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A UWB Planar Antenna for 5G Smartphones and Wireless Applications

Md. Tanvir Rahman Jim, Md. Monwar Hossain, Md. Kawsar Ahmed

Abstract: ***We describe a compact planar antenna for enhancing bandwidth, suitable for ultra-wideband devices like smartphones. In order to attain an ultra-wideband response of 6.5478GHz, the partial ground plane structure is applied to the suggested design in this paper. The total dimensions of the proposed antenna are 36× 30×0.79 mm³ (853.2 mm³). Throughout the whole frequency range of 2.782GHz to 9.3298GHz, (S11 ≤−10 dB), the antenna's gain and directivity vary from 2.30 dB to 3.72 dB and 2.59 dBi to 3.9 dBi, respectively. The suggested design's performance parameters exhibit a respectable return loss of -26. 983. The VSWR is 1<VSWR<2 across the entire band, and it is 1.087 at 3.33GHz. All of the significant requirements have been satisfied by the time domain and frequency domain analyses. The 2018 edition of the Computer Simulation Technology (CST) Microwave Studio Suite was used to carry out all of the characteristic parameters. This idea will encourage the development of high performance ultra-wideband antennas for 5G devices.***

Index Terms: 5G; Ultra-Wideband Antenna; WiMAX; Lower 5G; Partial Ground Plane; High Efficiency; CST.

Abbreviations:
WLAN: Wireless Local Area Networks
UWB: Ultra-Wideband
HPBW: Half Power Beamwidth
TD: Time Domain
FEM: Finite Element Method
FIT: Finite Integration Technique
FCC: Federal Communication Commission
CST: Computer Simulation Technology

I. INTRODUCTION

5G technology is leading the way in the quickly changing wireless communication market, offering previously unheard-of connectivity and data speeds [1]. An important enabler that makes high-speed data transfer, accurate positioning, and immersive experiences possible is ultra-wideband (UWB) technology [2]. In this regard, the incorporation of UWB planar antennas into 5G devices presents a wealth of opportunities [3], providing improved performance and opening up a plethora of creative uses [4]. The UWB band, which is 3.1–10.6 GHz, was established by the Federal Communication Commission (FCC) [5].

Taking into account that UWB spectrum is shared with other technologies and standards, such as the 3.6 GHz IEEE 802.11y wireless local area networks (WLAN) (3.6575–3.69 GHz), 4.9 GHz public safety WLAN (4.94–4.99 GHz), and 5 GHz IEEE 802.11a/h/j/n WLAN (5.15–5.35, 5.25–5.35, 5.47–5.725, 5.725–5.825 GHz) and C band(4-8GHz) [6].This study offers a thorough examination of the design factors, difficulties, and solutions related to creating a UWB planar antenna that is especially suited to the limitations and specifications of contemporary smartphones [7]. To guarantee excellent performance and smooth integration, every factor—from size restrictions, radiation efficiency, and manufacturability to frequency range coverage—needs to be carefully considered [8]. This initiative intends to advance the state-of-the-art in mobile communication and pave the path for the next generation of 5G-enabled devices through thorough design and cross-disciplinary collaboration [9]. Several methods, such loading two symmetrical open-ended slits on the radiating patch, slots, and FSS structures [10], have been proposed to achieve UWBA with band notch [11]. The development of 5G applications, which will enable extremely fast data transfer rates, low latency, and widespread connectivity, promises to bring about dramatic changes across industries [12]. Furthermore, the expanded capabilities of 5G networks foster the growth of immersive education, remote work [13], and IoT breakthroughs, paving the way for a future in which connectivity enables previously unheard-of levels of productivity [14], efficiency, and ease. The implementation of UWB technology for portable handheld devices was becoming more and more difficult due to the high antenna size [15]. Thus, one of the main goals of UWB antenna designers was size minimization. A MIMO antenna array with four ports is described in [16]. With measurements of 30 × 40 × 1.6 mm³, the matching antenna has an impedance bandwidth of 58.56%, gain of 3.5 dB, and efficiency of 85% [20]. The author of study presented an antenna with a peak gain of about 4.16 dBi for sub-6 GHz 5G wireless applications [21]. The antenna's frequency range was 3.40 to 3.59 GHz. In introduces an elliptical patch antenna for Sub-6GHz applications [22]. Its total dimensions are 50 × 30 × 1.6 mm^3. Based on Rogers Duroid RO3003 substrate, the authors in developed, tested, and manufactured a 35 ×33× 0.76 mm3 low-profile antenna for LTE and Sub-6GHz applications [23]. The antenna uses coplanar waveguide feeding and has a wide frequency range [24]. The remainder of the paper is organized as follows: Section II goes into great detail about design and

