A Compact Ultra-Wideband mmWave Antenna for 5G Wearable Applications

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***Abstract*—This paper presents a compact ultra-wideband millimeter wave antenna fed by coplanar waveguide (CPW). The proposed antenna integrates a circular radiating patch with an arc-shaped slot and a dumbbell-shaped defected ground structure (DGS), enhanced by optimized F-shaped tuning stubs. Fabricated on a flexible polyethylene terephthalate (PET) substrate, the design achieves a compact size of $6\times10\times0.127$ mm^3. The results indicate that the antenna has a bandwidth of 26.40-51.59 GHz, which covers the Ka-band and 3GPP n257/n259/n260/n261 5G NR bands. The radiation efficiency is stable from 84.6% to 96.6%, and the peak gain reaches 4.85 dBi. Its broadband performance, miniaturized dimensions, and mechanical flexibility render it suitable for integration into 5G wearable communication systems.**

Keywords*——coplanar waveguide (CPW); ultrawideband (UWB); mmWave antenna; 5G application.

I. Introduction

Millimeter wave band (30-300 GHz) has become a key solution to overcome the capacity limitations of Sub-6GHz band with its ultra-wide bandwidth and high-speed capabilities. As standardized by The Third Generation Partnership Project (3GPP), the 5G mmWave spectrum encompasses the FR2 band (24.25-52.6 GHz). It includes critical subbands such as n257 (26.5-29.5 GHz), n259 (39.5-43.5 GHz), and n260 (37-40 GHz). Notably, the Ka-band (26.5-40 GHz) has emerged as a primary focus for mmWave communication research due to its relatively lower atmospheric attenuations (compared to 60 GHz band) and abundant spectrum resources [1]. The Federal Communications Commission (FCC) of the United States has prioritized 28 GHz and 38 GHz bands for 5G deployment, targeting high-density scenarios requiring multi-gigabit throughput, such as smart wearable systems.

These advancements impose dual challenges on antenna design: supporting multi-standard mmWave broadband operation for ultra-high speed transmission, and developing compact low profile structures for miniaturization and conformal device integration. While CPW-fed antennas have gained attention in designing compact UWB antennas due to their structural simplicity and broadband potential, existing designs face trade-offs between size, bandwidth, and fabrication complexity. Conventional designs either exhibit excessive dimensions [2], insufficient bandwidth coverage [3], or rely on multilayer configurations that complicate fabrication processes [4]. The DGS techniques have demonstrated bandwidth enhancement capabilities in [5], but they have problems of large size and unstable radiation efficiency.

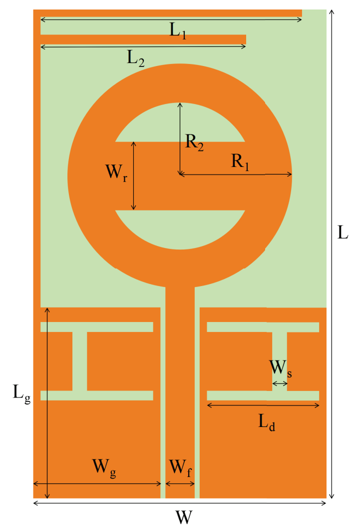

Fig. 1. Physical geometry of the proposed antenna structure. Detailed dimensions: W = 6 mm, L = 10 mm, Lg = 3.9 mm, Wg =2.6 mm, Ld = 2.3 mm, Wf = 0.6 mm, Ws = 0.3 mm, Wr = 1.4 mm, R1 = 2.3 mm, R2 = 1.5 mm, L1 = 5.35 mm, L2 = 4.05 mm.

To address these challenges, this paper proposes a compact CPW-fed UWB antenna on a PET substrate of $6\times10\times0.127$ mm^3 . The design achieves a 26.40-51.59 GHz operational bandwidth with stable radiation efficiency and acceptable peak gain.

