

# Dual-Band e-Shaped Antenna for RFID Reader

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**Abstract** – This paper proposes two dual-band antenna designs with e-shaped slot which operate at two different Radio Frequency Identification (RFID) frequencies. The e-shaped antennas are designed at 2.45 GHz & 5.8 GHz, and at 0.92 GHz & 2.45 GHz. In addition, the optimized antennas are fabricated using two different Taconic substrates with permittivity of 3.54 and 3.2 respectively. Based on the simulation and measurement conducted, the dual-band e-shaped antenna provided higher gain compared to the previous dual-band e-shaped antenna designed using the FR4 board. For the dual-band antenna operates at 2.45 GHz & 5.8 GHz the obtained gains are 9.74 dB and 10.5 dB respectively. While, for the dual-band antenna operates at 0.92 GHz & 2.45 GHz, the gains of 6.16 dB and 8.93 dB are recorded at their resonances. The functionality of these antennas is proven as an RFID reader both at Ultrahigh frequency (UHF) and at microwave frequency (2.45 GHz).

**Keywords:** e-shaped slot antenna, dual-band, RFID.

## I. INTRODUCTION

The use of Radio Frequency Identification (RFID) has been popular since its first implementation during the World War II. RFID system provides a wireless identification and tracks capability which has driven to various usability with technological improvement added. RFID consists of two parts; reader and antenna. Both of them have antenna build-in as a medium of communication between each other. This makes antenna as an essential part in RFID system. At present, the implementation of RFID can be found in many types of industries depending on the operating frequency of the system. The frequency of RFID system lies between Low Frequency (LF) and Microwave Frequency (MCF). Table 1 shows the list of frequency range in RFID system. The implementation of the frequency is different for some countries. For example, in Europe the Ultra High Frequency (UHF) band allocates around 800MHz while in USA, Japan and Australia cover around 900MHz frequency.

Table 1: Frequency range for RFID system [1]

	Frequency Band	Frequency Range
LF	Low Frequency	125-134.2 kHz
HF	High Frequency	13.56 MHz
UHF	Ultra High Frequency	840-960 Hz
MCW	Microwave Frequency	2.4GHz/5.8GHz/24GHz

As the tag passes through the reader's antenna, it transmits the data kept in the tag's chip to the reader by the electric/magnetic coupling [1]. The reader antenna should be compact and has sufficient readability within the restricted power. The demand on UHF and Microwave system is extremely high because it covers longer range and higher data rate. It is difficult to design an antenna at low frequency because the size of antenna will become larger. There are some designs that introduce the slot and gaps around the patch to reduce the antenna size at low frequency [2].

Usually, the RFID system only caters for one specific frequency because the manufactured RFID reader works at one frequency. However, some studies have been conducted in designing a multi-band RFID antenna. In [3], dual-band antenna is designed for UHF band but at different frequency (800 MHz and 900 MHz) to cater for RFID system for Europe and USA. The proposed circular patch antenna is loaded with U-shaped slot to exhibit the broadband resonance. The dual-band RFID reader antenna can also be designed at different frequency band [4-5]. The dual-band RFID reader antenna mostly comes with a complicated structure and bigger size. In [4] the antenna is designed at 2.45 GHz and 5.8 GHz frequency band with relatively high gain; 9.56 dBi and 10.17 dBi respectively. However, the overall antenna size which composed by ground plane, U-shape copper strip and rectangular ring printed on RT5880 superstrate is quite large (150 mm x 150 mm x 7.5748 mm). In [5], dual-band antenna has been designed with the curved and rectangular slots to operate at 911 MHz - 925.6 MHz and 2.32 GHz - 2.52 GHz band. The compact dual-band RFID reader antenna with same frequency band has been designed in [6]. The antenna is designed using FR4 board with 18 MHz and 80 MHz bandwidth.

## II. DUAL-BAND E-SHAPED ANTENNA DESIGNED AT 2.45 GHz AND 5.8 GHz

Taking the design in [7], the dual-band RFID reader antenna is designed at 2.45 GHz and 5.8 GHz, and is optimized using the Taconic RF-35 substrate having thickness of 1.524 mm and permittivity of 3.54. Figure 1 shows the front view and the 3D view of dual-band e-shaped antenna. The overall size of the optimized antenna is 70 mm x 50 mm with e-shape slot  $W_1 = 13$  mm,  $W_2 = 12$  mm,  $L_1 = 11.5$  mm and  $L_2 = 6$  mm. The antenna is compact and simple because it applies single feed, single patch and single layer.