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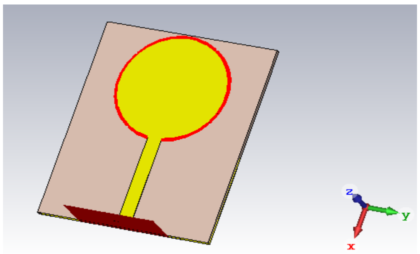
structures; Section III presents the results and discussions; and Section IV concludes with a conclusion

II. UWB ANTENNA DESIGN AND STRUCTURE

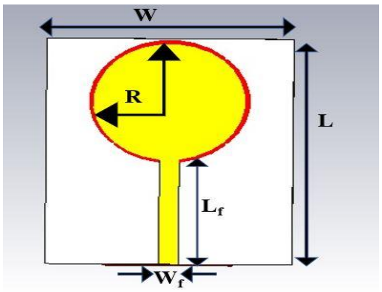
With the CST-MWS suite 2018, a UWB patch antenna study was completed. The intended UWB antenna's evolution process is depicted in Figs. 1(a), 1(b), and 1(c), respectively, along with a 3D perspective and the rear prototype. Rogers RT5880 (2.2, 0.0009), a relatively low lossy dielectric material with a thickness of 0.79 mm, is chosen for the design. The annealed copper used to make the ground plane has a thickness of 0.035 mm. and they are then optimized to an appropriate value [19].

Finally, the optimized volume of the low UWBA is 36 mm × 30 mm × 0.79 mm. The feedline length (L_f) is 17.70 mm and the feedline width (W_f) is 2.4 mm. A 50 Ω microstrip feedline technique is used to energize the proposed antenna Table II provides a summary of the optimized parameters list for the suggested UWB antenna.

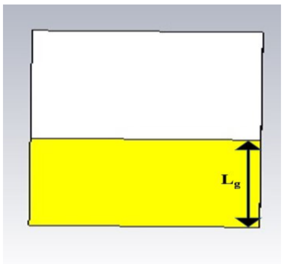
The area of the ground plane is 16.10×30 mm^2. In this research work, waveguide port excitation k = 8.5 is utilized during port creation and the line impedance is adjusted at 50 Ω the excitation coefficient (k) is calculated to be between 4.64 and 8.68.



(a) 3D view



(b) Top view



(c) Back view

[Fig.1. Proposed UWB Antenna]

As shown in Fig. 1(c), the area of the partial ground plane is 16.10×30 mm^2. The suggested UWB planar antenna's partial ground plane effects its bandwidth, antenna volume, and good impedance matching [19]. The suggested UWBA's design parameters are shown in Table I.

Table-I: Parameter's List UWBA

Title	Symbol	Weight (mm)
Length	L	36
Width	W	30
Radius of circular patch	R	9.5
Ground length plane's length	L_g	16.10
Substrate thickness	h	0.79
Feeder length	L_f	17.70
Feeder width	W_f	2.4

