Improving UWB Microstrip Antenna using Corrugated Compact Design for Wireless Communication Systems

Adam R. H. Alhawari
Department of Electrical Engineering, College of Engineering, Najran University, Najran, Saudi Arabia
aralhawari@nu.edu.sa

***Abstract*—This work experiments a design of another compact ultra-wideband microstrip antenna for wireless communication systems. The design uses a simple corrugating technique on the radiator patch. Likewise, its ground plane is modified to attain ultra-wideband antenna albeit the trifling structure. Altogether, the combination measuring only 48 x 30.4 x 1.6 mm^3 on etched FR-4 material substrate. Its return loss measurement agreeably exhibits an ultra-wideband bandwidth range at approximately 12.8 GHz (3.2 GHz-16 GHz). It shows moderate gain of 2-7 dBi across its operation bandwidth. Furthermore, it comes with extra offer of higher radiation efficiency and omni-directional pattern than old-fashioned bigger sized antennas. Overall measured results of its performance are agreeable with the simulated one.**

***Index Terms*— Compact; Corrugations; Microstrip Antenna; Ultra-wideband.**

I. Introduction

Today the ambiance of digital intelligence leaps on rapid advancement in every walk of life. What was once considered science fictions; is now common reality in our daily life. Every organization vibrantly encourages innovations and technology like never before to beat fierce competitions. This reality also is very relevant for invention of competent miniature antenna designs that operatable at broader frequency of ultra-wideband (UWB) systems [1], [2]. Among the favourite research that lingers within the wireless communication industry is on microstrip monopole antenna due to its promising design simplicity, cost-effective, uncomplicated fabricating techniques, omni-directional radiation pattern and broader frequency bandwidth to accommodate endless demand for more efficient and speedier transfer of larger data size than ever imagined. The well-known slogan: ‘sky is the limit’ witnesses how the industry continues to push the limit.

Unfortunately, most of the explored UWB microstrip antenna designs covering the UWB bandwidth [3]-[12] are generally designed with disappointing sizes. Cynically, some even came short of performance due to its size. This was found either measured when operate within the explored bandwidths or worse, at wider bandwidths. It is a major disappointment in overcoming the main challenges of data transfer issues.

For instance, a UWB fractal-based monopole antenna in [8] where the bandwidth of the antenna was enhanced by increasing the unit-cells of the fractal tree, which was done without any alteration to the physical size of the antenna.