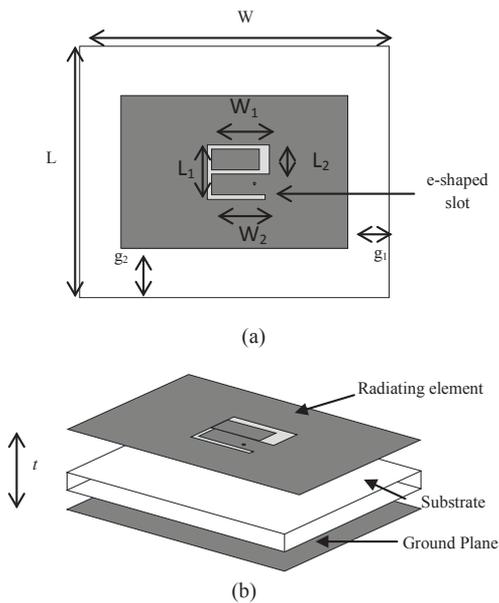


Figure 1: (a) front view and (b) 3D view of dual-band e-shaped antenna

Figure 2 shows the simulation results of antenna with and without the e-shaped slots. Without the slots, the higher return loss is seen at 3.86 GHz and 5.42 GHz. By applying the optimized e-shaped slot, the value of return loss at desired frequency has been decreased to -18.92 dB at 2.45 GHz and -22.39 dB at 5.8 GHz. By adding a slot in the radiating patch, the resonance frequency can be adjusted and at the same time a compact antenna can be obtained.

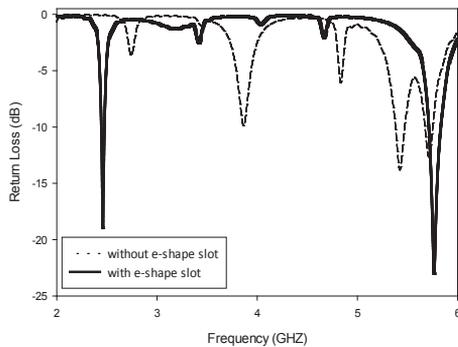


Figure 2: The simulated return loss of antenna with and without e-shaped slot (substrate used: RF-35)

By introducing the gap around the radiating patch, it will affect the value of return loss and frequency. From Figure 3(a), by increasing the gap  $g_1$  helps to reduce the number of

unwanted return loss at other frequency. While increasing the value of gap  $g_2$  can improve the value of return loss. From the parameter study conducted, the best return loss value can be achieved at radiating patch of 15.0 mm x 11.37 mm with substrate size of 70 mm x 50 mm.

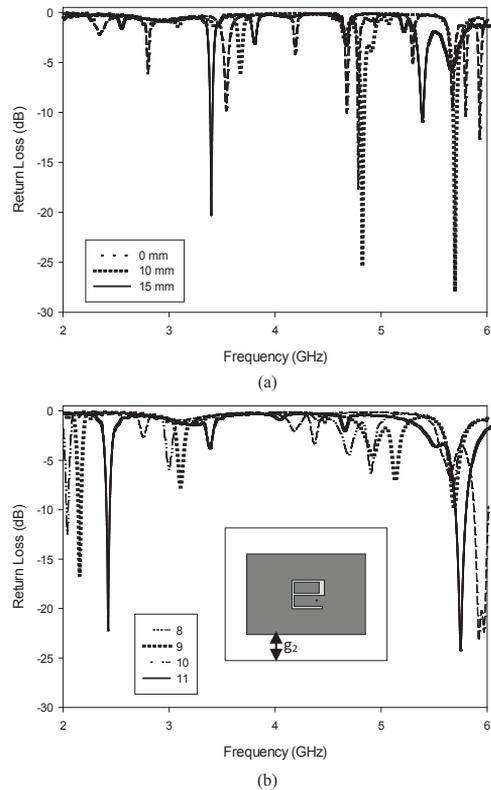


Figure 3: The effects of varying the (a)  $g_1$  and (b)  $g_2$  for dual-band e-shaped antenna (substrate used: RF-35)

The designed dual-band e-shaped antenna is measured using a vector network analyzer. Figure 4 shows the simulation and measurement return loss of the antenna. The desired operating frequencies are slightly shifted to 2.46 GHz and 5.83 GHz. At low frequency, the simulated return loss is 18.92 dB while the measured return loss is 15.62 dB. At high frequency, the simulated and measured return loss is nearly the same. Based on Table 2, it can be summarized that the measured results are agreed with the simulated results.