III. RESULT AND DISCUSSION

A broad bandwidth spanning from 2.782GHz to 9.3298GHz is displayed by the UWB antenna with changed ground structure, as shown by the matching reflection coefficient curve in Fig 2. This operational band spans the entire 3.1-10.5 GHz UWBA 5G band, which is widely utilized. Throughout the whole frequency range of coverage, it also exhibits an excellent reflection coefficient profile (-26.983 dB at 3.33 GHz). Its 6547.8MHz bandwidth is quite large. The frequency domain and time domain are in close proximity to one another. At 3.33 GHz, the UWBA's VSWR is 1.087 and fluctuates between 1-2 (Fig. 3). It confirms that the antenna's impedance matching is good. Fig. 4 shows the UWB's 3D and linear gain and directivity graphs. The directivity and gain at 3.33 GHz are 2.935 dBi and 2.601 dB, respectively. Within the frequency range of 2.782 GHz to 9.3298 GHz, the directivity and gain vary from 2.59 dBi to 3.9dBi and 2.30 dB to 3.72 dB. The UWBA antenna also exhibits a respectable gain and directivity profile, as shown in Fig. 4(c).

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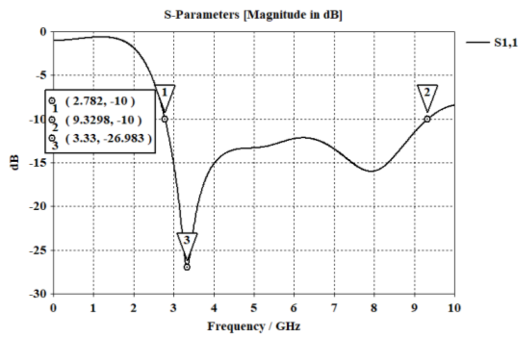
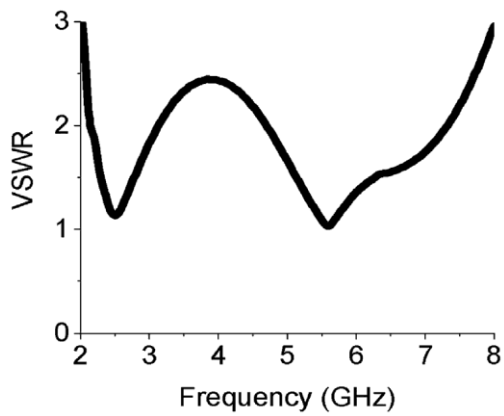


[Fig.2. Reflection Coefficient of the UWBA]



[Fig.3: VSWR the Proposed UWBA]

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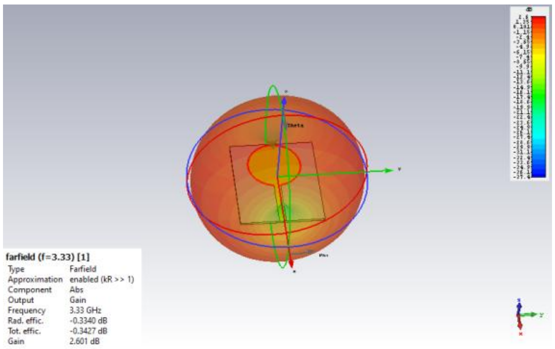
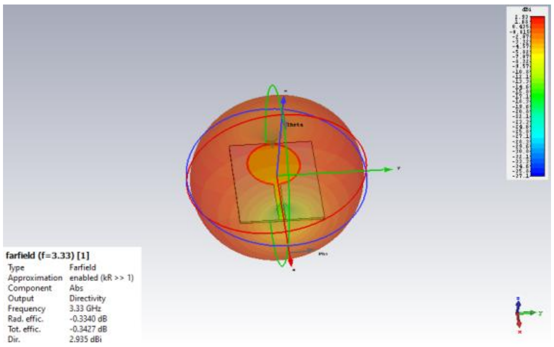
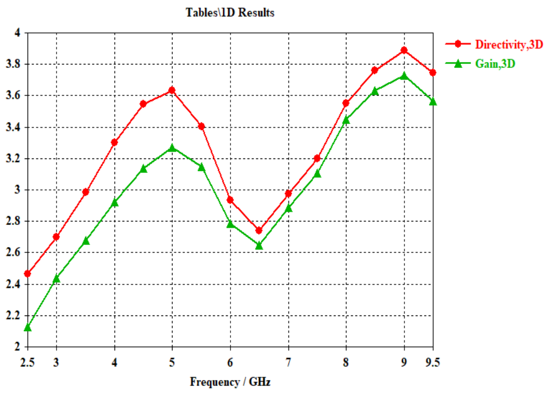


