Compact, Omni-Directional, Circularly-Polarized mm-Wave Antenna for Device-to-Device (D2D) Communications in Future 5G Cellular Systems

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***Abstract*—A simple, compact, omni-directional, circularly-polarized (CP) millimeter-wave antenna for Device-to-Device (D2D) communications in the next generation (5G) cellular systems is reported. It is a CP omni-directional antenna operating at 28 GHz for mobile terminals. The antenna combines a vertical electric monopole element with four magnetic elements to coherently excite parallel electric and magnetic dipoles. This combination generates the omni-directional CP radiation. The overlapping -10-dB impedance and 3-dB axial ratio (AR) bandwidth is from 27 to 28.5 GHz, which covers the 28 GHz frequency band proposed for 5G mobile cellular networks (i.e., from 27.5 to 28.35 GHz). The antenna has an omni-directional radiation pattern at 28 GHz whose peak realized RHCP gain is 2.08 dBic and whose 3-dB AR beamwidth is wide, from elevation angles 3° to 136°. Mass production of the antenna is possible by PCB manufacturing technologies. The overall size is 3.44 mm × 3.44 mm × 1 mm (*ka* = 1.1017). Consequently, it could be embedded in many current popular, smart wireless devices such as cell phones, laptops, digital watches, and smart glasses as well as their future versions for operation in 5G cellular networks.**

***Index Terms*—5G cellular networks, Device-to-Device (D2D) communications, millimeter-wave antennas, omni-directional patterns, circular polarization**

I. Introduction

Device-to-Device (D2D) communication is an evolutionary technology anticipated for future 5G cellular networks. It will bring significant improvements in system capacity, spectral efficiency, communication range and channel reliability as a consequence of its advantages for realizing spatial diversity [1]. Figure 1 describes two types of D2D communications proposed for 5G system: data replay and direct D2D communications. In these D2D applications, portable wireless devices must be capable of communicating with any other nearby devices. Within this scenario, CP antennas with omni-directional patterns are key components. They will provide superior radiation coverage and will avoid polarization mismatches which occur in devices with only LP performance [2] – [4].

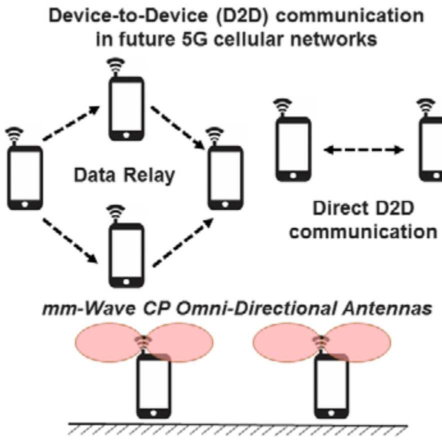


Fig. 1. Application diagram of mm-Wave omni-directional CP antennas for D2D communications in 5G cellular networks.

It is well-known that 5G broadband cellular networks have already been planned which will utilize the millimeter wave (mm-Wave) frequency spectrum. Experimental results have proved that the 28 GHz frequency band is suitable for such 5G mm-Wave cellular systems [5]. Thus, compact omni-directional CP antennas operating at 28 GHz are very good candidates for D2D applications in 5G cellular networks.

Although some CP omni-directional antenna designs can be found at GPS or WLAN bands [6], [7], they cannot be simply rescaled to mm-Wave bands due to physical constraints. To date, only one reported design [8] realizes CP omni-directional radiation at 37 GHz in the mm-Wave band. However, its size is quite large (diameter: 38 mm = 4.7 λ_0). Consequently, it is not suitable to embed it into small portable devices like smart watches and glasses.

As the first of its kind, we will demonstrate a simple, compact (diameter: 3.14 mm = 0.32 λ_0) mm-Wave omni-directional CP antenna at 28 GHz. Its performance characteristics confirm that is an outstanding candidate for D2D applications in future 5G cellular networks.

