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DESIGN AND CONSTRUCTION OF MICROSTRIP UWB ANTENNA WITH TIME DOMAIN ANALYSIS

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Abstract—In this paper, a compact design and construction of microstrip Ultra Wide Band (UWB) antenna is proposed. The proposed antenna has the capability of operating between 4.1 GHz to 10 GHz. The antenna parameter in frequency domain analysis have been investigated to show its capability as an effective radiating element. Furthermore, time domain Gaussian pulse excitation analysis in UWB systems is also demonstrated in this paper. As a result, the simulation results demonstrated reasonable agreement with the measurement results and good ultra-wideband linear transmission performance has also been achieved in time domain.

1. INTRODUCTION

Antenna becomes a part of electrical devices in wireless communication system after late 1888, Heinrich Hertz (1857–1894) were first demonstrated the existence of radio waves [1]. The UWB technology opens new door for wireless communication system, since the current wireless system increasing exponentially. Back from spark-gap impulse to pulse radio, UWB system plays a dominant role in communication system as the antenna is one of the wireless communications components. Recently, UWB technology with an extremely wide frequency range has been proposed for imaging radar, communications, and localized applications [2]. In 2002, Federal Communication Commission (FCC) authorized unlicensed use of UWB band ranging from 3.1 GHz to 10.6 GHz. Since then, the design of broadband antennas has become an attractive and challenging area in the research of the system design [3]. In general, the antennas for UWB systems should have sufficiently broad operating bandwidth for impedance matching and high-gain radiation in desired directions. Among the

UWB antenna design in the recent literature, the monopole planar antenna type is widely used due to its wide bandwidth, simple structure and low cost. It has become one of the most considerable candidates for UWB application. Several designs of monopole planar UWB antenna have been proposed [6–12]. However, some of these antennas involve complex calculation and sophisticated fabrication process. Therefore, we propose a simpler method to design the UWB antenna based on microstrip rectangular patch calculation using simple transmission line model.

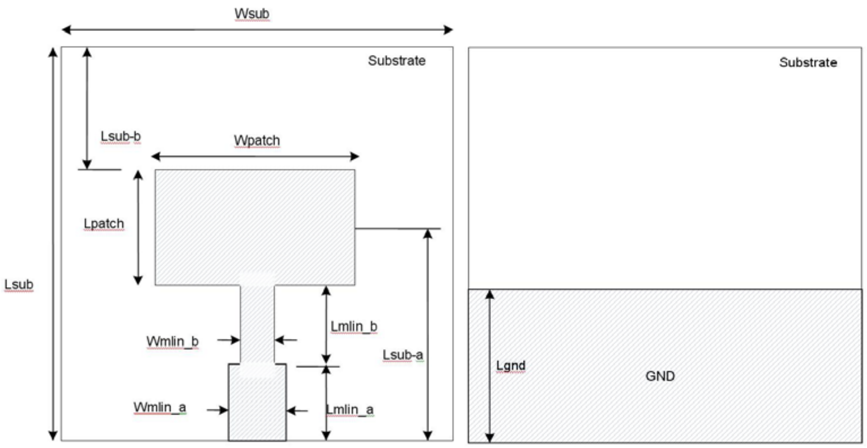
This paper is organized as follows. In Section 2, the proposed antenna design geometry and experimental setup is presented. Section 3 discussed on the results and discussion in three parts, namely, parametric study, time domain analysis and experimental results and discussion. In this section, the comparison of the simulation results using the software tools and the measured result of the fabricated antenna are demonstrated. Section 4 summarizes and concludes the study.

2. THE PROPOSED ANTENNA DESIGN GEOMETRY AND EXPERIMENTAL SETUP

In this paper, the proposed rectangular patch antenna parameters are calculated based on transmission line modal analysis [3] and the detailed geometry and parameters are shown in Figure 1 and Table 1, respectively. For modeled rectangular patch antenna, the signal excites through SMA connector which is modeled based on simulation tools of CST Microwave Studio. The simulation results with ground patch, Lgnd of 34 mm is carried out and this is followed by the parametric study on the height of the ground patch and width of the feed microstrip line.

