1

A SMALL UWB ANTENNA WITH SLOTTED GROUND PLANE

Yusnita Rahayu
Tharek Abd Rahman
Razali Ngah

1.1 INTRODUCTION

There is always an increasing demand for smaller antenna size, greater capacities and transmission speeds, which will certainly require more operating bandwidth in the near future. Research works on UWB antennas have been reported in many literatures. Many techniques to broaden the impedance bandwidth of small antennas and to optimize the characteristics of broadband antennas have been widely investigated. Some examples of the techniques used to improve the impedance bandwidth of the planar monopole antenna include the use of beveling technique, cutting notches at bottom, and a dual feed. The radiators may be slotted to improve the impedance matching, especially at higher frequency.

In this chapter, a small UWB antenna is presented. The effect of two notches cut at the bottom edges of patch antenna to impedance bandwidth is discussed. Slotted or notched ground plane is also taken into consideration. This modified truncated ground plane acts as an impedance matching element to control the impedance bandwidth of a rectangular patch. This is because the truncation creates a capacitive load that neutralizes the inductive nature of the patch to produce nearly-pure resistive input impedance.

1.2 ANTENNA GEOMETRY

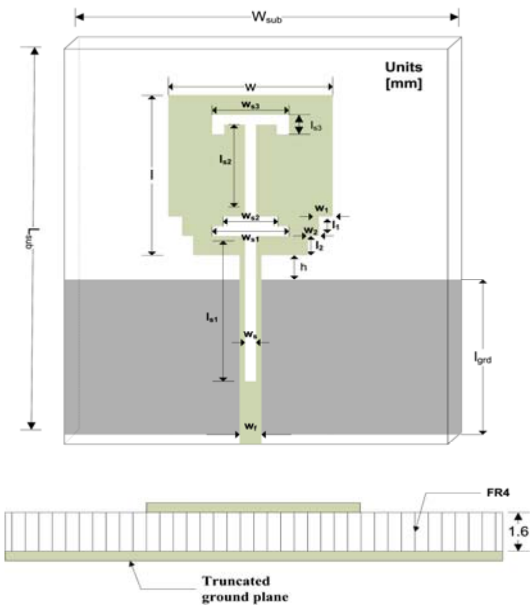
This proposed antenna originates from conventional rectangular monopole and is realized by adding T slots for both patch and feeding strip. To design this UWB antenna, three techniques have been applied to the proposed antenna: (i) two notches placed at the two lower corners of the patch, (ii) a partial ground plane and (iii) T slots, which can lead to a good impedance matching.

By selecting these parameters, the proposed antenna can be tuned to operate in the 3.2 GHz to 10.5 GHz frequency range. The simulation results are obtained from Zeland simulation, which are based on the FDTD method.

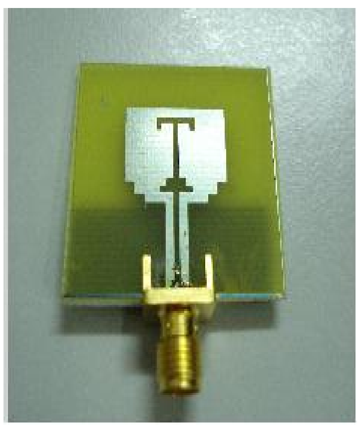
Figure 1.1(a) and Figure 1.1(b) show the geometry and photograph of the proposed T slot UWB antenna, respectively. As shown in Figure 1.1(a), the antenna has a compact dimension of 30 mm x 30 mm (W_{sub} x L_{sub}), fabricated on FR4 substrate with thickness of 1.6 mm and has a relative dielectric constant (ε_r) of 4.7. The radiator is fed by a microstrip line of 3 mm width (w_f). On the front surface of the substrate, a rectangular patch with size of 15 mm x 12 mm (w x l) is printed. The two notches size of 1.5 mm x 12 mm (w_1 x l_1) and 1 mm x 9 mm (w_2 x l_2) are at the two lower corners of radiating patch.

The distance of h between the rectangular patch to ground plane printed on the back surface substrate is 1 mm, and the length (l_{grd}) of truncated ground plane of 11.5 mm. The excitation is a 50 Ω microstrip line printed on the partial grounded substrate. The slot size of w_s, w_{s1}, w_{s2}, w_{s3}, l_{s1}, l_{s2}, l_{s3} are 1, 5, 3, 6, 11, 7, 2 mm, respectively.

The effect of two notches at the bottom patch, T slots and slotted ground plane to the input impedance will be discussed in the next sections.



