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A small novel ultra wideband antenna with slotted ground plane

[1]Yusnita Rahayu , [2]Razali Ngah and [2]Tharek Abd. Rahman
[1]Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Kuantan, Pahang
[2]Wireless Communication Centre (WCC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Johor
Malaysia

1. Introduction

A few years after the early investigation on ultra wideband (UWB) wireless system, considerable research efforts have been put into the design of UWB antennas and systems for communications. The UWB technology brings the convenience and mobility of wireless communications with higher data rates. Designed for short range, wireless personal area networks (WPANs), UWB is the leading technology for freeing people from wires, enabling wireless connection of multiple devices for transmission of video, audio and other high bandwidth data. UWB short-range radio technology complements other longer-range radio technologies such as WiFi, WiMAX, and cellular wide area communications. Freescale Semiconductor was the first company to produce UWB chips in the world (L. Jianxin, 2006). Its XS110 solution has been commercialized to the market. It provides full wireless connectivity delivering more than 110 Mbps data transfer rate supporting applications such as streaming video, streaming audio, and high rate data transfer at very low levels of power consumption.

Through literature survey, there are two vital design considerations in UWB radio systems. One is radiated power density spectrum shaping must comply with certain emission limit mask for coexistence with other electronic system (FCC, 2002). Another is that the design source pulses and transmitting/receiving antennas should be optimal for performance of overall systems (Z.N. Chen et al., 2004). Emission limits will be crucial considerations for the design of source pulses and antennas in UWB systems. The FCC regulated the spectral shape and maximum power spectral density (-41.3 dBm/MHz) of the UWB radiation in order to limit the interference with other communication systems.

Even though the UWB technology has experienced many significant developments in recent years, however, there are still challengers in making this technology live up to its full potential. The main challenge in UWB antenna design is achieving the extremely wide impedance bandwidth while still maintaining high radiation efficiency. By definition, an UWB antenna must be operable over the entire 3.1 GHz – 10.6 GHz frequency range (FCC, 2002). Therefore, the UWB antenna must achieve almost a decade of impedance bandwidth, spanning 7.5 GHz. The high radiation efficiency is also required especially for UWB

applications to ensure the transmit power spectral density requirement achieved. Conductor and dielectric losses should be minimized in order to maximize radiation efficiency. High radiation efficiency is imperative for an UWB antenna because the transmit power spectral density is excessively low. Therefore, any excessive losses incurred by the antenna could potentially compromise the functionality of the system.

In addition, a nearly omni-directional radiation pattern is also desirable in that it enables freedom in the receiver and transmitter location. This implies maximizing the half power beam-width and minimizing directivity. It is also highly desirable that the antenna feature low profile and compatibility for integration with Printed Circuit Board (PCB) (L. Jianxin, 2006).

2. UWB Antenna Design Consideration

Antennas play a critical role in the UWB communication systems and the choice of a specific UWB antenna design has to be based on the application main requirements. Currently, modern telecommunication systems require antennas with wider bandwidth and smaller dimensions than conventionally possible. This has initiated antenna research in various directions, one of which is by using UWB antennas.

Today the state of the art of UWB antennas focuses in the microstrip, slot and planar monopole antennas with different matching techniques to improve the bandwidth ratio without loss of its radiation pattern properties (M.A. Peyrot Solis et al., 2005). The expected antennas are small size, omni-directional patterns, and simple structure that produce low distortion but can provide large bandwidth.

In the past, one serious limitation of microstrip antennas was the narrow bandwidth characteristic, being 15% to 50% that of commonly used antenna elements such as dipoles, and slots (J.F. Zurcher & F.E. Gardiol, 1995). This limitation was successfully removed achieving a matching impedance bandwidth of up to 90%. To increase the matching impedance bandwidth ratio it was necessary to increase the size, height, volume or feeding and matching techniques (R. Garg et al., 2001). Variety of matching techniques have been proposed in the literature reviews, such as the use of slot (Albert K,Y. Lai et al., 1992), (Seok H. Choi et al., 2004), bevel or taper at the bottom of patch (E. Guillanton et al., 1998), notch and partial ground plane (Seok H. Choi et al., 2004) and dual feed (Z.N. Chen et al., 2006), (S. Boris et al., 2005), (H. Ghannoum et al., 2006). Radiators may be slotted to improve the impedance matching, especially at higher frequency (Z.N. Chen et al., 2006). Fractal antenna may also be used to obtain low VSWR UWB performance (Khan, S. N. et al., 2008).

The planar monopole antennas are promising antennas for UWB applications due to their simple structure, low profile, easy to fabricate and UWB characteristics with nearly omni-directional radiation patterns (L. Jianxin, 2006), (N.P. Agrawall et al., 1998), (Chun Y. Wu et al., 2005). Planar monopole antennas feature broad impedance bandwidth but somewhat suffer high cross polarization radiation levels. The large lateral size or asymmetric geometry of the planar radiator causes the cross-polarized radiation. Fortunately, the purity of the polarization issue is not critical, particularly for the antennas used for portable devices (Z.N. Chen, 2006). There are several UWB planar antenna designs, including planar half disk antenna (T. Yang & W. A. Davis, 2004), planar horn antenna (S. H. Lee et al., 2005), and metal plate antenna (K. L. Wong et al., 2004), have been reported.

The critical issue in this UWB antenna design is the size of the antenna for portable devices. The reduction in antenna size presents various problems due to the performance penalties in antenna characteristics, such as impedance, efficiency, and bandwidth. Therefore, to miniaturize the antennas capable of providing ultra wide bandwidth for impedance matching and acceptable gain will be a challenging task. Small antennas are defined as those which have smallness in terms of size, wavelength, and function, and they are divided into four categories (K. Hirasawa & M. Haneishi, 1992). The first is electrically small antennas, which have a very small size compared to the wave length (λ). The second is physically constrained small antennas, which are not necessary electrically small, but are shaped in such a way that considerable size reduction is achieved in one plane. The third is physically small antennas, which have dimensions regarded as small in a relative sense. The last is functionally small antennas, which are antenna systems that achieved additional functions without increasing size. This proposed antenna meets those four categories as a small antenna. Its size is less than a wavelength, compact size in one plane, considerable smaller size compared to the antennas sizes in the references listed (Z.N. Chen et al., 2006), (Giuseppe R. & Max J. Ammann, 2006), (Seok H. Choi et al., 2004), (A. A. Eldek, 2006), (S. Boris et al., 2005), (H. Ghannoum et al., 2006), (T. Huynh & K. F. Lee, 1995), (Mayhew Ridgers, G., 2004), (Y.X. Guo et al., 1998) and suitable for many UWB applications.   The T slot for both patch and feeding strip is as a novelty design in terms of slot type.

The theory characteristic modes are also used to design and optimise the proposed UWB antenna. From the study of the behavior of characteristic modes, important information about resonant frequency and the bandwidth of an antenna can be obtained. The current behavior of the antenna are investigated in order to obtain new slotted UWB antenna.

3. T Slotted UWB Antenna

In order to obtain the ultra wide bandwidth, omni-directional radiation pattern, and small size antenna, four matching techniques are applied to the proposed UWB antennas, such as the use of slots, the use of notches at the bottom of patch, the truncation ground plane, and the slotted ground plane. All these techniques are applied to the small UWB antenna without degrading the required UWB antenna's performance. The size of slots and notches are critically affect to the impedance bandwidth. The distance between truncation ground plane to the bottom of the patch is as matching point, where it determines the resonance frequency. To ensure the broad badwidth can be obtained, the proper designs on those parameters are required. The effect of notches, slot, truncation and slotted ground plane to the antenna's performance will be discussed in next section in order to develop a design methodology to control the matching bandwidth of antenna.

