# Flexible Ink-printable Wideband Log-periodic Dipole Array Antenna for Millimeter-wave Applications


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***Abstract*—This paper presents a novel flexible ink-printable log-periodic wideband dipole array (LPDA) antenna for millimeter-wave applications. The antenna is fed by microstrip line through a wideband microstrip-to-coplanar stripline (CPS) balun. The antenna gain enhancement is achieved by adding three directors of decreasing length, based on the principle of Yagi-Uda antenna. The antenna gain remains ≥ 9.74 dBi over the whole operating frequency range of 23-28.5 GHz. The 10-dB bandwidth of the antenna is 21.8%, covering desired frequencies of 24.5 GHz and 28 GHz.**



***Keywords—wideband; flexible; log-periodic dipole array antenna; millimeter-wave; ink-printable***


## I. Introduction

In recent years, millimeter-wave (mmWave) frequency band has drawn great interest from both academia and industry because of its strong potential in delivering high data rate services. For example, mmWave band includes 24.5 GHz allocated for industrial, scientific and medical (ISM) band, and 28 GHz for the 5th generation (5G) mobile communication applications [1]. To accommodate the available bandwidth in mmWave, wideband antennae are thus designed, among which log-periodic dipole array (LPDA) antenna has advantages of low cost, broad bandwidth and high gain [2]. Additionally, LPDA antenna shows great potential in flexible antenna design and fabrication, such as ink-printed planar antennas for wearable application and on-body medical applications [3]. In [4], an LPDA antenna with substrate integrated waveguide (SIW) was reported. However, this technology is not suitable for flexible ink printing fabrication due to conductive via holes are required for constructing SIW. It motivates us to investigate an LPDA antenna design using flexible ink-printable substrates.

This paper presents a design of an inkjet-printable wideband LPDA antenna operating at mmWaves, covering both 24.5 and 28 GHz. To the best of our knowledge, this is the first time that a LPDA antenna is proposed to be fabricated on a textile substrate. The designed LPDA antenna is fed with standard 50-Ω microstrip line and microstrip-to-coplanar stripline (CPS) balun. From the simulation, this antenna can achieve a 10-dB bandwidth of 21.8% and a gain of over 9.74 dBi over the frequency range from 23 to 28.5 GHz.

## II. Proposed Antenna Design

The layout of the proposed antenna is shown in Fig. 1. It consists of a microstrip line feed, a broadband microstrip-to CPS balun, LPDA antenna and directors. Besides, the backside ground is also acting as the reflector. The conductive patterns of this antenna are to be printed with UTDot silver nanoinks, which has resistivity of 10 μΩ·cm. The selected substrate is a 0.35-mm thick polyester fabric, whose dielectric constant is 2.2 followed by the characterization method in [3].

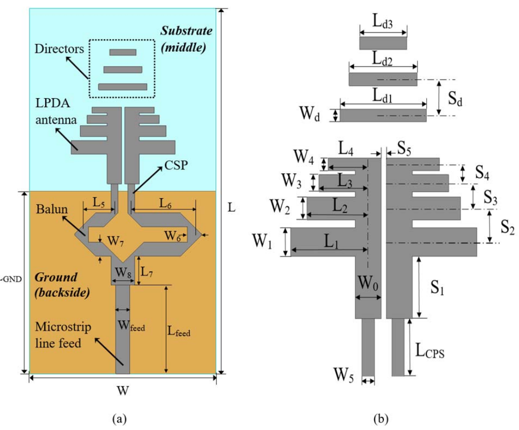


Fig. 1. Structure of proposed antenna with denoted dimensions. (a) overview of the design (b) dimensions of LPDA antenna

According to the design principle of LPDA antenna, firstly, the scale factor $\tau$=0.75 and spacing factor $\sigma$=0.112 are determined. Then, the length of the longest dipole $L_1$ should be a quarter of the effective wavelength corresponding to the lowest resonant frequency $f_{min}$=24.5 GHz. All other dimensions of the LPDA antenna are determined by [5]:

$$S_{n+1} = 4\sigma L_n \qquad (1)$$

$$\frac{L_{n+1}}{L_n} = \frac{W_{n+1}}{W_n} = \tau \qquad (2)$$

where $n$ = 1, 2, 3, 4 is the number of dipole elements.

Based on the design principle of Yagi-Uda antenna, three directors with decreasing length are added for antenna gain enhancement. The lengths of the directors should be between

0.4 λ and 0.5λ. In this case, the longest director is determined as 0.43λ, and the successive ones have shorter length [5].

