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Coplanar waveguide-fed Ultra-Wideband antenna with WLAN Band

Chaiyong Soemphol and Niwat Angkawisittpan
Research Unit for Computational Electromagnetics and Optical Systems (CEMOS),
Department of Electrical Engineering, Faculty of Engineering, Mahasarakham University, Thailand

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ABSTRACT

A coplanar waveguide fed ultra-wideband antenna with extended transmission band to WLAN frequency is investigated. The proposed antenna consists of a modified semi-circular patch and staircase of ground plane. The prototype is fabricated on a low cost FR4 substrate with dielectric constant of 4.4 with thicknes of 0.8 mm. The overall dimensions of proposed UWB antenna are 34 mm x 40 mm. The simulation and experimental results have been shown that the proposed antenna archives low VSWR over transmission bandwidth from 2.10 - 12.7 GHz to cover both WLAN and UWB bands. The average gain is 3.87 dBi. It depicts nearly omni-directional radiation pattern like dipole antenna. Moreover, the fabricated prototype antenna shows a good agreement between the simulated and measured results.

Corresponding Author:

Chaiyong Soemphol
Research Unit for Computational Electromagnetics and Optical Systems (CEMOS),
Department of Electrical Engineering, Faculty of Engineering, Mahasarakham University,
Kantarawichai, Maha Sarakham, 44150, Thailand.
Email: chaiyong.s@msu.ac.th

1. INTRODUCTION

In 2002, the US Federal Communication Commission (FCC) permitted the authorization of using the unlicensed frequency band starting from 3.1 GHz to 10.6 GHz for commercial Ultra Wide Band (UWB) communication applications [1]. The UWB communication systems have been found to use in many applications, for instant cable TV, asset management, radar and imaging, security applications and medical applications [2-3]. The most important part of UWB communication systems are an antenna because it is used to capture or radiated the electromagnetic waves from the atmosphere. Therefore, overall performances of the UWB system depend on antenna performance. Currently, there are many antenna designs that can achieve broad bandwidth to be used in UWB systems such as the Vivaldi antenna [4], bi-conical antenna [5], log periodic antenna [6] and spiral antenna [7]. However, there are some limited to use these antennas in this system, for example some of antennas have large physical dimensions as well as the radiation pattern of antenna is not suitable for either indoor wireless communication. Hence, many research groups have focused on the design of UWB antenna on small printed antennas due to their ease of fabrication and their ability to be integrated with other components on the same PCBs [8-12].

Nowadays, it is well known that Wireless Local Area Network (WLAN) has helped to simplify networking by enabling multiple computer users to simultaneously share resources in a home or business without additional wiring [13]. WLAN requires three bands of frequencies: first band is at 2.4 GHz (2400 – 2484 MHz), second band is at 5.2 GHz (5150 – 5350 MHz) and third band is at 5.8 GHz (5725-5825 MHz). According to the second and third band of WLAN that have been overlayed to UWB band, therefore previous studies have proposed many notched band UWB antennas using different approaches to avoid interference problems [14-22]. However, modern communication devices such as smartphone, laptop computers have been developed to be compack, flat as well as compatible with many functions. Hence, it is challenged to develop an appropriate antenna for these devices that can be compatible with all applications.

In this work, we propose a coplanar waveguide-fed UWB antenna with extend to cover the first frequency band of WLAN. A modified semi-circular patch is chosed as a radiating element. 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, four main parameters of antenna are studied. Those parameters were the bandwidth, the Voltage Standing Wave Ratio (VSWR), gain, and the radiation pattern of the antenna. Simulation and experimental results confirm that the proposed antenna archives a good reflection and radiation characteristics in the entire both of WLAN and UWB band. The last section summarizes the study.

2. MATERIAL AND METHOD

The main goal of the proposed antenna designs is to obtain a return loss lower than -10 dB in the 2.4 - 10.6 GHz band which cover both of WLAN and UWB applications. Fig. 1 depicts the geometry of the proposed coplanar waveguide fed UWB antenna. The radiating element or aperture is chosen semi-circular in order to achieve a wide bandwidth feature [23]. Therefore the proposed UWB antenna comprises of a modified semi-circular patch and a staircase shape of ground plane. The Coplanar waveguide (CPW) fed with a characteric impedance of 50 Ω is selected because it has wider bandwidth, lesser dispersion and low radiation loss. The width and length of proposed UWB antenna are calculated based on equation (1) and equation (2).

