Design Optimization of Stacked Patch Antenna for Ultrawideband Application

#Mohammad Tariqul Islam [1], Mohammed Nazmus Shakib [2], Norbahiah Misran [2], Baharudin Yatim [1]
[1]Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia,
Bangi 43600, Selangor, Malaysia, titareq@yahoo.com
[2]Dept. of Electrical, Electronic and System Engineering, Universiti Kebangsaan Malaysia [2] , Bangi 43600, Selangor, Malaysia, engmdns@yahoo.com

1. Introduction

Ultrawideband (UWB) communication systems have been recently received great attention in the wireless world. It is widely used technology in communications, radar, imaging and remote sensing applications [1]. It will be preferred that an antenna has bandwidth in excess of frequency range from 2.5 GHz to 10.25GHz to include the existing wireless communication systems such as WLAN system operating at 5.15 – 5.825 GHz, IEEE 802.16 WiMAX system operating at 3.3 – 3.6 GHz, C-band (3.7 – 4.2 GHz) satellite communication systems and UWB band (3.1–10.6GHz) [2]. The antenna aspects of UWB systems differ significantly from those narrowband systems. The design of practical antennas that radiate efficiently over an ultrawide bandwidth continues to be a challenging problem [3]. Due to the attractive merits of low profile, lightweight, ease of fabrication and wide frequency bandwidth, patch antennas are currently under consideration for use in ultrawideband (UWB) systems. However, conventional patch antenna suffers typically from a few percent of bandwidth. For this reason much effort is made to develop techniques and find configurations to broaden its impedance bandwidth.

Many studies have been devoted to investigating antennas for UWB radios. It is a common practice to use the stacked patches to increase gain and/ or impedance bandwidth of the microstrip antennas [4] .This reduces the impedance variation of the antenna with frequency, thus enhancing the impedance matching across a broad frequency band. Various arrangements of the stacked patch structures have been investigated [5]. In [6], several structures of stacked patches with a shorting wall were put forward to achieved a low profile of 0.024 λg with two layers of dielectric substrates (ε_r=2.33), but the maximum bandwidth falls back to 10%. A dual layer stacked patch antenna with 56.8% bandwidth has been proposed in [7] for UWB applications which does not increase the surface area and has a dimension of 26.5 × 18 × 11.5 mm^3. Another wide bandwidth by electromagnetically couple the V-shaped patch with the triangular PIFA has been proposed in [1]. UWB operation with 53% bandwidth has been achieved by folding the shorting wall of the triangular PIFA in their research. These techniques can also be applicable to dual-band and wideband applications, albeit more complicated geometrical configurations. More recently an ultrawideband suspended plate antenna consisting with two layers has achieved an impedance bandwidth of 72.7% [8]. A new antenna feed method [9] namely the folded-patch feed has been shown to improve the impedance bandwidth of a patch antenna. The rectangular U-shaped-slot patch antenna with a folded patch feed with the dimension of 18 × 15 × 7 mm^3 is shown to have an impedance bandwidth of 53.5% (VSWR$\leq$2) [10] and an E-shaped patch antenna with a folded-patch feed is described to have an impedance bandwidth of 73.78 % [9].

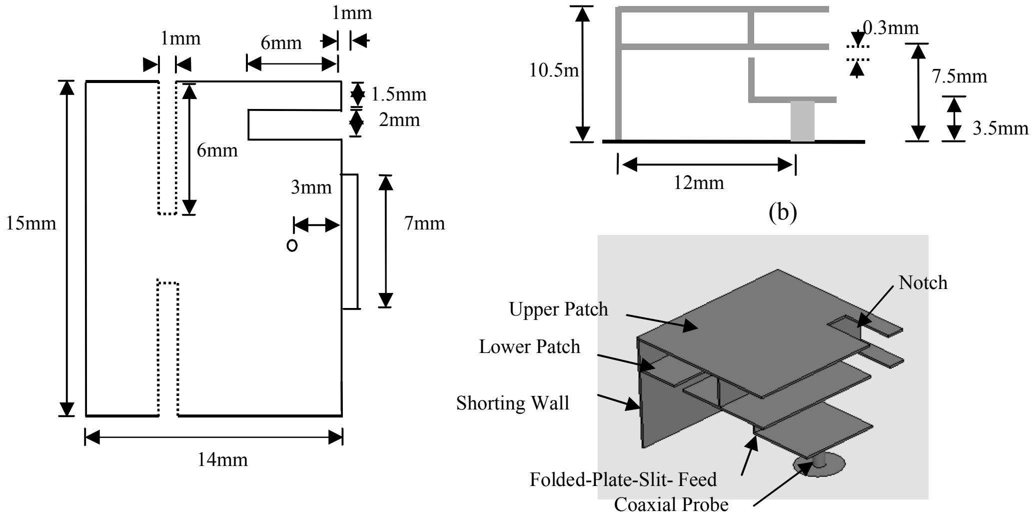
In this paper, a new antenna is proposed to adopt the folded plate slit feed with notched rectangular stacked patch which can dramatically improve the impedance bandwidth of a patch antenna. A wider impedance bandwidth is achieved compared to the design reported in [9].