(a) Geometry and coordinate system



(b) Prototyped of the antenna

Figure 1.1 Geometry and photograph of proposed UWB antenna

1.3 THE EFFECT OF NOTCHES TO THE INPUT IMPEDANCE

Cutting notches at the bottom techniques are aimed to change the distance between the lower part of the planar monopole antenna and the ground plane in order to tune the capacitive coupling between the antenna and the ground plane, thereby wider impedance bandwidth can be achieved. The size of notches should be properly designed while still maintaining the antenna's performance.

Figure 1.2 represents the simulated return loss curves of T slot antenna before and after cutting at the bottom edges. The optimized feed gap is 0.5 mm above the ground plane obtained from simulation. The ground plane as an impedance matching circuit and also it tunes the resonant frequencies. It is noted in Figure 1.2 that the first resonance occurs at 5.5 GHz for the patch with two notches at the bottom and 6 GHz for the patch with one notch. In fact, the quarter wavelength at this first resonant frequency (5.5 GHz) just equals to the length of the antenna and optimized by the simulation software.

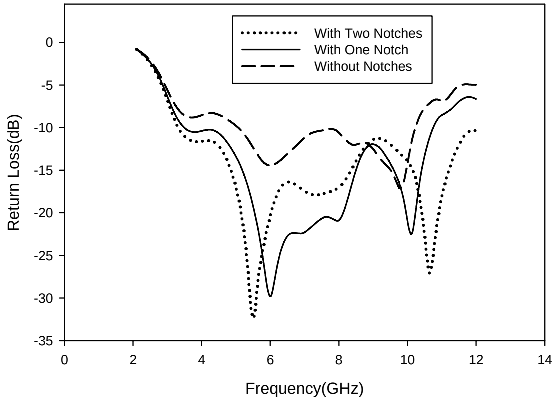


Figure 1.2 The simulated return loss of antenna by varying the notches at the bottom edges

The T slot antenna without notches at the bottom edges only provides the fractional bandwidth of 68%. This fractional bandwidth increases to 102% by cutting one notch at the bottom, while the maximum fractional bandwidth reach to 112% by applying two notches at the bottom of the patch antenna. Hence, the proper selection in the size of notches leads to the UWB characteristic.

1.4 THE EFFECT OF SLOT TO THE INPUT IMPEDANCE

Simulated return loss of the proposed antenna with and without T slot obtained using FDTD is shown in Figure 1.3. The T slots on the patch and the feed-line provide the significant improvement of return losses especially at higher frequencies and widened the bandwidth. The wideband behaviour is due to the fact that the currents along the edges of the slots introduce an additional resonance, which, in conjunction with the resonance of the main patch, produce an overall broadband frequency response characteristic.

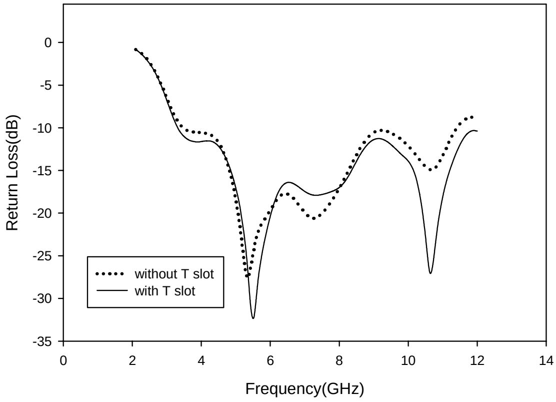


Figure 1.3 The simulated return loss of antenna with and without T slot

The slots also appear to introduce a capacitive reactance which counteracts the inductive reactance of the feed. Thus, the bandwidth broadening comes from the patch and T-slots, coupled together to form two resonances.

1.5 THE EFFECT OF SLOTTED GROUND PLANE TO THE INPUT IMPEDANCE

As mentioned previously, the modified truncated ground plane acts as an impedance matching element to control the impedance bandwidth of a T slot antenna. The efficient technique to determine the size of notches in the ground plane is by calculating the optimum feed gap between the ground plane and the bottom patch required without adding the notches. Then, the size of notches can be adjusted with respect to the optimum distance.

Figure 1.4 presents the geometry of staircase slotted ground plane. The width of this slotted ground plane is set to 0.5 mm. Lengths of slots are N1, N2, and N3 of 15, 12, and 9 mm, respectively.

