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Design and Realization of a Dual Wide Band Printed Monopole Antenna for WiFi and WiMAX Systems

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Abstract

A Printed monopole antenna was designed and manufactured with the wideband performances in two frequency bands. The antenna is compatible with WiMAX and WiFi standards. After reviewing a couple of literatures, the antenna was designed, analyzed and proven for two central frequencies, 2.5 GHz and 5.6 GHz, with much improved bandwidths. Finally, the antenna was manufactured with the overall size of 4 cm × 4.4 cm on Rogers (RO4003) substrate. The antenna is made into three L-shaped radiators. A 50 Ω microstrip feed line connects the port to the two L-shaped radiators of different lengths, thus providing two frequency bands. An inverted L-shaped radiator is printed on the less radiation upped side, to tune the antenna for wide band performances. The raised problem was solved with the integral equation solver of the Ansoft high frequency simulator structure (HFSS-IE). Optimal results are presented in this article: the simulation results in comparison with measured results. This antenna prototype's overall dimensions would be readjusted according to any industrial and manufacturing requests.

Keywords

HFSS-IE, Wideband Antenna, WiFi, WiMax

1. Introduction

Printed circuit board (PCB) antennas, notably most of patch antennas suffer from narrow bandwidth and low-power capacity [1].

Disadvantages encountered with Printed microstrip antennas [2]-[8] can be overcome with Printed monopole antenna, notably the narrow bandwidth which limits their uses in modern wideband wireless applications.

Considering the best of HFSS-IE simulator over normal HFSS [9], HFSS-IE simulator has been the selected design tool. The appreciable simulation results motivated us to manufacture this antenna which finally presents coherence while simulation results are compared with measurements.

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As applications, this antenna would be utilized for Wireless Local Area Networks (WLAN) systems based on IEEE802.11 as well as Wireless Metropolitan Local Area Network (WMAN) systems based on IEEE802.16a standards.

According to [11] [12], WiMAX systems based on IEEE 802.16a standards are compatible with bands ranging from 2 GHz to 11 GHz, expecting the bit rate from 70 to 100 Mb/s. The literature clarifies that wideband (WB) and ultra wideband (UWB) communication systems have received great attention in the wireless world due to their merits such as high data rate, low cost for short range access and remote sensing applications [13] [14].

In this paper, the reader is noticed that WiFi is interchangeable with WLAN while WiMAX is interchangeable with WMAN.

2. The Proposed Antenna Design and Results

Antenna is one of the most essential elements that characterize wireless systems.

A transmitted signal is considered UWB if the return loss' absolute bandwidth at −10 dB, exceeds 500 MHz [15]. Printed monopole antennas have been characterized with many possibilities for both wideband and UWB performance [13]-[16].

A couple of monopole antennas were surveyed such as inverted F [17] [18], inverted L [19] [20] and snake-like [21].

2.1. Design Methodology and the Proposed Antenna

HFSS-IE Simulator is available with HFSS version 14 and above. HFSS-IE is based on 3D full wave method of moments (MoM) electromagnetic Integral Equation to evaluate the surface currents of the object in question; then it calculates radiation and the scattering fields using the derived current [9] [10].

In our design, **Figure 1**, the shorter L-shaped radiating element is meant for the frequency band with resonance at 5.6 GHz while the longer L-shaped radiating element corresponds to the frequency band whose resonance is at 2.5 GHz. To tune the antenna for WB around 2.5 GHz and for UWB around 5.6 GHz, an inverted L radiator is printed on less radiation upped area of the antenna.

2.2. Simulated Results and Impedance (Z) Parameters

The return loss (RL) is such an important antenna characteristic that, throughout the design process, the RL is analysed to decide on the necessary bandwidth performance requirements. According to [22], the RL is defined as a measure of how much of the available power is not delivered to the load; a matched load has a zero reflection coefficient (Γ = 0) and thus has an infinity RL.

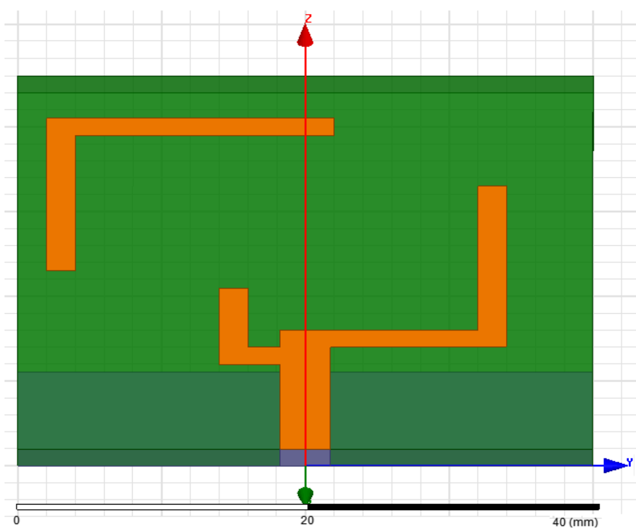


Figure 1. Three dimensional (3D) view of proposed antenna.

$$RL = -20\log|\Gamma|\,dB \qquad (1)$$

After all the parametric analysis and optimization, our design model's RL is presented in **Figure 2** and each band's impedance parameters are measured according to **Figure 3**.

The Smith Chart, **Figure 4**, shows the perfect matching of antennas' impedance with the 50 Ω feed-line, for both f_1 = 2.5GHz, and f_2 = 5.6 GHz.

Figure 5 and **Figure 6** show the radiation patterns while **Figure 7** and **Figure 8** show the radiation fields overlay and surface currents distribution for both frequency bands.

2.3. Total Efficiency and Voltage Standing Wave Ration (VSWR)

The antenna total efficiency is defined as "the ratio of radiated power to the incident power, which is approximated to e_T [23], such that

$$e_T = e_r e_c e_d \qquad (2)$$

where:

e_T is the total efficiency;

e_r is the mismatch efficiency, such that

$$e_r = 1 - |\Gamma|^2 \qquad (3)$$

e_c is the conduction efficiency;

e_d is the dielectric efficiency;

$e_{cd} = e_c e_d$ is the antenna radiation efficiency.