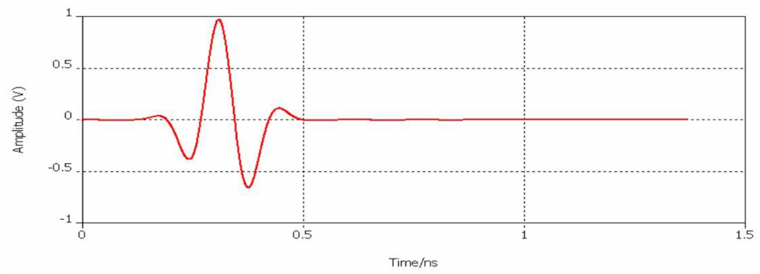
The simulation to optimize design is done using time domain analysis tools from CST Microwave Studio which provides wide range of time domain signal that are used in UWB system. The numerical analysis of the software tools are based on Finite Difference Time domain (FDTD) [4]. For comparison purpose, HFSS in frequency domain where the numerical analysis is based on Finite Element Method (FEM) [5] is performed. The input signal of Gaussian pulse as shown in Figure 2 is used for simulation in CST Microwave Studio because Gaussian signal offers a good mix between time and frequency domain compactness.

The antenna is then fabricated on FR4 substrate Printed Circuit Board (PCB) based on the simulation specification with dielectric constant (ε_r) of 4.4, loss tangent ($\tan\delta$) of 0.02, substrate thickness (h)

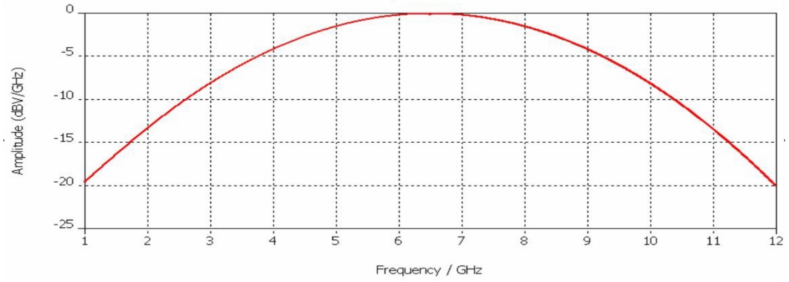


(a) Top view (b) Bottom view

Figure 1. The design geometry of the proposed antenna patch UWB antenna.



(a) Gaussian Pulse



(b) Power Spectrum Density

Figure 2. Excitation signal in time domain of the proposed antenna.

Table 1. The detailed parameters for proposed antenna patch UWB antenna.

Symbol	**Size (mm**
Wsub	36
Lsub	34
Lsub_a	17
Lsub_b	11.5
Wpatch	18
Lpatch	11
Wmlin_a	3
Lmlin_a	5.5
Wmlin_b	2.5
Lmlin_b	6
Lgnd	11

of 1.6mm, and copper foil thickness (t) of 35 μm. The measurement is done using calibrated HP8733ES Network Analyzer. For simulation as well as measurement, the frequency swept from 1 GHz to 12 GHz is investigated. The simulation results displayed in the later section demonstrate reasonable agreement with the measurement results.

3. RESULTS AND DISCUSSION

The results and discussion are divided into three parts which consist of parametric study, time domain analysis and experimental results and discussion. In Section 3.1, parametric study including the simulated results of return loss, group delay, radiation patterns and efficiency of the proposed antenna will be discussed. On the other hand, in Section 3.2, the time domain analysis where electric probe is placed at different positions to investigate the transmitted and received pulse signals. Experimental results are presented in Section 3.3 where the measured results of the fabrication antenna and the simulated results are compared and discussed.

