Design of Double Layers Miniaturized Trimmed Semi-Rectangular Monopole with Partial Ground Plane for Short Ranges Wireless Systems

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Abstract **—** This paper presents a new miniaturized design of antenna with extremely wide bandwidth. The design consists of trimmed half rectangular patch printed on a 10x13 mm^2 substrate of Rogers Duroid RT5880Lz with relative permittivity of ϵr=1.96 and loss tangent of 0.0009. The monopole has a partial modified ground plane structure to enhance the impedance matching and to provide wider bandwidth from 2.6 GHz to 15.7 GHz with reflection coefficient less than -10 dB. The proposed design has been tested, optimized, and experimentally measured for verifications; simulated and measured results have achieved high concord. The presented monopole is suitable for short range wireless systems as well as lower 5G bands applications.

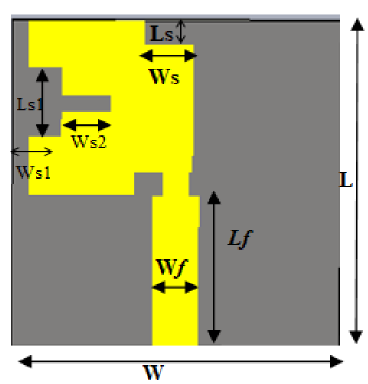
Index Terms **—** Lower 5G, patch, short range systems, UWB antenna.

I. INTRODUCTION

Recently, miniaturized antennas with wide operating frequencies have gained more attention in the modern wireless communication systems [1-3]. This is due to the significant features of such antennas in extremely reduced structure size, high speed data rates, simplicity, and power consumption results for in longer battery life. Hence, varies of ultra wide band antennas have been introduced and published recently to satisfy the dramatic increment in the demand of wireless systems [4-12]. These antennas have different geometric designs, structure sizes, and performance as well; it has been observed that the majority of them have large structure size as ultra wideband designs in [13-15]. Their sizes are 36x35, 39x38, and 53x49 mm2, respectively. Thus, the size can be an obstacle to implement the monopole in compact wireless systems. In addition, some proposed antennas do not cover the entire UWB allocated for short communication system by FCC from 3.1 GHz to 10.6 GHz [16] for instance the design in [14]. Moreover, several UWB antennas have low power gain which is a critical factor for wireless system and plays a vital role in saving the battery life [17-19]. Based on that, the proposed monopole antenna in this paper has overcome these shortages without scarifying in the main performance parameters. This design is characterized by miniaturized structure size, high impedance matching, and high power gain. Also, the antenna has an omni directional radiation pattern in total. Thus, the design can be placed in any position within the gadget or device and has wider radiation. The patch is suitable for short ranges wireless applications, lower fifth generation systems, and many ultra wide band applications [20].

II. PROPOSED MONOPOLE DESIGN

Two dimensional design and fabricated model of the suggested miniaturized 13x10 mm^2 antenna are shown in Figs. 1 (a, b, and c) labeled with parameters revealed in Table 1. As demonstrated in the former figure, the antenna has a partial ground plane at which I-shape slots placed to enhance impedance matching leading to wider bandwidth as presented in details in the following section. The proposed design consists of a trimmed half rectangle made on a substrate of Rogers RT 5880LZ material with relative permittivity of ϵr=1.96 and loss tangent of 0.0009. The monopole is fed by a 6.5 mm long and 1.8 mm wide microstrip feeding line with a characteristic impedance of 50 ohm. The patch has been designed using an industrial standards modeling software and fabricated for more verifications.



(a)

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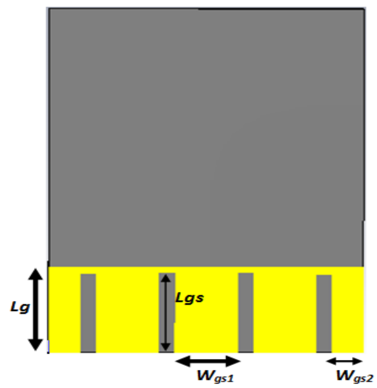


(b)

(c)

Fig. 1. (a) Geometry of the proposed antenna top layer, (b) bottom layer, and (c) image of fabricated design.