Γ is the voltage reflection at the input antenna terminals,

$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \qquad (4)$$

Z_{in} is the antenna input impedance;

Z_0 is the transmission feed line's characteristic impedance;

The voltage standing wave ratio (VSWR) is generally referred to as the measure of antenna impedance matching with the feed line's impedance. Mismatches result in standing waves (SW) along the feed line. VSWR

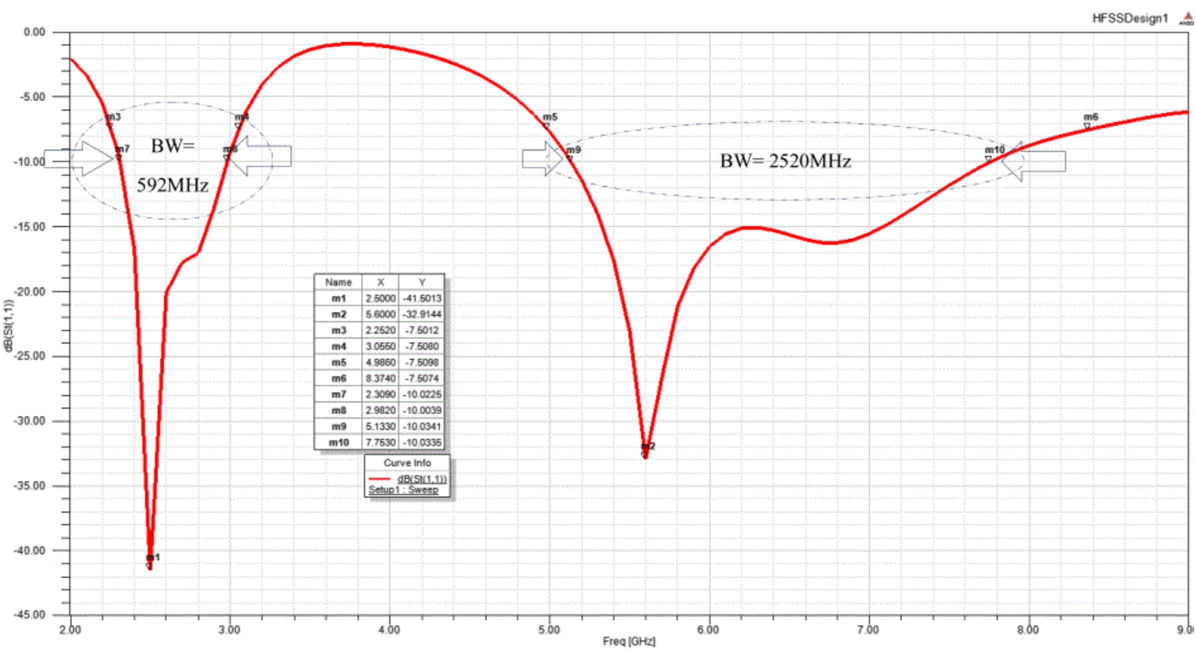
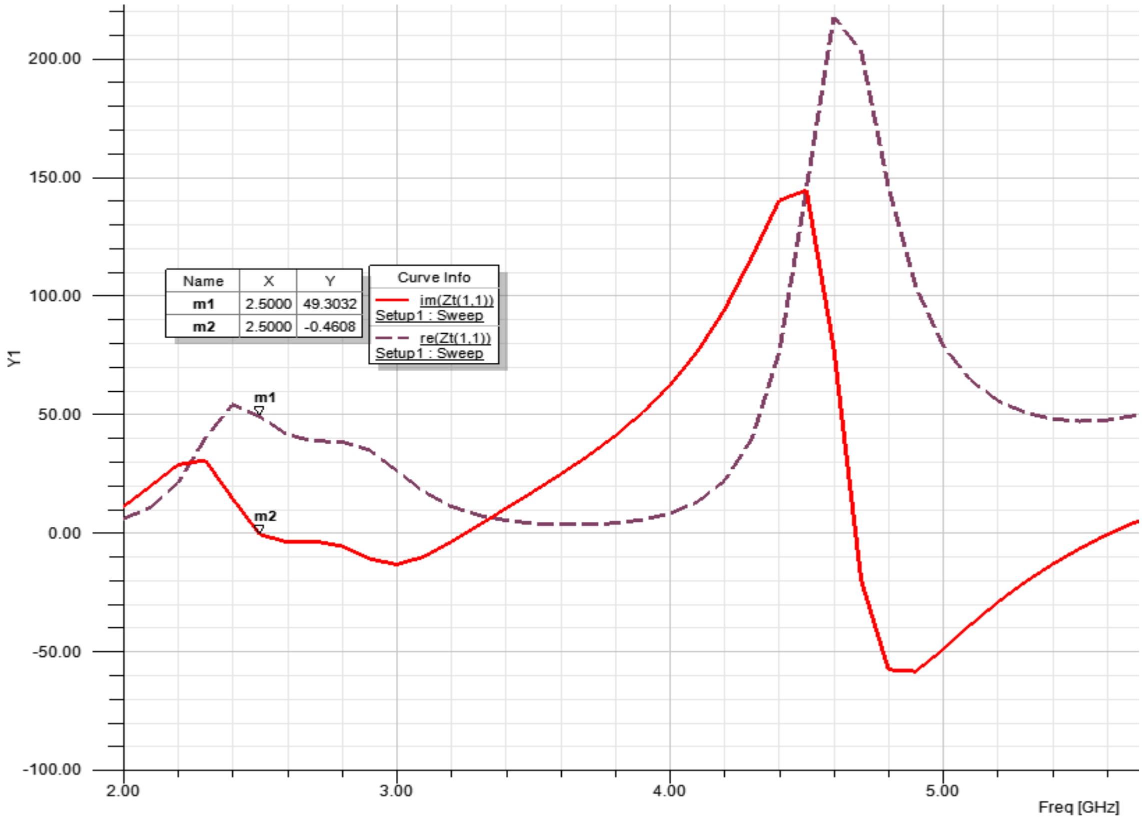
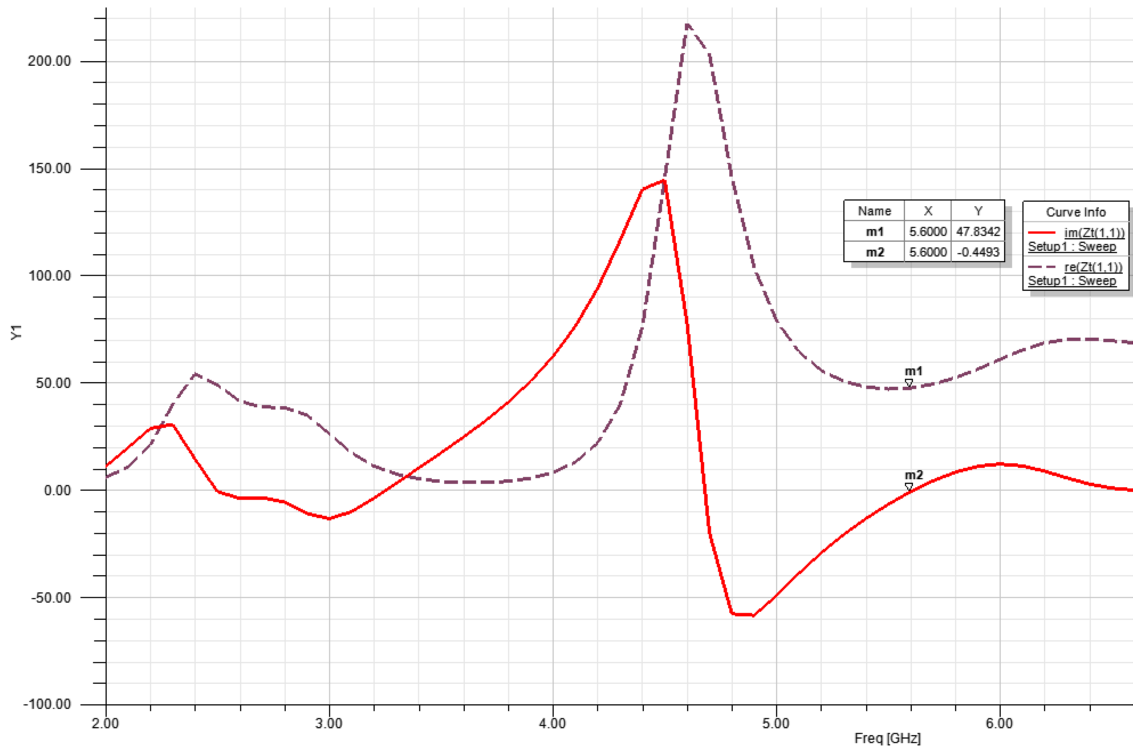