3.1 Antenna Geometry

This proposed antenna, shown in Figure 1, originates from conventional rectangular monopole and is realized by adding T slot for both patch and feeding strip. The antenna has a compact dimension of 30 mm x 30 mm (W_{sub} x L_{sub}), designed on FR4 substrate with thickness of 1.6 mm and relative dielectric constant (ε_r) of 4.7.
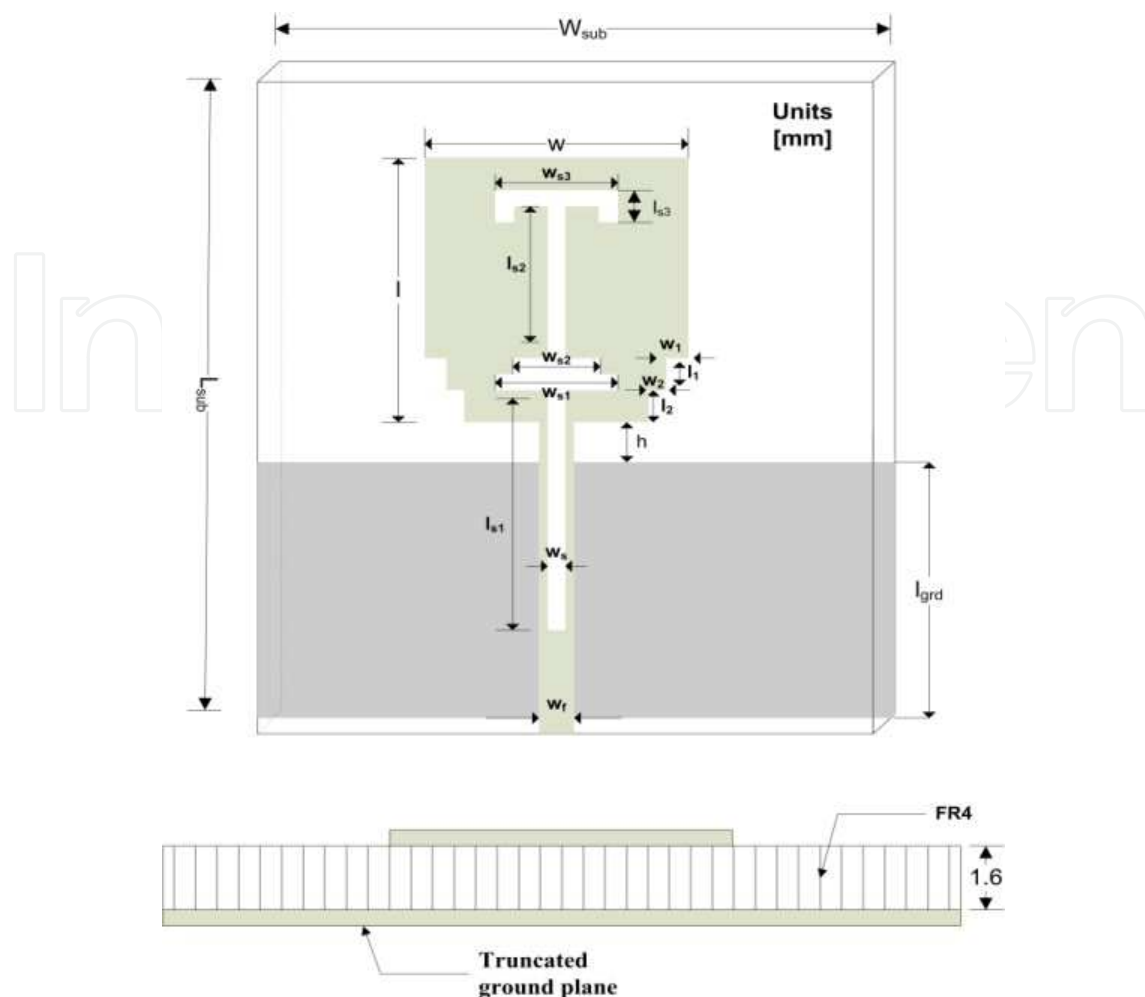
Fig. 1. Geometry of T slotted UWB antenna

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 main objective in this antenna design is to reduce the size. Obviously, it is difficult to do this without degrading the antenna performance but the main question is whether this degradation is acceptable or not for a given application.

3.1.1 Effect of notches at the bottom of patch radiator

Figure 2 shows the rectangular monopole antenna with various steps notches cutting at the bottom edge. The feed width (w_f) is set to be 3 mm and the feed length (f_l) is set to be 12.5 mm. The first and third notch dimensions are (1 x 1) mm² and the second notch is (1 x 1.5) mm². 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. This technique is confirmed by the simulation result shown in Figure 3.
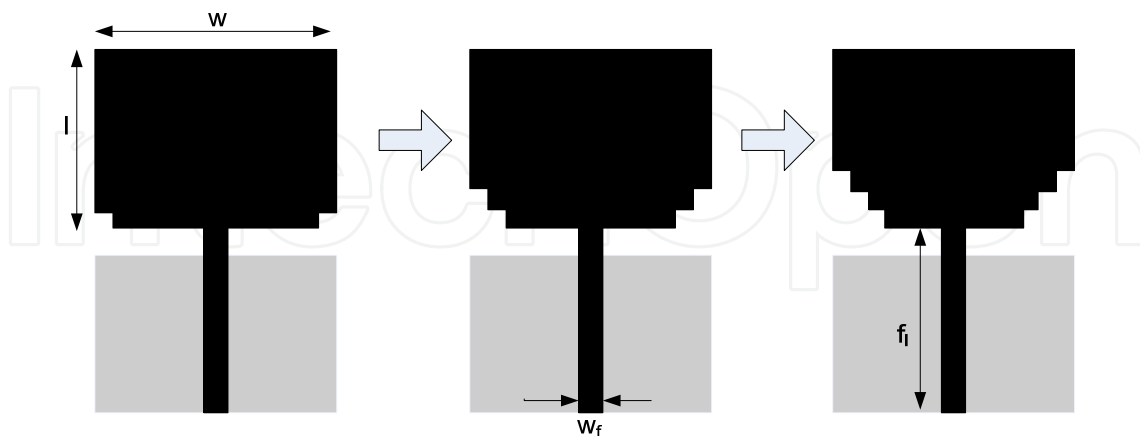

Fig. 2. Various steps notches cutting at the bottom of patch radiator
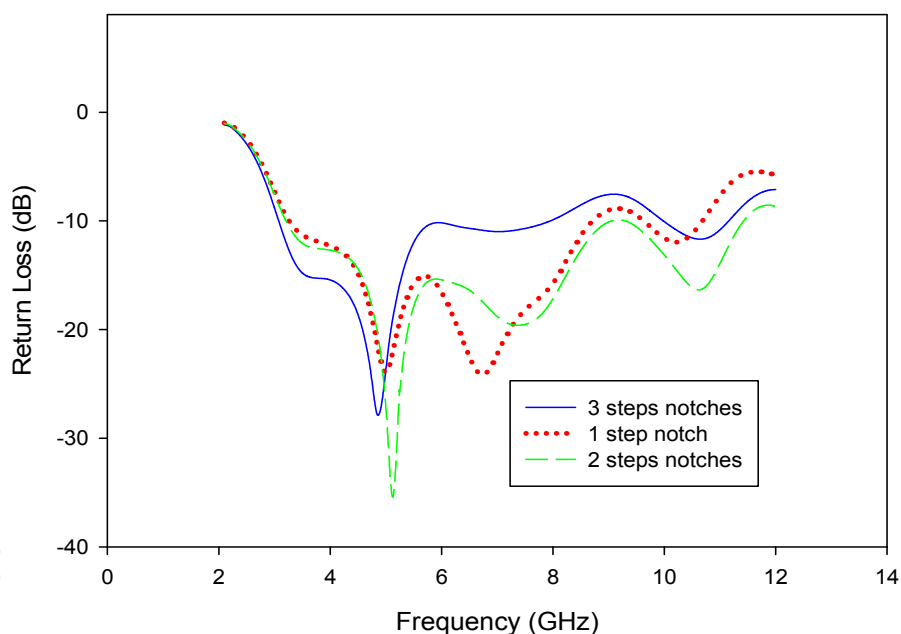

Fig. 3. Simulated return loss of various steps notches cutting at the bottom of patch radiator

As shown in Figure 3, the return loss of antenna with three steps notches cutting at the bottom edge is the worst curve with respect to -10 dB. This is due to its notch variation is more abrupt, thus the bandwidth is smaller. For the two steps notches, the return loss curve is the best, covering 3.17 GHz to 11.5 GHz of frequency ranges. While one step notch at the bottom provides a good matching bandwidth at below 9 GHz and start degrading at higher frequencies.

