A Compact Patch Antenna for Ultrawideband Application

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Abstract*—A compact microstrip line fed tapered-shaped slotted ultra-wideband(UWB) antenna is presented. The new design is composed of a rectangular slotted patch with a compact size of 21.44 × 23.53 mm^2 and fed by microstrip transmission line of 50 Ω. The proposed antenna is simulated onto a less expensive FR4 substrate which has a height of 1.6 mm. There achieved a wider bandwidth of 8.51 GHz (3.49-12 GHz) with good impedance matching, constant gain, 5.76 dBi of maximum gain and stable radiation pattern results in the proposed antenna more appropriate for using UWB communication applications compared to existing antennas. The proposed antenna is designed and simulated in HFSS and CST Microwave Studio software to see the antenna performance.

***Keywords*—UWB;patch;slot; low cost;microstrip feed line.**

I. Introduction

Now-a-days ultra-wideband (UWB) technology with an operating frequency ranging from 3.1-10.6 GHz as low cost, low complexity, high gain, high data resolution, low interference, lightweight and easy to construct have turned it into various wireless communications applications. It must be electronically small in size and low cost without hampering its performance as well as high gain, stable radiation pattern, linear phase variation, low profile is also needed to satisfy the prerequisite for UWB applications. Designing a compact, high gain and cost effective UWB antenna is still a challenge to antenna designers and researchers in academia and industry. Planar antennas for ultra-wideband applications have already proposed by researchers. The most acceptable antenna for UWB applications is printed slot type antenna. Here a wide-slotted antenna has a broader bandwidth than narrow slotted antenna.

Since the Federal Communications Commission (FCC) declared unlicensed bandwidth of 3.1 to 10.6 GHz for radio communication in 2002 [1] , antennas with ultra-wide bandwidth have been broadly researched and developed. In a UWB system, the antenna is one of the most effective passive element and attracted substantial research work in recent years. Among the challenges of designing a cost-effective, compact, smaller size, wide bandwidth and easy fabrication is a prerequisite for UWB applications [2-6]. In the last three decades, the printed microstrip slot antennas were significantly researched due to its various number of benefits including stable radiation pattern, low profile, high gain and easy inexpensive fabrication. Various printed wide-slot coplanar waveguide (CPW) antennas have been stated [7, 8]. Besides, monopole slotted antennas have been testified to gain the characteristics of wide bandwidth [3].The proposed microstrip antenna acquires the operating bandwidth of -10 dB which has the range of 3.49-12 GHz that covers UWB region. The proposed antenna size has been reduced and performance has been improved. To construct the UWB antennas with filtering characteristic, various number of methods have been proposed by designing numerous slots on either radiated patches or ground planes, like rectangular patch shaped [9],circular disk shape[10] Cross shaped [4] and Hexagonal-shaped [8] slot. The proposed antenna with a tapered-slotted ground plane and rectangular slotted patch which gives better bandwidth and gain than [11, 12]. As we know that the resonant frequency is shifted to lower frequency if the side slot width increases. As a result, we use a tapered slot ground for achieving better bandwidth. In recent times, for wideband applications, a printed wide-slot antenna is designed [13]. The proposed antenna is cost effective as FR4 is used as substrate material rather than expensive materials such as Rogers RT [14] and Shieldit Super [11].

A planar microstrip patch with tapered slotted ground plane structured antenna with a compact dimension of only 21.44 × 23.53 mm^2, that is smaller than the antennas proposed in [2, 8, 11, 15] , for the ultra-wideband application. After designing a tapered slot ground with the microstrip-fed rectangular slotted patch as a radiating element, this proposed antenna reached a wide bandwidth extending from 3.49 to 12 GHz.

II. Antenna Design and Structure

Fig. 1 demonstrates the structure and configuration of the proposed microstrip patch antenna. Generally, Because of having only one resonance part the bandwidth of microstrip patch antenna is not wide in range. It can be possible to gain broad bandwidth if there are more than one resonant parts where each one operates independently. The proposed antenna contains a tapered-shaped slot scraped out of the ground plane with a rectangular slotted patch and a microstrip-fed-lined for radiation. The distance between the rectangular slotted patch and the ground plane (*h*) defines the matching between slot antenna and the feed line. The patch is composed of the rectangular slot with different cuts ln, wn, wp.