3.1. Parametric Study

Parametric study has been conducted to optimize the design of the antenna. This study is crucial as it gives approximation measure before antenna fabrication can be done. Figure 3 shows return loss S_{11} (dB)

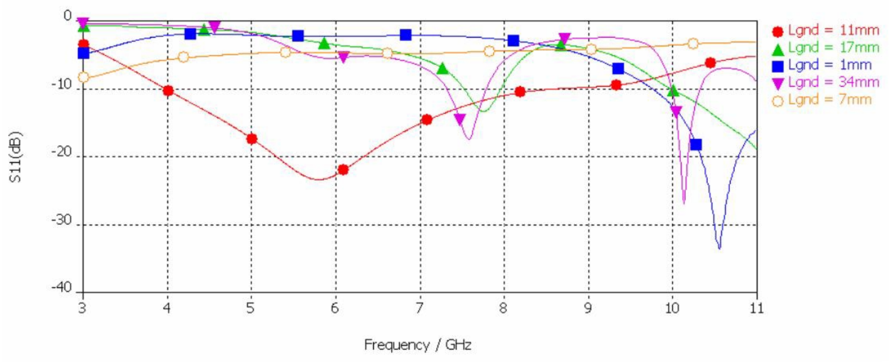


Figure 3. Parametric study of return loss (S_{11}) over the the lengths of ground patch.

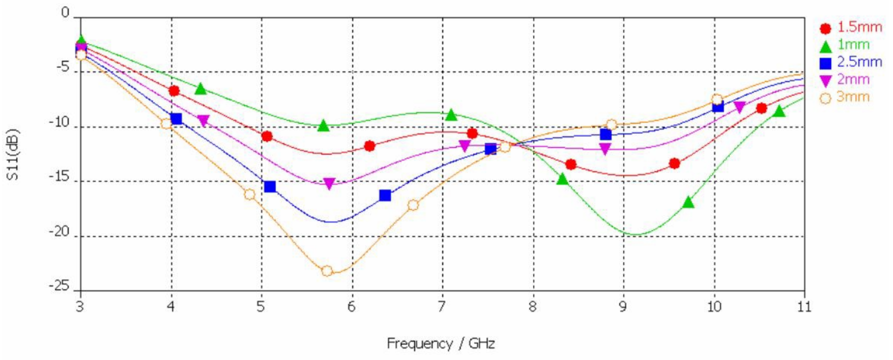


Figure 4. Parametric study of return loss (S_{11}) over the width of second feed line.

over function of length ground patch. It is observed that for Lgnd of 34 mm, the antenna is able to operate as a narrowband antenna. However, the return loss of the antenna improves dramatically when the length ground patch reduces gradually and the best result is obtained at the height of gound plane, Lgnd of 11 mm. The partial ground shows better return loss compared to full ground patch on the bottom because the antenna is transformed from patch-type to monoploe-type by the partial ground.

In order to further improve its overall bandwidth, two steps of feed line are used. The first feed line is connected to SMA center pin with width of 3 mm while the second feed line width has been used as the optimization function in this studies. The optimized result of second

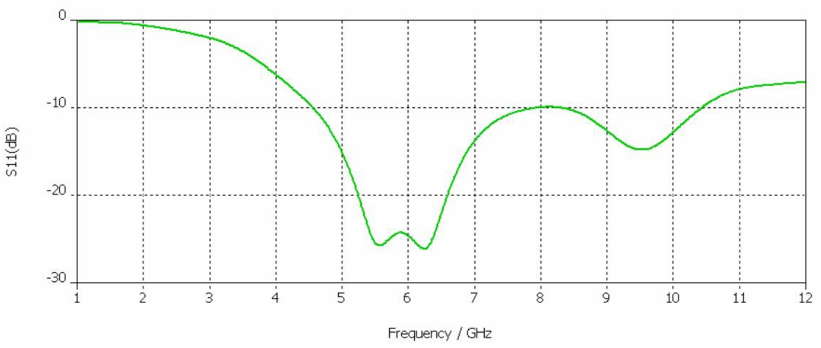


Figure 5a. Return loss of the optimized proposed antenna.