Table 1: The presented half rectangular antenna parameters in mm

Parameter	Value in mm	Parameter	Value in mm
L	13	Lg	3.5
W	10	Lgs	3.25
H	0.9	Wgs1	2
Wf	1.8	Wgs2	1
Lf	6.5	Ls	1
Ls1	2.5	Ls2	2

III. MODELING RESULTS AND EXPERIMENTAL MEASUREMENTS

In general, narrow band antenna contains single resonant frequency while ultra wide band antenna has multiple resonant frequencies together creating the ultra-wideband width [21]. According this concept, the presented antenna contains two main resonant frequencies at 5.8 GHz and 10.6 GHz creating a wide bandwidth starting from 2.6 to 15.7 GHz as shown in Fig. 2. Measured and simulated reflection coefficients have an acceptable alignment with minor deviations due to popular causes for instance measuring and fabrication equipment tolerance, soldering effects etc.

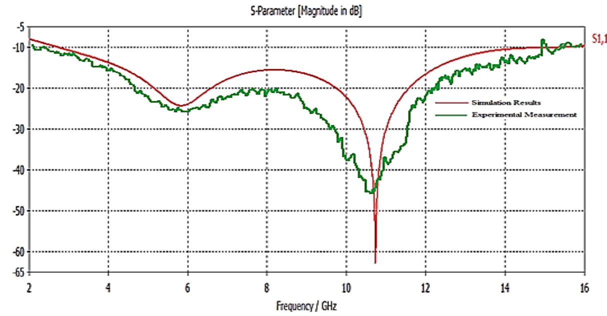


Fig. 2 reflection coefficient (S11) in dB versus operating frequency in GHz

As part of the optimization and analysis process, the proposed monopole parameters and several substrate materials have been examined for improving performance in terms of bandwidth and radiation pattern while maintaining minimized structure size. Numerous popular dielectric materials, which are Polyimide, FR-4, and Rogers RT 5880LZ with relative permittivity of 3.5, 4.3, and 1.96 respectively, have been studied. Figure 3 displays reflection coefficient parameter for the previous materials versus operating frequency. Obviously, using Rogers RT 5880LZ (εr =1.96) bandwidth is the widest with extremely diminished power loss and S11 reaches below -60 dB. Thus, at this resonant frequency, the accepted power by the radiator is more than 99.9% of input power [2]. Figure 4 illustrates the antenna reflection coefficient (S11) with and without I-shape slots. It is clearly overserved that the significant effects of this modification on the impedance matching and bandwidth. Besides, the microstrip feeding line width plays key role in the optimization process. Since the feeding line is transferring the input power into radiator structure where both have to be at high matching. Figure 5 displays multiple values of wf in mm where the optimum S11 is obtained at 1.8 mm.

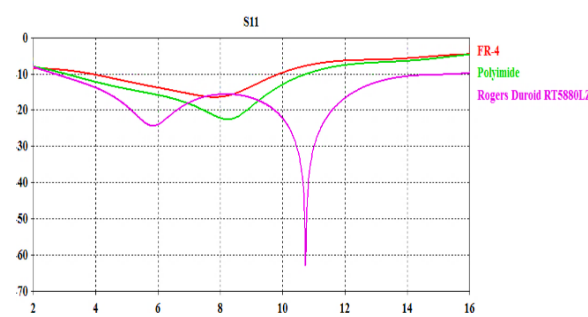


Fig. 3. Reflection coefficient in dB vs frequency in GHz using several popular substrate materials (Polyamide, FR4, and Rogers Duroid RT5880 LZ).

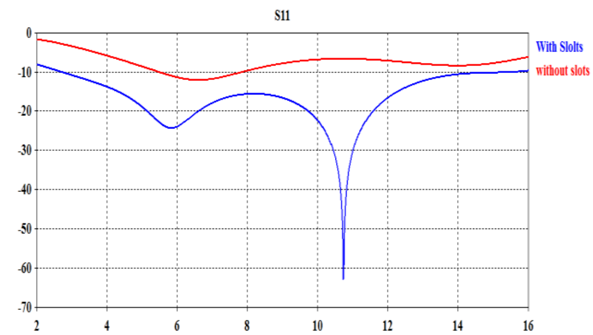


Fig. 4. The S11 parameter in dB for the proposed antenna showing the effect of the partial ground plane structure (DGS).