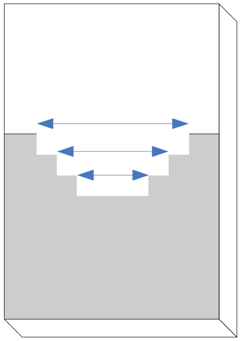


Figure 1.4 The geometry of slotted ground plane

Figure 1.5 and Figure 1.6 show the simulated return loss for various slots on the ground plane. In Figure 1.5, the patch radiator antenna is cut only one notch at the bottom edge. While, in Figure

1.6 there are two notches cut at the bottom of patch. It is clearly shown from the graphs, by cutting more slots on the ground plane, its return loss are getting worst. Thus, the gap of patch radiator to ground plane is critically effect to the input impedance of antenna. To improve its return loss, the length of slots ground plane need to be adjusted.

By varying the lengths of slots of ground plane, it is possible to tune the impedance matching as shown in Figure 1.7. From the simulation, the lengths of slots of N1, N2, N3 of 10, 7, 3 mm give the best return loss.

Figure 1.8 and Figure 1.9 show the comparison simulated return loss and VSWR for antenna with and without slotted ground plane. The return loss of antenna with slotted ground plane is varying around 15 to 20 dB with VSWR less than 2.

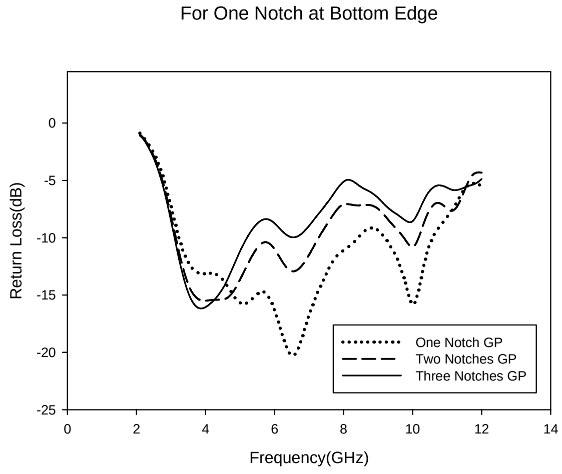


Figure 1.5 The simulated return loss of slotted ground plane with one notch cut at bottom of patch radiator

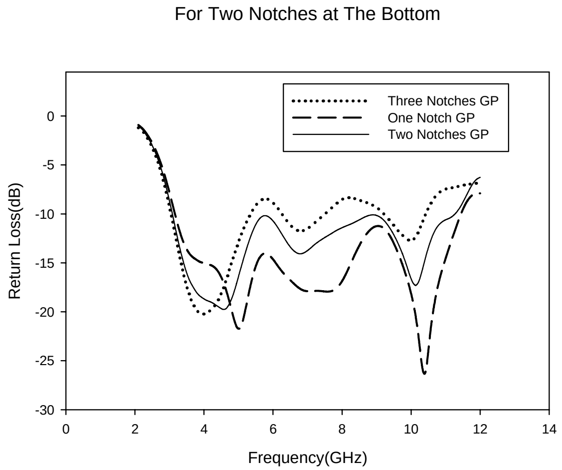


Figure 1.6 The simulated return loss of slotted ground plane with two notches cut at bottom of patch radiator

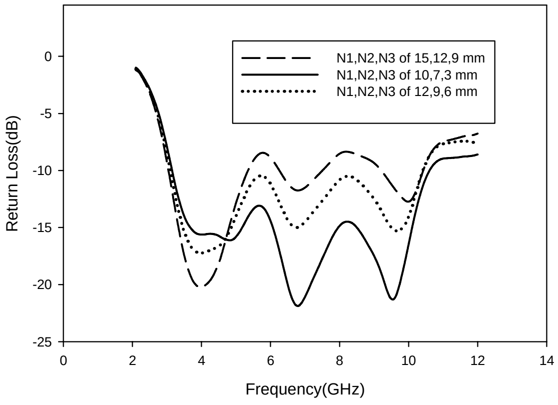


Figure 1.7 The simulated return loss of various lengths of slots ground plane

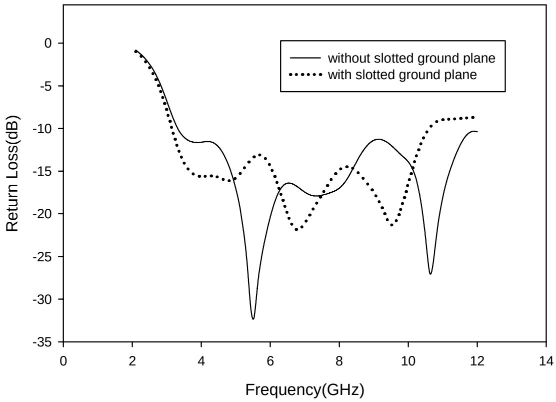


Figure 1.8 The comparison simulated return loss with and without slotted ground plane