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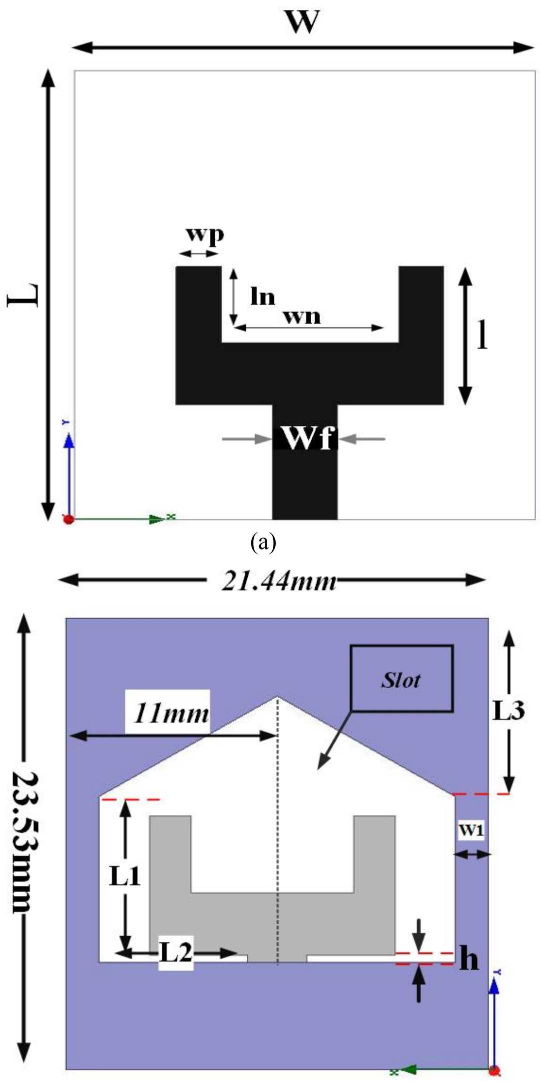

Fig. 1. The geometry of the proposed antenna. (a) Top view. (b) Bottom view.

By changing the value of ln, wn, and wp we can gain the ultra-wide bandwidth for the wideband application. Both the ground plane and the rectangular slotted patch are designed on a low-cost FR4 substrate which thickness is 1.6 mm, loss tangent 0.02 and relative permittivity of 4.6. The tapered slotted ground plane has a durable combination with the feeding construction. High gain, good range of bandwidth, and stable radiation patterns can be reached by choosing properly shaped slot at patch and ground plane. The entire dimensions of the proposed antenna are only 21.44 × 23.53 mm2, which is one of the smallest and cost effective UWB slotted antennas. The adjusted different constraints of proposed antenna are: W = 21.44 mm, L = 23.53 mm, l = 7.24 mm, wp = 2.11 mm, ln = 4 mm, wf = 3 mm, L1 = 8.66 mm, L2 = 7.52 mm, L3 = 9.30 mm, w1 = 1.98 mm, h = 1.6 mm.

III. Results and Discussion

The simulation of the proposed antenna was done with two simulation software called HFSS and CST. High-Frequency Structural Simulator (HFSS) based on finite element method and Computer Simulation Technology (CST) based on finite-difference-time-domain method. As a result, the graph value of the simulation may vary slightly for this two different working methods of the simulation software. The very first step of the design of the proposed antenna we have tested different patch shape to gain an ultra-wide bandwidth. We noticed that by improving the coupling between the rectangular slot and feed line and changing slot size and shape, good impedance matching can be achieved. Fig. 2 shows the different patch shape starting with proposed one. We have fed the rectangular slotted patch with a 50 Ohm transmission line. Here, the rectangular slotted patch element applied as the microstrip termination line which gives more wideband performance compared to the other ones. It is noticed that by using tapered ground slot structure, high-frequency performance can be enhanced, and a wider bandwidth can be achieved by using a tapered-shape slot coordinated with a rectangular slotted patch than with a circular, rectangular, elliptical or square-shaped slot. Fig. 3 defines the various simulated result of Reflection coefficient (s11) of different shapes of the patch in HFSS which can help us to choose the right shape of the patch for UWB application. Fig. 4 represents the reflection co-efficient (s_{11}) of the proposed antenna with and without ground plane. We can see that by using tapered slot ground we are able to gain ultra wideband frequency band

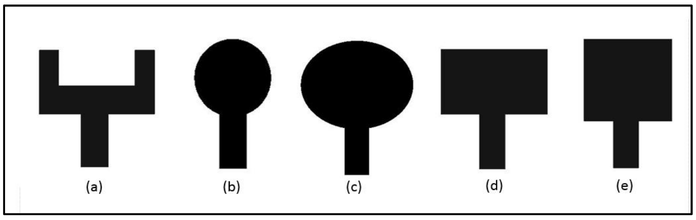

Fig. 2. Various patch structure: (a) rectangular slotted (proposed) (b) circular (c) elliptical (d) rectangular and (e) square shape.

