Investigation of UWB Antenna Slot Effect

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Abstract— **The increase of mobile applications requires antenna ever smaller. In this paper there are several designs of slotted circular antenna have been purpose for ultra-wide band (UWB) and multiband application in the range of 3.67-10.10GHz with a partial ground. This antenna was fabricated on FR4 substrate with thickness of 1.6mm and relative permittivity (Ɛr) of 5.4. Each of the antenna size is 28.5mm x 25mm x 1.6mm. The antenna slot is then modified to investigate the effect of the slot on ultra-wide band (UWB). The modification cause the different effects where the bandwidth getting bigger; band notch and multiband is produced. The antenna that obtain from parametric study is fabricated and measured. Experimental result are compared with simulated result in this paper.**

Keywords- ***UWB antenna, Slotted circular antenna, Partial ground, Width, Length, Angle.***

I. INTRODUCTION

The Federal Communications Commission allocated the frequency band 3.1-10.6 GHz for the UWB services in 2002 [1]. Since then, UWB systems have been extensively developed. The UWB system for data communications is especially suitable for home networking systems referred as a technology of wireless personal area networks (WPANs). The home networking system is widely used in multimedia devices such as HDTVs, DVDs, cameras, and personal computers through the UWB service channels. The antennas of UWB systems are embedded into these multimedia devices. There are many design requirements for UWB antenna such as wide impedance bandwidth of 3.1−10.6GHz, small size, good omnidirectional radiation pattern and stable gain. For UWB systems, the antenna with a band-notch function is also necessary to provide rejection of the interference from the wireless local area network service (IEEE 802.11a) band, 5.15-5.825 GHz.

Therefore, a band stop filter in this band would be required to reduce the inference between UWB systems and these systems. To avoid adding new circuits to the communication system, band-notching technique can be applied directly to various UWB planar antennas by loading the UWB antenna with a resonant slot at the center frequency of the stop band [2] -[7].

These configurations are based on adding the slot on the radiating patch. The methods to realize a band-notch function have been studied by using the various shaped slots [8]–[10], tuning stubs [11], [12], spurlines [13], embedded resonant cells [14], and parasitic elements [15]. Although these methods are able to achieve a frequency band-notch function, their bandwidth of the notched frequency cannot be easily tuned due to the difficulty in the input impedance match [16].

In this paper, there is an antenna that can be operate in UWB, which can produce another output by adding a slot. Different result is obtained by adjusting the slot on the antenna, where the slot size is being modified according to the length, width and the angle of the slot. In addition to that we study about characterization of the slotted on UWB and compared with simulation and measurement.

II. ANTENNA DESIGN

To begin with, the dimensions of the circular patch were calculated as parameters given:

TABLE 1: Parameter of the antenna

	Calculation	Simulation
Center Frequency	6.85 GHz	6.85 GHz
Substrate Permittivity (Ɛr)	5.40	5.40
Radius of Circular Patch (a)	4.67mm	6.35mm
Thickness of Substrate (h)	1.60mm	1.60mm
Length of Groud (Lg)	18.44mm	12.75mm
Width of Ground (Wg)	21.84mm	25.00mm

Since the frequency is ultra-wide band so the formula for the antenna design as shown in equation (1) – (9):

Center Frequency

$$= \frac{upper\ frequency - lower\ frequency}{2} + lower\ frequency \quad (1)$$

Radius of circular patch

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \tag{2}$$

Where F is:

$$F = \frac{8.791 \times 10^9}{fr\sqrt{\varepsilon r}} \tag{3}$$

Width of Patch

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{4}$$

Effective Dielectric Constant

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left[1 + 12\,\frac{h}{W}\right]^{-\frac{1}{2}} \tag{5}$$

Extension of Length

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \tag{6}$$

Length of Patch

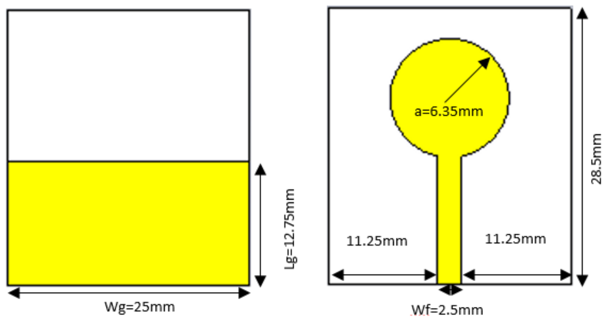
$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{7}$$

