Progress In Electromagnetics Research Letters, Vol. 56, 123–128, 2015

A Novel Meander Line Microstrip Log-Periodic Dipole Antenna for Dual-Polarized Radar Systems

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Abstract—A novel log-periodic dipole antenna for dual-polarized radar systems is presented. The proposed antenna employs meander line technology and matched loads. The simulated and measured results show that the -6 dB reflection coefficient bandwidth of the dual-polarized antenna covers the desired band of 2–8 GHz and the port isolation is higher than 32 dB, along with -20 dB cross-polarization discrimination for both E- and H-planes.

1. INTRODUCTION

Dual-polarization antennas are widely used in wireless communication systems, mobile communication base stations, deploying frequency reuse or polarization diversity [1–3]. By means of frequency reuse, dual-polarization antennas can double the capacity of communication systems. And can reduce the multi-path fading of received signals in land-based mobile communication systems by means of the polarization diversity [4]. Moreover, polarization-diversity is preferred over spatial-diversity for it leads to a lower installation cost. This is because the polarization-diversity usually requires one antenna, while the spatial-diversity usually requires two antennas [5].

In recent years, log-periodic dipole antennas (LPDAs) have attracted much attention due to their frequency response characteristics, design simplicity and directivity. The realization of the radiating elements in printed technology is particularly attractive due to its easy fabrication into linear or planar arrays, low-profile geometries, low-cost, light-weight, and easy integration with microwave integrated [6–8].

In this paper, a novel meander line microstrip log-periodic dipole antenna for dual-polarized radar systems is presented and optimized, working in the reference frequency band 2–8 GHz. The specific interest is focus on its dual polarization, wide impedance band, reduced cross-polarization components, high isolation between the input ports providing the polarization diversity and suitable scanning capabilities. This paper is organized as followings: in Section 2, the geometry and design of the proposed antenna are presented. The accuracy of designed parameter values and verification of the proposed antenna are carried out with measurements in Section 3. Finally, conclusions are briefly shown in Section 4.

2. ANTENNA CONFIGURATION

The novel dual-polarized radiating element proposed here is shown in Fig. 1. It consists of two orthogonal log-periodic dipole antenna (as shown in Fig. 2). Meander line technology is employed in order to reduce the antenna dimension. Matched load is employed to optimize the impedance bandwidth (the blue part). Jump wire is employed as shown in Fig. 1(b) (the pink part). To grant an inexpensive

Received 14 August 2015, Accepted 18 September 2015, Scheduled 30 September 2015

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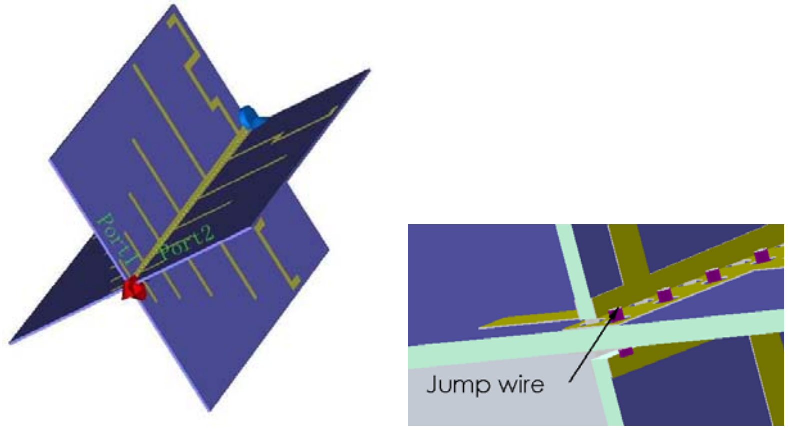


(a) (b)

Figure 1. Configuration of the proposed dual-polarized meander line microstrip log-periodic dipole antenna. (a) Whole model. (b) Jump wire.

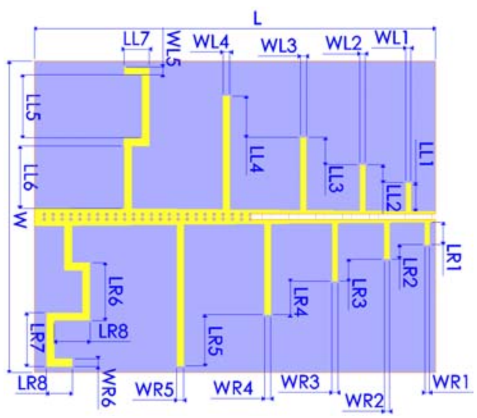


Figure 2. Geometry of the log-periodic radiating element.