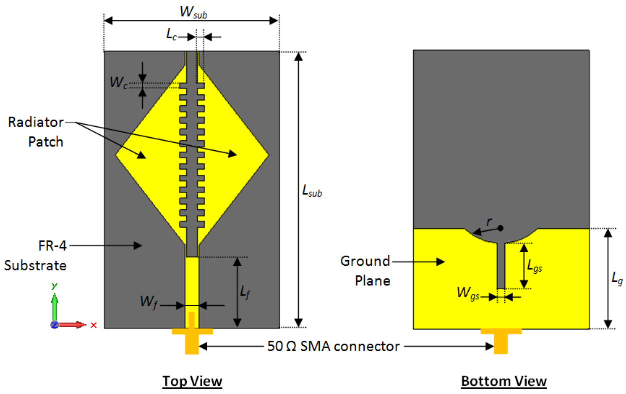


Figure 1: Antenna configuration

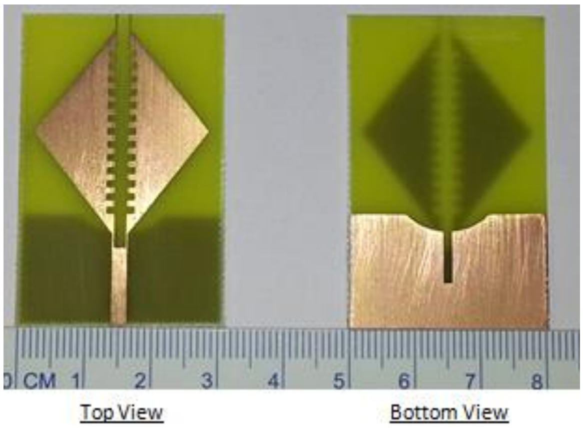


Figure 2: Photograph of the fabricated antenna

Another similar UWB antenna problem was detected in [9-10], which those designs mainly revealed the effect of size and techniques of fabrication on their performance. The design in [9] was reported as a monopole antenna that enhances bandwidth using rotated L-shaped slots and parasitic structures. The other design in [10] is a dual-band CPW-fed octagonal slotted patch antenna covering the operating bands of WLAN, WiMAX and UWB applications. The dual-band operation was achieved using an octagonal slot, L-shape stub, and two-stepped rectangular patch. While the designs in [11-12] are compact, they share the problem of complicated design, which drags to fabrication with those in [9-10]. The earlier design in [11] is a tuning fork-shaped notched UWB microstrip antenna. The bandwidth of that antenna was increased using rectangular radiating patch and an arc-shaped strip in between radiating patch and feed line. One more in [12], is an enhanced UWB antenna design using multiple notches and finite ground plane. The antenna provides a 10 dB bandwidth in excess of 8 GHz in the UWB band at an evidently very compact size of 25 x 25 mm^2. Nevertheless, their complexities are at the expense of being economical. Therefore, the demand keeps pushing the limits on designing better UWB antennas that offer all these qualities at once: small size, flexible design, easier fabrication, improved overall performance and inexpensive cost. A more recent report of a promising miniaturized UWB antenna with metamaterial for WLAN and WiMax applications was proposed in [13]. The antenna design was also considered more complicated as it is using fractalization of the radiating edge and slotted ground structure approach with partial metamaterial loading by introducing modified rectangular split-ring resonator (SRR). In spite of the encouraging results of a peak average gain approximately 2.14 dBi with radiation efficiency of 76.6% in all its operating bands, the size is 38 x 38 mm^2 – bigger than in [12].

Responding to the enigma, this paper proposes a cheaper compact microstrip UWB antenna for UWB communication applications by modifying corrugated design [14] through experimenting in simulations. The optimized findings turned into certain geometry by implementing a simple corrugating technique on the radiator patch, which was placed on a modified ground plane to reach UWB bandwidth. Congruently, the simulation results show reasonable agreement with the measurement results. Briefly, it showed overall good impedance matching, high radiation efficiency, good peak gain, and stable radiation patterns throughout operating bandwidth of 3.2–16 GHz (12.8 GHz).

II. STRUCTURE OF THE DESIGNED ANTENNA

The mentioned geometry of the proposed antenna is shown in Figure 1 and the photo of the fabricated antenna is shown in Figure 2. Post-optimization provided details on the geometrical parameters of the antenna and these are collectively presented by Table 1. The figures of design parameters rely on the best optimized values obtained from the simulation. Parametric study of the design shows that the dimensions used in Table 1 are the best for UWB performance. The antenna consists of radiator patch with corrugations connected to a 50 Ohm microstrip feeding strip which was all deposited onto the top surface of the substrate, as illustrated in Figure 1. Meanwhile, the ground plane can be seen at the bottom surface of the material substrate. Simulations of this design technique promise significant improvement of operating bandwidth and radiation performance of the microstrip antenna.

In details, the impedance bandwidth of the proposed antenna depends on several geometrical parameters such as radiator patch and ground plane dimensions, as well as the dimensions of the corrugations. Effects of these parameters on the return loss of the proposed antenna were investigated by varying one parameter at a time and fixing the others by the help of the simulator. The results are shown in Figures 3-8. Figure 3 shows a difference between the simulated results of the input impedances of the proposed antenna between the one with and the other one without corrugations, which evidently supporting the expectation of enhancement by applying corrugation on the radiator patch. The operational bandwidth performance demonstrates that there are significant elevations in terms of bandwidth and return loss respectively for the antenna with corrugations compared to the other antenna without corrugations. Figures 4 and 5 demonstrate the effect of resizing the corrugations dimension; the length and the width of the corrugating respectively. Impressively we found that, the optimal bandwidth is achievable at the dimension as small as 0.5 x 0.5 mm^2. In Figures 6 and 7, the alteration of the ground plane dimensions went through multiple simulations to study the effect of different values on *Lgs* and *Wgs*. From the stated figures, obviously the input impedances of the proposed antenna can evidently be improved by choosing the best functioning values of *Lgs* and *Wgs* when it was simulated. This feature may be useful in antenna fine tuning. Figure 8 shows the simulated return loss with different values of *r*. It was discovered through simulation that, the most optimized value of '*r*' is around 9 mm, where the frequency response of the antenna is efficiently enhanced as illustrated in Figure 8. Meanwhile the working range stops at $r = 0$ mm, whereas the antenna's performance is unstable and stated: "failed to fulfill the UWB requirement" as shown in Figure 8. This 'r' plays a vital key parameter in order to tune the bandwidth impedance of the proposed antenna. It apparently goes easier design-wise, tinier size and cheaper cost with etching the FR-4 material substrate on printed circuit board (PCB) techniques to yield this amusing performance in suiting the UWB specifications.