2. Antenna Design Structure

The geometry of the proposed antenna is presented in Fig. 1 where the design dimension of the antenna is 15mm by 15mm by 10.5mm. The folded plate is made of a bended 0.2 mm thick copper sheet. The probe is shouldered to an SMA connector whose central conductor (of 50 ohm coaxial probe) goes through the rectangular ground plane of 80mm× 80 mm. The folded feeding plate is suspended above the grounded plane and positioned in such a way that the antenna is asymmetrical about the x-axis. A shorting wall with the same width as the upper radiating elememt is connected to the ground plan is introduced in this design mainly used for reduction the overall size of the antenna as well as to support the whole radiating element above the ground plane and increase few percentage of impedance bandwidth. A notched rectangular radiating element is stacked with another notched H-shape radiating element. A rectangular two notches are cut on the patch of the proposed antenna that can improve the impedance matching and bandwidth.

The probe feed with diameter of 1 mm is located on the horizontal central line of the folded patch feed with 12 mm away from the left edge. The longer probe length will cause more probe inductance. With the aid of folded plate slit feed design, the probe length is shortened, leading to a smaller probe inductance. It is important to note that the overall height of the proposed antenna is 10.5 mm, while the length of the probe used is 3.5 mm only. Therefore a thick antenna is achieved without increasing the probe inductance. This helps widen the impedance bandwidth of the antenna significantly. The electromagnetic coupling exists between the vertical section of the patch and slit feeding plate, the vertical section of the feeding plate and the horizontal section of the patch radiator, as well as the horizontal section of the feeding plate and the ground plane form a broadband feeding structure. The horizontal section of the feeding plate increases the capacitance at the feed point to compensate for the increase in the inductance due to the long probe across a broad impedance bandwidth.

Further enhancement of impedance bandwidth is achieved due to extra electromagnetic coupling in between stack patch of this design. The proposed antenna has notched rectangular patch stacked with notched rectangular H shaped patch structure when viewed from 3D. The above specific shape patch for the slots and the stacked patch configuration allowed us to obtain a satisfactory matching across the frequency band of interest. A probe length of 3.5mm was set to define the distance between the radiating patch and the ground plane that determines the antenna's impedance match. The probe length keeps the real part of the input impedance as close to 50 Ω.



(b)

(a) (c)

Figure 1: Geometry of the Proposed Antenna: a) Top view, b) side view, c) 3D view.

3. Antenna Performance and Analysis

The antenna has been simulated with commercially available finite-element analysis package, that is Ansoft High Frequency Simulation Software (HFSS^{TM}). The simulated return loss of the proposed antenna is depicted in Fig. 2. From the return loss curves, it is clearly seen that the proposed antenna has bandwidth of 121.51% (10dB return loss), which ranges from 2.5 to 10.24 GHz, which covers the UWB frequencies mentioned earlier. Such a wide bandwidth is attributed to the resonances introduced by the antenna structure. Fig. 3 shows the simulated input impedance of the antenna. The real part of the input impedance was optimized to be as close as possible to 50 Ω, over a wide frequency range.