Width of Substrate

$$W_g = 6h + W \tag{8}$$

Length of Substrate

$$L_g = 6h + L \tag{9}$$



(a) (b)

Fig. 1 Geometry of Basic design antenna (a) front view (b) back view

III. RESULT AND DISCUSSION

A. *Basic Ultra-wideband Antenna.*

TABLE 2: RESULT OF BASIC UWB ANTENNA

Fig. 1	Bandwidth (GHz)	Gain (dB)		
		3GHz (a)	6GHz (b)	9GHz (c)
	6.432	1.796	2.377	3.654

Fig. 2 shows the S11 parameter result which is the result is still in uwb frequency range which is 3.672GHz to 10.104 GHz and below -10db. Fig. 3 shows the radiaton pattern,at frequency of 3,6 and 9GHz the proposed design an omni-directional. With the increase of frequency, the propose design the antenna still in omni-directional.

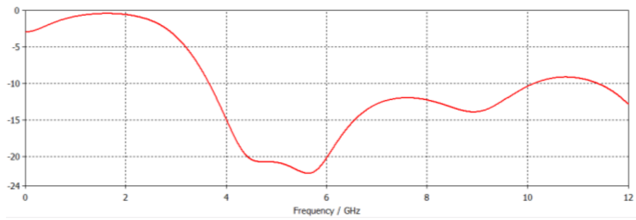
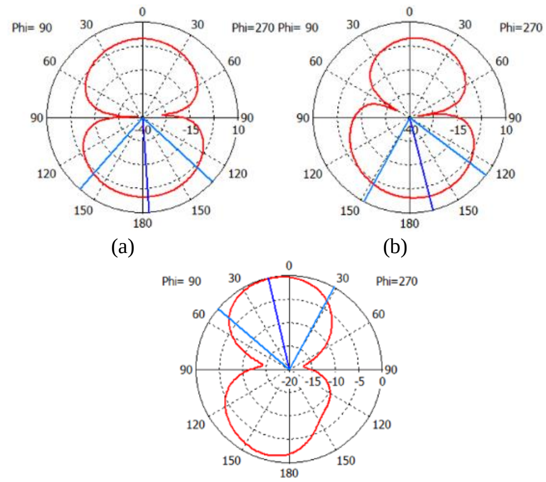


Fig. 2 s11 parameter of basic design antenna.



(a) (b)

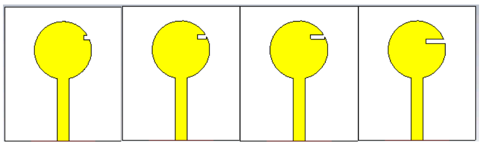
(c)

Fig. 3 Radiation pattern of basic design UWB antenna.

B. *UWB antenna with horizontal slot on the right side with different widths.*

TABLE 3: RESULT OF UWB ANTENNA WITH HORIZONTAL SLOT ON THE RIGHT SIDE.

Fig. 4	Length (mm)	Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	1.2	6.336	1.795	2.366	3.836
b	2.0	6.024	1.795	2.354	4.455
c	3.0	5.388	1.796	2.327	5.063
d	4.0	4.812	1.814	2.199	2.238



(a) (b) (c) (d)

Fig. 4 Configuration of the UWB antenna horizontal slot on the right side.

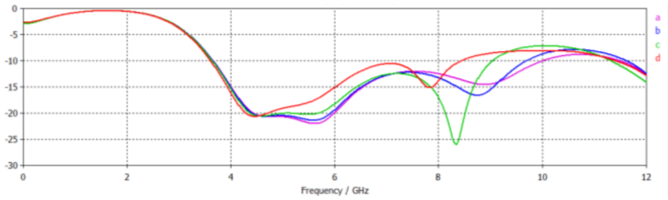


Fig. 5 s11 parameter of antenna with slot on the right side with different width.