There is an important phenomenon in Figure 3 at the first resonance occurs at 5.2 GHz for the patch with two notches at the bottom. When the antenna has only one and three notches at the bottom, the first resonances are 4.9 GHz and 5.1 GHz, respectively. Both first

resonances are shifted slightly, but still not far from 5.2 GHz. In fact, the quarter wavelength at this first resonant frequency (5.2 GHz) just equals to the length of the antenna and optimized by the simulation software.

Notches	f_L (GHz)	f_U (GHz)	Absolute BW (GHz)	Fractional BW (%)
0	3.56	9.05	5.49	87
1	3.27	8.7	5.43	90
2	3.17	11.5	8.33	113
3	3.07	7.98	4.91	88

Table 1. The effect of notches to the simulated -10dB bandwidths of the proposed antenna

Table 1 shows the effect of two notches at the bottom of the patch to the antenna bandwidth. The basic rectangular patch antenna with a length of 12 mm and a width of 15 mm only provides the fractional bandwidth of 87%. This fractional bandwidth increases to 90% by cutting one notch at the bottom, while the maximum fractional bandwidth reach to 113% by applying two notches at the bottom of the patch antenna. Then, the fractional bandwidth decreases again by cutting three notches. Hence, the proper selections in the size of notches lead to the UWB characteristic.

3.1.2 Effect of Feed Gap and Slotted Ground Plane

The feed gap between ground plane to the bottom of patch is known given crucial effect to the impedance bandwidth. The 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.

Slotted or notched ground plane is also taken into consideration. The size of notches should be properly designed while still maintaining the antenna's performance. 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 4 illustrates the simulated return loss curves for different feed gaps to the ground plane of T slotted antenna. It is shown in Figure 4 and Table 2 that the -10 dB operating bandwidth of the antenna varies with the variation of the feed gap (*h*) and the dimension of the ground plane. The optimal feed gap is found to be 1 mm with the fractional bandwidth of 116%.
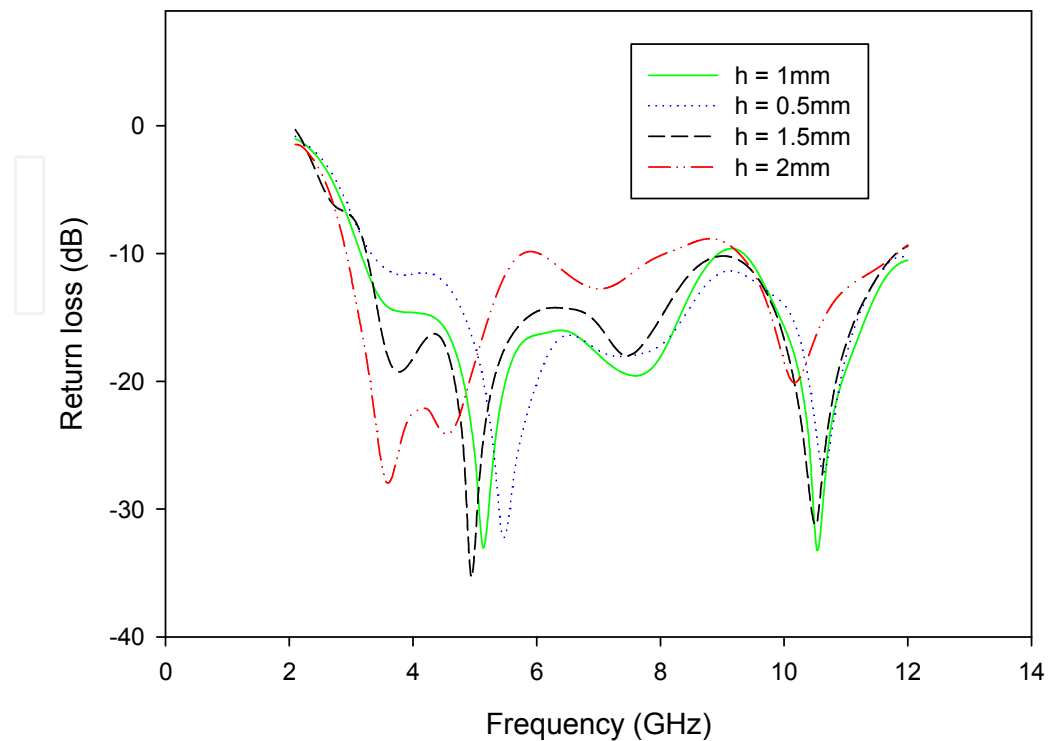
Fig. 4. Simulated return loss curves of T slotted antenna for different feed gaps

h (mm)	f_L (GHz)	f_U (GHz)	Absolute BW (GHz)	Fractional BW (%)
0.5	3.27	12	8.73	114
1.0	3.17	12	8.83	116
1.5	3.27	11.8	8.53	113
2.0	2.98	8.17	5.19	93

Table 2. Simulated -10dB bandwidths of the T slotted antenna for different feed gaps

It can be seen in Table 2 that the -10 dB bandwidth of T slotted antenna does not change much with the variation of the feed gap of the ground plane below 1.5 mm. But beyond this ranges, it will degrade the impedance bandwidth performance. These simulated results indicate that the antenna bandwidth is dependent on the feed gap of the ground plane, since the ground plane serves as an impedance matching circuit.