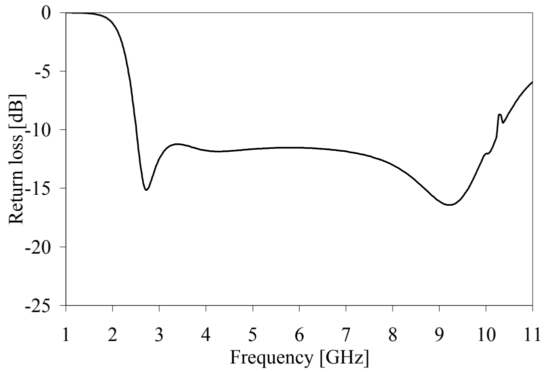


Figure 2: Simulated return loss of proposed antenna

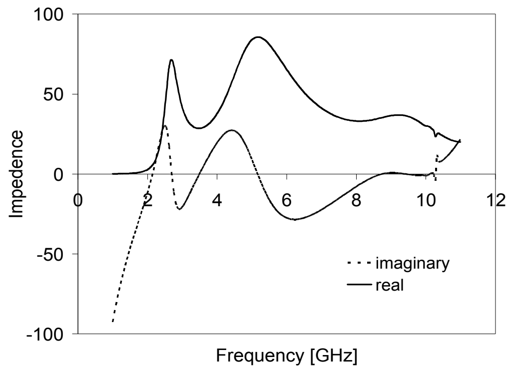
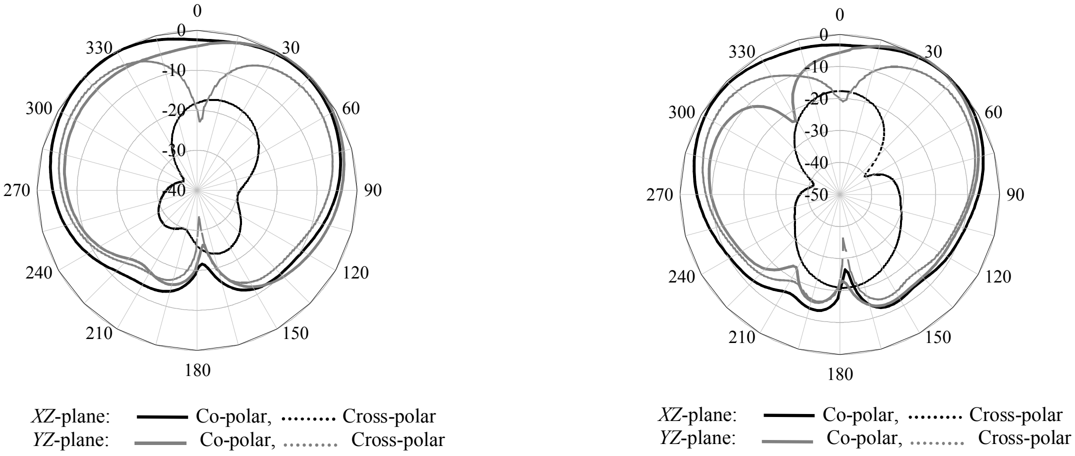


Figure 3: Simulated input impedance of proposed antenna.

Fig. 4 shows the simulated xz-plane and yz-plane radiation pattern of the proposed antenna at 3.34 and 6.3GHz. As shown in figure, the designed antenna display good radiation patterns at 3.34GHz and 6.3GHz. The asymmetry characteristics of the cross-polarization pattern are clearly shown in the figure which is due to the thick substrate structure of the design. The peak cross-polarization level of the antenna is observed to be about -12dB and -13dB below the copolarization level of the main lobe at *xz*-plane at the frequency of 3.34GHz and 6.3GHz respectively. Notable, the radiation characteristics of the proposed antenna are nearly identical to those of the conventional patch antenna.



(a) (b)

Figure 4. Simulated radiation pattern of the proposed antenna at a) 3.4GHz, b) 6.3GHz.

In Fig. 5, a parametric study on the proposed antenna has been performed to investigate the effects of the antenna parameters on the impedance matching. The length of notch equals 2 mm is used in the control model. As shown in figure, with decreasing the notch length experiences better matching at the lower resonance but at the expense of reducing the upper edge frequency, resulting in a reduction in the bandwidth. The simulated maximum gain in the *xz*-plane is greater than 6 dBi across the operating frequency as shown in Fig. 6. The gain is affected by the size of the ground plane.