Figure 2. The simulated RL.



(a)



(b)

Figure 3. Impedance (Z) parameters: (a) for 2.5 GHz band; (b) for 5.6 GHz band.

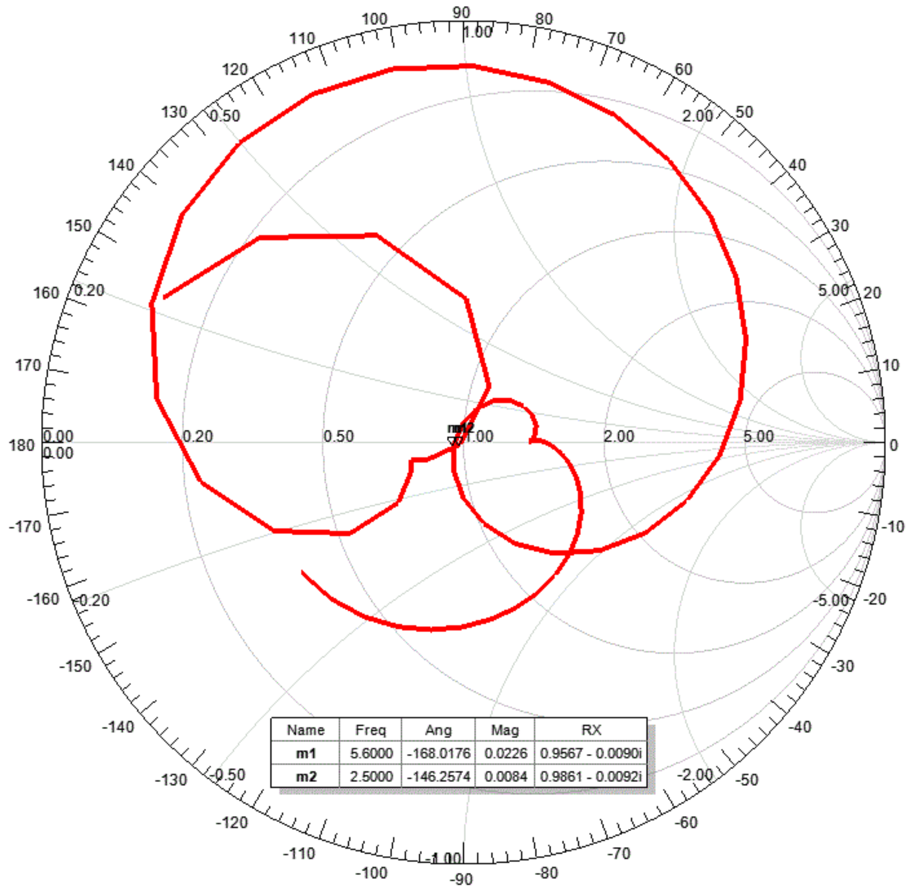


Figure 4. The Smith Chart's impedance measurement.

is mathematically defined.

$$\mathrm{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (5)$$

In case of our design, the antenna radiation efficiency (e_{cd}) is assumed unity since the antenna is simulated under perfect electric conduction (PEC) boundary and measurements after implementation were done under well isolated environment; which means the total antenna efficiency evaluated here is equal to the mismatch efficiency.