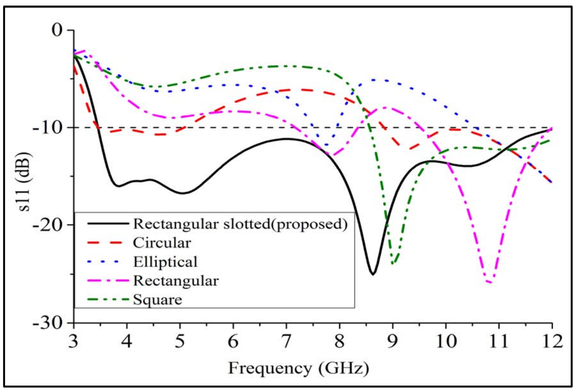

Fig. 3. Simulated s11 for dissimilar patch shapes.

Fig. 5 shows the VSWR result against frequency where the entire bandwidth (3.49 - 12 GHz) in VSWR ≤ 2 in HFSS and CST. Fig. 6 demonstrates the simulated reflection coefficient against frequency for the proposed antenna in both HFSS and CST. We found that the proposed antenna shows a wide bandwidth performance from 3.49 to 12 GHz. Fig. 7 shows the simulated peak gain of the proposed antenna. It has an average 4.2 dBi peak gain. The maximum appreciated gain is 5.4 dBi at 7.9 GHz. The simulated radiation efficiency in HFSS and CST is displayed in Fig.8. We can see that the proposed antenna reached a maximum radiation efficiency of 98.3%. Fig. 9 indicates the proposed antenna's simulated radiation patterns of the two major planes specifically, – xz and –yz planes for three different operating frequencies of 3.5, 6.5, and 9.5 GHz. We can see that the radiation patterns are almost omnidirectional in the yz-plane at a low frequency of 3.5 GHz with low cross-polarization values.

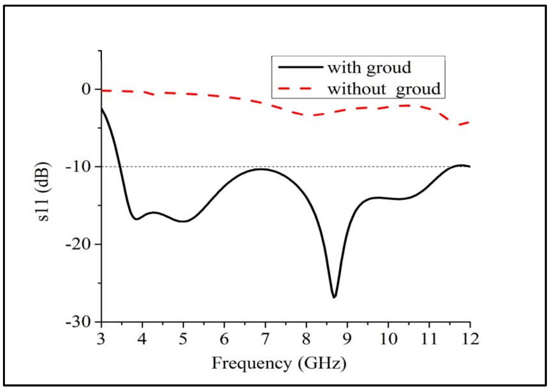

Fig. 4. Simulated s_{11} with and without ground.

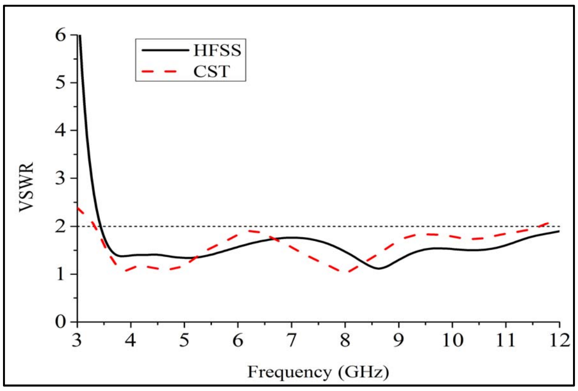

Fig. 5. Simulated VSWR in HFSS and CST.

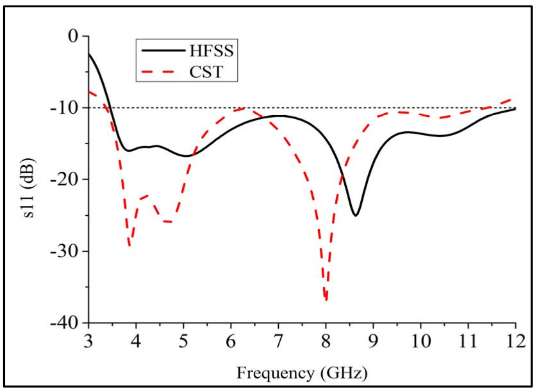

Fig. 6. Reflection coefficient (s_{11}) of the proposed antenna with HFSS and CST.