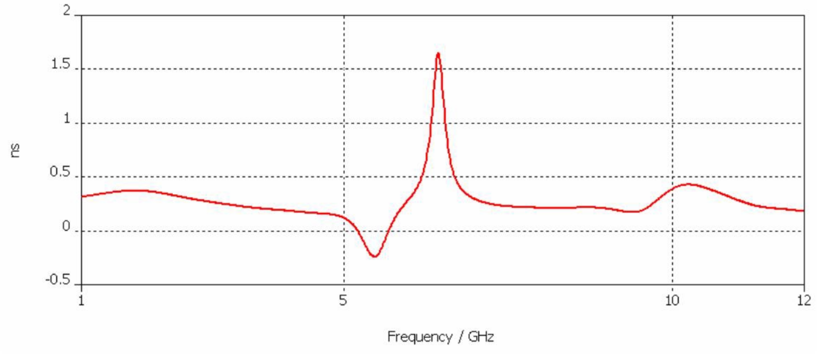


Figure 5b. Group delay of the optimized proposed antenna.

feed line width is at 2.5 mm and it is shown in Figure 4. This technique leads to good impedance matching and subsequently, the bandwidth increases gradually. Figure 5 shows the return loss and group delay of the optimum design. From the figure, the simulated group delay shows less variation on broader bandwidth except for sharp changes at the middle of the center frequency at 6.85 GHz.

Antenna radiation pattern demonstrates the radiation properties on antenna as a function of space coordinate. For a linearly polarized antenna, performance is often described in terms of the E and H-plane patterns [1]. The E-plane is defined as the plane containing the electric field vector and the directions of maximum radiation while the H-plane as the plane containing the magnetic field vector and the direction of maximum radiation [2]. The x-z plane elevation plane with some particular azimuth angle φ is the principle E-plane while for the x-y plane azimuth plane with some particular elevation angle

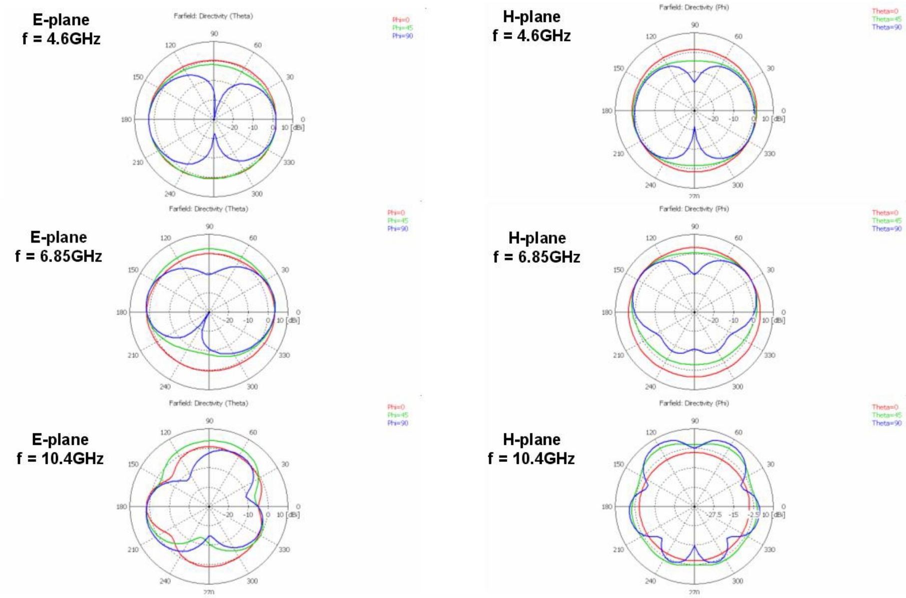


Figure 6. Radiation Pattern of the antenna patch UWB antenna.

θ is the principle of H-plane [3]. Figure 6 shows the simulated two-dimensional E and H-plane at three frequencies. In the E-plane, the value of azimuth angle φ of $0°, 45°$ and $90°$ while in H-plane, the value of elevation angle θ of $0°, 45°$, and $90°$ are taken into consideration. The plot for radiation is utilized for three frequencies within pass band, which are 4.6 GHz at the lower bound, 6.85 GHz at the middle bound and 10.4 GHz at the upper bound.

The simulated results of maximum gain in dBi and radiation efficiency of the designed antenna are as shown in Figures 7(a) and 7(b), respectively. The gain and efficiency are simulated at the fix point on azimuth angle of φ at $0°, 45°$ and $90°$ and at different elevation angle of θ. It is observed that the gain pattern is not the same for all angle of φ but the efficiency remains the same.