Thus, referring to the measured antenna impedances in **Figure 3**; keeping in mind that the standard impedance for the microstrip feed-line is 50 Ω, the total antenna efficiency is now calculated for both 2.5 GHz and 5.6 GHz respectively, according to Equations (3) and (4); the VSWR is computed according to (5).

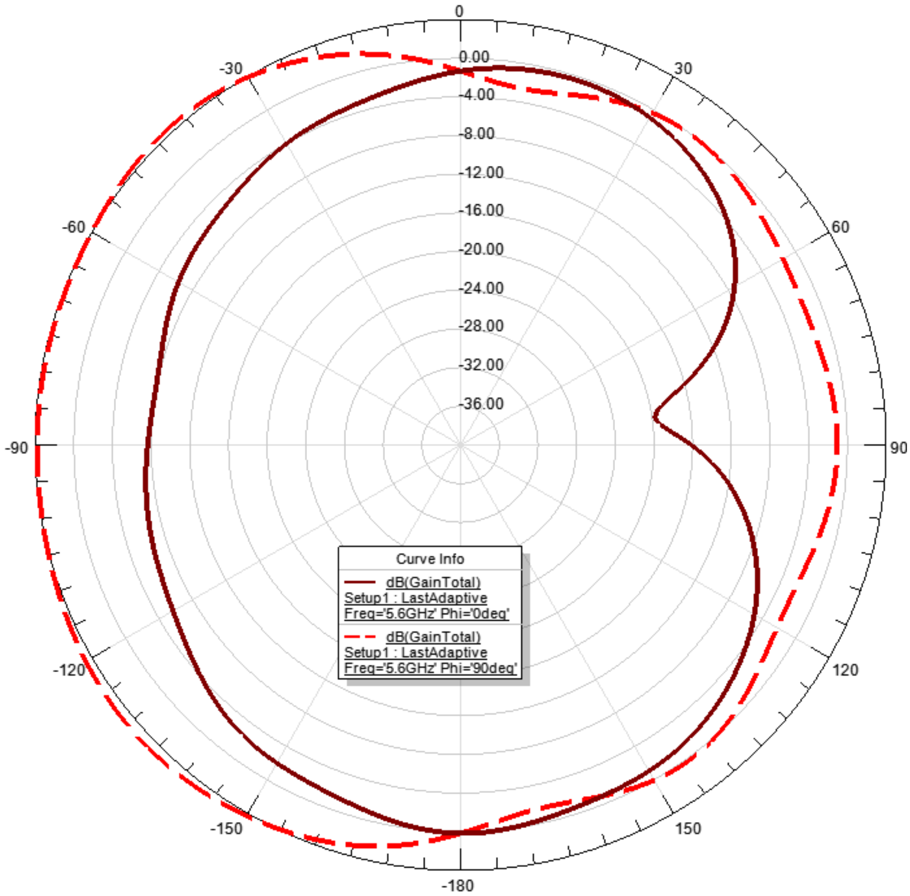
- ☐ When the antenna is operated at 2.5 GHz,

$$\Gamma = \frac{49.3 - j0.46 - 50}{49.3 - j0.46 + 50} = -(0.007 + j0.0046)$$

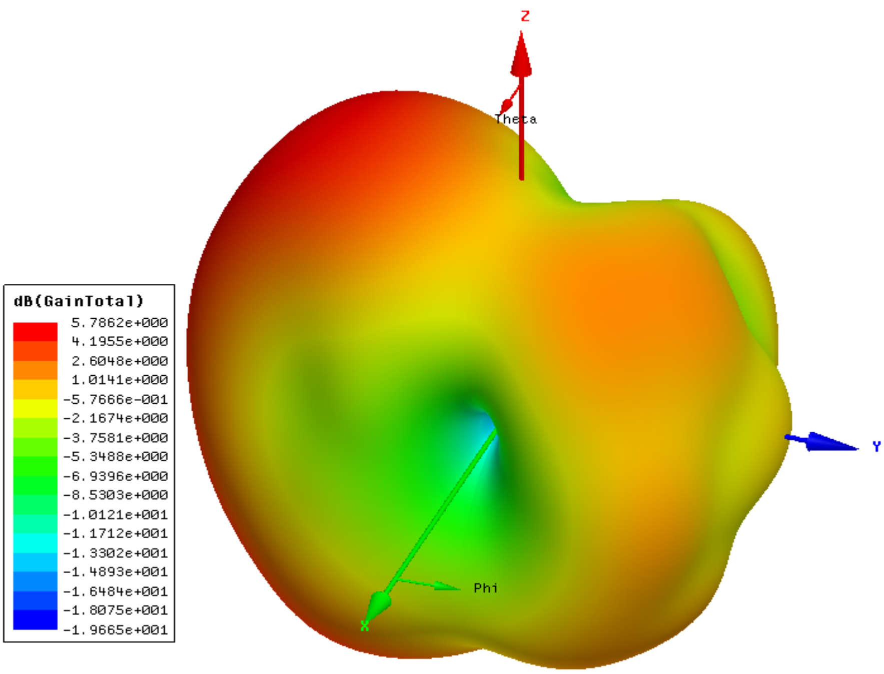
- ✧ $e_{T(2.5\mathrm{GHz})} = 1 - |\Gamma|^2 = 99.16\%$
- ✧ VSWR = 1.017.
- ☐ When the antenna is operated at 5.6 GHz,

$$\Gamma = \frac{47.83 - j0.45 - 50}{47.83 - j0.45 + 50} = -(0.0221 + j0.0045)$$

- ✧ $e_{T(5.6\mathrm{GHz})} = 1 - |\Gamma|^2 = 97.74\%$
- ✧ VSWR = 1.046.