As shown in Figure 5(a), the return loss < -10 dB always occurs over the frequency range when the input impedance is matched to 50 ohm. The real part (R_e) is close to 50 Ω while the imaginary part (I_m), as shown in Figure 5(b), is not far from zero for the four different feed gaps. When h is 1mm and 1.5 mm, R_e varies tardily at the level of 50 Ω whilst I_m remains small across wide frequency range, leading to a UWB characteristic. However, when h rises to 2 mm, R_e varies more widely and I_m also fluctuates significantly across the frequency range, thus resulting in impedance mismatch at the antenna and hence the decrease of the operating bandwidth. The peak value of resistance is as high as 100 ohms, while the maximum reactance is around 35 ohms.
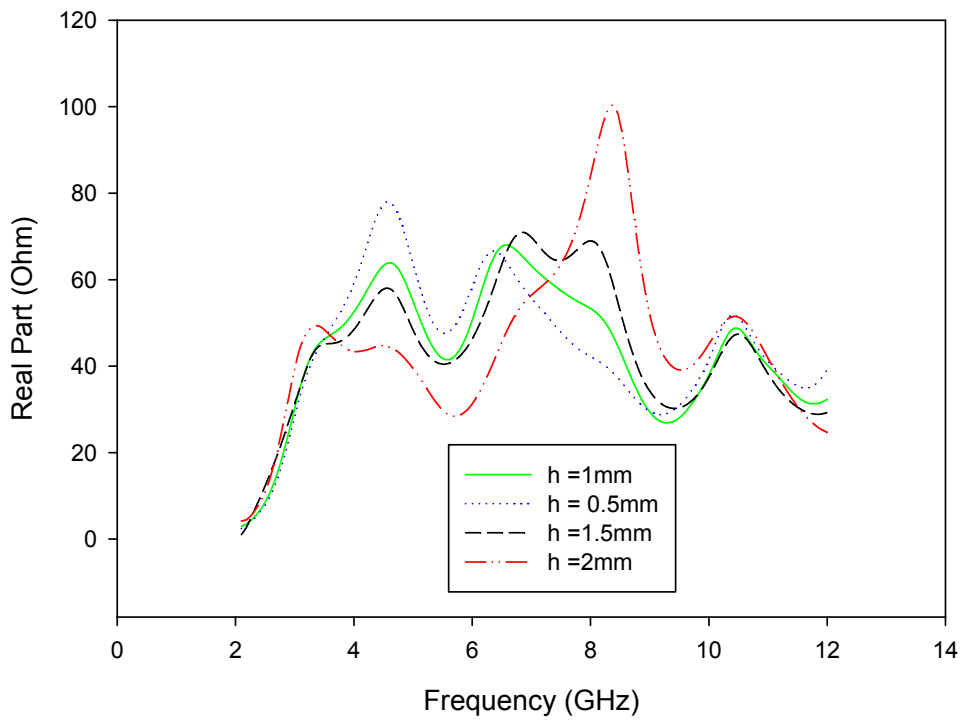
(a)
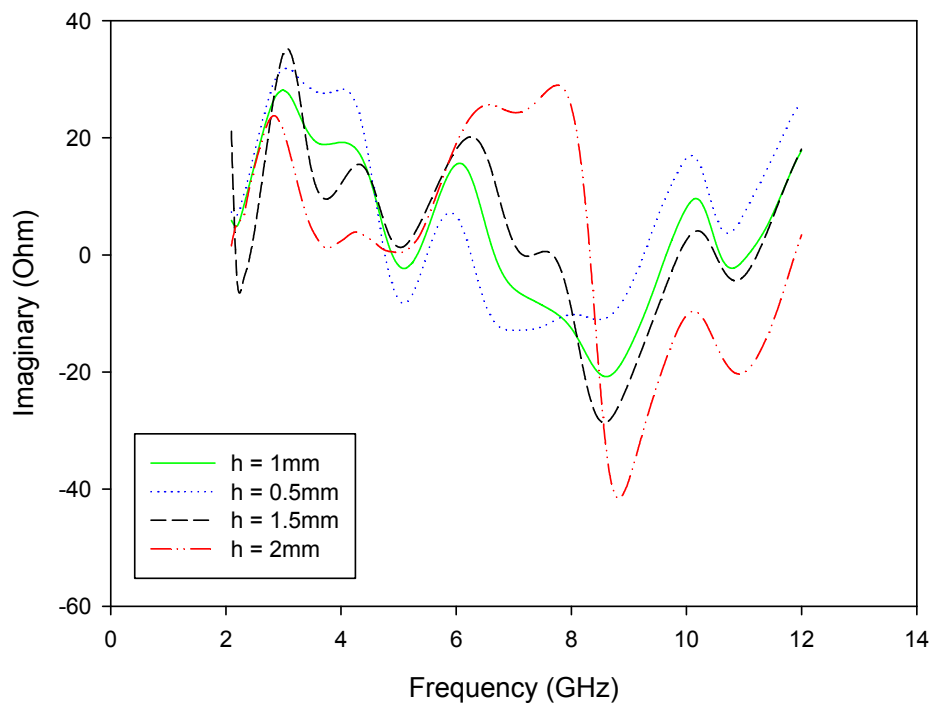
(b)

Fig. 5. Simulated input impedance curves of T slotted antenna for different feed gaps: (a) real part and (b) imaginary part

As mentioned previously, the ground plane acts as impedance matching of the antenna. Modify the partial ground plane to staircase slotted ground plane has improved the return loss of antenna, especially at higher frequency. The geometry of staircase slotted ground plane is shown in Figure 6.
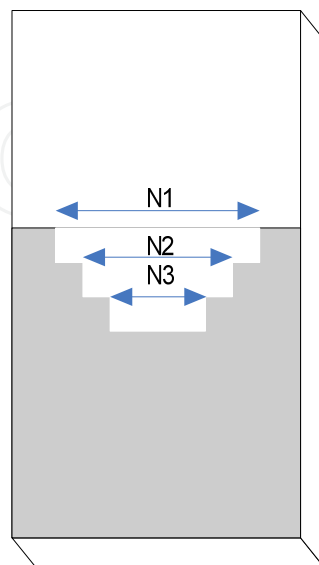

Fig. 6. Geometry of staircase slotted ground plane

Figure 6 shows the geometry of staircase slotted ground plane. By varying the lengths and the widths of slots of ground plane, it is possible to tune the impedance matching as shown in Figure 7.
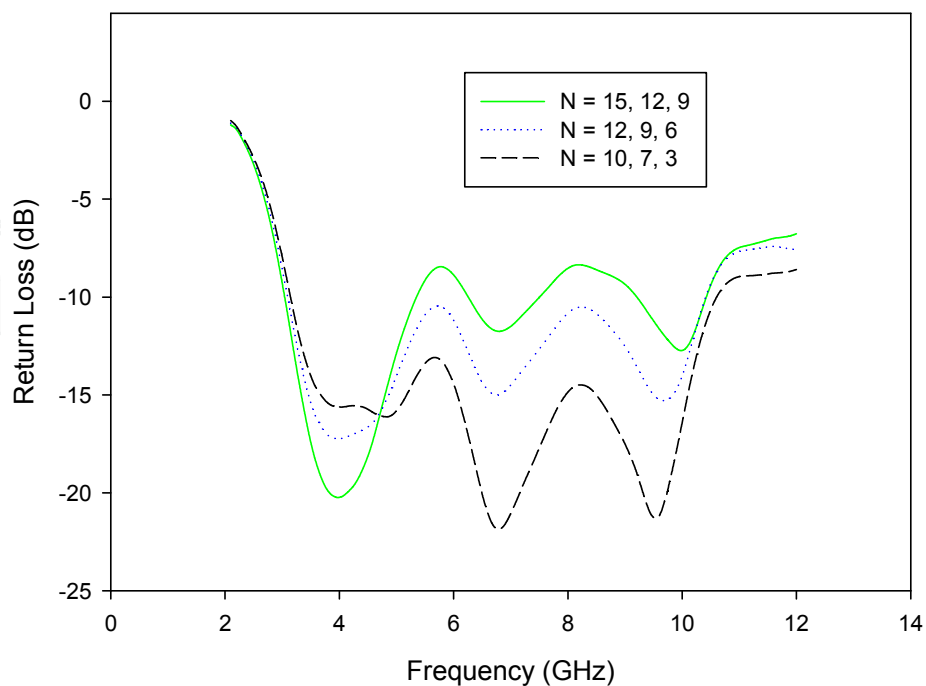
Fig. 7. The effect of various length slotted ground plane to the antenna performance

The width of this slotted ground plane is set to 0.5 mm. The optimum feed gap for T slotted antenna is found to be 0.5 mm above the slotted ground plane. The gap of patch radiator to ground plane is critically effect to the input impedance of antenna. From the simulation, the lengths of slots of N_1, N_2, N_3 of 10, 7, 3 mm give the best return loss for both slotted antennas. It is shown that by increasing the length of slotted ground plane caused degrading the impedance bandwidth of antenna performance.
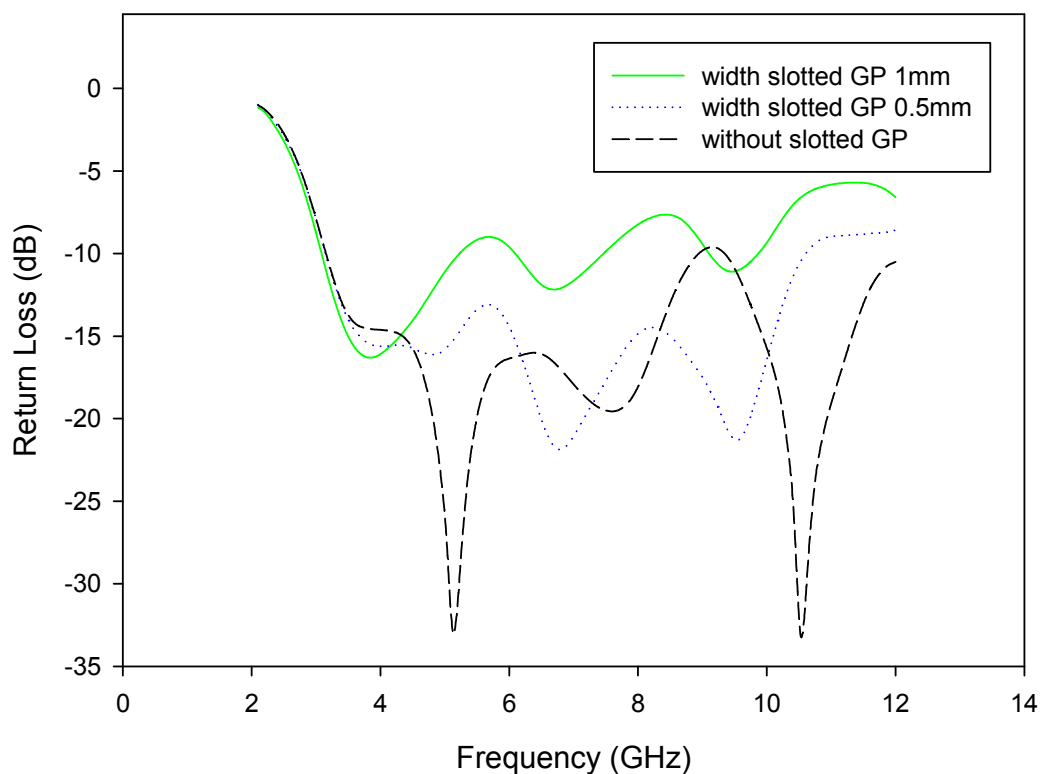
Fig. 8. The effect of various width slotted ground plane to the antenna performance