II. Antenna Design and Performance

A. Antenna Design and Operating Principle

The reported antenna is shown in Fig. 2. It is printed on a single piece of Rogers Duroid™ 5880 substrate whose thickness is 1mm and whose relative dielectric constant is 2.2. The center conductor of the 50Ω coaxial feed line (Type 047-50 from Shenzhen Kansai Industrial LTD) acts as a vertical monopole. Four meandered arms are connected to it at its apex. Each arm has pieces traversing the top and bottom surfaces of the substrate that are connected by a plated via. An annular metallization layer is enclosed by the bottom strips of the four arms and is connected directly to the outer surface of the coax. The current distributions on all five elements are shown in Figure 3. The loop currents form a vertical magnetic dipole, which is parallel to the electric dipole formed by the monopole, and in phase with it. As a result, omni-directional CP radiation is generated.

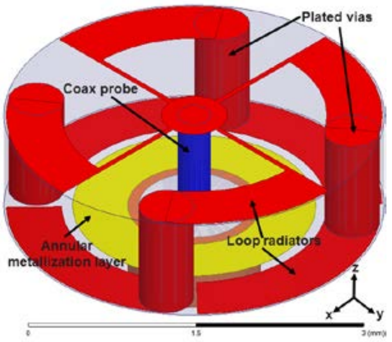


Fig. 2. Antenna configuration.

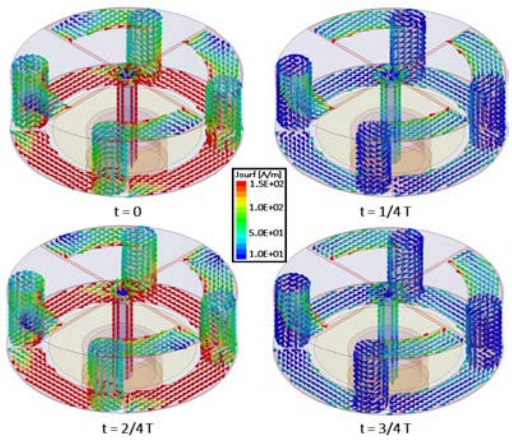


Fig. 3. Current distributions within one source period at 28 GHz.

B. Antenna Performance

The antenna exhibits very good radiation performance. As shown in Fig. 4, the overlapping -10-dB impedance and 3-dB AR bandwidth is from 27 to 28.5 GHz, which covers the 28 GHz frequency band, 27.5 to 28.35 GHz, proposed for 5G systems. Its realized gain patterns at 28 GHz are given in Fig. 5. Very good omni-directional CP radiation patterns are observed. The peak realized RHCP gain is 2.08 dBic. The 3-dB AR beamwidth in the ϕ = 0° azimuth plane is also wide, from the elevation angles 3° to 136°.

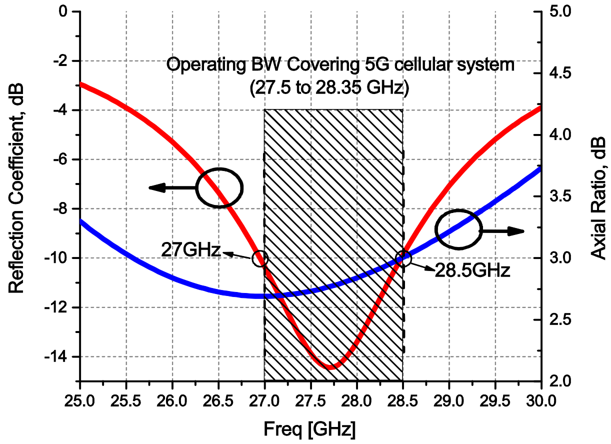
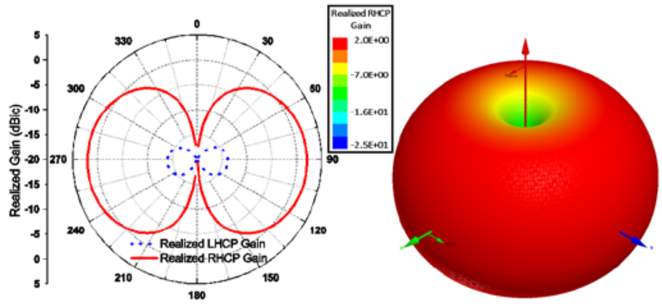


Fig. 4. Simulated reflection coefficient and AR bandwidth.



(a) (b)

Fig. 5. Simulated realized gain patterns at 28 GHz. (a). RHCP and LHCP 2D patterns in the ϕ = 0° plane; and (b) RHCP 3D pattern.

III. References

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