Table 1
Antenna Dimensions

Parameter	L_{sub}	L_f	L_c	L_g	L_{gs}	W_{sub}	W_f	W_c	W_{gs}	r
Dimension (mm)	48	12.3	1.25	17.4	7.82	30.4	3.0	1.0	1.3	9.2

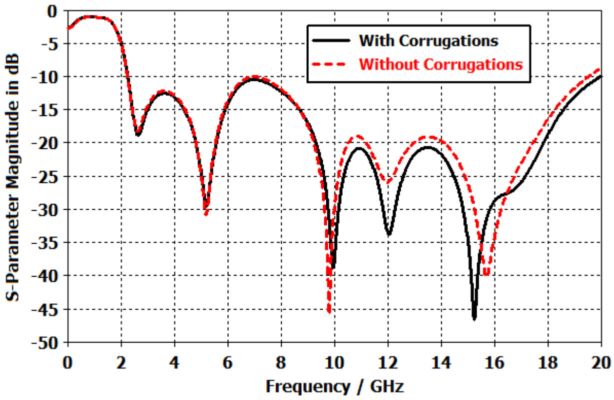
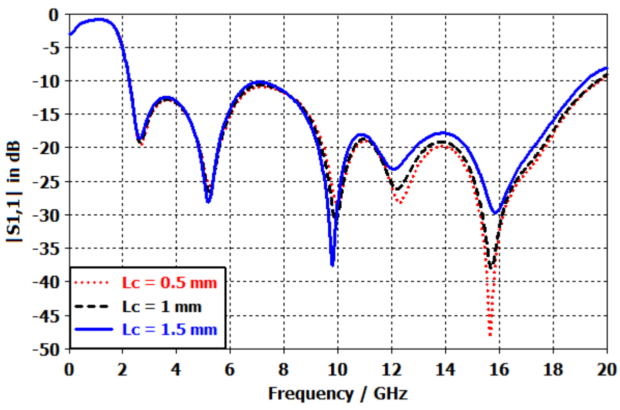