Figure 8 presents the effect of various width slotted ground plane to the antenna performance. The width slotted ground plane of 1 mm has degraded the antenna return loss above -10 dB. This is due to the width slot has brought the antenna to much more capacitive and far away from the resonance point. The staircase slotted ground plane has improved the return loss around at 9 GHz for T slotted antenna with the width slot of 0.5 mm. It is also shown that the staircase slotted ground plane has removed the lower and upper dip resonances for slotted antenna. The return loss curves fluctuate around -15 dB. The T slotted with slotted ground plane antenna cover frequency range of 3.17 GHz to 10.6 GHz with fractional bandwidth of 108%.

The simulated return loss curve for various number of slotted ground plane for antenna is depicted in Figure 9. It is clearly shown that by increasing the number of slotted ground plane has degraded the antenna performance and led the antenna to much more capacitive especially at higher frequency range.
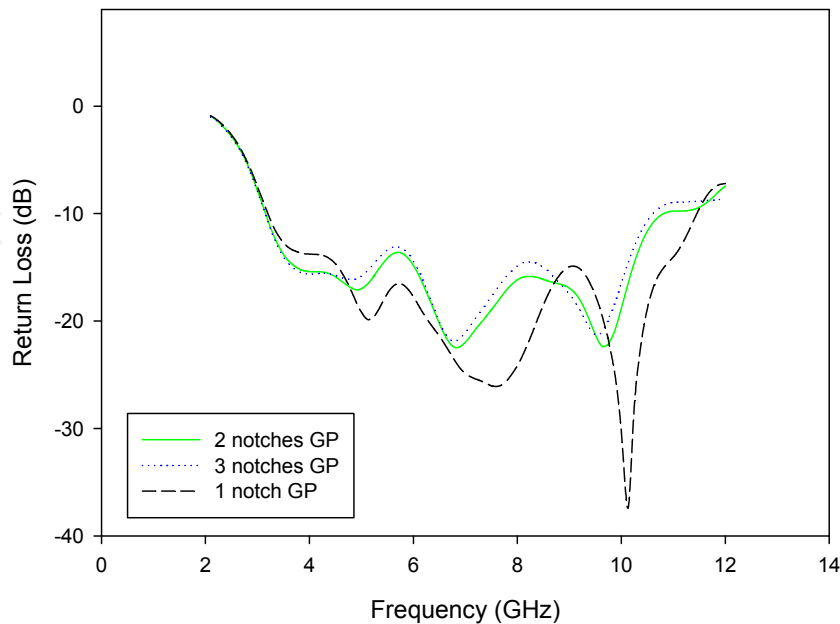
Fig. 9. The effect of various number slotted ground plane to the antenna performance

3.1.3 Effect of Various T slot
The simulated return loss for various T slots antennas is shown in Figure 10. It shows that the T slots have improved the return loss at mid frequencies range, while slightly shifted the upper edge resonance. The return loss provides a very broad bandwidth below -15 dB.
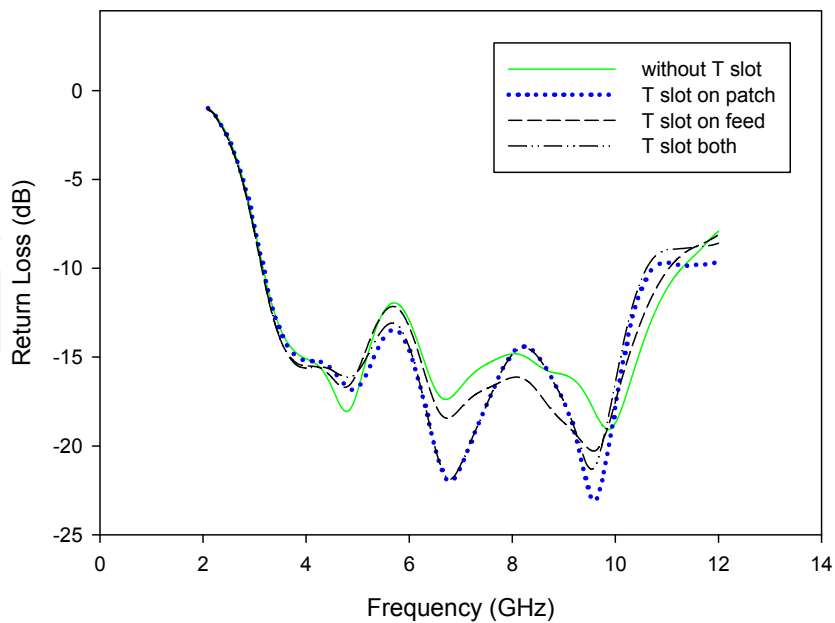

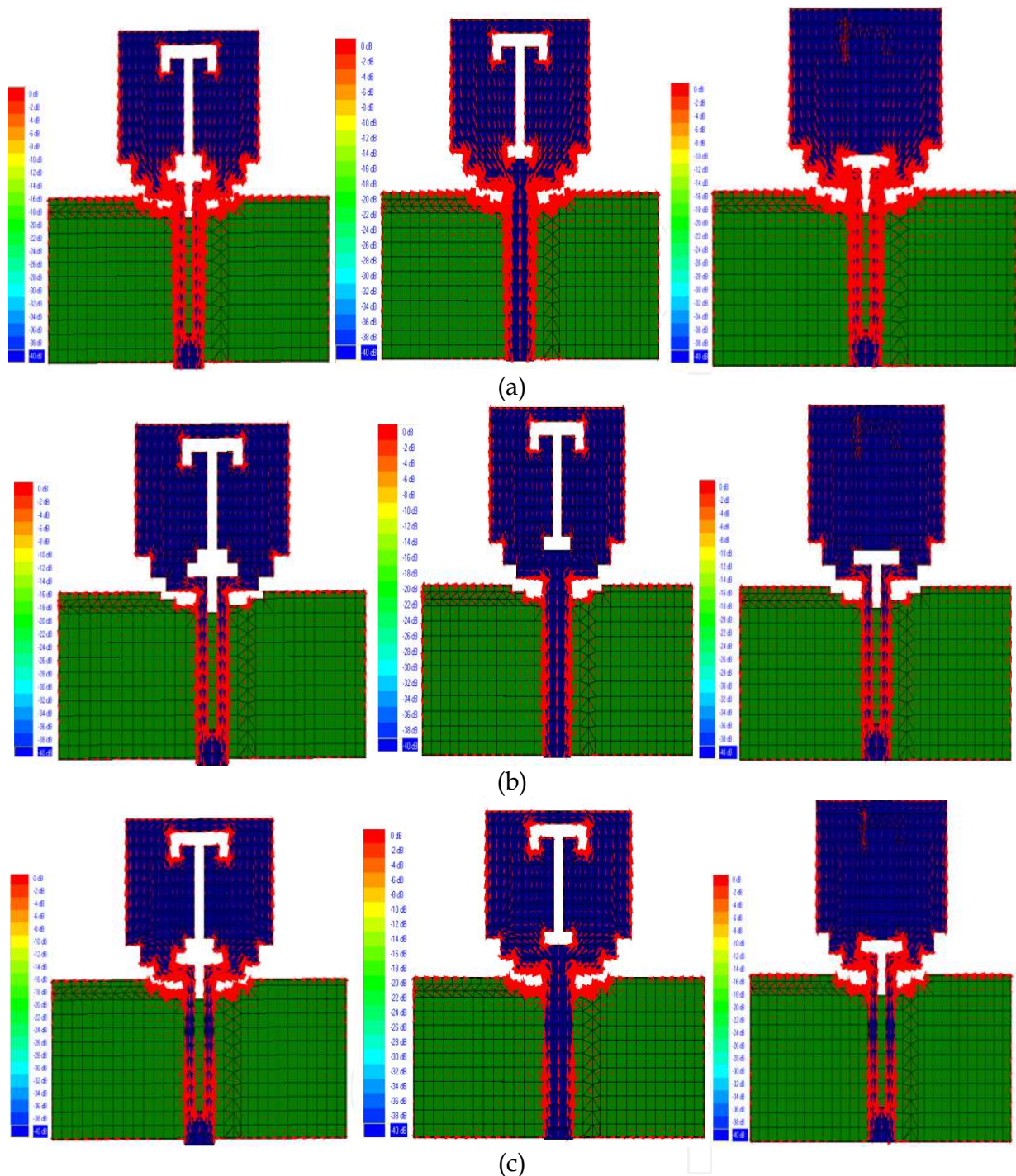Fig. 10. The simulated return loss of various T slots design for antenna with slotted ground plane