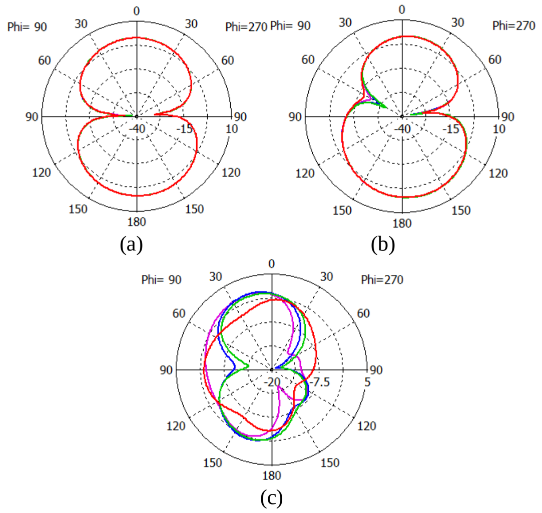


Fig. 6 Radiation pattern of UWB antenna with slot on the right side with different width.

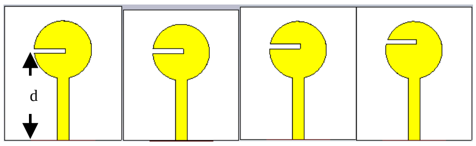
Fig. 5 shows the s11 parameter result of slot effect on UWB antenna. As the graph show when the width of the slot getting bigger the UWB frequency range getting narrower. Fig. 4(a) shows the best result from other designs and the result is shown in table 3. Fig. 6 shows the radiation pattern of each slot on the antenna.

C. UWB antenna with horizontal slot on the left side.

TABLE 4: RESULT OF UWB ANTENNA WITH HORIZONTAL SLOT ON THE LEFT SIDE.

Fig. 7	Distance (mm)	Notch Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	18.5	1.860	1.804	0.876	3.268
b	19.0	1.524	1.807	1.071	3.213
c	19.5	1.704	1.811	1.021	3.233
d	20.0	1.188	1.822	0.610	3.180

Fig. 7 shows the configuration of antenna design with a slot on the left side. Each parameter of the slot is exactly the same but at different distance from the feedline. What can be concluded in the Fig.8 the farther the distances, the narrower bandwidth for the band notch. In this case the best result is Fig. 7(d) as shown in table 4. Fig. 9 shows the radiation pattern.



(a) (b) (c) (d)

Fig. 7 Configuration of UWB antenna with horizontal slot.

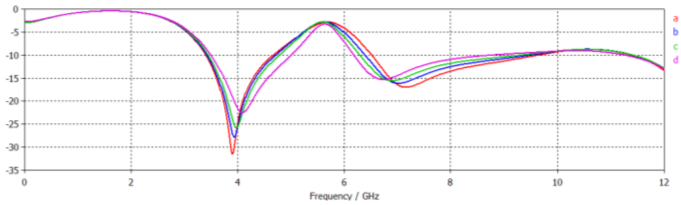


Fig. 8 s11 parameter of antenna with horizontal slot on the left side.

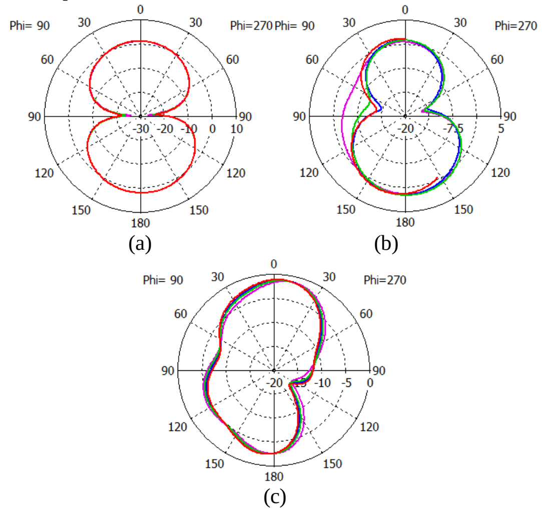


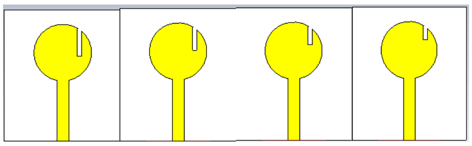
Fig. 9 Radiation pattern of UWB antenna with horizontal slot on the left side.

