Dual Band Microstrip Antenna for Wireless LAN Application

A. Asrokin, M. K. A. Rahim, and M. Z. A. Abd. Aziz

Wireless Communication Centre (WCC)
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
Email: awi1982@yahoo.com, mkamal@fke.utm.my, matjoin@yahoo.com

Abstract--This paper discusses the design of the multiband microstrip antenna operating at frequency 2.4 GHz and 5.2 GHz. The aim of the project is to design a dual band microstrip antenna which will be operating in the wireless LAN band, IEEE 802.11 a/b/g. The dimensions of the single elements of the operating frequencies were calculated using transmission line model. Two elements of inset fed microstrip antenna were used for each frequency band. In this paper, there are four elements to cover the frequency band for WLAN application. The simulation process was done using the Agilent ADS software. The scaling factor of 1.03 has been chosen for the design starting from the lowest resonating frequency at 2.4 GHz band, while at 5.2 GHz band, the scaling factor is 1.05. The difference on the scaling factors was contributed by the losses that occurred when combining both of the antenna elements from both bands of frequency. The antenna has been fabricated on the FR4 microstrip board with $\varepsilon_r = 4.5$ and tan $\delta = 0.019$ using the wet etching technique.

Index Terms— Inset fed, microstrip antenna, multiband, WLAN.

1. Introduction

Wireless local area network (WLAN) applications nowadays has become more popular especially the 2.4 GHz ISM band. Newer laptops incorporated WiFi and Bluetooth technologies to connect to portable devices such as handsets and PDAs or to fixed devices such as printers. IEEE 802.11a, operating at 5 GHz band offers higher data rate than the IEEE 802.11b/g which operates at 2.4 GHz band. Nowadays, there are a lot of efforts on combining the WLAN, a/b/g bands together. Such new designs [2], [3], [4], [5], [6] are either provide inadequate coverage of the frequency band or not suitable for integration in some portable devices [1].

Research on dual band and multiband antennas have gone tremendous development throughout the century, and the most common design of the multiband antenna is the fractal antennas such as Sierpinski [7], [8], [9], carpet [10], hexagon [11], [12], and many more [13], [14].

This paper presents a technique to achieve multiband antenna using 2 element of square patch microstrip antenna using inset feed for each frequency band at 2.4 GHz band and 5.4 GHz band.

This project tries to achieve the selected range of frequencies but after fabricating the antenna, the antenna experience frequencies shift which make the frequency bands out of the IEEE 802.11b/g range.

2. Design Procedure

The prototype antenna was fabricated on FR4 board, with the relative dielectric constant, $\varepsilon_r = 4.5$, the thickness for the substrate is 1.6 mm, and the dielectric loss tangent is 0.019. The antenna was fabricated using wet etching technique.

Two elements of inset feed microstrip antenna, have been designed for each band of frequency using the log periodic technique, as proposed by A. Rahim [15], [16]. For the 2.4 GHz elements, the first or lowest resonating frequency is selected at 2.4 GHz. The next element is scaled at 1.03 which operates at 2.49 GHz.

For the 5 GHz band, the scaling factor of 1.05 has been used to design the elements. The first resonating frequency chosen is at 5.19 GHz and the next is at 5.45 GHz.

As mentioned earlier, there are four elements of inset fed antenna required. So, two elements of the antennas will be operating at 2.4 GHz band and the other two elements will be operating at 5 GHz band.

The parameters of the single elements can be calculated using equations below.

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{2}$$

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$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-\frac{1}{2}} \quad (3)$$

$$\Delta L = \frac{0.412h(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

The resonant input impedance had been calculated using the equations below.

$$R_{in}(y = y_0) = \frac{1}{2(G_1 \pm G_{12})}\cos^2\left(\frac{\pi y_0}{L}\right) \quad (5)$$

which G_1 = conductance of the microstrip radiator.

$$G_1 = \frac{I_1}{120\pi^2} \quad (6)$$

$$I_1 = \int_0^{\pi}\left[\frac{\sin\left(\frac{k_0 w}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta \quad (7)$$

The mutual conductance, G_{12} is shown in equation below.

$$G_{12} = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{k_0 w}{2}\cos\theta\right)}{\cos\theta}\right]^2 J_0(k_0 L\sin\theta)\sin^3\theta d\theta \quad (10)$$

The characteristic impedance of the line can be calculated using the line calculator provided in the Agilent ADS software. The equation for the characteristic impedance is shown below.