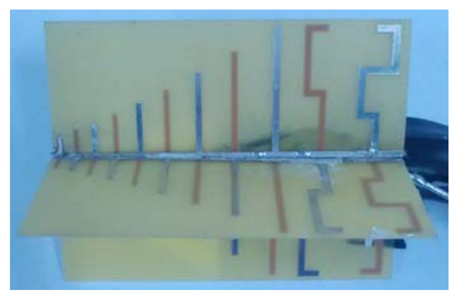


Figure 3. Photograph of the fabricated dual-polarized meander line log-periodic antenna.

realization, commercially available dielectrics 1.5-mm-thick FR4 ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$) have been chosen.

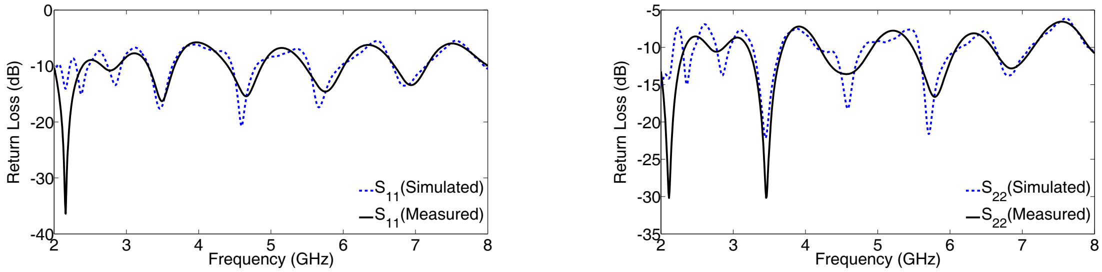
The performances of the antenna are studied numerically by using the common commercially available simulation software — CST MWS. The antenna configuration finally selected has the following dimensions: $L = 67$ mm, $W = 52$ mm, $LL1 = 4.7$ mm, $LL2 = 3.0$ mm, $LL3 = 4.6$ mm, $LL4 = 7$ mm, $LL5 = 10.5$ mm, $LL6 = 10.5$ mm, $LL7 = 4.3$ mm, $LR1 = 3.7$ mm, $LR2 = 2.4$ mm, $LR3 = 3.7$ mm, $LR4 = 5.6$ mm, $LR5 = 8.6$ mm, $LR6 = 9.7$ mm, $LR7 = 9$ mm, $LR8 = 6$ mm, $LR9 = 4.3$ mm, $WL1 = 0.8$ mm, $WL2 = 0.9$ mm, $WL3 = 1.0$ mm, $WL4 = 1.1$ mm, $WL5 = 1.3$ mm, $WL6 = 1.3$ mm, $WR1 = 0.8$ mm, $WR2 = 0.9$ mm, $WR3 = 1.0$ mm, $WR4 = 1.1$ mm, $WR5 = 1.3$ mm, $WR6 = 1.3$ mm.

3. ANTENNA PERFORMANCE

The antenna as discussed above has been realized, and a photograph of the antenna is shown in Fig. 3.

To characterize the return loss as well as isolation for the two individual ports of the dual-polarized antenna, two ports S-parameter measurement results are carried out with an Agilent E8362B network analyzer.

The magnitude of the scatting parameters of the two-port radiation element is shown in Fig. 4. The reflection coefficients of the two input ports are lower than -6 dB in the whole frequency band of



(a) (b)

Figure 4. Simulated and measured return loss for both ports of the dual-polarized antenna. (a) Return loss for port 1. (b) Return loss for port 2.

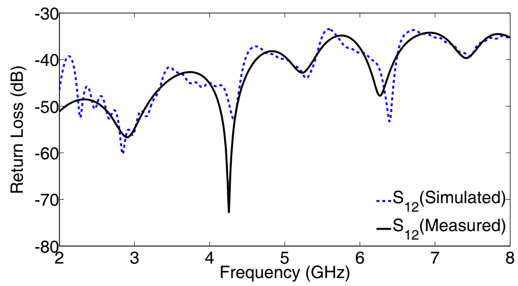


Figure 5. Simulated and measured isolation between the two ports of the dual-polarized antenna.

interest. If the usual threshold of -6 dB is considered for ultra-wide band matching purpose, the results lead to the possibility of using the antenna in a wide band for dual-polarized radar systems.