D. UWB antenna with top-right vertical slot at the right side and different lengths.

TABLE 5: RESULT OF UWB ANTENNA WITH TOP-RIGHT VERTICAL SLOT AT THE RIGHT SIDE.

Fig. 10	Length (mm)	Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	6.0	> 10	1.800	2.167	3.891
b	5.0	> 10	1.797	2.286	3.662
c	4.0	5.304	1.800	2.328	3.966
d	3.0	5.832	1.797	2.356	4.878

Fig. 10 shows the different of slot antenna length in vertically position. Based on Fig. 11 the shortest length of the slot gives bigger bandwidth as the result shown in table 5. Fig. 12 shows the radiation pattern.



(a) (b) (c) (d)

Fig. 10 Configuration of UWB antenna with top-right vertical slot.

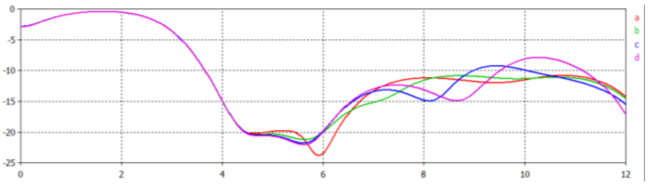


Fig.11 s11 parameter of antenna with top- right vertical slot.

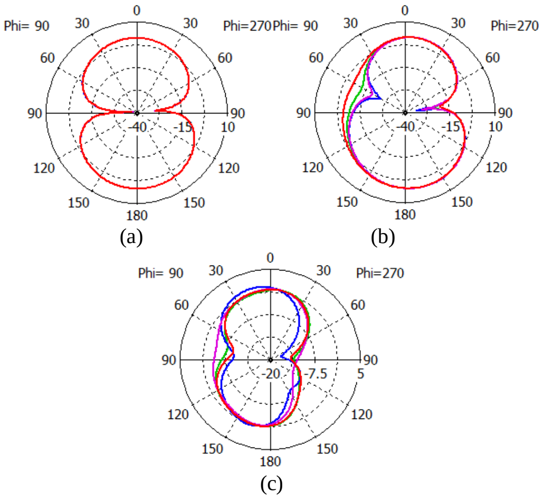
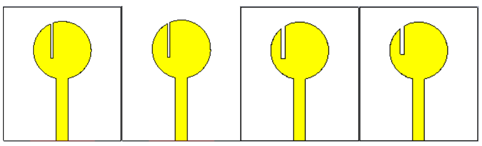


Fig. 12 Radiation pattern of UWB antenna with top-right vertical slot.

E. UWB antenna with top-left vertical slot with different lengths and widths.

TABLE 6: RESULT OF UWB ANTENNA WITH TOP-LEFT VERTICAL.

Fig. 13	Length x Width (mm)	Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	7.6 x 0.6	6.720	1.803	2.358	3.994
b	7.3 x 0.4	7.005	1.731	2.305	4.007
c	7.0 x 1.0	> 10	1.799	2.349	3.966
d	6.0 x 1.0	> 10	1.799	2.189	3.912



(a) (b) (c) (d)

Fig. 13 Configuration of UWB antenna with top-left vertical slot.

Fig. 13 shows top-left verticl slot of the patch.Fig. 14 shows that design Fig. 13(b) obtained the wider bandwidth in UWB range. Table 6 shows that is obviously when the length and width of the slot decreasing the bandwidth getting bigger, while the bandwidth will be out of range when increasing the size of width. Fig. 15 shows the radiation pattern.

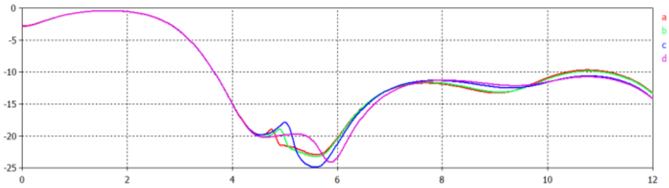


Fig. 14 s11 parameter of antenna with top-left vertical slot.