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

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

Where c is the light velocity, f_r is the resonance frequency, ε_r is relative permittivity of substrate and ε_{eff} is effective permeability that can be determined by equation (3).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} ; \frac{W}{h} > 1 \tag{3}$$

Based on equation (1), (2) and (3) the prototype UWB antenna is fabricated on low cost FR4 Printed Circuit Board (PCB) substrate with a relative permittivity (ε_r) of 4.4 and loss tangent of 0.02. The thickness of substrate is 0.8 mm. The optimized dimensions of proposed geometry are given in Table 1.

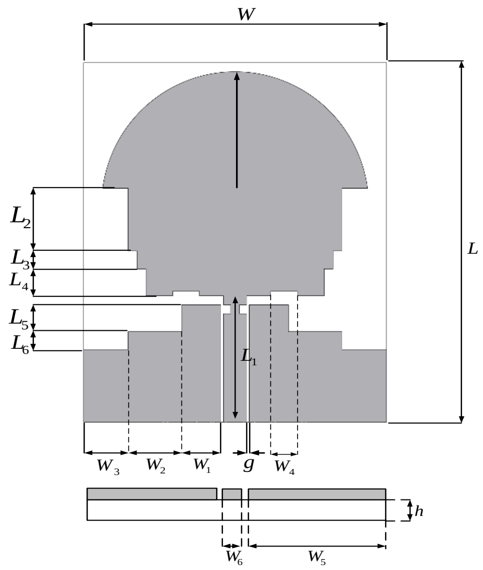


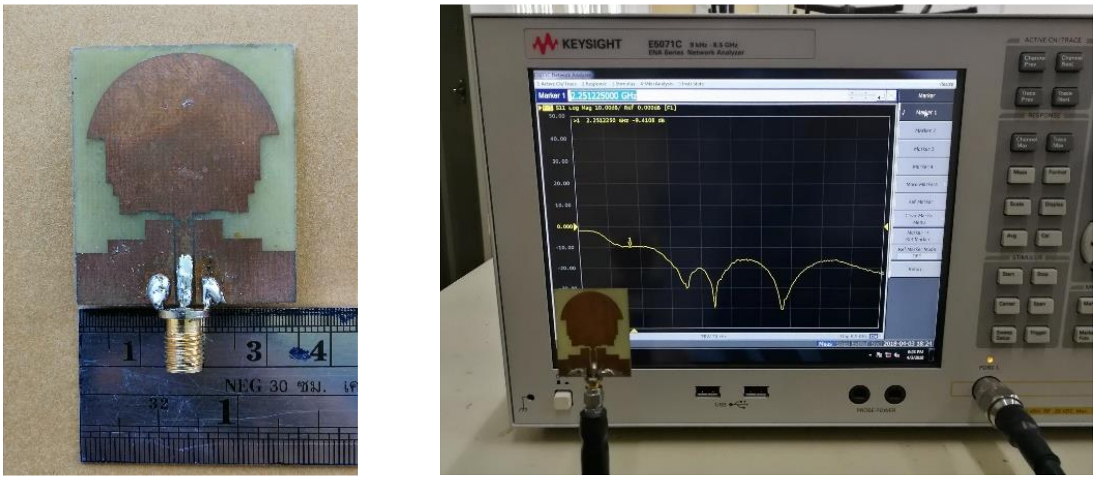
Figure. 1 Geometry of the proposed antenna

Table 1 Dimension of the proposed antenna

Parameters	Value (mm)	Parameter	Value (mm)
L	40	W	34
L_1	14	W_1	4.4
L_2	7	W_2	6
L_3	2	W_3	5
L_4	3	W_4	3
L_5	3	W_5	15.4
L_6	2	W_6	2.6
h	0.764	g	0.3

3. RESULTS AND ANALYSIS

The fabricated proposed antenna is depicted in figure 2. For testing the antenna, there are four main characteristics to be measured; bandwidth, Voltage Standing Wave Ratio (VSWR), gain and radiation pattern. All the measurements of the proposed antenna are monitored using Keysight E5071C ENA Vector Network Analyzer.



(a) (b)

Figure 2 (a) The fabricated antenna and (b) the experimental setup

The first parameter that we had to consider for our design is the bandwidth. A comparison of return loss (S_{11}) between simulation and measurement results of proposed antenna are illustrated in figure 3. The proposed antenna has a wide operational bandwidth for $S11 \leq -10$ dB, as summarized in TABLE II. It has been observed that the proposed antenna archives a wide bandwidth from 2.10-12.20 GHz (141.25%) and 2.10-12.70 GHz (143.24%) for simulated and measured, respectively. The wide bandwidth of antenna is obtained by the combination of multiple resonances, predominantly due to the 4.20, 6.15 and 9.7 GHz. It is worth noting that the impedance bandwidth of the antenna covered the entire bandwidth required for WLAN and UWB technology There are is good agreement between both results. The slightly discrepancies are due to the fabrication tolerance.

