

The Design and Optimization of Planar LPDAs

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Abstract— A significant space reduction of a Planar Log-Periodic Dipole Array (LPDA) is achieved in this work. This reduction was performed by utilizing the first order iteration meander shape dipole in the design of a planar LPDA. The minimization procedure is illustrated in this work by presenting two designs for a Euclidean LPDA with linear dipoles and a meander LPDA operating over the entire S frequency band. Both designs are compared through the main common characteristics of an antenna: return loss response, radiation pattern and the maximum gain. The agreement between the results of both designs was very good and the properties of the meander LPDA were identical to those of the Euclidean LPDA.

1. INTRODUCTION

As the numerous demands and applications that require the use of large sections of the EM spectrum appeared in the 1950's, antenna designers attempted to create antennas that do not depend on the operating frequency of the application needed to be used with. This type of antennas was later named "frequency independent antennas" [1]. A type of antenna which closely parallels the frequency independent concept is the wire log-periodic structure, found by DuHamel and Isbell [2] and studied by Carrel [3]. In the design of wire LPDAs, half wavelength dipoles of different dimensions are connected and fed by a transmission line through a boom. The lengths of the largest and the smallest elements in a wire LPDA are controlled by the operating frequency limits, while the remaining elements lengths are related to each other by the geometry constant (τ) and the spacing factor (σ), which define the log-periodic performance. However, as the operating frequency exceeds the UHF range, wire dipoles and conventional feeding transmission lines become inadequate for LPDA design. In addition, wire dipoles can be bent, damaged or truncated which affects LPDA's performance by producing side lobes and reducing the F/B ratio [4]. For these reasons, planar LPDAs were studied [5–7].

For applications where space and size are constrained; size reduction of a planar LPDA is preferable. Different attempts were performed to reduce the size of planar LPDA by using Koch dipoles and quasi-fractal geometries [8, 9]. In this work, the size of a planar LPDA was reduced by the design of a planar LPDA with a first order iteration meander line as a basic element of the array. Two identical designs of planar meander and Euclidean LPDA are illustrated and compared in this paper LPDA. The selection of the first order meander dipole shape is justified. The measured results for both designs show that the miniaturized meander LPDA characteristics are very similar to the characteristics of the Euclidean LPDA.

2. LPDA DESIGN DESCRIPTION

A schematic and photo for both designs is shown in Figures 1(a)–(c). The planar LPDAs consist of N flat dipoles fabricated on a substrate of thickness t . The dipoles are placed on the top layer of the substrate and on the bottom layer, alternatively. A single coaxial cable was used to feed the antenna. The cable's outer metallic cylinder, which represents the ground, is filled with Teflon® while the center conductor is embedded through the Teflon®. To ensure a balanced feeding, the cylinder of the coaxial was soldered to the bottom layer of the LPDA while the center conductor (RF) was connected to the top layer at the smallest element of the LPDA using a small via through the substrate. In this way, the need of using a balun is fulfilled, and thus, the antenna design is simplified. The two designs were fabricated on RO4003C Roger substrate with a thickness of 32 mil and dielectric constant $\epsilon_r = 3.38$.

For both designs, the geometry constant (τ) was adjusted to be 0.9 and the spacing factor (σ) was equal to 0.16. The resultant apex angle (α) was 8.88° and 12 elements were needed to cover the entire S band according to the design equations for LPDA. The relation between the design

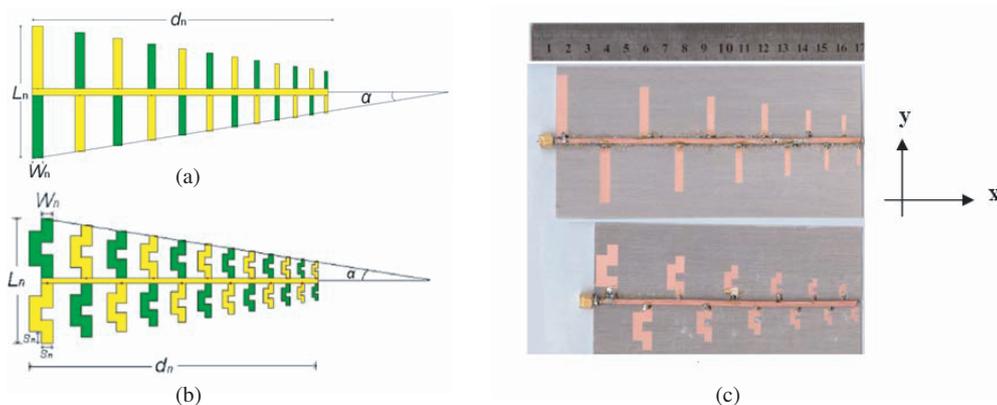


Figure 1: (a) Schematic of the Euclidean log-periodic antenna design, (b) schematic of the meander log-periodic antenna design, and (c) photo of the fabricated prototypes.