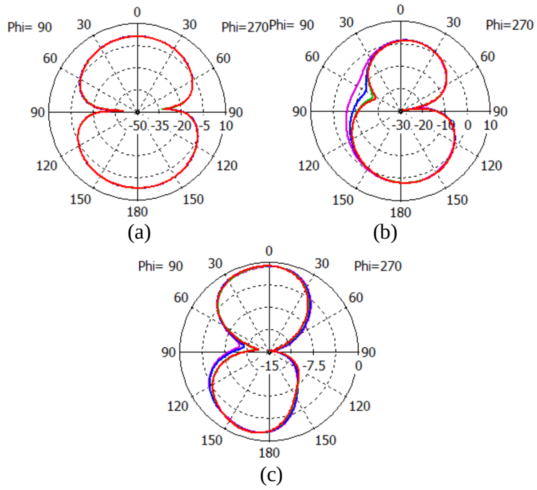
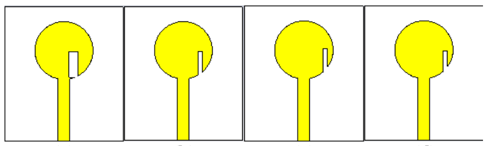


Fig. 15 Radiation pattern of UWB antenna with top-left vertical slot.

F. UWB antenna with bottom-right vertical slot with different lengths and widths.

TABLE 7: RESULT OF UWB ANTENNA WITH BOTTOM-RIGHT VERTICAL SLOT.

Fig. 16	Length x Width (mm)	Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	5.5 x 2.0	0.660	1.666	1.627	3.039
b	5.0 x 1.0	2.988	1.776	1.774	2.826
c	4.8 x 1.0	3.552	1.793	2.138	2.204
d	4.3 x 1.0	3.240	1.793	2.138	2.204



(a) (b) (c) (d)

Fig. 16 Configuration of UWB antenna with bottom- right vertical slot.

Fig. 16 shows the changes of the lengths and widths value for the slot antenna and being shifted slowly to the right side. Result in Fig. 17 shows wider width of the slot gives a narrower bandwidth, while the other with narrow slot than Fig. 16(a) produce a wider bandwidth and the length need to be decrease to. Radiation are shown in Fig. 18.

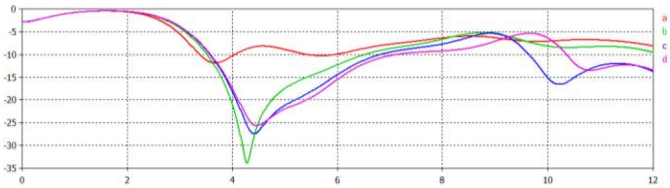


Fig. 17 s11 parameter of antenna with bottom- left vertical slot.

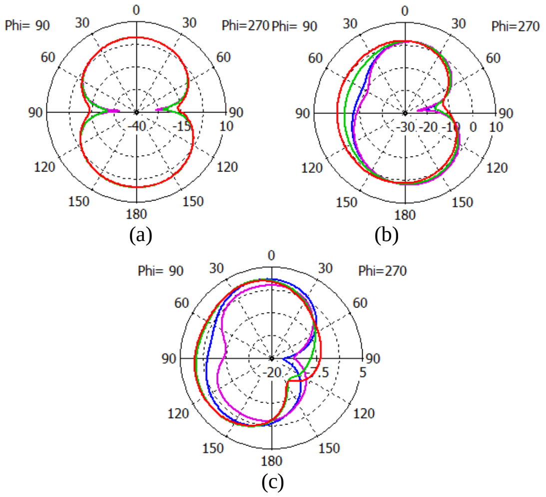


Fig. 18 Radiation pattern of UWB antenna with bottom-right vertical slot with different lengths and widths.

G. UWB antenna with bottom- left vertical slot with different lengths and widths.

TABLE 8: RESULT OF UWB ANTENNA WITH BOTTOM-LEFT VERTICAL SLOT.