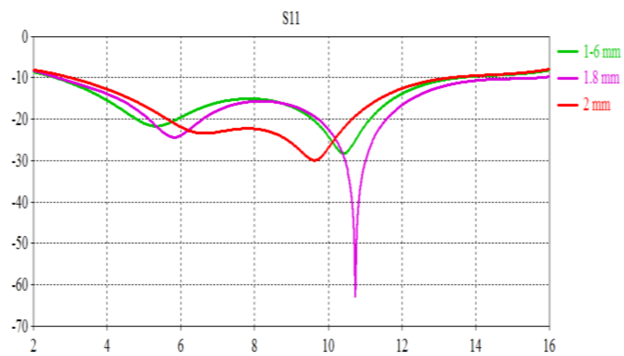
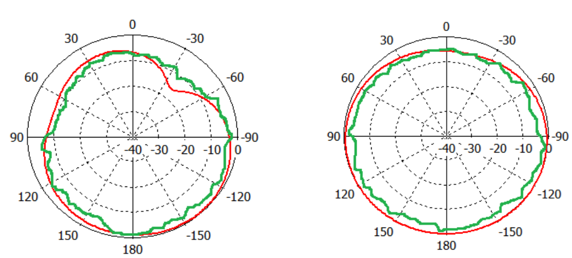


Fig. 5. Studying the width parameter of the feeding line (wf) for the presented design.

Figure 6 shows the presented antenna normalized radiation pattern at the two orthogonal planes elevation (E) and azimuth (H) at 5.8 GHz, and 10.6 GHz. the radiation patterns are revealed at the two orthogonal planes, E plane or elevation plane and H plane or azimuth plane in polar forms. Throughout the entire bandwidth, the radiation pattern at the azimuth plane has an omni-directional pattern. Besides, elevation plane has approximately bi-directional form with minor distortion. Hence, the presented patch is independent of placement position during the broad bandwidth. Also, the measured power gain of the proposed monopole has been plotted over the wide bandwidth in Fig. 7. It can be noticed that the design has high gain with a maximum of 6 dB.



(a)

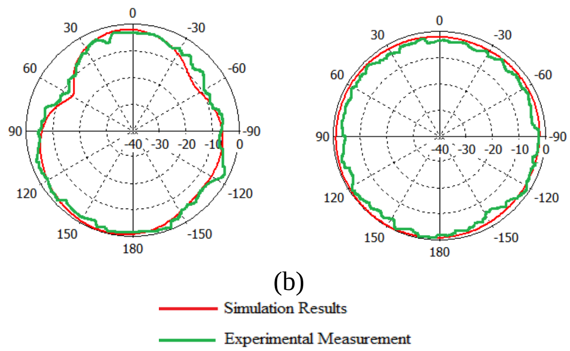


Fig. 6. The normalized radiation pattern for E and H planes in polar form at the two resonant frequencies.

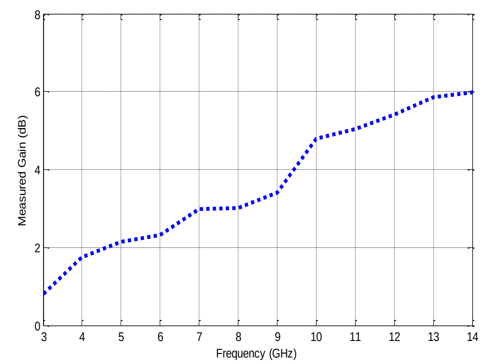


Fig. 7. Measured power gain in dB vs the operating frequency.

IV. CONCLUSION

A novel miniaturized antenna design is proposed for ultra wideband systems. The monopole is minimized with a total size of (13 x 10x 0.9 mm^3), while retaining high features performance. The presented monopole has an extreme wide bandwidth ranging from 2.62 GHz to 15.7 GHz with a bandwidth of more than 13GHz which covers the band set by FCC [16]. The antenna is characterized is by an omni-directional pattern through the operating frequency. Lastly, the trimmed design has competing performance in comparison with several other larger structure designs which makes it exceedingly appropriate for extremely compact wireless applications.

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