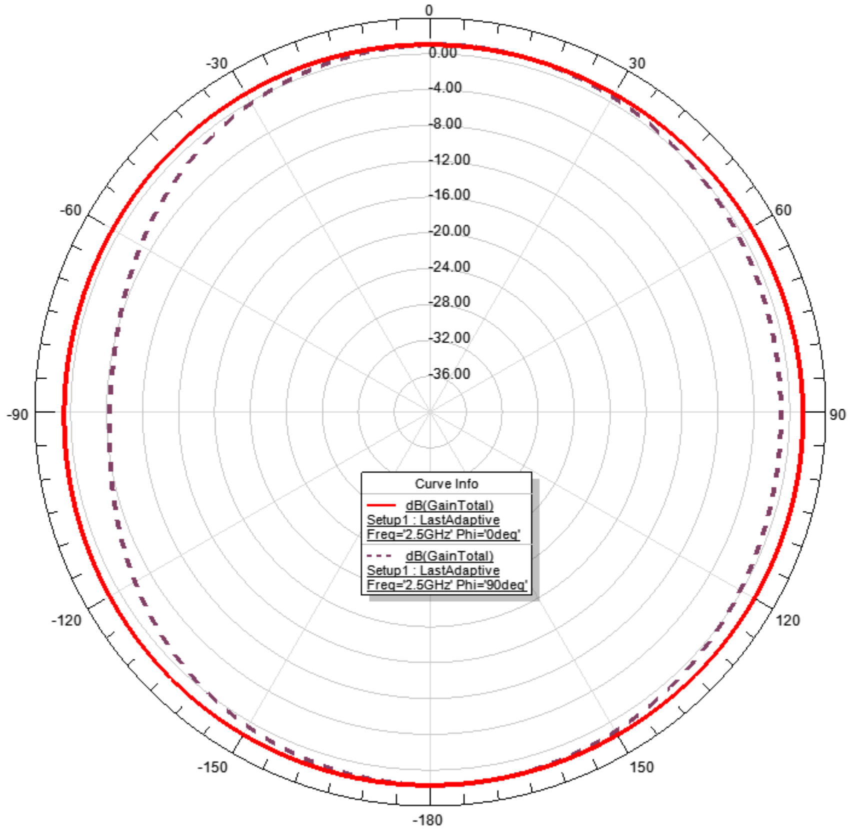


(a)

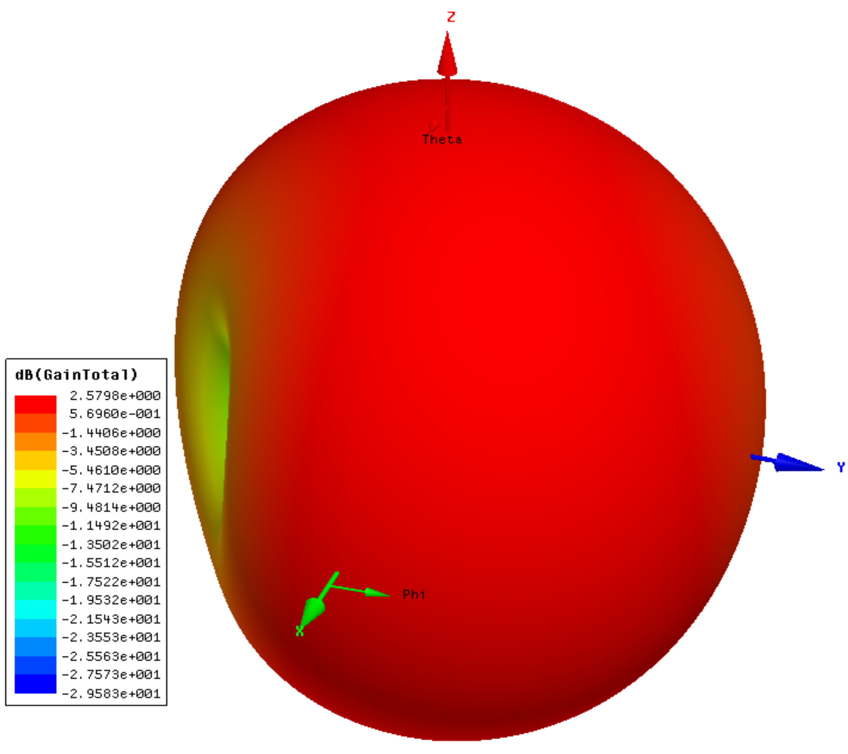


(b)

Figure 5. Radiation patterns at 5.6 GHz (a) E-H Radiation Pattern; (b) 3D Polar plot.