(a) Gain at 3.33 GHz

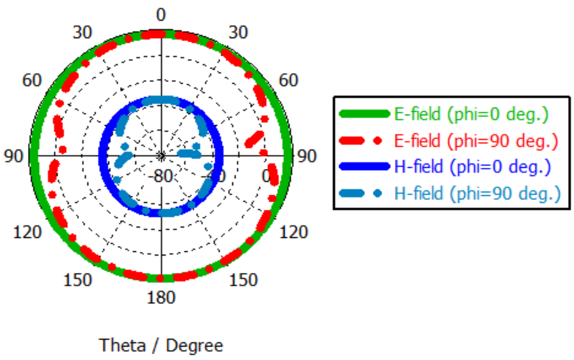


(b) Directivity at 3.33 GHz



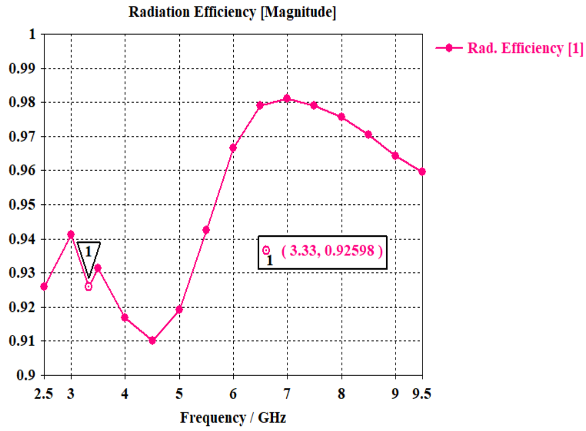
(c) linear curve

[Fig.4: Gain and Directivity of the UWBA]



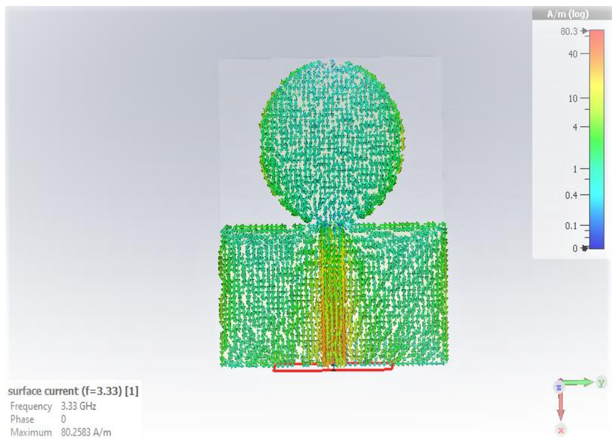
[Fig.5: E and H Fields of the UWBA]

The planned compact UWBA's E and H fields are shown in Fig. 5 at a resonance frequency of 3.33 GHz for both phi = 0 deg and 90 deg. The major lobe is oriented at 174◦ at phi = 0◦◦ and at 180◦ phi = 90◦◦, as can be shown in Fig. 5. At phi = 0˚ and phi = 90◦, the main lobe magnitudes are 17.4 and 17.3 dBV/m, respectively. At phi=0◦, the half power beamwidth (HPBW) is 85◦, and at the centre frequency of 3.33GHz, the side lobe level is -0.9 dB. Additionally, the main lobe magnitude for the magnetic field (H- field) is -35.1 dBA/m at phi = 0◦ and -35.7 dBA/m at phi = 90◦. The suggested UWBA antenna's radiation pattern is seen to be omnidirectional.