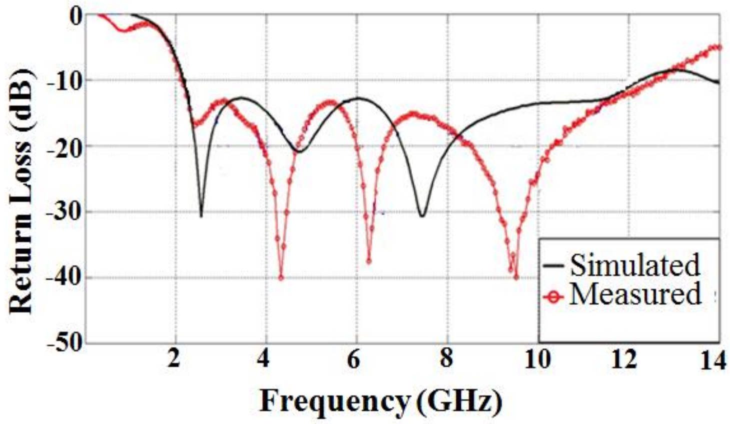


Figure 3. Simulated and measured return loss of the proposed antenna

Table 2 The bandwidth of proposed UWB antenna

	f_c(GHz)	BW(GHz)	BW(%)
Simulated	7.15	2.10 -12.20	141.25
Measured	7.40	2.10-12.70	143.24

The second parameter that we had to take in to account for our design is the VSWR of the antenna. VSWR is parameter that indicates the amount of mismatch between an antenna and the feed line connecting to it. Fig. 4 present the VSWR of proposed antenna. It is observed that the proposed antenna offers a low VSWR (<2) over 2.10 – 12.70 GHz as concluded in Table 3. From these results, our proposed antenna achieves a VSWR value under 2 with wide range that mean this antenna can be described as having a good match and it can be considered suitable for most antenna applications.

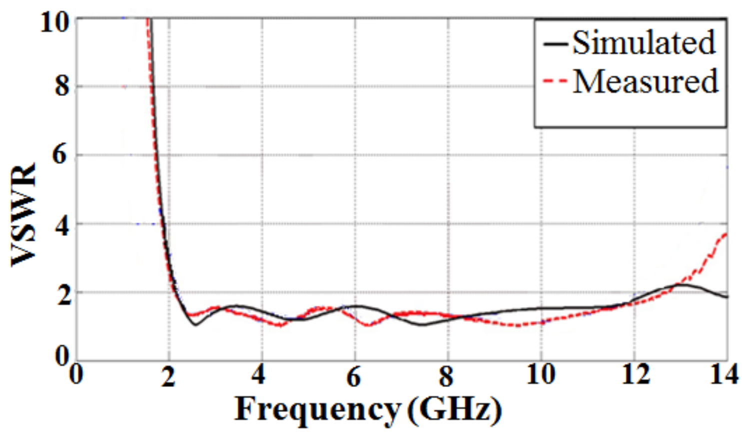


Figure 4 Simulated and measured VSWR of the proposed antenna

Table 3 The summarized of VSWR of proposed UWB antenna

Frequency (GHz)	VSWR	
	Simulation	**Measurement**
2.50	1.108:1	1.525:1
3.50	1.592:1	1.365:1
4.50	1.465:1	1.023:1
5.50	1.477:1	1.678:1
6.50	1.477:1	1.108:1
7.50	1.064:1	1.405:1
8.50	1.329:1	1.301:1
9.50	1.484:1	1.289:1
10.50	1.540:1	1.203:1

The third parameter is the gain of antenna. Antenna gain is the parameter that shows how strong a signal an antenna can send or receive in a specified direction. In this work, two-antenna method is used to measure gain of proposed antenna as shown in Fig. 4 and antenna gain is calculated by equation 4.

$$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi r}\right)^2 G_r G_t \quad (4)$$

Where P_r and P_t are a received and transmitted power of antenna, respectively. G_r and G_t are gain of receive and transmitted antenna, respectively, and r is the distance between two antenna.