(a)

(b)

(c)

Fig. 11. The simulated current distribution for T slotted antenna with slotted ground plane: (a) 3 GHz, (b) 5.5 GHz, (c) 9 GHz

Figure 11 shows various modified of T slotted antenna with their current distribution at 3, 5.5 and 9 GHz, respectively. Figure 11(a) presents the current distribution of antenna with both T slot on patch and feed, T slot on patch only, and T slot on feed only at 3 GHz. The T slot has resulted much more vertical current through antenna radiator. Most vertical electrical current is distributed near the T slot edges and lead to impedance matching at 3

GHz. The vertical current is most concentrated near the patch edges and slots rather than distributed on the antenna surface at 5.5 GHz and this cause the decrement of the intensity of vertical electrical current on antenna surface. For the antenna's current distribution at 9 GHz, the horizontal current mode occurs on the antenna surface. And it is also shown that some vertical current start flowing down to the base.
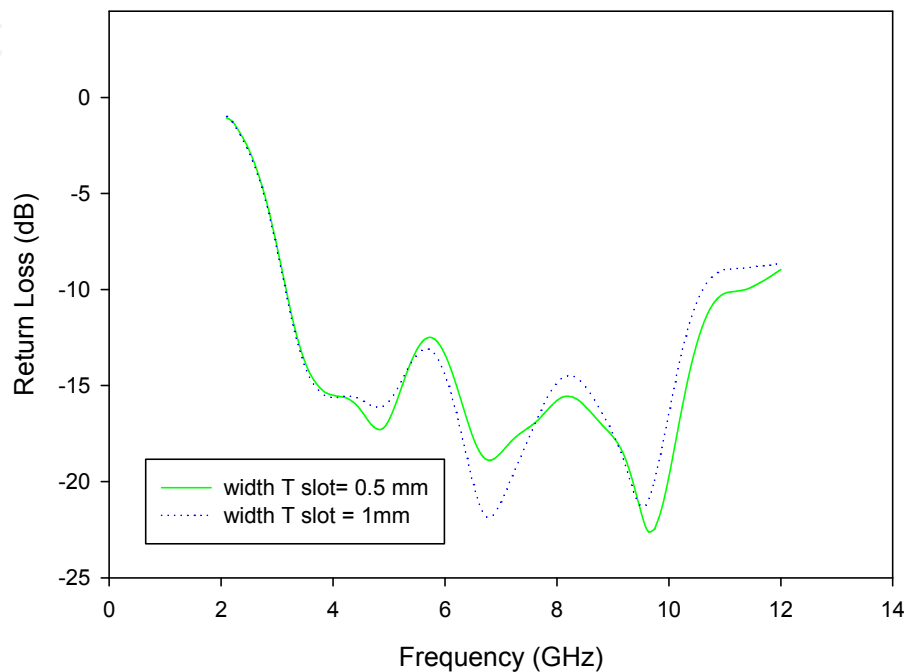

Fig. 12. The simulated return loss for various width of T slots design

Figure 12 shows the return loss of T slots with 0.5 mm and 1 mm width, respectively. From the results, there is not a significant effect to the antenna's return loss performance by decreasing the slot width. The optimum width is found to 1 mm.

3.2 Prototype and Measurement Results

The photograph of T slotted UWB antenna has been developed and shown in Figure 13. In this prototype, measurements are done by using a 50-Ω SMA connecter which is soldered at the bottom edge of microstrip line and connected to network analyzer by an RF cable. The RF cable significantly affects the performance of antenna under test. However, some differences in the simulated and measured results are expected, since in the simulation model the mismatch due to the adapter and connector used are not taken into consideration. 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. In addition, since the antenna is fed by a microstrip line, misalignment can result because etching is required on both sides of the dielectric substrate. The alignment error results degradation to the antenna performance.
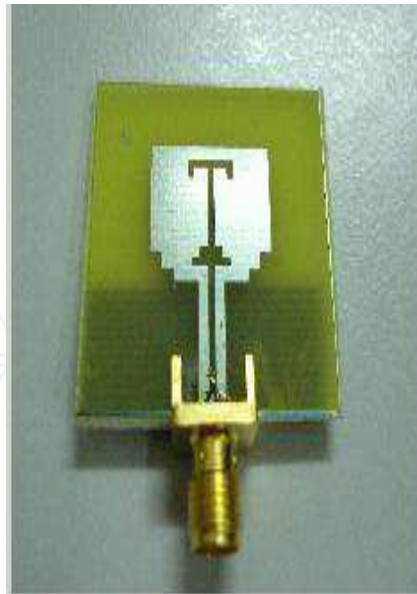
Fig. 13. Prototype of T slotted UWB antenna

As shown in Figure 14, the measured return loss curves for both T slotted antennas with and without slotted ground plane are reasonably close to the simulated results. It is shown that both results have produced multiple resonances frequencies, which shifted from the simulated resonances, but they are still covering the UWB bandwidth requirement. For T slotted antenna with slotted ground plane as shown in Figure 14(a), the frequency ranges cover 3 GHz to 10.23 GHz with respect to -10 dB of return loss. While the second antenna without slotted ground plane as shown in Figure 14(b), the return loss covers 2.3 GHz to 10.4 GHz. From this measured results, the antenna without slotted ground plane is better than the antenna with slotted ground plane in terms of the impedance bandwidth. This is due to the antenna with slotted ground plane need very accuracy in alignment between the slotted ground plane and patch on both sided of substrate during fabrication. The distance of patch to the ground plane is also very small of 0.5 mm. The misalignment occurred affects the impedance bandwidth. The measurements confirm the UWB characteristic of the proposed slotted UWB antennas, as predicted in the simulations.

