Coplanar waveguide-fed ultra-wideband antenna with WLAN band

Chaiyong Soemphol, 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 modified 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 constructed on a low cost FR4 substrate. The overall dimensions of proposed UWB antenna are 34 mm x 40 mm. The result has 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. It is illustrated that our proposed technique is a good choice for designing any structure of microstrip antenna which appropriate to use for many wireless communication systems.

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 frequency band that start from 3.10 GHz to 10.60 GHz were allowed for many applications to communicate in the ultra wide band (UWB) commercial by US federal communication commission (FCC) [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. Vivaldi antenna [4], bi-conical antenna [5], log periodic antenna [6] and spiral antenna [7] are the one choice of antenna that can be UWB systems. However, there are some limited to use these antennas in this system, for example some of antennas have large physical dimensions as well as if we use these antennas with indoor wireless communication devices, thier radiation pattern are not sutable. So, it is very importace that antennas which used in wireless communication should have light weight, cheap, easy to construct as well as easy to install.

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 [8]. 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 different approaches of notched band UWB antennas which using to avoid electromagnetic interference problems [9-17]. 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 that a single antenna covers a wide band to include all wireless applications [18].

Planar antennas play an important role among other types of antennas because of their many advantages for example it has a small sized, inexpensive, simple design and easy to use with other communication devices [19, 20]. Although planar antennas have many advantages, the main disadvatade of the patch antennas is there have narrow bandwitdh, therefore it is challenge for the researchers to design wide band antenna using different techniques to fulfill the ultra wide band requirements without much compromising with other parameters [18]. Many research groups have focused on the design of UWB antenna on small printed antennas with different structure [21-25]. However, majority of these designs have not covered all the major bands of WLAN. The methods for improving the frequency range of antenna are proposed. By added a strip for WLAN [26-28], or using asymmetric coplanar strip antennas [29-31]. Another way to increase the bandwidth using antenna is using modified radiating patch and ground plane [32].

In this work, we propose a simple technique to modified 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, presents the design of antenna and experimental setup for testing antenna performance. Section 3 present the results discussion, 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 our antenna archives a good reflection and radiation characteristics in the entire both of WLAN and UWB band. The last section summarizes of the study.

2. MATERIAL 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. Figure 1 depicts he structure of the proposed staircase-shaped coplanar waveguide fed for UWB antenna. Its geometrical evolution from a coplanar waveguide-fed strip monopole antenna [33]. The radiating element or aperture is chosen semi-circular in order to achieve a wide bandwidth feature [34]. Therefore, the modified semi-circular patch and a staircase shape of ground plane are comprised in our designed UWB antenna. The coplanar waveguide (CPW) fed with a characteric impedance of 50 Ω is selected. The width and length of proposed UWB antenna are calculated based on (1) and (2).

$$W = \frac{c}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (2)$$

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 (3).

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

Based on (1), (2) and (3) the low cost FR4 printed circuit board (PCB) substrate is used for the construction of prototype UWB antenna. This PCB borad has 0. 8 mm of thickness, 4.4 of relative permittivity and 0.02 of tangent loss. The dimensions of designed antenna have been optimized in the simulation and the final dimension value are given in Table 1.