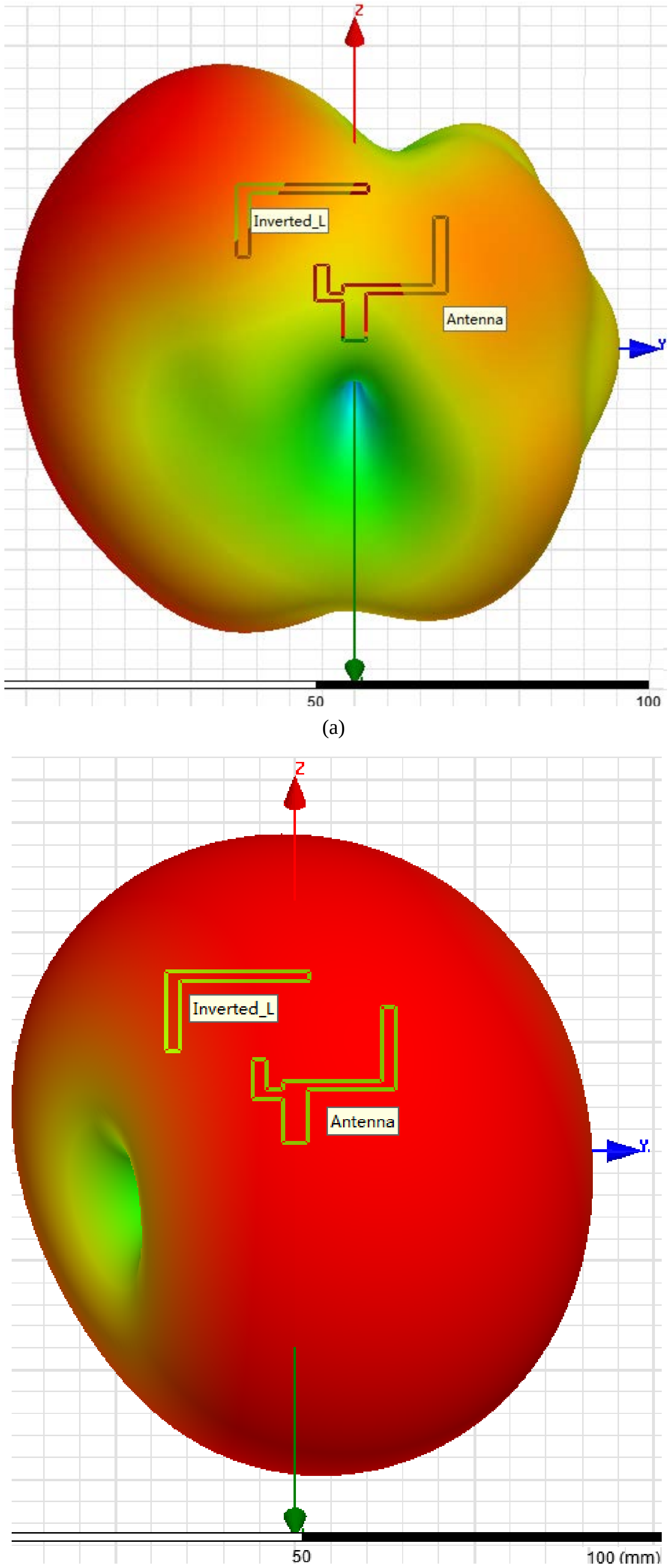


(a)



(b)

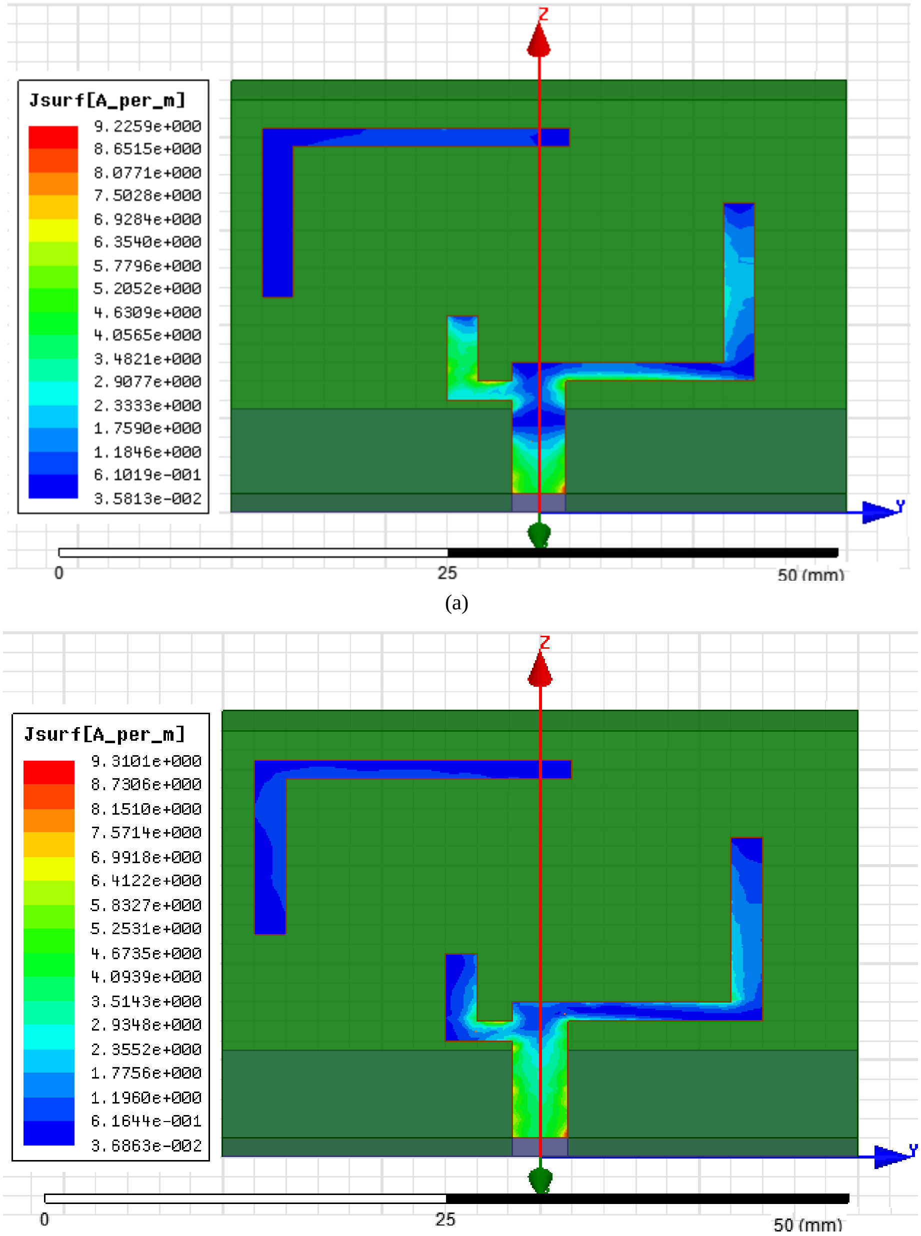
Figure 6. Radiation patterns at 2.5 GHz (a) E-H Radiation Pattern; (b) 3D Polar plot.



(a)

(b)

Figure 7. 40% Radiation fields overlays: (a) at 5.6 GHz; (b) at 2.5 GHz.



(a)

(b)

Figure 8. Surface current distribution: (a) at 5.6 GHz; (b) at 2.5 GHz.