From experimental experiences, the multiple resonances of return loss occurred on the proposed antennas are due to these antennas printed in the front of FR4 substrate. It has been investigated during the return loss measurement of many wideband antennas that have been developed. In addition, the FR4 substrate quality needs to be taken into consideration. It should be used within six months after purchased in order to avoid the oxidation process. The poor quality of FR4 substrate used produces a poor measured return loss and need longer time during etching process. Thus, perfect impedance match is not easily obtainable. These fabrication processes are important, because a slight error could result in major degradation in antenna performance.
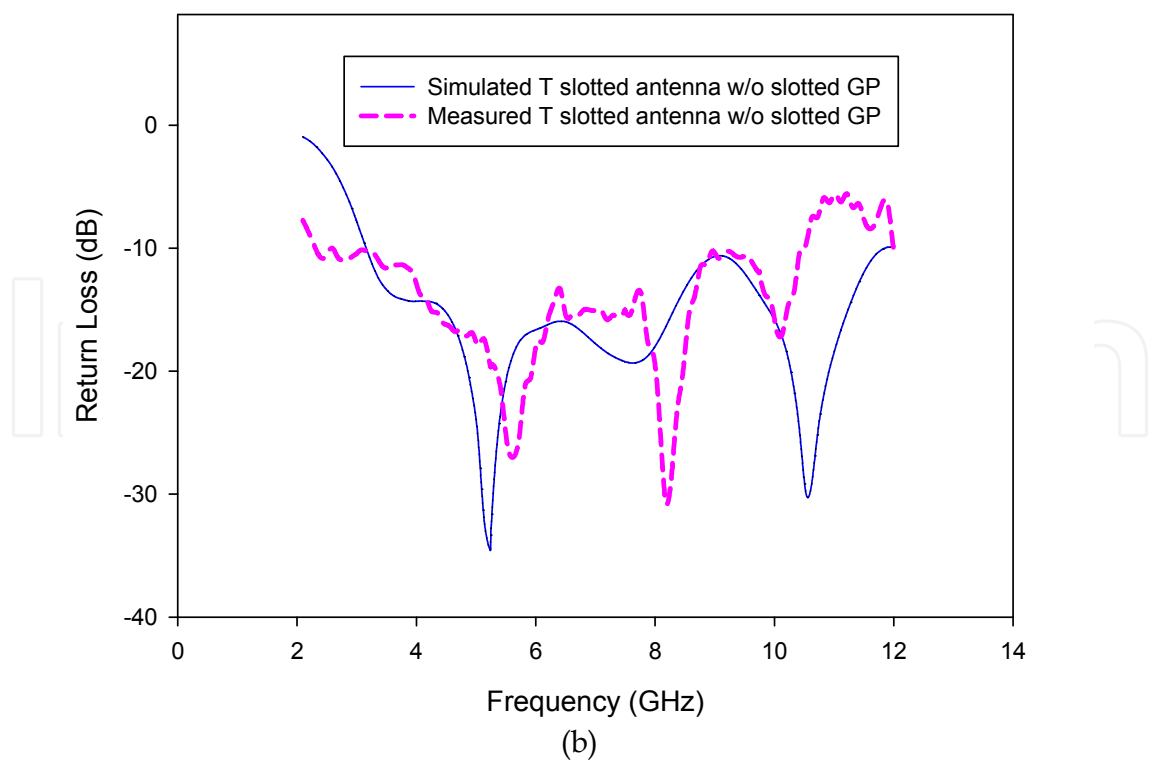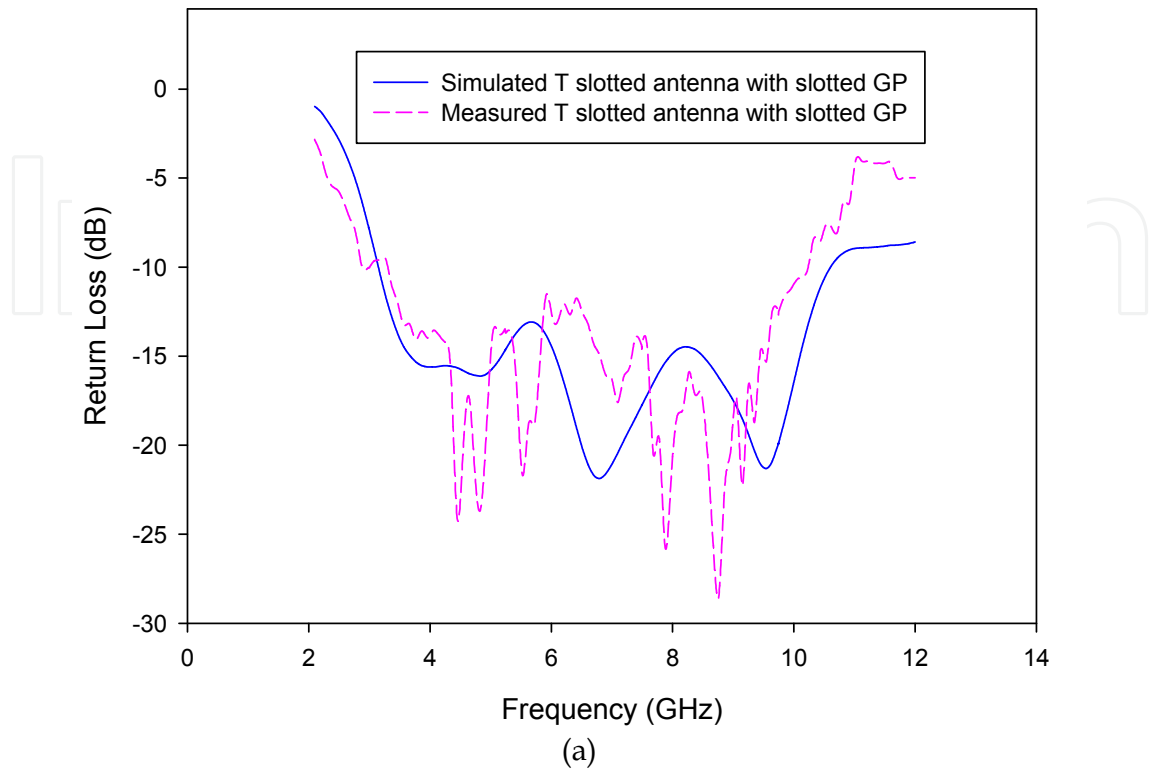
(a)

(b)

Fig. 14. The measured and simulated return loss for T slotted antenna: (a) with slotted ground plane and (b) without slotted ground plane

E-Plane   H-Plane
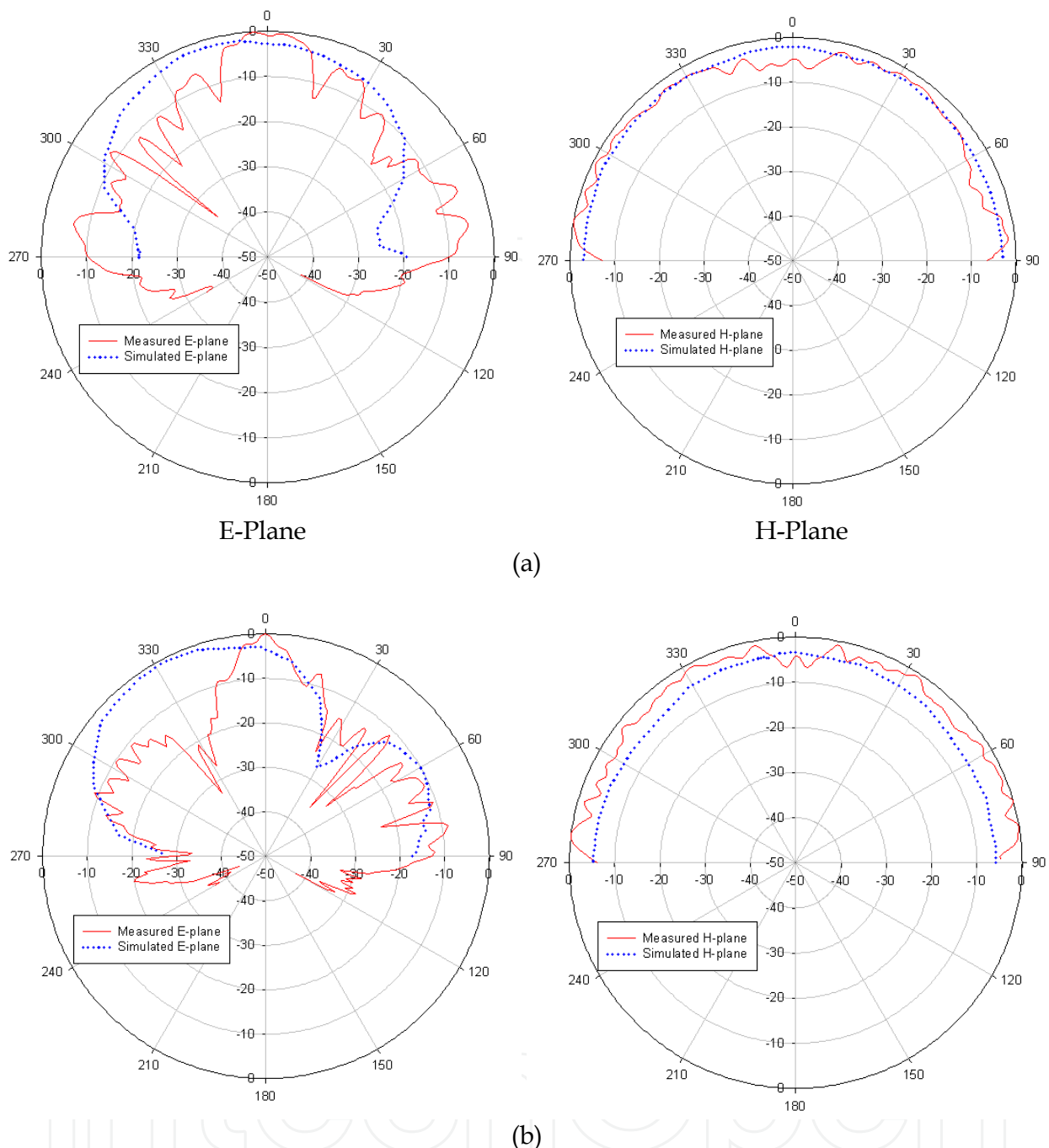
(a)