The proposed antenna is fed by microstrip line. Therefore, a wideband microstrip-to-CPS balun is designed for unbalance-balance transition. The right arm of the balun is a quarter effective wavelength longer than the left one.

All the antenna dimensions marked in Fig. 1 are summarized as shown in Table I.

TABLE I. PARAMETERS OF ANTENNA DESIGN (UNIT: MM)

| Para. | Value | Para. | Value | Para. | Value |
|---|---|---|---|---|---|
| L | 25 | $W_3$ | 0.557 | $L_{d3}$ | 1.798 |
| W | 12.7 | $W_4$ | 0.418 | $W_d$ | 0.418 |
| $L_{GND}$ | 15 | $W_5$ | 0.495 | $S_d$ | 1.178 |
| $L_1$ | 2.450 | $S_1$ | 0.5 | $L_{CPS}$ | 2 |
| $L_2$ | 1.837 | $S_2$ | 1.098 | $L_5$ | 2 |
| $L_3$ | 1.378 | $S_3$ | 0.823 | $L_6$ | 4.064 |
| $L_4$ | 1.033 | $S_4$ | 0.617 | $L_7$ | 2 |
| $W_0$ | 0.990 | $S_5$ | 0.2 | $W_6$ | 0.94 |
| $W_1$ | 0.940 | $L_{d1}$ | 3.298 | $W_7$ | 0.94 |
| $W_2$ | 0.742 | $L_{d2}$ | 2.598 | $W_8$ | 1.88 |
| $L_{feed}$ | 6.06 | $W_{feed}$ | 0.94 | | |

## III. SIMULATED RESULTS

Fig. 2 shows the simulated return loss and realized gain of the proposed LPDA antenna with directors and microstrip line feeder. The antenna achieves a 10-dB bandwidth of 21.8% and operates from 23 to 28.5 GHz covering the desired mmWave band (24.5 GHz and 28 GHz). The overall gain ranges from 8.017 dB (at 23 GHz) to 9.74 dB (at 28 GHz). Generally, the realized gain of the antenna remains above 9.74 dBi over the operating frequency band.

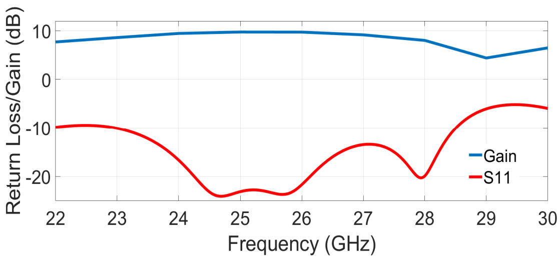


Fig. 2 Return loss and realized gain of the proposed antenna

The co-polarized radiation patterns of the proposed antenna at 24.5 GHz and 28 GHz are plotted in Fig. 3. It confirms the stable end-fire radiations at operating frequencies, which both E-plane (*xz*-plane) and H-plane (*yz*-plane) propagate along the horizontal plane, showing good agreement with the potential design purpose, i.e. wireless communication for on-body wearable application. For brevity, the cross-polar radiation patterns with omni-direction are not presented in this paper.

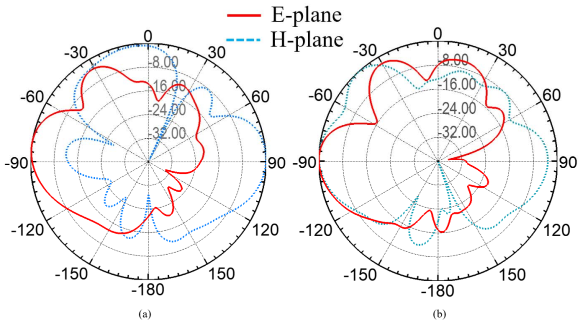


Fig. 3. Copolar radiation patterns of proposed antenna. (a) 24.5 and (b) 28 GHz

## IV. CONCLUSION AND FUTURE WORKS

In this paper, an ink-printable wideband LPDA antenna with microstrip line feeder is presented. The proposed antenna achieves stable gain of over 9.74 dBi between 23-28.5 GHz, which covers the desired 5G mmWaves bands. The achieved 10-dB bandwidth is 21.8%. The radiation patterns affirm its potential applications in future wearable and on-body area wireless networks. Our future work includes fabrication of the designed antenna and its characterization in an anechoic chamber.

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