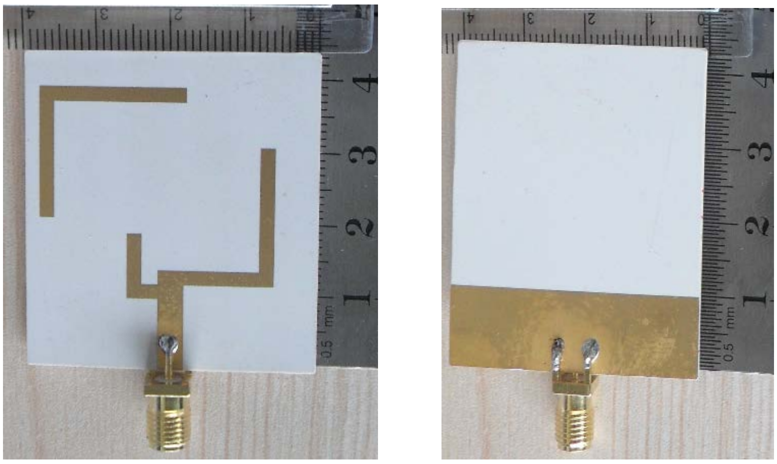
2.4. Manufacturing Results

With the satisfactory simulation results in hands, the antenna design model was manufactured as per pictures in **Figure 9**. The two dimensional (2D) radiation test results for one sample product presented in **Figures 10-12** are coherent with the simulated results.

3. Discussions

Analyzing the simulation RL, the −10 dB bandwidth (BW) approximates to 592 MHz, or 2390 MHz - 2982 MHz in the first frequency band as well as 252 MHz, say 5133 MHz - 7753 MHz in the second band. With these bandwidths, the design qualifies for dual wideband antenna [15].

The antenna mismatch total efficiency is very good in both frequency bands.



(a) (b)

Figure 9. Picture of the manufactured antenna: (a) top view; (b) bottom view.

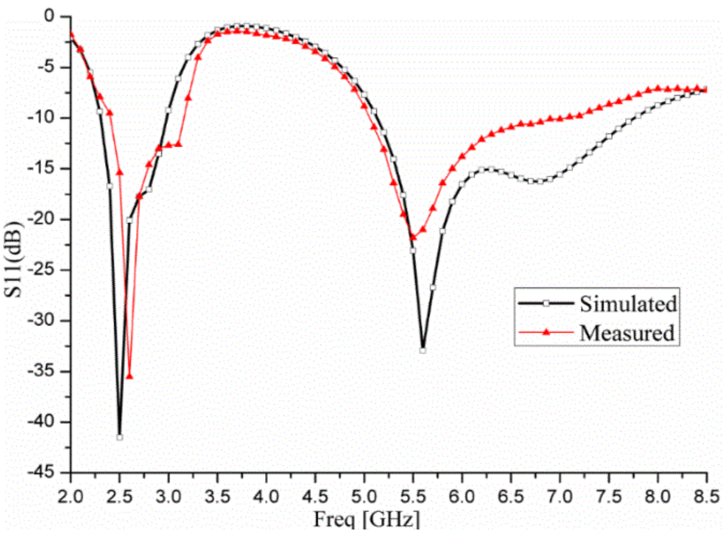


Figure 10. Simulated versus measured RL.

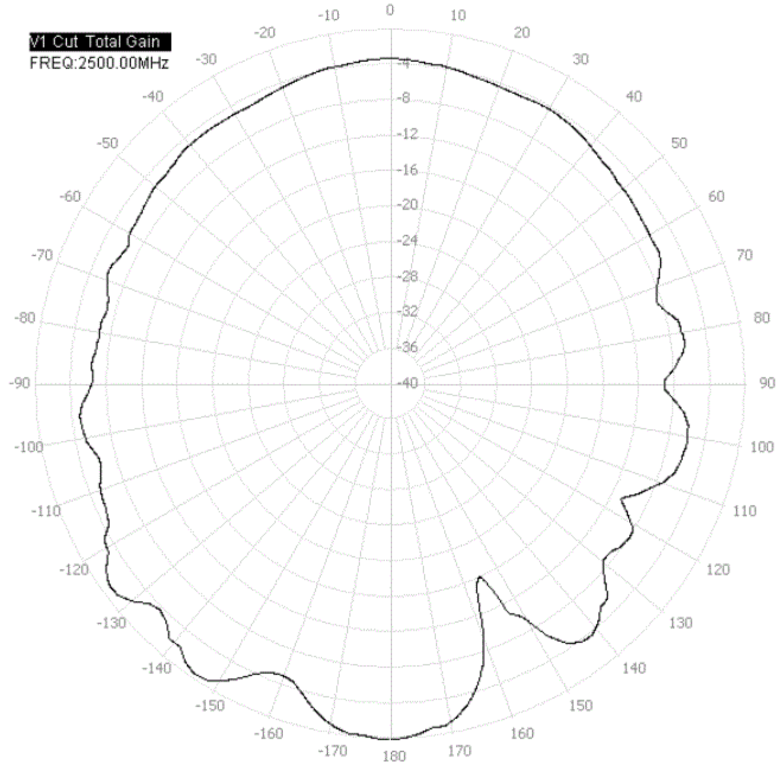
Looking at the measurements results, however, this antenna suffers from losses and signal degradation due to interconnect effects [24], just upon the port welding.

It has been noticed that the port may not be soldered by directly pressing it against the substrate's edge; rather, a small gap would be left or otherwise the radiated power distorts. On the other hand, when the gap in between the port and the substrate edge is slightly increased to about 1mm, the environmental conditions interfere to affect the integrity of the signal transmitted to the antenna.