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\varepsilon_{reff}}}\ln\left[\frac{8h}{w_0} + \frac{w_0}{4h}\right] & \frac{w_0}{h} \le 1 \\ \frac{120\pi}{\sqrt{\varepsilon_{reff}}}\left[\frac{w_0}{h} + 1.393 + 0.667\ln\left(\frac{w_0}{h} + 1.444\right)\right] & \frac{w_0}{h} > 1 \end{cases} \quad (11)$$

The distance between element N and element N+1 is determined according to the next higher frequency element of the antenna. So, as proposed by A. Rahim, to obtain all frequencies pass through element N, the input looking into the next higher frequency must be high impedance before the next element is connected to the schematic diagram. This following step is continuously repeated after all elements are connected. The single element microstrip antenna's feed are a quarter wavelengths long for its resonating frequency.

The width and length of the patch are equal, and the width of the feed line is fixed to 3 mm [15], [16].

The schematic diagram was simulated through Method of Moments (MoM) simulation using Agilent Advance Design System software.

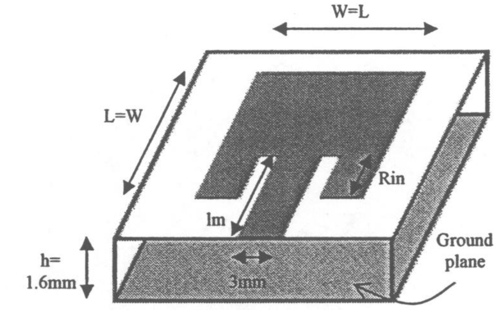

Figure 1: Three dimensional view of the single element.

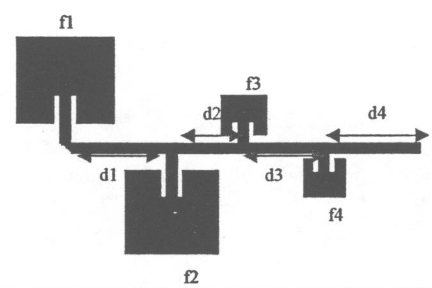

Figure 2: Layout for the multiband LPA.

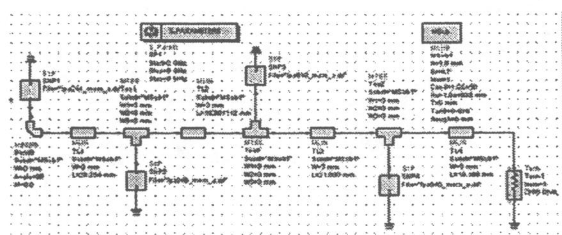

Figure 3: Schematic diagram for the dual band antenna.

Table 1: Design parameters of the Multiband LPA

	Freq (GHz)	W=L (mm)	Rin (mm)	lm (mm)	dm (mm)
F1	2.41	28.981	9.447	15.746	28.36
f2	2.49	27.948	9.091	15.185	18.75
f3	5.19	13.444	4.610	7.304	21.59
f4	5.45	12.803	4.403	6.956	27.63

3. Experimental Results

Figure 4 shows the return loss measurement and simulation of the multiband LPA. The bandwidth at the 2 GHz band is 9.17% while at 5 GHz, the bandwidth is 7.47%.