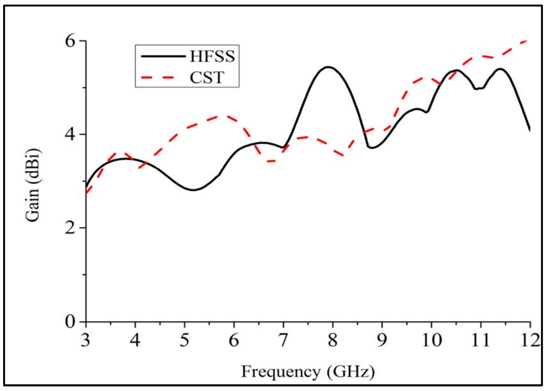

Fig. 7. Simulated Gain with HFSS and CST.

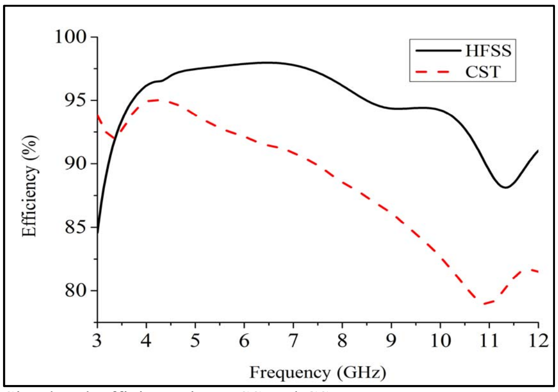

Fig. 8. Simulated Efficiency in HFSS and CST.

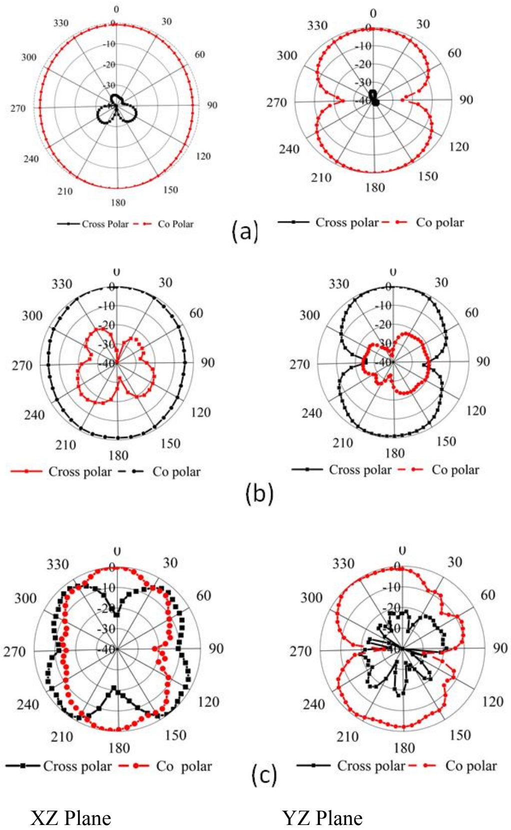

Fig. 9. Simulated radiation patterns at different frequencies. (a) 3.5 GHz; (b) 6.5 GHz (c) 9.5 GHz.

TABLE I. COMPARISON BETWEEN THE PROPOSED UWB ANTENNA WITH EXISTING ANTENNAS

Antennas	BW GHz (–10 dB)	Dimension Area (mm^2)	FB(%)	Gain (dBi)
[2]	3.7 - 18	26 × 28	131.7	3.97
[6]	2.71 – 12.61	25 × 23	129.2	Not reported
[7]	3 – 11.2	22 ×24	115.5	3.6
[8]	3.3 - 20	27 × 23.5	143.3	5.11
[13]	3.2 - 20	31×31	144.8	5.1
[14]	2.6 - 12.3	39 × 40	130.2	5.52
Proposed	3.49 - 12	21.44 × 23.53	109.8	5.76

The radiation pattern is also omnidirectional in yz-plane at a medium frequency of 6.5 GHz. At 9.5 GHz, the radiation pattern is omnidirectional with both xy-plane and yz-plane. We can figure out that the radiation patterns are extraordinarily in stable condition during ultra-wideband. Table I shows the comparison between the proposed antenna and other existing UWB antennas. The considered parameters are antenna bandwidth, the size of the antenna and gain. The proposed antenna has shown decent performance in most of the conditions stated in Table I.

IV. CONCLUSION

The design and simulation of a compact rectangular slotted patch antenna with dimensions of 21.44 × 23.53 mm^2 have been presented. The proposed antenna covers a rectangular slot patch and a tapered-shape ground plane with a thickness of 1.6mm between them. The simulation indicates that the proposed antenna attains decent impedance matching constant-gain, excellent efficiency and stable omnidirectional radiation patterns with an impedance bandwidth of 109.8% (3.49 – 12 GHz) which covers the entire UWB band. The proposed antenna is quite simple in design and easy to fabricate for UWB applications with low manufacturing cost.

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