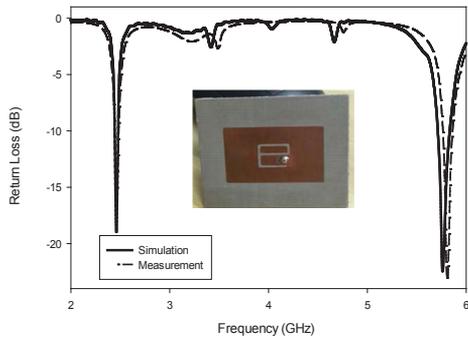


Figure 4: The simulated and measured return loss of dual-band e-shaped antenna (substrate used: RF-35)

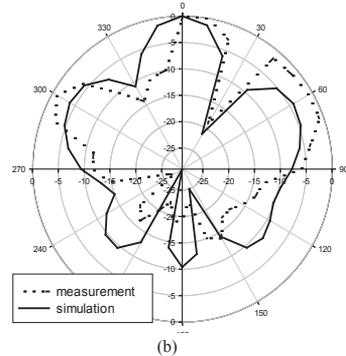


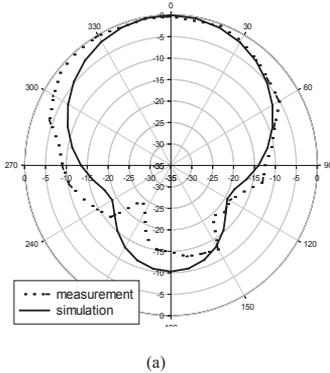
Figure 5: Radiation Pattern for dual-band e-shaped antenna at (a) 2.45 GHz and (b) 5.8 GHz

However, the obtained gains are much higher compared to the gain obtained in [7]. This is because the simulated total efficiency of the antenna is high due to the low tangent loss of the RF-35 substrate compared to the tangent loss of the FR4 board.

Table 2: Simulation and measurement results of dual-band e-shaped antenna (substrate used: RF-35)

	Simulation		Measurement	
	Frequency (GHz)	Return Loss (dB)	Frequency (GHz)	Return Loss (dB)
Frequency (GHz)	2.45	5.8	2.46	5.83
Return Loss (dB)	-18.92	-22.39	-15.62	-22.96
Bandwidth (%)	1.80	2.00	1.78	1.70
Gain (dB)	9.74	10.5	7.91	12.63

Figure 5 shows the radiation pattern for the e-shaped antenna at lower and upper bands. From Figure 5 (a), the radiation for lower band frequency is said to be directional but at upper frequency (Figure 5 (b)) the radiation is directed at certain angle.



### III. DUAL-BAND E-SHAPED ANTENNA DESIGNED AT 0.92GHz AND 2.45 GHz

Figure 6 shows the simulation of S11 for 0.92 GHz and 2.45 GHz antenna with and without the existence of e-shaped slots. Without the slot, the first and second operating frequencies are seen at 1.7 GHz and 2.5 GHz. By adding the optimized e-shaped slot in the radiating element, the first resonant frequency is reduced to 0.92 GHz and the next operating frequency is obtained at 2.45 GHz. Hence, by adding slot, the current path is lengthened and it can miniature the size of the antenna. With adding slot also can creates other resonances.

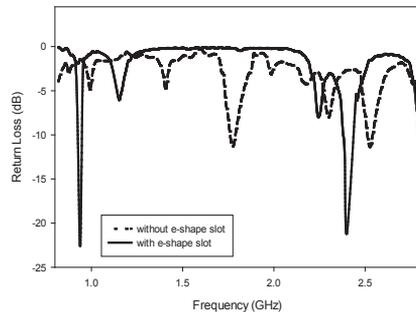


Figure 6: The simulated return loss of antenna with and without e-shaped slots antenna (substrate used: TLC-32)

The simulated return loss for various substrates' size is shown in Figure 7. Figure 7 shows the effects of varying the gap  $g_1$  and  $g_2$  of the antenna. The frequency shifting can be seen as the gap is increased. When varying the  $g_2$ , it gives effect to the upper frequency. By increasing the  $g_2$ , the frequency becomes shifted to the right. The overall size of the antenna operates at 0.92 and 2.45 GHz are 150 mm x 120 mm with the thickness of 6.35 mm. The size of rectangular patch is 110 mm x 73 mm

with the e-shaped slot dimension  $W_1 = 30$  mm,  $W_2 = 28$  mm,  $L_1 = 26$  mm and  $L_2 = 14$  mm.