For implementing frequency reuse, the basic requirement is to have good isolation between the two ports providing the polarization diversity, else it may lead to inter-channel interference [9]. In such systems, maximum performance occurs when the two polarizations are orthogonal and the antenna features high isolation between the two polarization [10]. The magnitude of the isolation coefficient grants a high isolation as shown in Fig. 5, where better than 32 dB isolation is observed throughout the designed frequency range.

Another fundamental requirement of the design is the low level of cross-polarization. Radiation patterns for both ports as an individual element are measured at 2, 5 and 8 GHz. Co-polarized and cross-polarized patterns are measured for both E- and H-planes. The co-polarization and cross-polarization components for both the E- and H-planes are show in Fig. 6 and Fig. 7, in black and blue lines, respectively, to evaluate the polarization purity for different frequency.

As depicted in Fig. 6 and Fig. 7. Better than -20 dB cross-polarization discrimination is achieved for both ports and both planes.

The radar cross section of the proposed antenna at 4, 5, 6, 7 GHz is shown in Fig. 8. When electric field vector direction is along X axis and plane wave incidents along the $-Z$ axis, the maximum scattering direction is along the Z axis at 4 and 5 GHz. It is along the $-Z$ axis direction at 6 and 7 GHz. It is the same when electric field vector direction is along Y axis.

A broadband dual-polarized printed antenna is proposed in literature [11]. The antenna yields a bandwidth of more than 17% at both ports, the port isolation is higher than 32 dB. The cross-polar levels are just below -18 dB, which is 2 dB higher than the antenna proposed here. A high isolation dual-polarized patch antenna using integrated defected ground structure is presented in letter [12]. The isolation between the two ports is just more than 20 dB which is 12 dB lower than the antenna designed in this paper.

Generally, the results from the simulation and measurement are generally in good agreement, although slight deviations are seen. The deviations may be due the manufacture inaccuracies in the feed-point implementation.