Fig. 19	Length x Width (mm)	Bandwidth (GHz)	Gain (dB)		
			3GHz	6GHz	9GHz
a	3.9 x 0.6	5.688	1.798	2.301	3.784
b	4.4 x 0.4	3.708	1.794	2.248	2.513
c	4.9 x 1.0	3.180	1.789	2.102	2.439
d	5.3 x 0.4	2.964	1.775	1.863	3.602

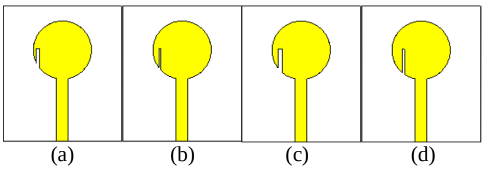


Fig. 19 Configuration of UWB antenna with bottom- left vertical slot.

Fig. 19 shows UWB antenna with a narrow slot at the bottom part of the patch. Fig. 20 shows in order to get the indicated bandwidth, the length of slot needs to be smaller as shown in table 8. .The radiation pattern shows in Fig.21.

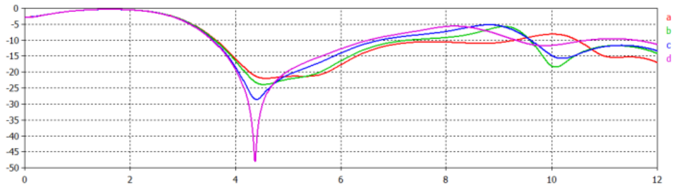


Fig. 20 s11 parameter of antenna with-bottom vertical slot.

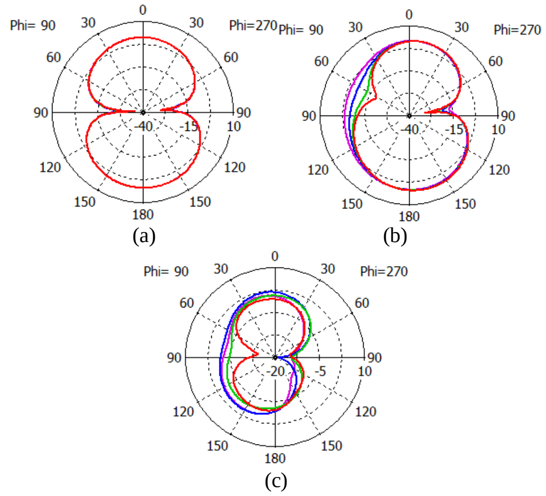


Fig. 21 Radiation pattern of UWB antenna with bottom- left vertical slot with different lengths and widths.

H. UWB antenna with 30 degrees angle different lenghts of slot.

TABLE 9: RESULT OF UWB ANTENNA WITH 30 DEGREES ANGLE.

Fig. 22	Distance (mm)	Length x Width (mm)	Notch frequency (GHz)	Gain (dB)		
				3GHz	6GHz	9GHz
a	12.0	4.0 x 0.4	-	1.803	2.278	3.075
b	11.5	5.0 x 0.4	-	1.804	2.139	3.467
c	11.0	6.0 x 0.4	0.168	1.796	1.940	3.697
d	10.5	7.0 x 0.4	0.240	1.807	2.162	3.713

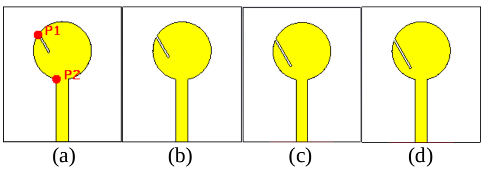


Fig. 22 Configuration of UWB antenna with different lengths.

Table 9 shows that Fig. 22(c) is the best result for UWB antenna for the notch frequency at frequency 5.4GHz - 5.568GHz as shown in Fig. 23. Fig. 24 shows the radiation pattern.

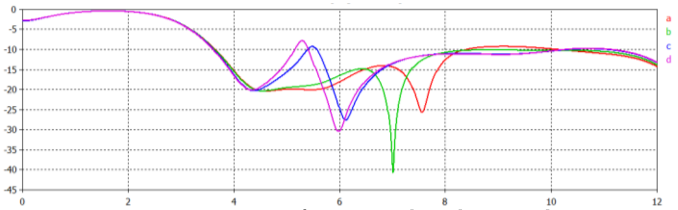


Fig. 23 s11 parameter of antenna with 30 degree angles.