3.2. Time Domain Analysis

In order to validate the efficiency of the antenna, the pulse base signal is excited with Gaussian pulse. It can be related to the dispersion of receive signal compared to transmitter signal. Figure 8 shows the radiated E field which is virtually place probe in simulation to study the effect of radiated signal. From this figure, the antenna is

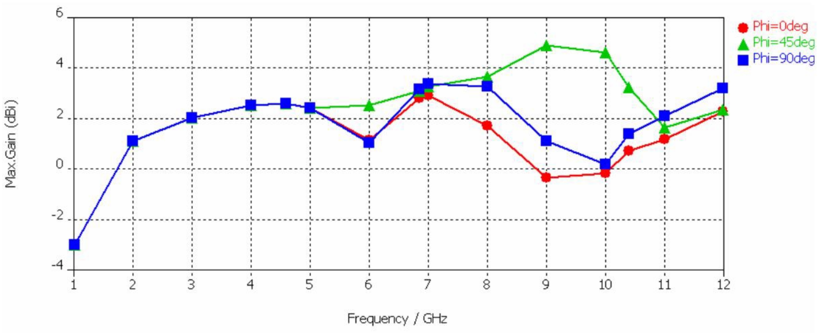


Figure 7a. Maximum gain.

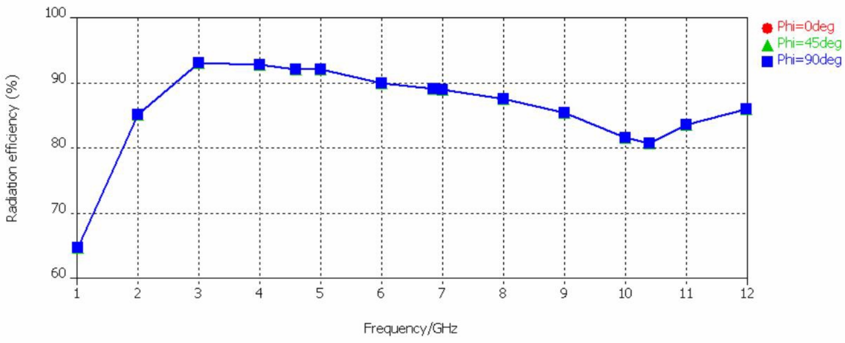


Figure 7b. Radiation efficiency (η).

fixed at azimuth angle φ of 90°, and the probe is placed at three different positions for θ of $0°, 45°$ and 90°. It is proved that the proposed antenna has good potential in transmitting UWB signals with minimum distortion. Furthermore, the time domain UWB pulse signal received by the electric probe shows stable performance where the received pulse signal is almost identical to the transmitted pulse signal.

3.3. Experimental Results and Discussion

The optimum design from simulation model has been fabricated on PCB and the antenna prototype is shown in Figure 9. The comparisons plot between the two different numerical technique analysis and measured results of return loss (dB) using constructed antenna prototypes are shown in Figure 10. The measurement result show similarity between simulated results further verifies the performance of the antenna.