Figure 3: Simulated return loss result with and without corrugations



4: Simulated return loss with different values of *Lc*

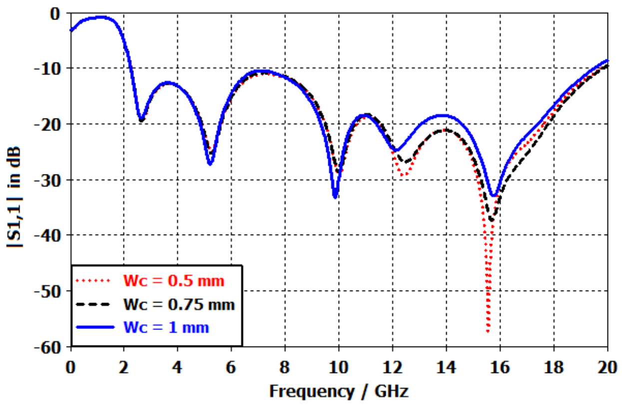


Figure 5: Simulated return loss with different values of *Wc*

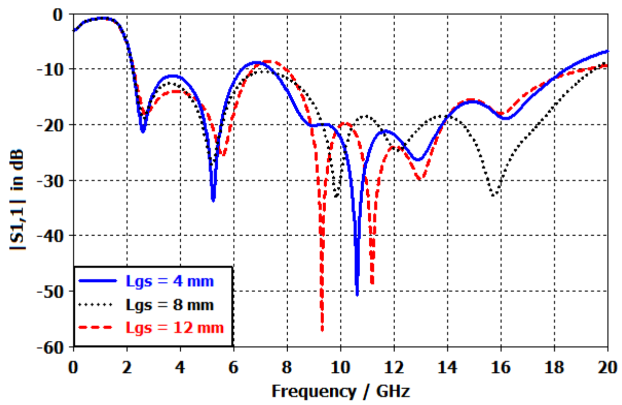


Figure 6: Simulated return loss with different values of *Lgs*

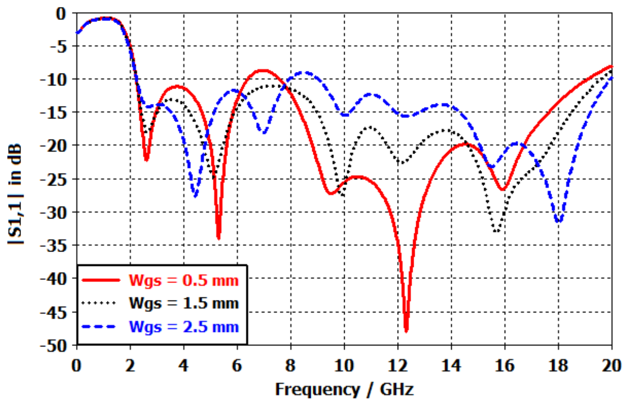


Figure 7: Simulated return loss with different values of *Wgs*

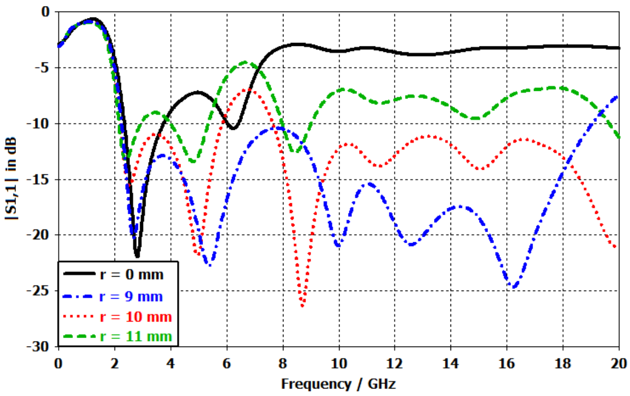


Figure 8: Simulated return loss with different values of *r*

III. RESULTS AND DISCUSSION

The proposed antenna was fabricated on an economical epoxy-based (FR-4) substrate with a dielectric constant (ε_r) of 4.4, tangential loss (δ) of 0.02 and thickness of 1.6 mm. Its return loss (the photo shown in Figure 2) was measured using a vector network analyzer (Anritsu 37347D). For comparison purposes, the simulated and measured results are depicted in Figure 9. As the measurement result demonstrates, the 10 dB return loss bandwidth of the proposed antenna is about 12.8 GHz (3.2 GHz-16 GHz), which indicates that the antenna exhibits UWB bandwidth feature satisfying the VSWR requirement of less than 2 for the same frequency band. The measured and simulated responses were in good agreement, thus, verifying the design processes. The small difference between the measured and simulated results are due to the common and unavoidable mismatch between feeding line and SMA connector as well as imperfections of the standard PCB fabrication processes which were absent in the ideal simulation.

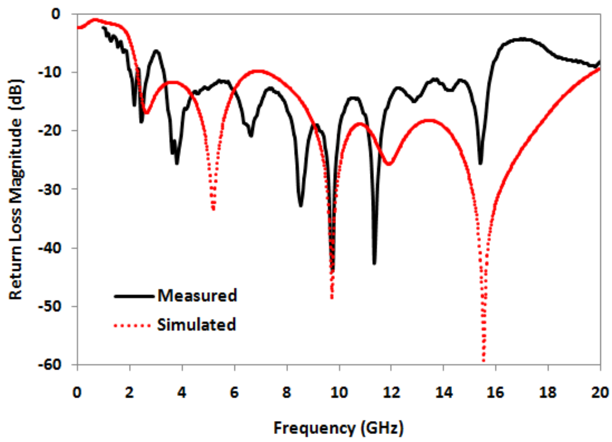


Figure 9: Measured and simulated return loss

The compact size of proposed antenna is 48 x 30.4 x 1.6 mm^3. The significant size reduction goes along well with the pursuit of creating cost-effective compact UWB devices. Apart from that, it is proven to perform better compared to the designs recently reported in [6], [8], [10], [13], [15] in terms of return loss, gain and radiation efficiency as shown in Table 2. Figure 10 and 11 depicts the gain and the radiation efficiency of the design antenna respectively. It is clear that the proposed antenna has a good gain from 2 dBi to 7 dBi with high radiation efficiency more than 96% over its entire operational bandwidth. Interestingly, the results of both simulation and measurement yielded higher antenna gain at higher frequencies from this design.

