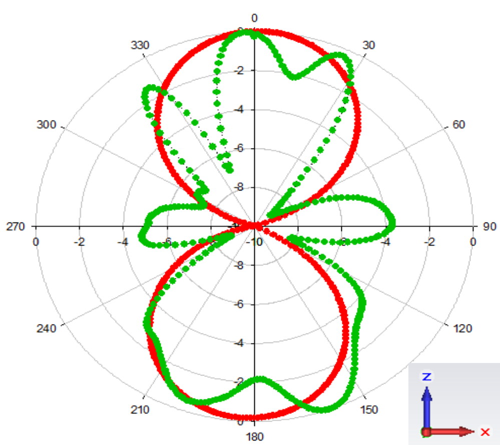
Figure 4 shows the radiation pattern between the simulation and measurement for Design B. Figure 3(a) shows the radiation pattern for *y-z* plane at 2.47GHz. The omnidirectional pattern can be seen for y-z plane. The narrow beam width indicates that the radiation energy is focused on the direction of the main lobe. Meanwhile, Figure 3(b) shows the radiation pattern for *x-y* plane at 2.47GHz. The results showed the back lobe of this pattern was bigger compared to the main lobe. Figure 3(c) shows the radiation pattern for *z-x* plane at 2.47GHz. The measurement and simulation results showed good agreement with each other. However, the measured radiation pattern has main lobe, two side lobes, and one back lobe with the direction at *180°*.The main lobe direction for simulation results was at *0°* for x-z plane.



(a)



(b)



(c)

Figure 4 Radiation Pattern at 2.47GHz for (a) *y-z* plane, *Ø = 90°*, (b) x-y plane, *θ=90°*, and (c) z-x *plane*, *Ø = 0°*

4.0 CONCLUSION

This paper presented the printed dipole modified with director and reflector. This antenna can be used to design a printed dipole at 2.4GHz for WLAN application. The reflector was added to concentrate the radiation in the main direction. Simulation results showed that the antenna has a maximum gain of 4.927dB compared to the basic printed dipole with a director and a reflector. After that, the director was added to enhance the radiation concentration. The antenna presented a maximum gain of 5.989dBi. Previously, the basic antenna achieved a maximum gain of 6.085dBi. The efficiency of Design B was higher than Design A which was 82%. Experimental works including fabrication and measurement of the printed dipole are still conducted in our research laboratory to verify the theoretical design and evaluation.

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