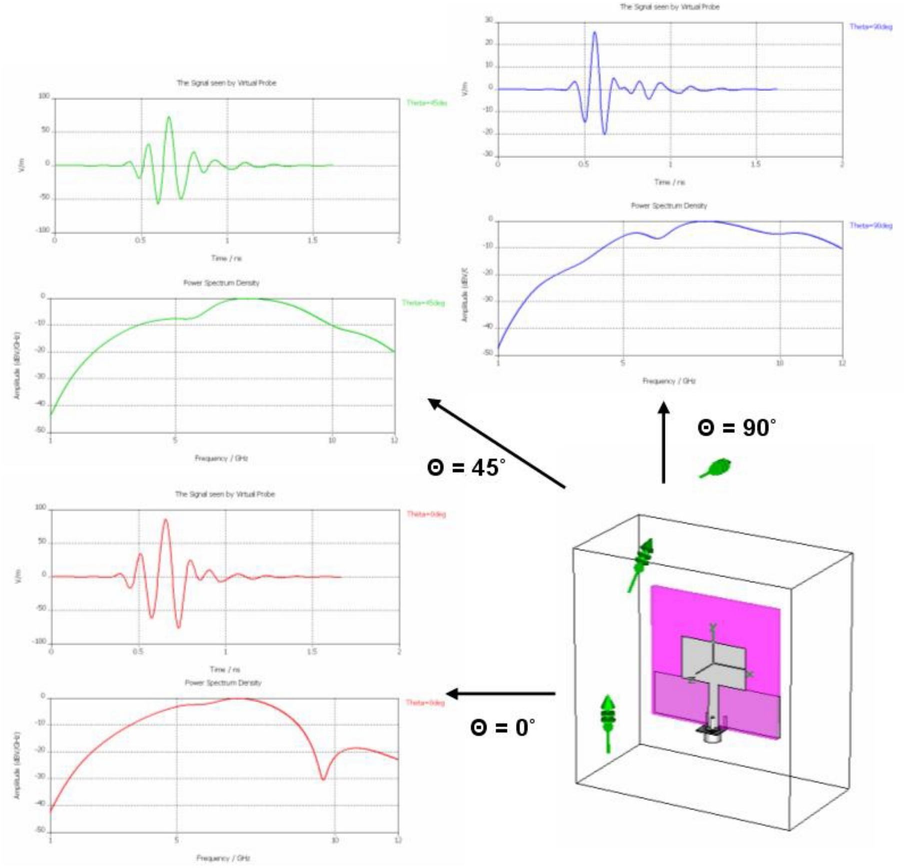


Figure 8. Probe signal in time domain.

Table 2. The measured and simulated operating frequencies with their bandwidths.

Sample Antenna		HFSS	CST Microwave Studio	Measured
Rectangular patch antenna with partial ground	Operating Frequency/ BW	3.8 - 9.6GHz (BW = 5.8GHz)	4.6 -10.4GHz (BW = 5.8GHz)	4.6 - 9.6GHz (BW = 5GHz)

Figure 9. Fabricated antenna.

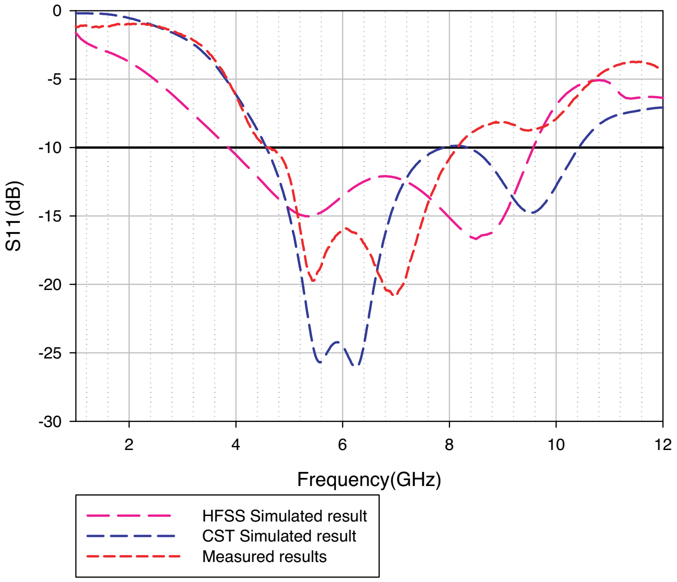


Figure 10. Measured return loss with simulation results.

Table 2 represents the measured and simulated operating frequencies with their bandwidths for comparison purpose. The proposed antenna demonstrates the capability to operate between 4.6 GHz to 9.6 GHz. The antenna can be considered as ultra wideband antenna since the operating bandwidth is 5 GHz and it is based on FCC rules where the fractional bandwidth must be more than 500 MHz or 20% from the center frequency.

4. CONCLUSION

In this paper, we proposed an UWB antenna which can support large bandwidth excited by a time domain pulse base signal to ensure the UWB signal is transmitted and received effectively. By variation on the size of the ground patch at bottom layer, the optimization on return loss has been realized and the potential as the key parameter on return loss improvement has been demonstrated. Furthermore, stepped impedance matching technique applied on the microstrip feed line is proved to provide further enhancement of the antenna performance in term of impedance bandwidth. A further improvement of the proposed antenna will be done in near future to provide a stop band at approximately 5 GHz to 6 GHz frequency range that is capable of reducing potential interference between UWB and WLAN or HYPERLAN/2 communication system when the signals of two radio systems are collided.

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