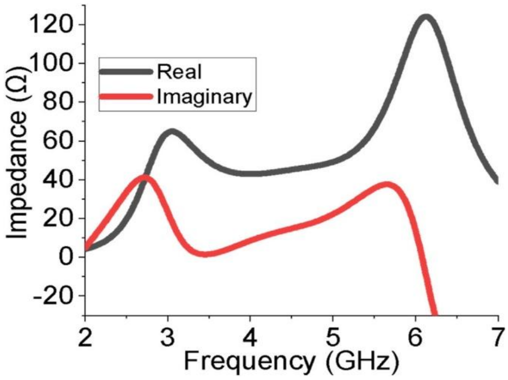


[Fig.6: Efficiency of UWBA]

Roger RT 5880, a low loss material, and appropriate impedance matching allow the design UWBA to exhibit exceptional radiation efficiency. It consistently retains 91% or higher, as shown in Fig. 6. At 3.33GHz, the UWBAA's radiation efficiency is 92.598%, indicating that it can perfectly radiate the majority of received power (91-98.33). Fig. 7 shows the surface current distribution at 3.33 GHz. At 3.33 GHz, the central frequency is 80.2583 A/m. According to the color indication, the maximum current distribution is shown at the circular patch's edge and the microstrip feed. Fig. 8 shows the impedance profile of the UWBA. At 3.33 GHz, the UWBAA's input impedance is (50+j.5755) Ω, which is extremely near to 50 Ω pure resistive. Maxwell's equation is solved in CST by a time domain (TD) solver using the finite difference time domain (FDTD) approach and a frequency domain solver using the finite element method (FEM). It takes two to solve these two distinct approaches to the same issue. The finite integration technique (FIT), which operates on the integral version of Maxwell's equations, is the source of both the TD and FD solvers. Table II displays the designed UWBA's results summary.



[Fig.7: Surface Current at 3.33 GHz]



[Fig.8: Z-Parameters of the UWBA]

Table-II: Key Parameters of the UWBA

Description	Value
Lower cut off (dB)	2.782
Upper cut off (dB)	9.3298
Bandwidth (GHz)	6.5478
Resonant frequency	3.33
Return loss (dB)	-26.983
VSWR	1.087
Gain(dB) at 3.33 GHz	2.601
Surface current	80.2583 A/m
Directivity (dBi) at 3.33 GHz	2.935
Maximum radiation efficiency (%)	98.33
Impedance (Z) at 3.33GHz	50 + j0.5755

A comparison between our developed UWBA suggested antenna and a few recently published UWB antennas is shown in Table III below. It is evident that our suggested antenna has a maximum bandwidth, high efficiency, small size, and low volume.

Table-III: Comparison

Parameter	Ref. Number				Our work
	[15]	[16]	[17]	[18]	
Size (L×W×h) mm^3	55× 30× 1.6	35×33 ×0.76	30.2 ×36.4 ×1.6	40.1×3 5.5× 1.6	36×30 ×0.79
Substrate material	FR4	Rogers Duroid RO3003	FR4	FR4	Rogers RT 5880
Operating Frequency Range (GHz)	2.25- 5.50	2.48 - 2.55, 4.23- 5.42	3.43- 3.80	2.8-4.6	2.782- 9.3298
Centre frequency	3.24	≈ 2.5, 4.5	3.5	3.008	3.33
Reflection coefficient (dB)	≈-38	-25, -22	-30.77	-41.35	- 26.983
Peak Gain (dB)	1	5, 5.5	5	1.89	3.72
BW (GHz)	3.24	1.07, 1.19	0.37	1.78	6.5478
VSWR	-	-	1.05	1.5	1.073
Maximum Efficiency (%)	-	≈ 93.3	95	-	98.33

IV. CONCLUSION

In conclusion, this work introduces a planar antenna that is thoughtfully built for 5G (UWB) smartphones and wireless applications. With re-configuration capabilities, the suggested receiving antenna can span the UWB frequency range of 2.872 to 9.3298 GHz. The maximum distribution of current and efficiency are 80.2583A/m and 98.33%, respectively. The key to getting a UWB antenna with an acceptable gain and omnidirectional radiation qualities is configurability and enhanced performance. Based on the data provided, it can be concluded that the suggested planar antenna offers the best performance and minimal volume among its competitors for 5G UWB applications.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted with objectivity and without any external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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