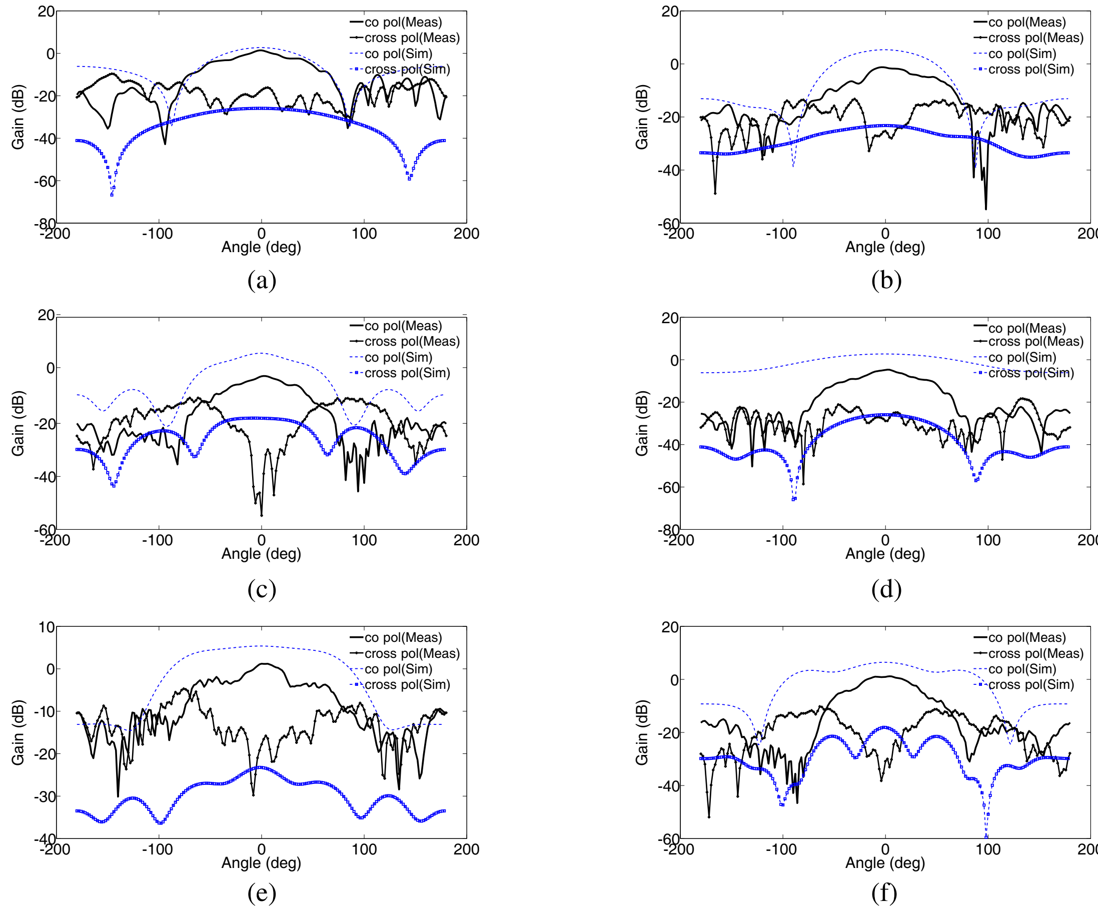
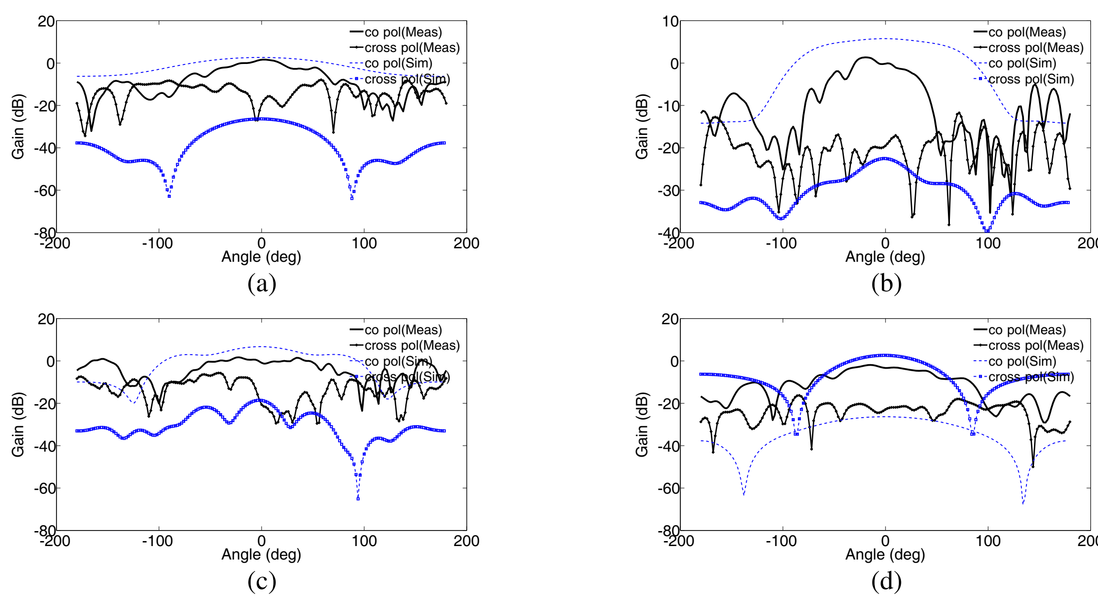
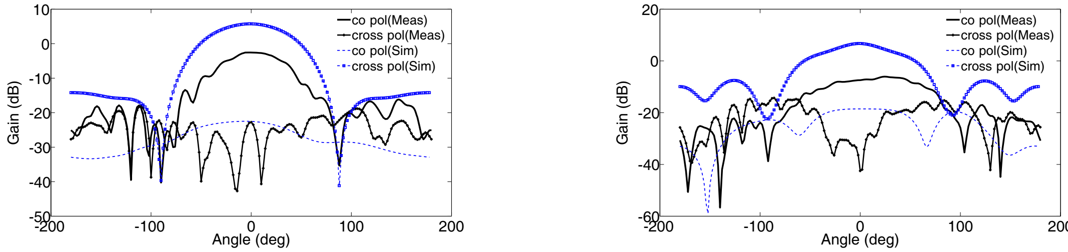