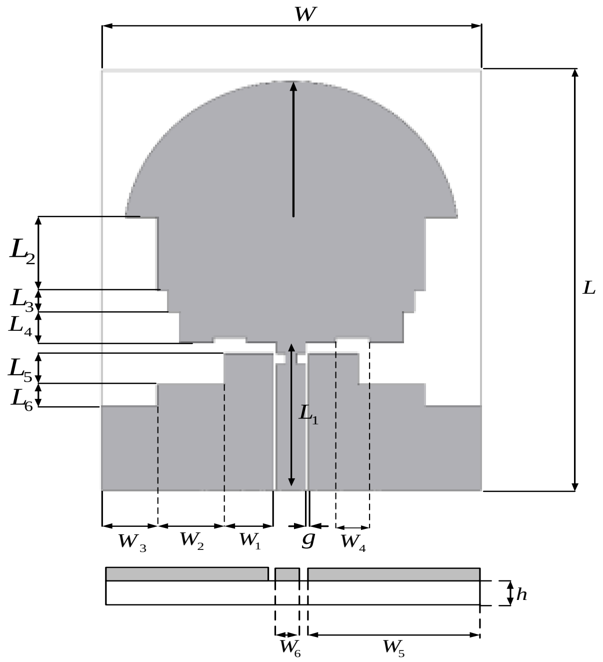


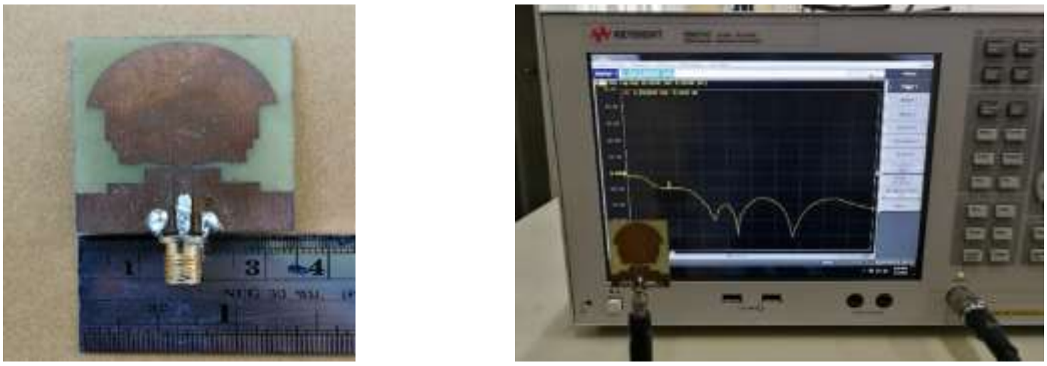
Figure 1. Structure of modified UWB antenna

Table 1. The final dimension value of the desinged 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

Figure 2 shows the fabricated proposed UWB antenna. For testing the UWB 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 have to consider for our testing is the bandwidth. A comparison of return loss (S_{11}) between simulation and measurement results are illustrated in Figure 3. The proposed antenna has a wide operational bandwidth for S_{11} lower than -10 dB, as summarized in Table 2. It has been observed that the antenna can archive a wide bandwidth from 2.10-12.20 GHz (141.25%) and 2.10-12.70 GHz (143.24%) for simulated and measured, respectively. A combination of multiple resonance frequency at 4.20 GHz, 6.15 GHz and 9.70 GHz causing the antenna to have a wider frequency. It is noteworthy that the bandwidth of the antenna's impedance bandwidth covering all the necessary technology for WLAN and UWB. Both simulation and measurement results are the same. There is a slight deviation in which a shift of the scale in the fabrication process.

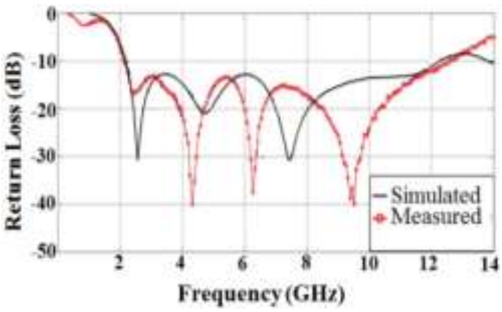


Figure 3. Simulated and measured return loss of the proposed antenna

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 Figure 4 present the VSWR of proposed antenna. It has been shown that our 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.

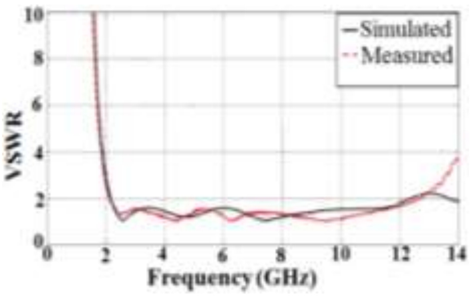


Figure 4. Simulated and measured VSWR of the UWB antenna

Table 3. The summarized of VSWR of the UWB antenna

Frequency (GHz)	VSWR	
	Simulation	Measurement
2.50	108.1:1	1.525:1
3.50	1.592:1	1.365:1
4.50	465.1:1	1.023:1
5.50	1.477:1	1.678:1
6.50	1.477:1	1.108:1
7.50	064.1:1	1.405:1
8.50	1.329:1	1.301:1
9.50	1.484:1	1.289:1
10.50	540.1:1	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. Figure 5 depicts the antenna gain measurement setup. Then the collected datas are use to calculated the antenna gain follow the (4).

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

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.

A plot of the simulation and measurement antenna gain is presented in Figure 6. The simulation result shows the average gain 4.59 dBi and it show a peak gain at thequency 6.50 GHz with peak 6.27 dBi. The experimental result shows the average gain 3.87 dBi, with a peak gain of 6.28 dBi at 5.50 GHz. Based on these results, it is found that both results are acceptable. However, there are some different that due to loss from the connector and the signal line that used in the experiment.

The fourth parameter is the radiation pattern of the antenna. Figure 7 and Figure 8 present the simulated and measured antenna radiation patterns. In Figure 7 (a)-(b) present the coverage E-plane radiatin pattern, it has been shown that the proposed antenna provides bi-directional and omnidirectional coverage in the H-plane as shown in Figure 8 (a)-(b).