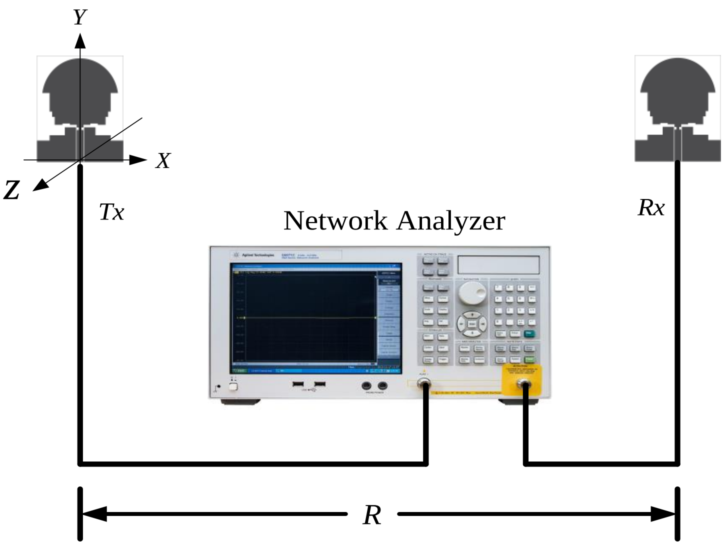


Figure 5. Experimental setup for measurement antenna gain

A plot of the simulation and measurement gain is presented in Figure 6. The simulation has average gain 4.59 dBi, with a peak gain of 6.27 dBi at 6.50 GHz, while an average measurement gain is 3.87 dBi, with a peak gain of 6.28 dBi at 5.50 GHz. Based on these results, it is found that There are is good agreement between both results. However, there are some different that due to loss from the connector and the signal line that used in the experiment.

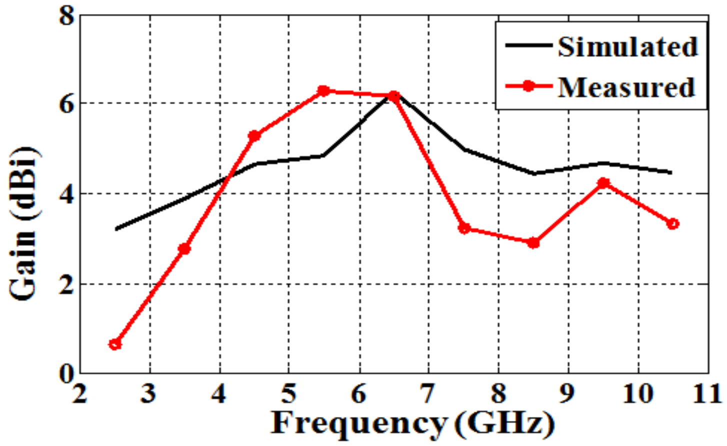
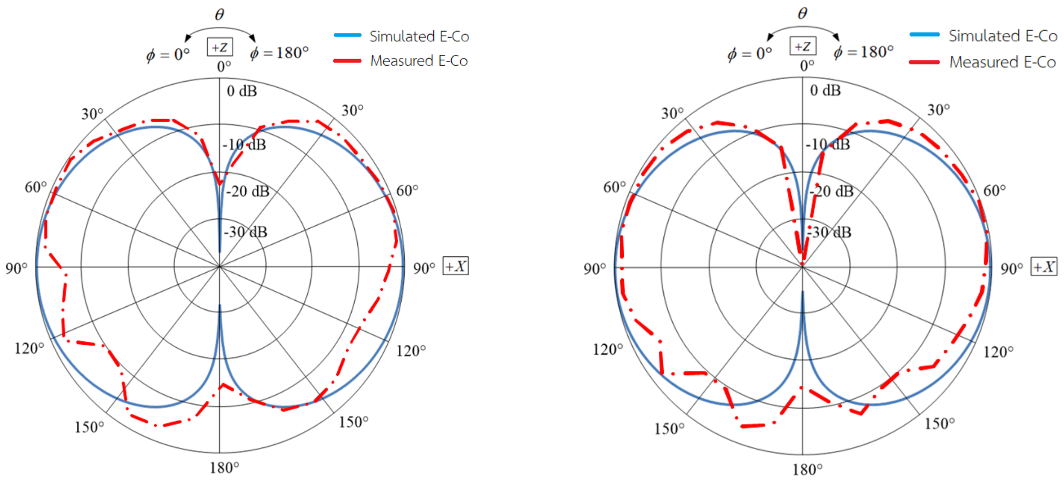