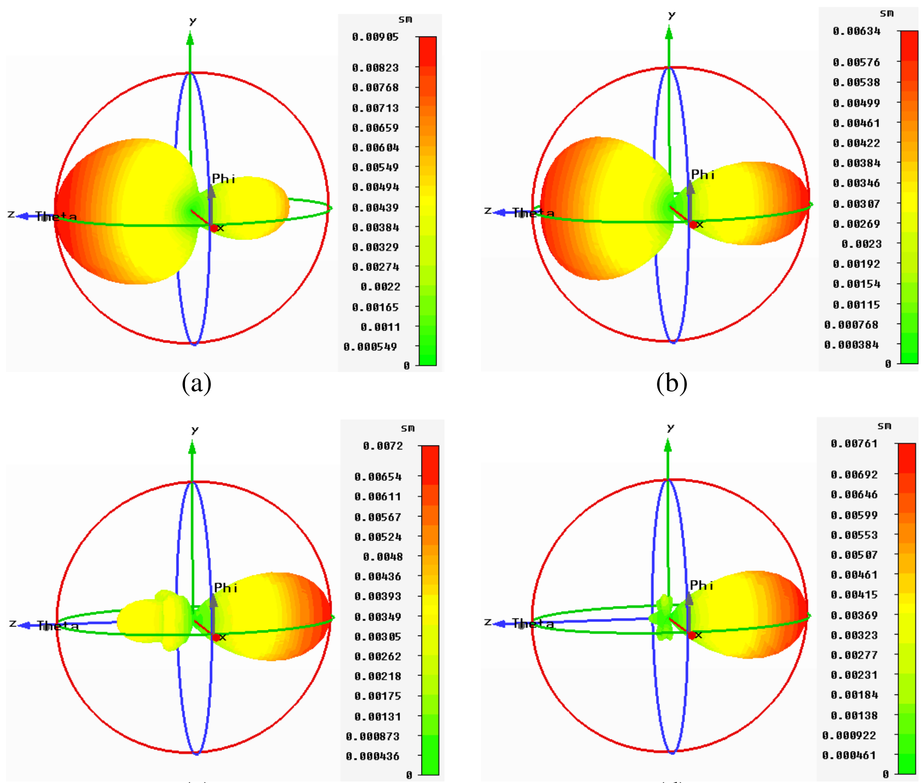
Figure 6. Simulated (blue dashed) and measured (black solid) radiation gains for Port 1. (a) Radiation pattern in the E-plane for Port 1 at 2 GHz. (b) Radiation pattern in the E-plane for Port 1 at 5 GHz. (c) Radiation pattern in the E-plane for Port 1 at 8 GHz. (d) Radiation pattern in the H-plane for Port 1 at 2 GHz. (e) Radiation pattern in the H-plane for Port 1 at 5 GHz. (f) Radiation pattern in the H-plane for Port 1 at 8 GHz.





(e) (f)

Figure 7. Simulated (blue dashed) and measured (black solid) radiation gains for Port 2. (a) Radiation pattern in the E-plane for Port 2 at 2 GHz. (b) Radiation pattern in the E-plane for Port 2 at 5 GHz. (c) Radiation pattern in the E-plane for Port 2 at 8 GHz. (d) Radiation pattern in the H-plane for Port 2 at 2 GHz. (e) Radiation pattern in the H-plane for Port 2 at 5 GHz. (f) Radiation pattern in the H-plane for Port 2 at 8 GHz.



(a) (b)

(c) (d)

Figure 8. The radar cross section of the dual-polarized antenna. (a) RCS at 4 GHz. (b) RCS at 5 GHz. (c) RCS at 6 GHz. (d) RCS at 7 GHz.

4. CONCLUSIONS

The radiation and reflection characteristics of a novel log-periodic dipole antenna for dual-polarized radar systems have been investigated and presented in this paper. The cost and fabrication have been taken into accounts. By using meander line technology, the whole antenna structure is compact and can be easily arranged in large arrays. The impedance band width is wide by employing matched load. Besides, the antenna can provide low cross-polarization levels, high port isolation and regular radiation patterns. The promising features of the antenna make it a potential candidate for dual-polarized radar systems.

ACKNOWLEDGMENT

This work is sponsored by the National Natural Science Foundation of China (Grant No. 61171181), National Science and Technology Major Project of the Ministry of Science and Technology of China (2014ZX03003001-004), the Astronautical Supporting Technology Foundation of China (2013-HT-HGD06), and the Science Foundation of Aeronautics of China (Grant No. 20131837001).

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