Wideband simplified feed for printed log-periodic dipole array antenna

G.H. Zhai, Y. Cheng, D. Min, S.Z. Zhu and J.J. Gao

A novel simple approach is presented for designing a broadband single layer substrate printed log-periodic dipole array (PLPDA) antenna by using microstrip technology. The PLPDA antenna has the merits of wide bandwidth, low profile and light weight, which should be fed by the balanced line. The balanced line, created by the geometric features of the microstrip, provides a balun with a considerably wide bandwidth with low profile, broad bandwidth and low insertion loss etc. The prototype of the proposed microstrip printed log-periodic array at Ka band is designed and fabricated; the measured data are in good agreement with the simulated results.

Introduction: The peak radiation of the printed log-periodic dipole array (PLPDA) antenna is fixed and the radiation pattern is stable within the working frequency, which leads to it being a good candidate for wideband efficient communication applications [1]. Practically, the performance of the PLPDA antenna is mainly determined by the feeding system. At an early stage, the PLPDA antenna was designed by a double layer substrate [1]. The fabrication cost is reduced by using a single layer substrate, so the single layer substrate PLPDA soldered with two coaxial cables was proposed [2]. However, the feeding network brings significant fabrication error and misalignment in the millimetre-waves. A single layer slot PLPDA antenna fed by a coplanar waveguide (CPW) was proposed [3], but it suffers from high insertion loss, radiation loss, serious crosstalk and lower power handling capability. Recently, the substrate integrated PLPDA antenna was proposed [4], but the size of the new feeding network is larger than that of the microstrip.

In modern broadband communication systems, the wideband antenna should be indispensable with the linear phase-frequency function. However, the PLPDA antennas are mostly fed from the shorter end, and it introduces a nonlinear function of phase-frequency characteristics, which prevents their use for wideband communication [5]. To solve this problem, the antenna can be fed from the longer, lower frequency end. However, the antenna structure is composed of two-double layer substrates [5], or it is fed by the CPW with an air-bridge [6]. Therefore, those feeding structures increase the complexity and cost of the antenna.

In this Letter, the simplified microstrip technology is applied to feed the single layer substrate PLPDA antenna for the first time. It has the advantages of low profile, broadband, a simple feeding network and ease of integration to the planar circuits. The entire structure can be fabricated on a piece of printed circuit board (PCB). All the printed dipoles are cross-symmetrically spaced along the parallel feed lines on both sides of the dielectric substrate.

Antenna design: The geometry of the PLPDA antenna is shown in Fig. 1. The top metallic layer is in Fig. 1*a* and the bottom one is in Fig. 1*b*, respectively.

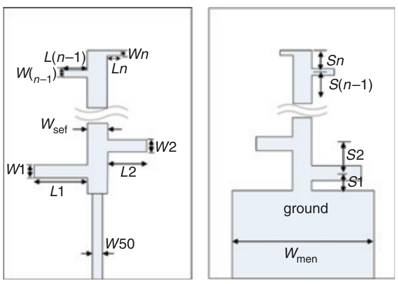

Fig. 1 *Geometry of PLPDA antenna with microstrip fed*

a Top layer
b Bottom layer

In this antenna design, the 50 Ω microstrip is directly transited to the two parallel transmission strips line, along which the dipole elements are cross-symmetrically distributed in the top and bottom metallic layers of the substrate. The array is fed from the longest element. One side of the substrate consists of a microstrip, one of the parallel strip lines, and the crossing dipole along the parallel line. The other side of the substrate consists of a truncated ground plane acting as the bottom layer of the microstrip, the other symmetric parallel strip line and the crossing dipole antenna printed in the opposite direction.

The parallel strip transmission line is a quarter-wavelength transformer between the microstrip and the dipole elements, so it brings a transform from the odd-mode of the microstrip to the even-mode of the driven dipole elements [7]. The edge of the microstrip ground serves as a reflector for the antenna to enhance the antenna gain. Thus, the parameter W_{men} is important for the far-field radiation and the antenna gain. Therefore, the parameters W_{men} will be discussed in detail.

Fig. 2 shows the simulated gain of the proposed antenna with different W_{men}. From the simulated results, the increases of W_{men} lead to the increase of the gain of the PLPDA antenna, especially at the high-frequency band. However, to a certain extent, the increasing of the gain is small in low frequency. The increase of the gain depresses the microstrip ground that acts as the reflector. Fig. 3 depicts the far-field radiation patterns for the *E*-plane and the *H*-plane at 35 GHz. It can be seen that the decreases of W_{men} can slightly improve the sidelobe and the front-to-back ratio of the proposed antenna.