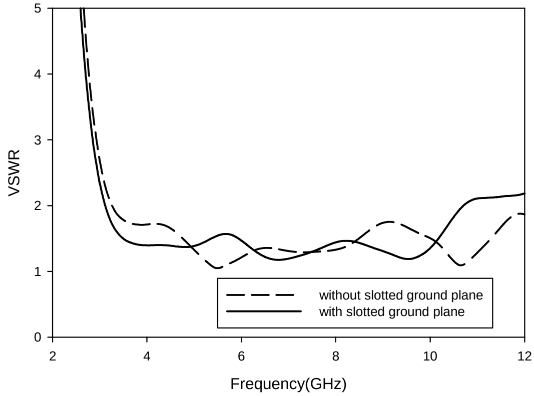


Figure 1.9 The simulated VSWR for with and without slotted ground plane

Figure 1.10 depicts the measured return loss and simulated return loss of antenna with feed gap of 1 mm above the ground plane. In this initial prototype, the ground plane is designed without slotted. The measured resonance frequencies are shifted from the simulated result but they are still covering the UWB bandwidth requirement of 3.2 to 10.5 GHz with respect to -10 dB. The return loss curves of frequency ranges above 10.5 GHz are getting worst.

The measurements are done by using a coaxial port which is soldered at the bottom edge of microstrip line. However, some differences in the simulated and measured results are expected, since in the simulation model discrete and not coaxial port is used. In reality the coaxial cable has a considerable effect, especially the length of its inner conductor, which is connected to the input of the antenna, creating an additional inductance.

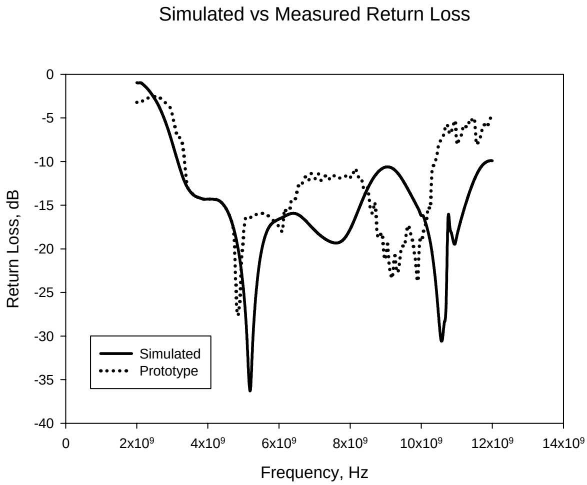
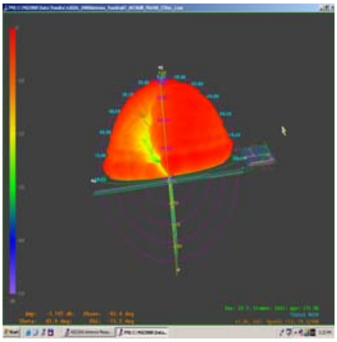


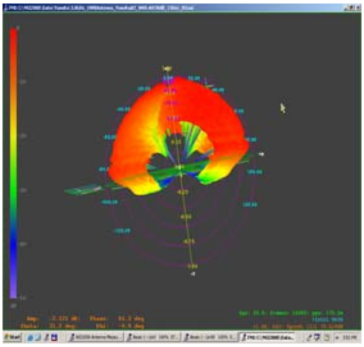
Figure 1.10 The simulated and measured return loss

1.6 RADIATION PATTERNS

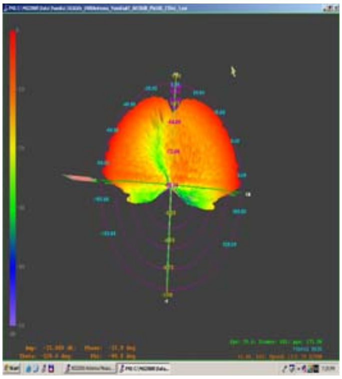
Figure 1.11 and Figure 1.12 presents the measured and simulated radiation pattern for proposed antenna, respectively. Figure 1.11, the 3D measured radiation pattern is for antenna without slotted ground plane, while in Figure 1.12, the simulated radiation pattern is for antenna with slotted ground plane. The radiation patterns are measured at frequencies 4, 5.8 and 10.6 GHz. The elevation pattern at phi 0 and 90 degrees, respectively. The radiation patterns for both types of ground plane are nearly omni directional.