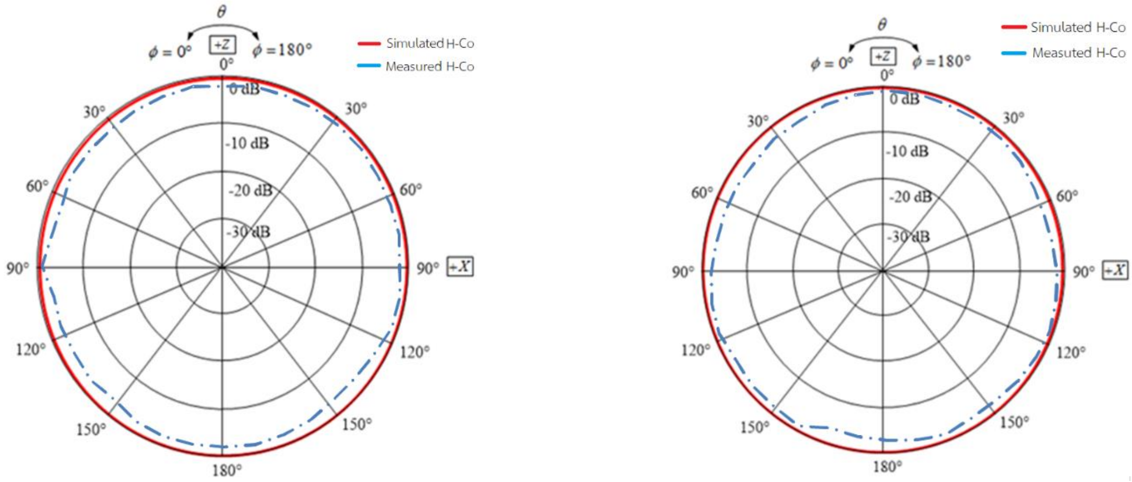
Figure 6. Simulated and measured gain of the proposed antenna

The fourth parameter is the radiation pattern of the antenna. Antenna radiation pattern demonstrate the radiation properties on antenna as a function of space coordinate [24]. For a linearly polarized antenna, performance is often described in terms of the E-plane and H-plane pattern [25]. 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 [26]. The simulated and measured radiation patterns are shown in Figure 7. and Figure 8. It has been shown that the proposed antenna provides bi-directional coverage in the E-plane as shown in Figure 7. (a)-(b), and omnidirectional coverage in the H-plane as shown in Figure 8. (a)-(b).



(a) (b)

Figure 7. Radiation patterns of the proposed antenna in the E-plane at (a) 2.5 and (b) 3.5 GHz



(a) (b)

Figure 8. Radiation patterns of the proposed antenna in the H-plane at (a) 2.5 and (b) 3.5 GHz

4. CONCLUSION

The design of a coplanar waveguide-fed antenna is proposed for WLAN and UWB applications. The obtained results indicate that the antennas have a return loss below -10 dB in the 2.10-12.70 GHz frequency band. The antenna archives a wide bandwidth covering entire WLAN and UWB operating band, with an average gain 3.87dBi and good radiation pattern. These results confirm that the proposed antenna is suitable for modern wireless communication systems and in particular, WLAN and UWB applications.

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BIOGRAPHIES OF AUTHORS

Chaiyong Soemphol was born in Surin, Thailand. He received his B.Eng. in Electrical Engineering with second-class honors from Khon Kaen University, Thailand in 2011. He also received his Ph.D. in Electrical Engineering from Khon Kaen University, Thailand in 2017. Since 2018, he has been with the Department of Electrical Engineering, Faculty of Engineering, Mahasarakham University, Maha Sarakham, Thailand as a Lecturer. His research interests include compact microstrip devices, metamaterial applications for RF, microwave sensor and wireless power transfer systems.

Niwat Angkawisittpan was born in Khon Kaen, Thailand. He received his B.Eng. in Electrical Engineering with honors from Khon Kaen University, Thailand in 1997. He received his M.Sc. in Electrical and Computer Engineering from Purdue University, Indiana, USA in 2003. He also received his Ph.D. in Electrical Engineering from University of Massachusetts Lowell, Massachusetts, USA in 2009. Since 2009, he has been with the Department of Electrical Engineering, Faculty of Engineering, Mahasarakham University, Maha Sarakham, Thailand as a Lecturer. His research interests include compact microstrip devices, Metamaterial applications for RF and microwave circuits and electromagnetic material characterization.