(b)

Fig. 15. The measured and simulated E and H planes (a) 4 GHz, (b) 5.8 GHz

The elevation patterns for the antennas are simulated at the H-plane ($\varphi = 0^0$, yz-plane) and E-plane ($\varphi = 90^0$, xy-plane). The E-plane pattern is the radiation pattern measured in a plane containing feed, and the H-plane pattern is the radiation pattern in a plane orthogonal to the E-plane. These both simulated results are compared to the measured H-plane and E-plane for 4 GHz and 5.8 GHz, as shown in Figure 15. The results show that the radiation patterns are changing as the frequency increases. The measured H-planes show omni-directional radiation pattern over the frequencies. The patterns resulted from the measurements have many ripples in amplitude due to many reflections into the field between the AUT and

probe. The reflections may come from the room (floor and ceiling), chamber scattering, antenna holder itself and track inside the anechoic chamber. Various types of leakage occur are also considered as pattern degradation. The most significantly is probably from improper cable connectors allowing excitation of the outside surface (Gary E. Evans, 1990). Leakage will be added to the measured pattern as degradation.

It is also noted from Figure 15 that with increasing frequency to 5.8 GHz, the E-plane patterns become smaller. Many ripples occurred in this frequency. The dips also present for various different angles. Even though the measured radiation patterns are slightly difference to the simulated ones, since their patterns are nearly omni-directional and their return losses are less than -10 dB, this proposed antenna meets the UWB requirements.

4. Conclusion

This chapter presents the design and development of T slotted UWB antenna with slotted ground plane. Four matching techniques have been applied in order to meet the UWB requirements such as T slots for patch and feeding strip, truncation ground plane, slotted ground plane and cutting notches at the bottom of patch radiator. The T slot for both patch and feeding strip is as a novelty design in terms of slot type. Performance analysis in simulation software has been done before the actual prototype developed. The effect of various cutting notches at the bottom of patch radiator, the effect of truncation and slotted ground plane, and the effect of various T slots design with current distribution behavior to antenna performance have been evaluated.

The T slotted antenna with slotted ground plane has shown the return loss varies from -15 dB to -20 dB. However, during fabrication process, the slightly shifted impedance bandwidth has occurred. This is due to the antenna with slotted ground plane need very accuracy in alignment between the slotted ground plane and patch on both sided of substrate. The distance of patch to the ground plane is also very small of 0.5 mm, where is this distance as the impedance matching.

5. References

A. A. Eldek, (2006). Numerical analysis of a small ultra wideband microstrip-fed tap monopole antenna. *Progress In Electromagnetic Research*, PIER 65, pp.59-69.
Albert K. Y. Lai et al. (1992). A novel antenna for ultra-wideband application. *IEEE Transactions on Antennas and Propagation*. Vol. 40(7). July, 1992.
E. Guillanton et al. (1998). A new design tapered slot antenna for ultra-wideband applications. *Microwave Opt. Technol. Lett*. Vol. 19: 286-289.
Federal Communications Commission (FCC), (2002). *Revision of part 15 of the commission's rules regarding ultra-wideband transmission systems*. First Report and Order, ET Docket 98-153, FCC 02-48. April, 2002. http://www.fcc.gov.
Giuseppe R. and Max J. Ammann, (2006). A novel small wideband monopole antenna. *Loughborough Antennas & Propagation Conference (LAPC)*, Loughborough University, UK, 11-12th April 2006.
Gary E. Evans. *Antenna Measurement Techniques*. Boston, London: Artech House. 1990.

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

J. F. Zurcher and F. E. Gardiol, (1995). *Broadband Patch Antenna*. Norwood, MA: Artech House.

Kazuhiro Hirasawa and Misao Haneishi, (1992). *Analysis, design, and measurement of small and low profile antennas*. Artech House, Boston, London.

Liang Jianxin, (2006). *Antenna Study and Design for Ultra Wideband Communication Applications*. *PhD Thesis*. Queen Mary, University of London.

M. A. Peyrot Solis, G. M. Galvan Tejada, and H. Jardon Aguilar, (2005). State of the Art in Ultra-Wideband Antennas. *2nd International Conference on Electrical and Electronics Engineering (ICEEE) and XI Conference on Electrical Engineering (CIE 2005)*. Mexico City, Mexico. 101 – 105. September 7-9, 2005.

Mayhew Ridgers, G. (2004). Wideband Probe-feed microstrip patch antennas and modeling techniques. *Thesis PhD*, University of Pretoria, Electrical, Electronic and Computer Engineering.

N. P. Agrawall, G. Kumar, and K. P. Ray, (1998). Wide-Band Planar Monopole Antennas. *IEEE Transactions on Antennas and Propagation*. Vol. 46(2): 294-295. Feb, 1998.

R. Garg et al. (2001). *Microstrip Antenna Design Handbook*. Artech House.

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

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

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

Y.X. Guo, K.M. Luk, K.F. Lee and Y.L. Chow, (1998). Double U-slot rectangular patch antenna. *Electronics Letters,* Vol. 34, No. 19, 17th September 1998.

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

Zhi Ning Chen et al, (2004). Considerations for Source Pulses and Antennas in UWB Radio Systems. *IEEE Transactions on Antennas and Propagation*. July, 2004. Vol. 52(7).
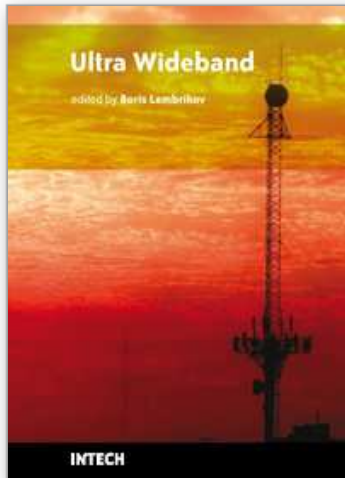
Ultra Wideband

Edited by Boris Lembrikov

Ultra wideband technology is one of the most promising directions in the rapidly developing modern communications. Ultra wideband communication system applications include radars, wireless personal area networks, sensor networks, imaging systems and high precision positioning systems. Ultra wideband transmission is characterized by high data rate, availability of low-cost transceivers, low transmit power and low interference. The proposed book consisting of 19 chapters presents both the state-of-the-art and the latest achievements in ultra wideband communication system performance, design and components. The book is addressed to engineers and researchers who are interested in the wide range of topics related to ultra wideband communications.

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