parameters are given by:

$$\tau = \frac{W_n}{W_{n-1}} = \frac{L_n}{L_{n-1}} = \frac{d_n}{d_{n-1}} \quad (1)$$

$$\alpha = \tan^{-1} \left[\frac{1 - \tau}{4\sigma} \right], \quad (2)$$

where the subscript (n) represents the n th element starting from the largest dipole.

The design of the largest element in both radiators was the first step for the design of the array. The largest element was designed so it resonates at $f = 2$ GHz. It was shown in [10] that the meander line resonates at the same resonance frequency of the Euclidean line when the total length of the meander line is larger than the total length of the Euclidean line. However, the vertical length of the meander line (L_n) should be less than the vertical length of the Euclidean line, which is the key of reducing the size of a planar LPDA.

The largest element of the Euclidean LPDA, including the width of the boom, is 70.8 mm length, while the total length for the same element in the meander LPDA is 62 mm. The width for both elements is 5.844 mm, which was obtained to achieve an equal width among the total length of the meander line. The dimensions for the other elements then found depending on Equation (1).

The total trapezoidal occupied area was 7528.7 mm² and 5714.72 mm² for the Euclidean and the meander LPDA respectively. This results show 24% space reduction, which is a considered a significant size reduction compared to previous works in minimization of planar LPDAs.

It should be noticed that using more iterations for the meander line design would result to a more miniaturized LPDA; meanwhile, the addition of iterations to the meander line will reduce its radiation resistance and its bandwidth [10]. This degrading in the basic element performance of the meander dipoles as the iteration order increases will be reflected on the total array.

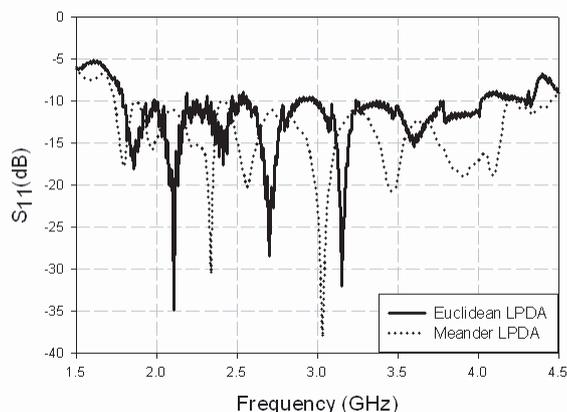


Figure 2: Measured return loss response for meander and Euclidean LPDAs.

3. DESIGN RESULTS

The full wave commercial software Zeland IE3D[®] based on MoM algorithm was used to simulate the designs. The simulation results were compared with the measurements, which have been carried out using an 8510C Agilent VNA, at the custom-built antenna chamber at SDSM&T. The measured return loss response is shown in Figure 2. Both designs exhibit a similar and very good return loss response with $|S_{11}|$ less than -10 dB over the 2–4 GHz design frequency range.

The measured normalized co-polarized and cross-polarized E -plane radiation patterns at different frequencies for both designs are depicted in Figure 3, while Figure 4 show the measured maximum gain. The co-polarized E -plane radiation pattern for both meander and Euclidean LPDAs exhibits symmetry around $\varphi = 0$. This symmetry is achieved because of using a balanced feeding method where the current distributes equally on the dipoles parts.

