Miniaturized LPDA Antenna for Portable Direction Finding Applications

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In this letter, a miniaturized log-periodic dipole array (LPDA) antenna operating from 1 GHz to 6 GHz is proposed for portable direction finding applications. To reduce the lateral size of an LPDA antenna, bow-tie elements and a top-loading technique are utilized and spacing factor is decreased to reduce the spacing between the LPDA elements. The proposed miniaturized LPDA antenna has the measured gain and front-to-back ratio ranging from 1.2 dBi to 3 dBi and from 7 dB to 22 dB, respectively.

Keywords: Log-periodic dipole array (LPDA) antenna, miniaturization, direction finding (DF), bow-tie element, top-loading.

I. Introduction

In recent years, wideband antennas have become an essential component for various wireless communication systems in military and industrial applications. One interesting application for wideband antennas is direction finding (DF). DF requires the ability to determine the angle in the azimuth plane from which a signal of interest originates, and to receive over a wide range of frequencies. In the beginning, DF techniques have been used in military applications to locate the sources of unidentified signals, and then, have been applied to various civilian applications for tracking and locating targets. A DF antenna for a fixed surveillance system is usually in a form of an array with multiple antenna elements arranged in circular formation. For the antenna elements, a class of antennas, such as dipole antennas, monopole antennas, bi-conical antennas,

log-periodic dipole array (LPDA) antennas, and Vivaldi antennas, have been used [1].

A DF antenna can also be used for man-portable applications and a compact, low-profile, light-weight, and wideband antenna is required for this purpose. Among various wideband antennas, LPDA antenna can achieve relatively high directivity over a very large frequency range [2]. Therefore, we focus on the LPDA antenna for miniaturization in this work. Various approaches with fractal-shaped dipole elements using fractal tree or Koch curve have been investigated to miniaturize the size of the LPDA antenna [3], [4].

In this letter, a compact LPDA antenna operating from 1 GHz to 6 GHz is proposed for portable DF applications. Bow-tie-shaped dipole elements and a top-loading technique are used to reduce the lateral size of an LPDA antenna, and the spacing factor in LPDA antenna is decreased to reduce the spacing between the LPDA elements. The size of the proposed antenna is compared with that of a standard LPDA antenna. All simulation data is obtained using CST Microwave Studio [5].

II. LPDA Antenna Design and Miniaturization

In most portable DF systems, a low-noise amplifier (LNA) with 15-dB to 20-dB gain is usually installed at the input of the DF antenna to detect weak signals [6]. In this work, the design specifications of a miniaturized LPDA antenna are chosen as a realized gain greater than 2 dBi and a front-to-back (F/B) ratio greater than 10 dB considering the miniaturization and the LNA gain.

The geometry of the proposed miniaturized LPDA antenna is presented in Fig. 1. First, a standard LPDA antenna by using the design procedure similar to that presented by Carrel [3] is modeled to achieve a directivity of about 8 dBi over a 1-GHz to 6-GHz frequency band. The scale factor τ of 0.85 and the
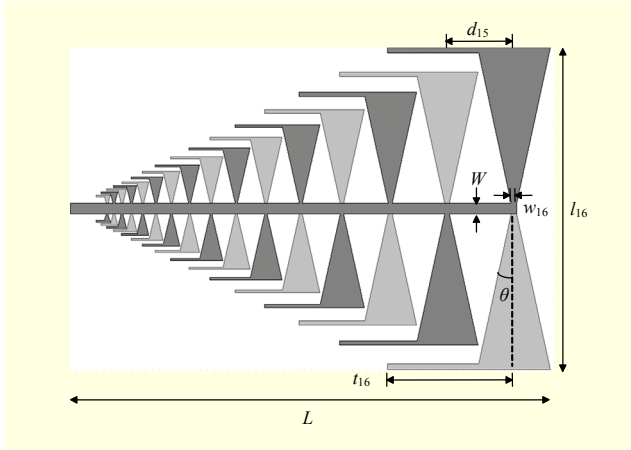
Fig. 1. Geometry of proposed miniaturized LPDA antenna.

spacing factor σ of 0.15 are selected, and the number of dipole array elements is determined to be 16. The LPDA antenna is assumed to be printed on FR4 substrate (ε_r=4.4, thickness=1.6 mm). The length of the longest dipole element is related to the lower frequency limit (1 GHz) and is selected to be 130 mm, which is a little shorter than half-wavelength at 1 GHz. The corresponding width of the longest dipole element and the lengths and widths of the remaining dipole elements can be calculated by using the known equations [2]. The total length of the designed standard LPDA antenna is 244 mm.