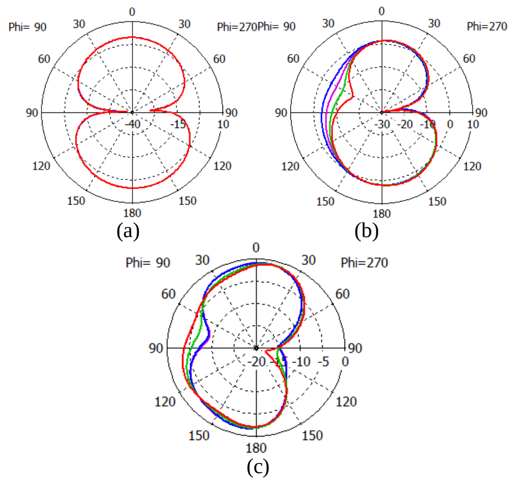
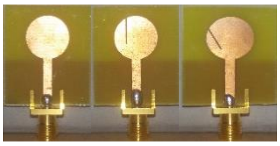


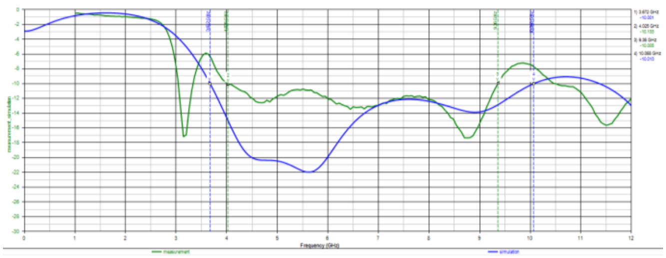
Fig. 24 Radiation pattern with 30 degrees angle different lenghts of slot.

I. Fabricated.

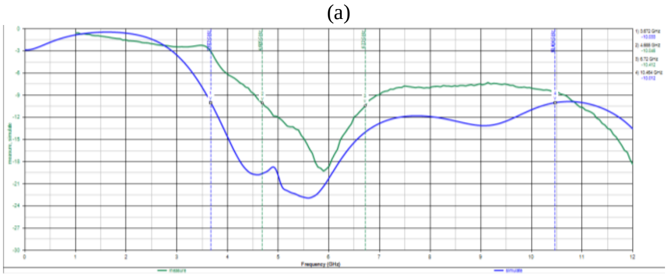


(a) (b) (c)

Fig. 25 shows the fabricated UWB antenna (a) Basic design antenna (b) UWB antenna with horizontal slot (c)UWB antenna with angle slot.

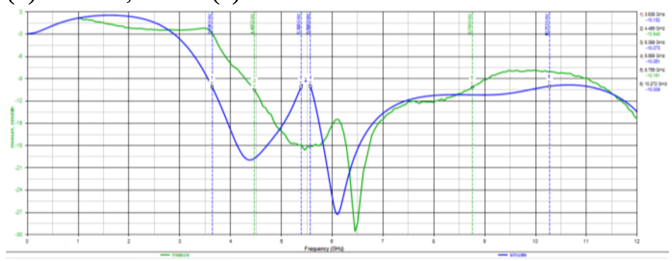


(a)



(b)

Fig. 29 shows the comparison of the simulation and measurement of return loss (s11). The percentage error of simulation and measurement for Fig 29(a) is 16.85%, Fig. 29(b) 69.99%, and 29(c) is 64.52%.



(c)

Fig. 29 shows the measuremt and simulation result for (a) Basic design antenna (b) UWB antenna with horizontal slot (c) UWB antenna with angle slot.

IV. Conclusion

A UWB patch antenna has been propose and implement in this paper. The UWB frequency can be wider and narrower by adjusting the width and length of the slot of the antenna depends on the side of the slot that will be placed. Band notched frequency also can be obtain by adjusting the degree of the slot and also depending to the position of the slot to. The notch frequency can be controlled by adjusting or change the value of the slot length. The obtain result shows that the propose antenna has a small size and offer a broad bandwidth. These features and the small size of the antenna make it attractive for future UWB application.

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