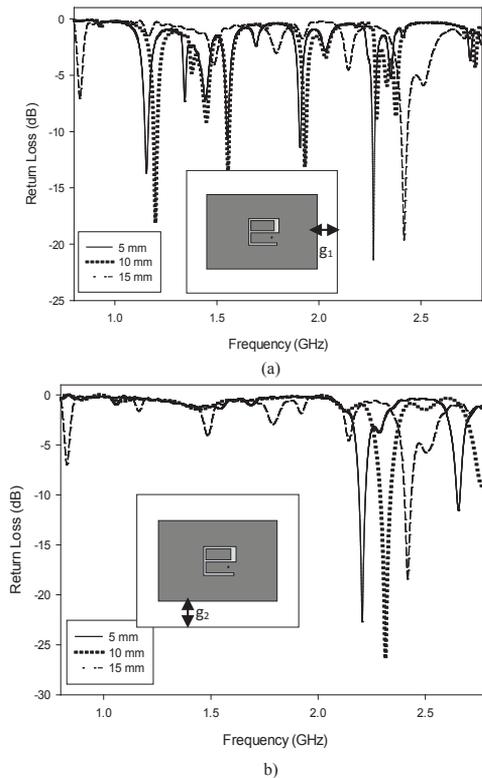


Figure 7: Simulation for varying the (a)  $g_1$  and (b)  $g_2$  for dual-band e-shaped antenna (substrate used: TLC-32)

Figure 8 shows the simulated and measured return loss of dual-band e-shaped antenna designed using the TLC-32 substrate. The matching properties are good at both 0.92 GHz and 2.45 GHz. However, the measured operating frequencies are shifted to the higher value due to the fabrication and measurement errors.

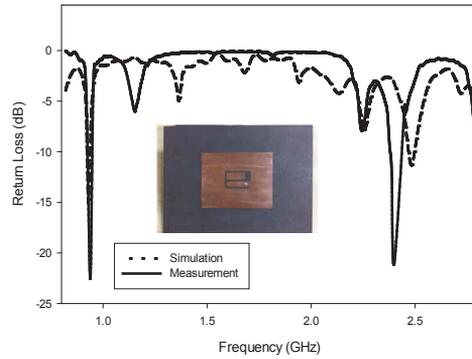


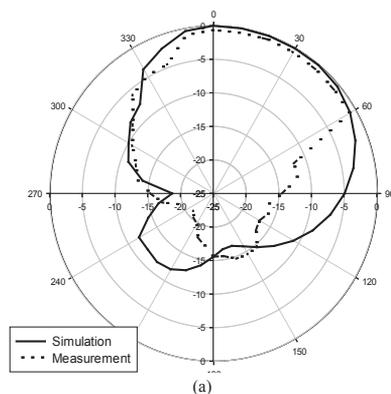
Figure 8: Simulation and measurement return loss of e-shaped antenna (substrate used: TLC-32)

The simulation and measurement of the antenna are compared as shown in Table 3. The gain of measurement is slightly smaller than the simulated value. However, the antenna is still operates at the desired band.

Table 3: Measurement and Simulation Results of e-shaped antenna (substrate used: TLC-32)

	Simulation		Measurement	
	Frequency (GHz)	Return Loss (dB)	Frequency (GHz)	Return Loss (dB)
Frequency (GHz)	0.92	2.45	0.93	2.48
Return Loss (dB)	-22.98	-20.94	-14.98	-11.48
Bandwidth (%)	1.48	2.47	1.48	2.51
Gain (dB)	6.16	8.93	6.66	7.92

From Figure 9, the radiation pattern shows the directional directivity at both frequency but at 0.92 GHz it directed at  $20^\circ$  for maximum lobe.



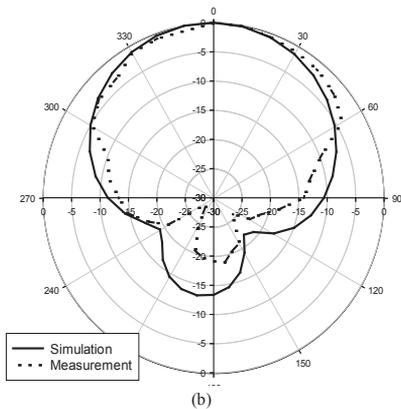


Figure 9: Radiation Pattern for dual-band e-shaped antenna at (a) 0.92 GHz and (b) 2.45 GHz.

#### IV. CONCLUSION

In conclusion, by adding slot, it can create other resonances and at the same time can reduce the size of the antenna. This is because theoretically by adding slot it can lengthen the current path. In addition, the Taconic substrate gives relatively the same result for simulation and measurement compared to the FR4 substrate especially when it comes to the higher frequency. By choosing a suitable substrate, it will give high radiation efficiency and will manage to produce the higher gain. This is also because the simulated total efficiency of the antenna is high due to the low tangent loss of the RF-35 substrate compared to the tangent loss of the FR4 board. However, thicker substrate is preferred for 0.92 GHz and 2.45 GHz antenna due to low frequency and bandwidth and constraints. The structure of the dual-band e-shaped antenna proposed in this paper is compact and simple because it applies single feed, single patch and single layer. The

functionability of these antennas is proven as an RFID reader both at the Ultrahigh frequency (UHF) and at microwave frequency (2.45 GHz).

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