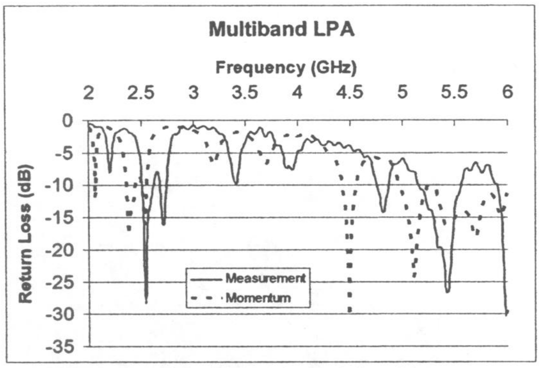

Figure 4: Return loss of the multiband LPA.

Figure 5 and figure 6 show the radiation patterns of the antenna. At 2.5 GHz, the cross isolation for E and H planes are 16.69 dB and 16.11 dB, while at 5.4 GHz, the cross isolation for E and H planes are 6.5 dB and 8.14 dB.

The half power bandwidth (HPBW) at 2.5 GHz for E and H planes are 86 degree and 74 degree. At 5.4 GHz, the HPBW for E and H planes are 60 degree and 52 degree.

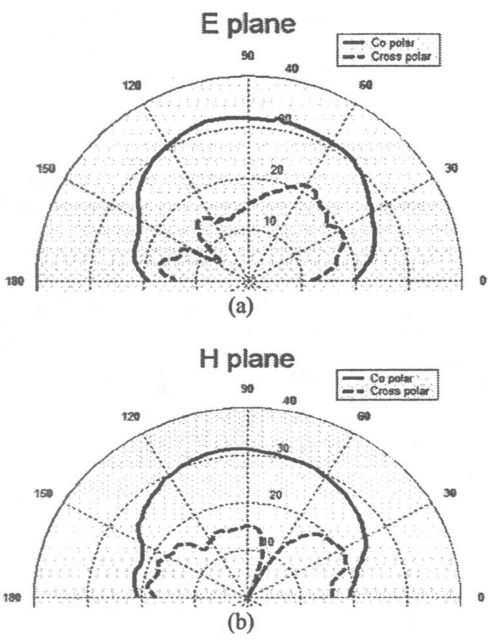

Figure 5: Radiation pattern at 2.5 GHz, (a), (b)

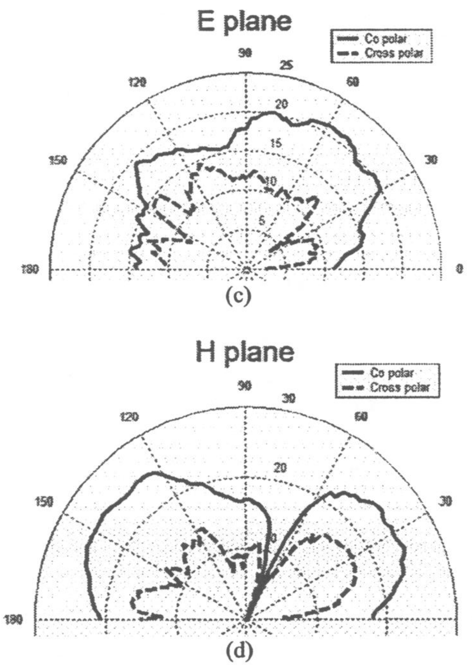

Figure 6: Radiation pattern at 5.4 GHz (c), (d).

4. Conclusion

A bandwidth of 9.17% for 2.5 GHz band and 7.47% for 5.4 GHz band has been achieved using two elements for each band. The bandwidth for the single element is up to 6%.

From the results, it can be concluded that the multiband LPA almost cover the wireless LAN band, IEEE 802.11 a/b/g. The problem of frequency shifting has occurred which made the desired operating frequency at 2.4 GHz shift to 2.5 GHz.

It seems that the idea of using LPA as elements to create a multiband antenna is a good idea, so that a selected frequency can be operated using a single antenna. It is different from fractal antennas, which the operating frequency, scales up and sometimes operates at undesired operating frequency.

For future work, the consideration of the frequency shift should be taken into account in designing the antenna and a better antenna modelling should be made so that the measured results should be closely match with the simulation results. Other kind of feeding technique can also be incorporated to the design so that bigger bandwidth can be achieved together with reducing the number of elements needed to cover the wireless LAN frequency bands.

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