(a) 4 GHz

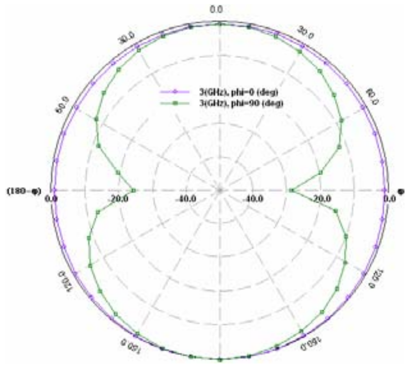


(b) 5.8 GHz

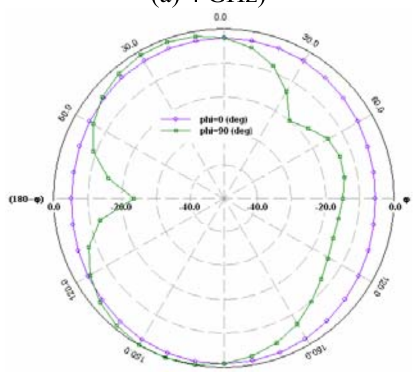


(c) 10.6 GHz

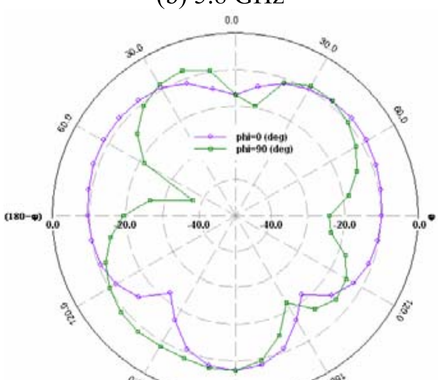
Figure 1.11 The measured radiation pattern for antenna without slotted ground plane



(a) 4 GHz)



(b) 5.8 GHz



(c) 10.6 GHz

Figure 1.12 The simulated radiation pattern for antenna with slotted ground plane

1.7 CONCLUSION

This chapter presents a small UWB antenna with and without slotted ground plane. Two notches, T slot and slotted ground plane are implemented to obtain the UWB characteristics. The measured return loss of antenna exhibits an ultra wide impedance bandwidth of 3.2 to 10.5 GHz with respect to -10 dB. The slotted on the ground plane improves the return loss of overall frequency range. The measured radiation pattern has shown an omni directional pattern. The contents of this chapter has been presented and published in the proceeding of International Conference on Computer and Communication Engineering (ICCCE 2008), May 13-15, 2008.

REFERENCES

Zhi Ning Chen, et al, Planar antennas, *IEEE Microwave Magazine*, Vol. 7, No. 6, Page(s): 63-73, December 2006.

Giuseppe R. and Max J. Ammann, A novel small wideband monopole antenna, *Loughborough Antennas & Propagation Conference (LAPC)*, Loughborough University, UK, 11-12th April 2006.

Seok H. Choi, et al, A new ultra-wideband antenna for UWB applications, *Microwave and Optical Technology Letters*, Vol. 40, No.5, pp. 399-401, 5th March 2004.

A. A. Eldek, Numerical analysis of a small ultra wideband microstrip-fed tap monopole antenna, *Progress In Electromagnetic Research*, PIER 65, pp.59-69, 2006.

Serge Boris, Christophe Roblin, and Alan Sibille, Dual stripline fed metal sheet monopoles for UWB terminal applications, *ANTEM*, Saint Malo, France, 15-17th June 2005.

Hassan Ghannoum, Serge Bories, and Raffaele D'Errico, Small-size UWB planar antenna and its behaviour in WBAN/WPAN applications, *IET seminar on Ultra* *wideband System, Technologies and Applications*, April 2006.

T. Huynh and K. F. Lee, Single-layer single-patch wideband microstrip antenna, *Electronics Letters*, Vol. 31, No. 16, 3rd August 1995.

Harmuth, H. F. Selective Reception of Periodic Electromagnetic Waves With General Time Variation. *IEEE Transactions on Electromagnetic Compatibility*. EMC-19. 1977. 137-144.