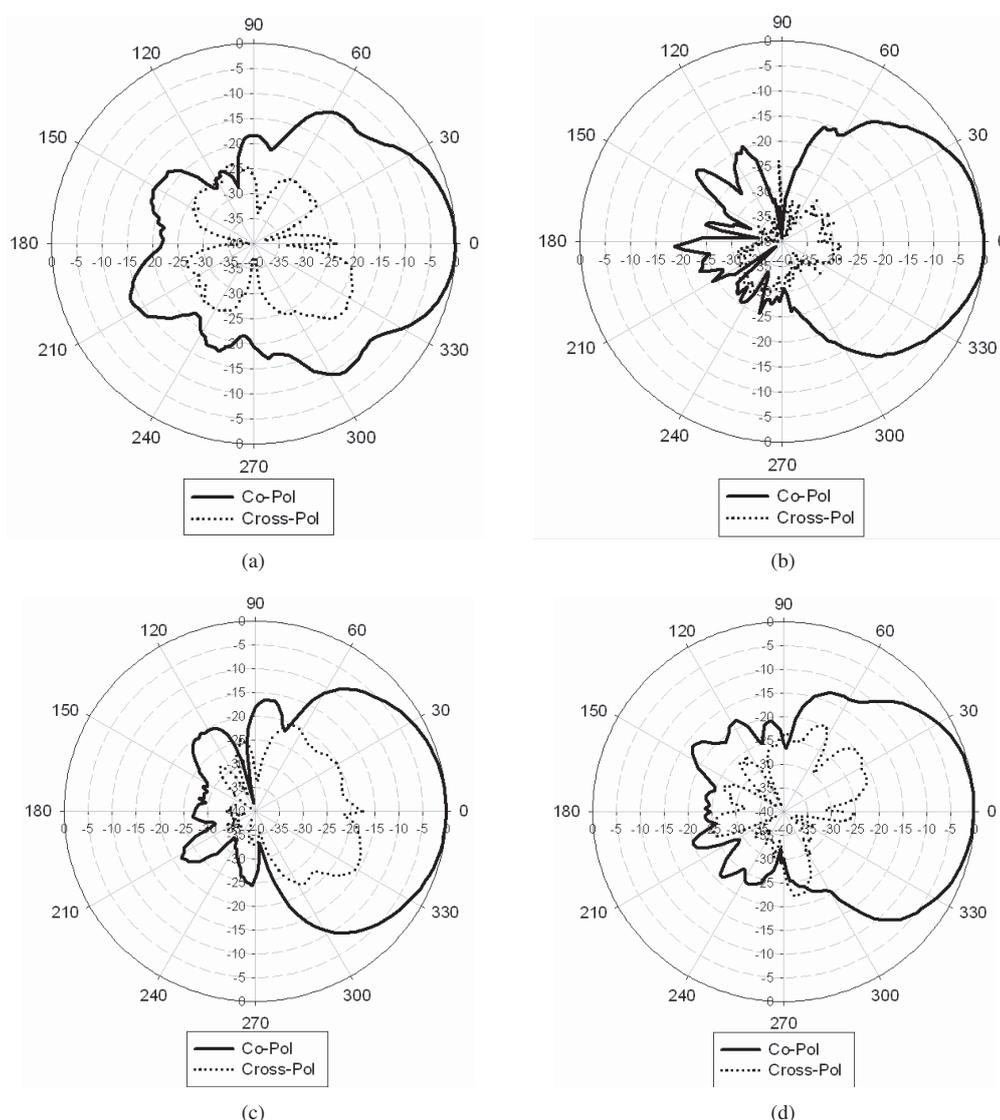


Figure 3: The normalized radiation pattern for: (a) Euclidean LPDA at $f = 3$ GHz, (b) Euclidean LPDA at $f = 4$ GHz, (c) Meander LPDA at $f = 3$ GHz and (d) Meander LPDA at $f = 4$ GHz.

The cross-polarized pattern in Figure 3 shows very low values and decreases as the frequency increases. However, the meander LPDA has higher cross-polarized radiation pattern, which still has very low values. A maximum gain of 7.5 dBi has been achieved for both designs over the design frequency.

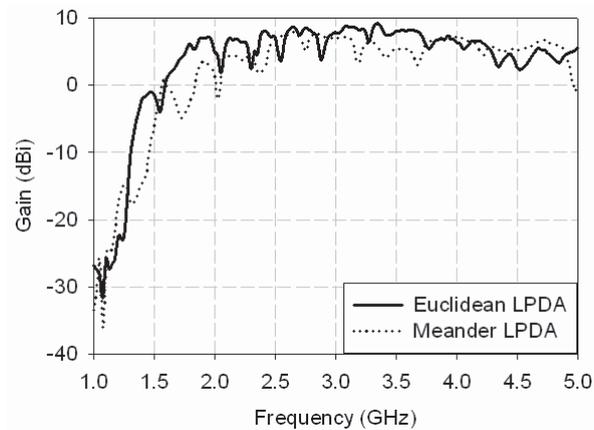


Figure 4: Maximum measured gain for Euclidean and meander LPDAs.

4. CONCLUSION

A size reduction for planar LPDA was shown in this work. The reduction in the occupied space for a planar LPDA was achieved by using the meander line instead of using the Euclidean line in the design. Both of the prototypes were shown and expressed. The comparison between the designs showed that reducing the size of the planar LPDA doesn't affect the main characteristics of the conventional LPDA.

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