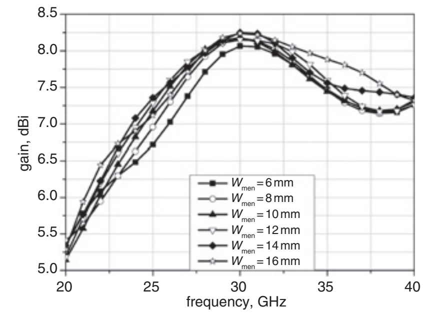

Fig. 2 *Simulated gain of proposed antenna with different* W_{men}

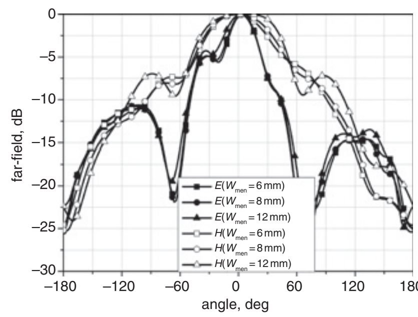

Fig. 3 *Simulated far-field of proposed antenna with different* W_{men} *at 35 GHz*

By considering the trade-offs among the side-lobe, front-to-back ratio and antenna gain, the parameter W_{men} is preliminarily chosen as 8 mm, and the number of the dipole elements N is equal to 4 and the other parameters of the proposed antenna can be designed and optimised by using full-wave simulation software HFSS. The antenna is fabricated on a Rogers5880 substrate with a thickness of 0.5 mm, $\varepsilon_r = 2.2$ and tan $\delta = 0.0009$. The detailed dimensions of the proposed antenna are: $W1 = 1.21$ mm, $W2 = 0.75$ mm, $W3 = 0.46$ mm, $W4 = 0.29$ mm, $L1 = 1.95$ mm, $L2 = 1.2$ mm, $L3 = 0.75$ mm, $L4 = 0.46$ mm, $S1 = 1.8$ mm, $S2 = 1.84$ mm, $S3 = 1.14$ mm, $S4 = 0.71$ mm, $W_{sef} = 1.6$ mm, $W_{men} = 8$ mm and $W50 = 1.5$ mm.

Results: The proposed PLPDA antenna at 20–40 GHz is designed, fabricated and measured. The measured and simulated return losses and gain of the proposed PLPDA antenna with its PCB layout are shown in Fig. 4. All the measured results shown include the losses of the 50 Ω microstrip and the 2.4–3.5 mm adapters.

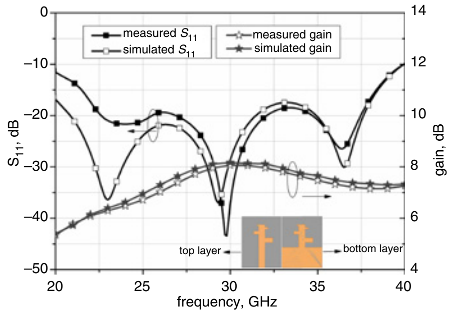

Fig. 4 *Measured S_{11} and gain of proposed PLPDA antenna with PCB layout*

Fig. 4 shows the measured return losses and gain of the proposed PLPDA antennas fed by the microstrip. It can be seen that $|S_{11}|$ is below -10 dB from 20 to 40 GHz. The peak gain of the antenna is 8 dB measured at 30 GHz.

The far-field radiation pattern of the proposed antenna is measured which shows similar characteristics. For brevity, only the 30 GHz radiation patterns are shown in Fig. 5, which shows that the front-to-back ratio is lower than -15 dB, and the cross-polarisation level is lower than -12.5 dB.

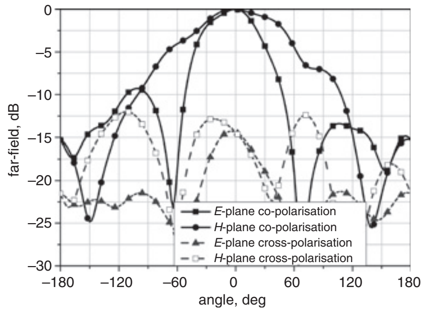

Fig. 5 *Measured far-field of PLPDA antenna at 30 GHz*

Conclusion: In this Letter, a novel simplified feed broadband PLPDA antenna by using microstrip technology is presented, and the prototype for the antenna has been designed and tested, which can be easily fabricated by using standard PCB techniques and conveniently integrated into planar microwave and millimetre-wave circuits. Good radiation characteristics of the PLPDA antenna have been observed. High gain, broadband, low insertion loss, low cost, low profile and simple design characteristics are verified by the simulated and measured results.

Acknowledgments: This work was supported in part by the NNSFC under grant 61201069, in part by the Research Fund for the Doctoral Programme of Higher Education of China under grant 20120076120035, and in part by the Open-Foundation of the State Key Lab of Millimetre-Waves under grant 201308.

30 June 2013
doi: 10.1049/el.2013.2184
One or more of the Figures in this Letter are available in colour online.

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