Table 2
Comparison of the Measured UWB antennas Performance

Reference	*Operating Bandwidth (GHz)*	*Gain (dBi)*	Radiation Efficiency (%)	Antenna Size (mm^3)
[6]	5.2 – 13.9	1 – 4	80	25 x 25 x 1.6
[8]	2.1 – 11.52	2 – 5.2	-	24 x 24 x 1
[10]	3.2 – 6.2	-1 - 5	73- 84	20 x 20 x 1.6
[13]	2.95–14.28	1.6 – 3.6	61 - 91	38 x 38 x 1.6
[15]	3.8 – 8.8	7 - 9	-	36 x 24 x 1.6
Proposed Antenna	3.2 - 16	2 - 7	better than 96	48 x 30.4 x 1.6

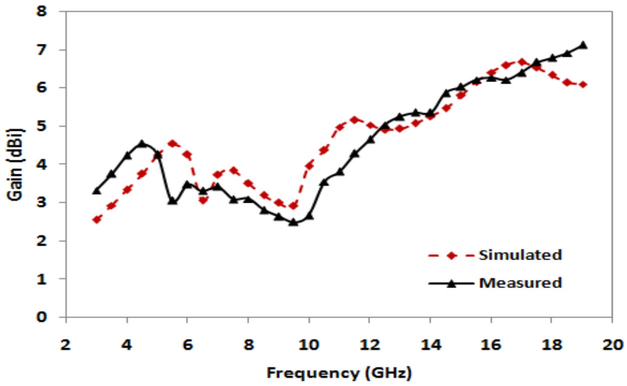


Figure 10: Measured and simulated gain versus frequency

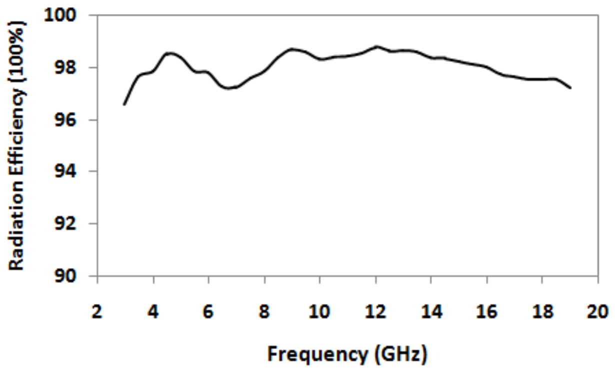


Figure 11: Radiation efficiency versus frequency

The simulated radiation patterns of the proposed antenna in the E-plane (y-z plane) and the H-plane (x-z plane) at 5, 8, 12 and 15 GHz are shown in Figure 12. We noticed that the proposed antenna exhibits approximately omni-directional radiation pattern over its whole frequency range (3.2 - 16 GHz).

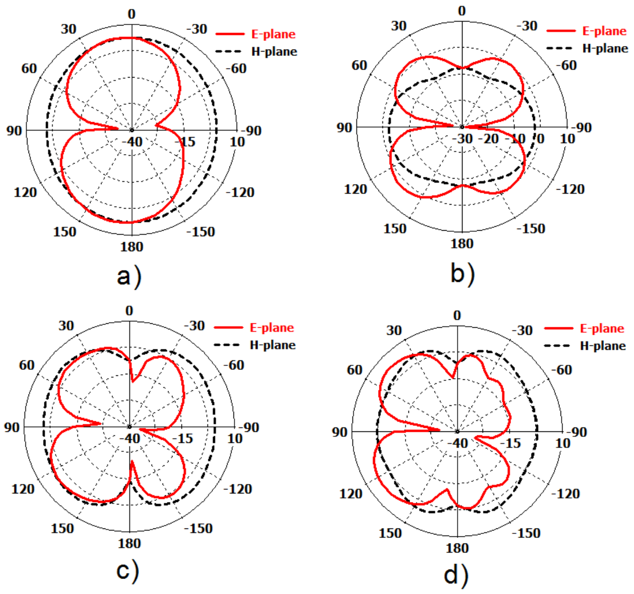


Figure 12: Radiation patterns at (a) 5 GHz, b) 8 GHz, c) 12 GHz and (d) 15 GHz

IV. Conclusion

A unique corrugating technique to easily design a compact microstrip antenna for UWB applications is introduced in details. It operates along 3.2–16 GHz band with optimum gain of 2–7 dBi at good radiation efficiency (better than 96%) across the operational bandwidth. It is comparably simpler and easier to design and fabricate compared to the above-mentioned compact microstrip antennas. Accordingly, it is agreeably in the queue with other competitive designs for the contemporary UWB applications in communication systems industry.

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