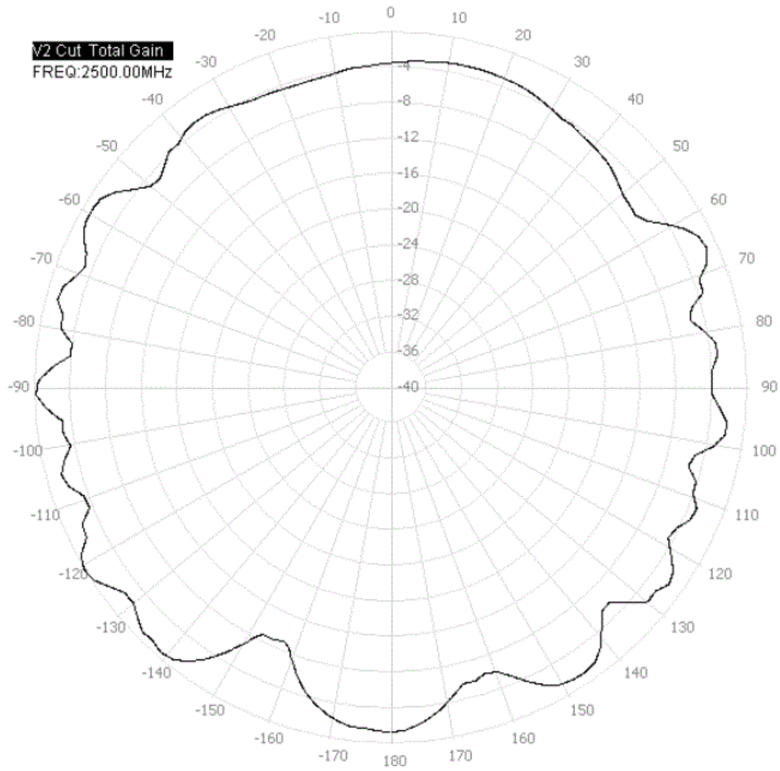
This antenna is a prototype sample which was not packaged in any commercial product. The encountered signal integrity problems due to port soldering would be carefully solved whenever preparing this antenna for the real applications of a miniature antenna for WiFi and WiMAX systems.

4. Conclusion

All the pre-set goals have been achieved. The antenna's overall performances were proven by both simulation and manufacturing results. The antenna was manufactured by a competent company while the related measurements were conducted in the University. For the tested three samples, results are all coherent; however, only one sample's 2D measured radiation patterns are presented in this article. The designed, manufactured and tested/

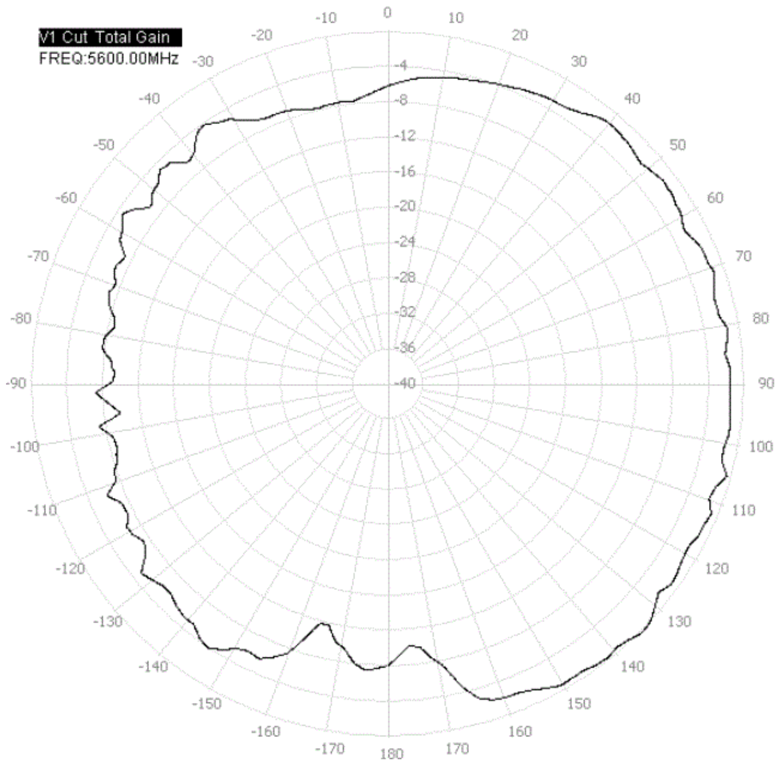


(a)

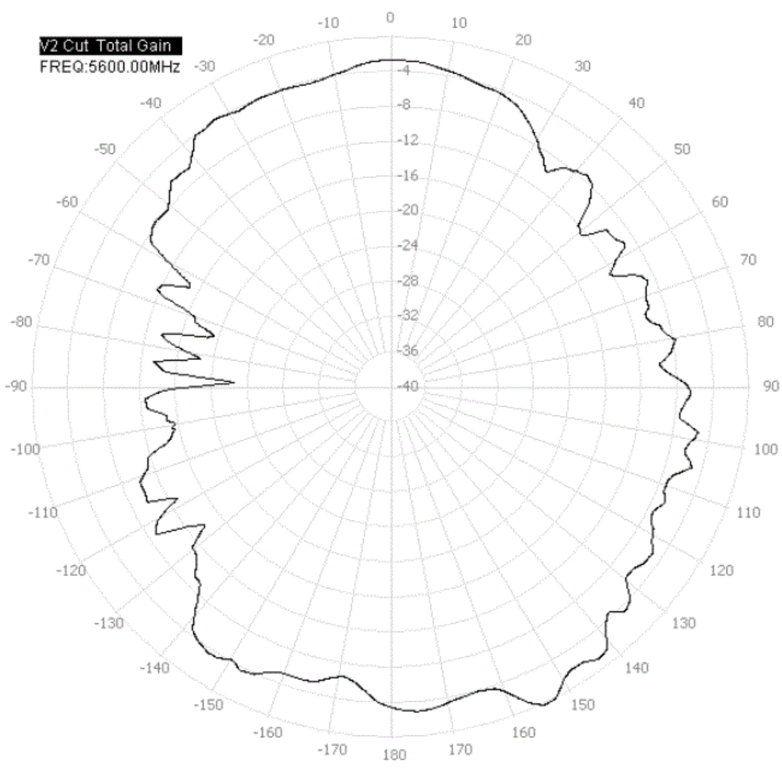


(b)

Figure 11. Measured 2D Radiation Patterns at 2.5 GHz for one sample product: (a) in horizontal direction; (b) in vertical direction.



(a)



(b)

Figure 12. Measured 2D Radiation Patterns at 5.6 GHz for one sample product: (a) in horizontal direction; (b) in vertical direction.

measured antenna system would be subjected to final product manufacturing, especially when there is any industrial request.

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