II. Antenna Design

The structure of the proposed antenna is shown in Fig.1. The antenna employs a CPW feed structure, and the main radiator is a circular metal patch. Broadband impedance matching is achieved through two arc-shaped slots etched symmetrically on the patch surface, combined with two dumbbell-shaped DGS and optimized F-shaped tuning stubs integrated into the ground plane. The design is implemented on a PET substrate, with a thickness of 0.127 mm, a dielectric constant (ε_r) of 3.2, and a loss tangent (tanδ) of 0.022. This configuration effectively enhances the bandwidth performance of the antenna while maintaining structural compactness.

III. Results and Discussion

The reflection coefficient of the proposed antenna is illustrated in Fig.2. The results show that the antenna achieves a wideband impedance matching below -10 dB in the 26.40-51.59 GHz band, and its absolute bandwidth reaches 25.19 GHz. This performance comprehensively covers both the Ka-band and 3GPP-defined subbands (n257, n259, n260, n261). Notably, the prominent resonances at 28.5 GHz and 38 GHz are precisely aligned with the FCC-preferred frequencies for 5G mmWave deployment, validating the practical significance of this design for 5G communication systems. As depicted in Fig.3, the antenna maintains stable radiation efficiency between 84.6% and 96.6% throughout the operational band. The peak gain exceeds 3 dBi at most frequencies and reaches 4.85 dBi at 47.5 GHz. Fig. 4 shows the 2D radiation pattern at the characteristic frequencies of 28 GHz and 38 GHz. They demonstrate favorable radiation properties in both E-plane and H-plane.

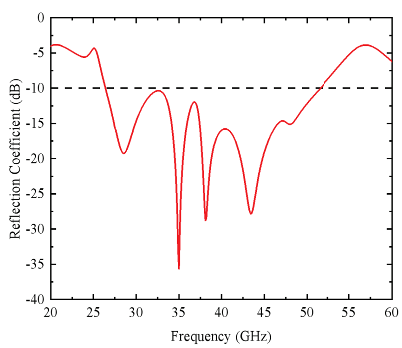

Fig. 2. Reflection coefficient of the proposed antenna.

IV. Conclusion

In this paper, we design a compact UWB mmWave antenna fed by CPW. Fabricated on a miniaturized PET substrate ($6\times10\times0.127$ mm^3), the antenna achieves an ultra-wide impedance bandwidth of 26.40-51.59 GHz, encompassing both Ka-band and multiple 3GPP-defined subbands. The antenna demonstrates stable radiation efficiency (84.6%-96.6%) and attains a peak gain of 4.85 dBi. The results confirm the favorable properties of the radiation pattern. In the future, inkjet printing technology is expected to be used to manufacture antenna prototypes, whose compact and flexible design shows significant potential for wearable applications. This design provides a technical reference for developing miniaturized broadband antennas in 5G mmWave wearable systems.

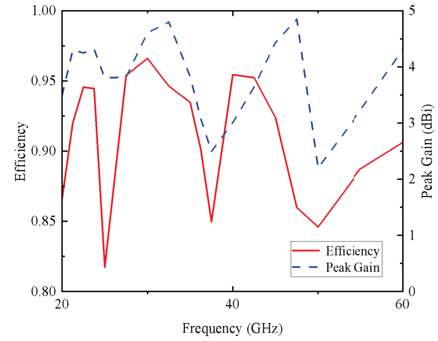

Fig. 3. Radiation efficiency and peak gain of the proposed antenna

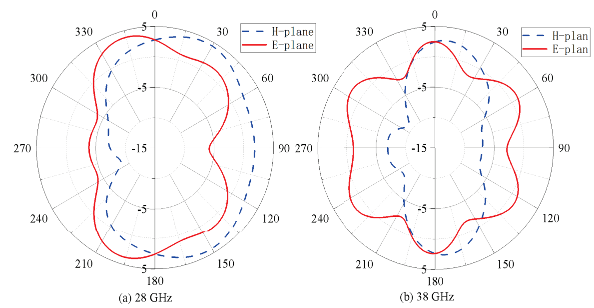

Fig. 4. Radiation pattern of the proposed antenna at frequencies (a) 28 and (b) 38 GHz

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