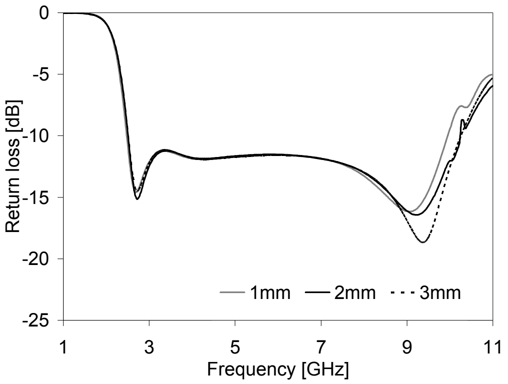


Figure 5: Effect on return losses with different width of the notch.

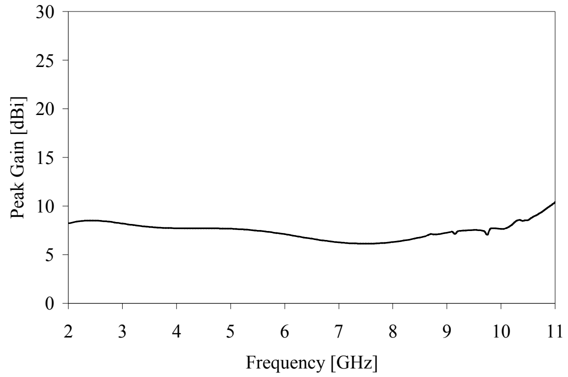


Figure 6: Simulated gain of proposed antenna.

4. Conclusion

In this article, a notched rectangular patch stacked with notched rectangular H shaped patch antenna configuration with folded slit plate feed has presented. The particular feeding technique, the optimized shape of the patch slots, and the stacked structure made it possible to satisfy return loss and radiation pattern requirements in the pertinent frequency band of 121.51% bandwidth covering the frequency range from 2.5 to 10.24 GHz. Despite the small area and thickness, this antenna can be made from copper sheet, so that it is easier to fabricate. Details of the antenna designs are shown, and the results with low-profile characteristics make this antenna suitable for UWB applications.

Acknowledgments

This work is supported by Institute of Space Science, UKM, Malaysia.

References

[1] H. Elsadek and D. M. Nashaat, “Multiband and UWB V-shaped antenna configuration for wireless communications applications,” IEEE Antennas and Wireless Propagation Letters, vol. 7, pp. 89-91, 2008.
[2] A. C. Lepage, X. Begaud, G. Le Ray, and A. Sharaiha, “UWB Directive Triangular Patch Antenna,” International Journal of Antennas and Propagation, vol. 2008, pp.1-7, 2008.
[3] H. G. Schantz, The Art and Science of Ultra-Wideband Antennas. Boston, MA: Artech House, 2005.
[4] R. Q. Lee and K. F. Lee, “Experimantal study of the two-layer electromagnetically coupled rectangular patch antenna,” IEEE Transactions on Antennas and Propagation, vol. 38, pp. 1298-1302, 1990.
[5] R. B. Waterhouse, “Design of probe fed stacked patched.” IEEE Transactions on Antennas and Propagation, vol. 47, no. 12, pp. 1780–1784, 1999.
[6] J. Ollikainen, M. Fische, and P. Vainikainen, “Thin Dual-resonant Stacked Shorted Patch Antenna for Mobile Communications,” Electronics Letters, vol. 35, no. 6, pp.437–438, 1999.
[7] M.A. Matin, B.S. Sharif, and C.C. Tsimenidis, “Dual layer stacked rectangular microstrip patch antenna for ultra wideband applications,” IET Microwave Antennas Propagation, vol. 1, no. 6, pp. 1192-1196, 2007.
[8] X. N. Low, Z. N. Chen, and W. K. Toh, “Ultrawideband suspended plate antenna with enhanced impedance and radiation performance,” IEEE Transactions on Antennas and Propagation, vol. 56, no. 8, pp. 2490-2495, Aug. 2008.
[9] C.Y. Chiu, H. Wong, and C.H. Chan, “Study of small wideband folded-patch-feed antennas,” IET Microwave Antennas Propagation, vol.2, no. 1, pp. 501-505, 2007.
[10] C.Y. Chiu, K. M. Shum, C.H Chan, and K.M. Luk, “Bandwidth enhancement technique for quarter-wave patch antenna,” IEEE Antennas and Wireless Propagation Letters, vol. 2, pp. 130-132, 2003.