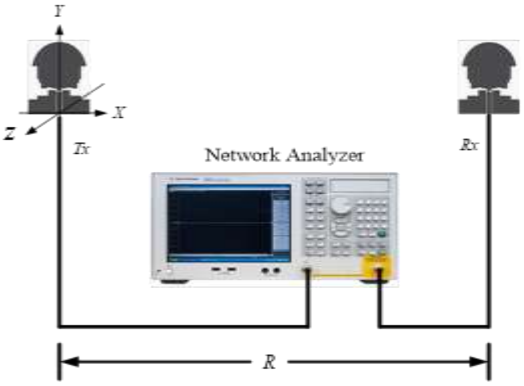


Figure 5. Experimental setup for measurement antenna gain

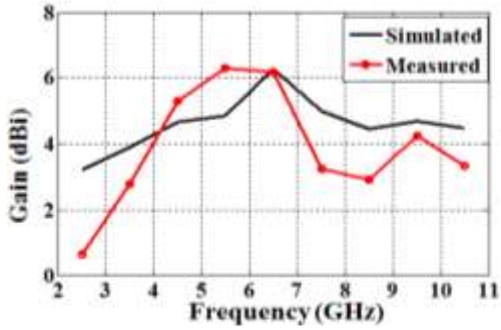
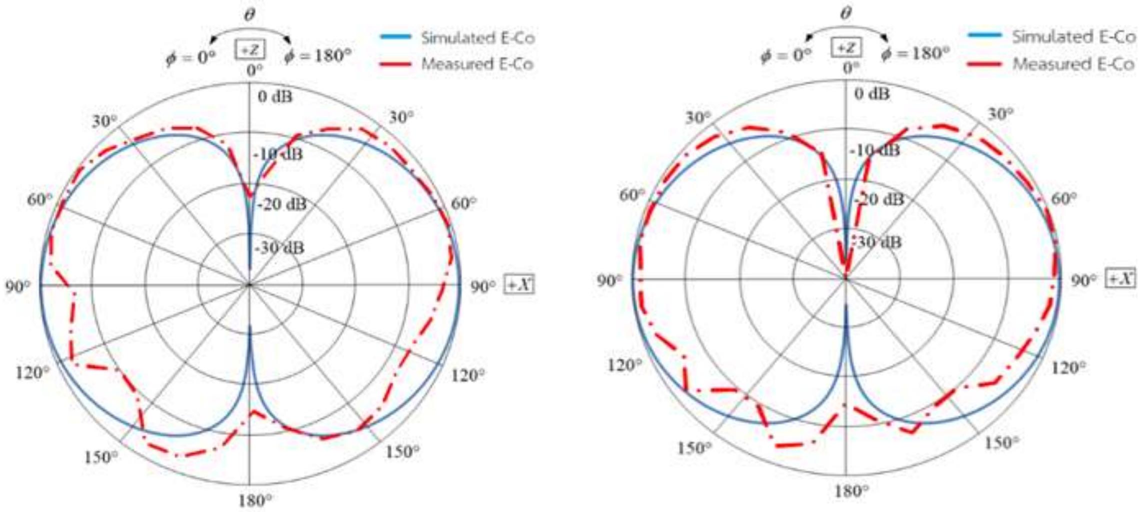
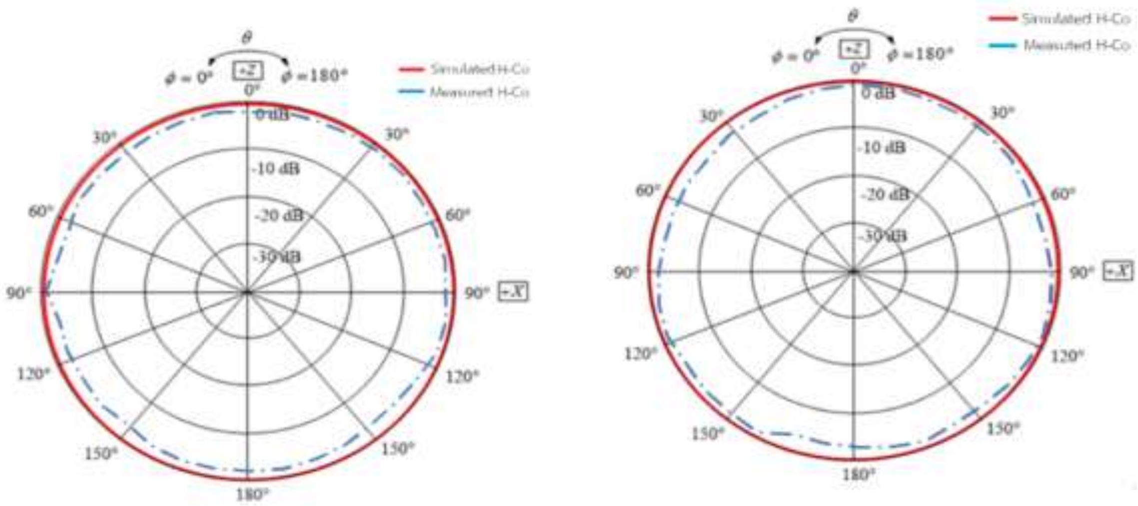


Figure 6. Simulated and measured antenna gain



(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

We have studied a way to extend the operating frequency of planar antenna. The design of a modified UWB antenna for WLAN and UWB applications with coplanar waveguide-fed is proposed in this work. Base on both simulation and experimental results we have confirmed that our designed antennas can be used for WLAN and UWB technology. The antenna can archive a return loss below -10 dB in the 2.10-12.70 GHz frequency band. The antenna archives a broad bandwidth covering entire WLAN and UWB operating band. An average gain of antenna is 3.87dBi and it has a good radiation pattern. Morover, these observations are an important step towards the design of broader banwidth planar antenna over different frequency regimes for next genaretion of wireless communication system.

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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.