The following design procedure is proceeded to miniaturize the standard LPDA antenna. Since, as the flare angle θ of a bow-tie antenna increases, its low-frequency limit is decreased and the bandwidth becomes broader, bow-tie-shaped dipole elements are first applied instead of the straight dipole elements to reduce the length of dipole elements. To further decrease the lateral size of the LPDA, a top-loading technique is employed to the bow-tie-shaped dipole elements. Next, to reduce the total length of the LPDA, the spacing factor σ decreases from 0.15 to 0.106.

Figure 2 presents the input reflection coefficient and the realized gain characteristics for three different LPDA antennas: original LPDA antenna (A), LPDA antenna with bow-tie dipole elements (B), and LPDA antenna with bow-tie elements and top-loading (C). We note that the length of the longest dipole element is reduced to l_{16}=88 mm owing to the bow-tie elements and top-loading, and the spacing factor of 0.106 is applied for all the three cases. The flare angle of the bow-tie elements is set to be θ=13º, and the length of the top-loading t_n is 0.4×l_n. When the bow-tie dipole elements are only added, the low-frequency limit shifts toward lower frequency, and the realized gain is decreased at low-frequency band, but it is enhanced at high-frequency band. As the top-loading elements are added to the bow-tie dipole elements, the low-frequency limit is further moved toward lower frequency, and the realized
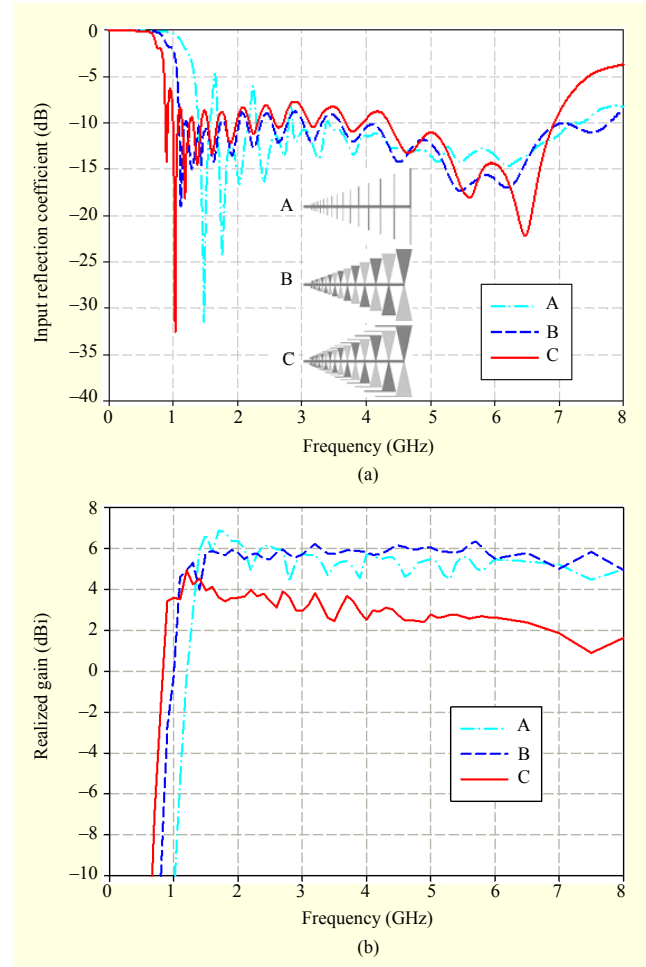

Fig. 2. Comparison of input reflection coefficient and realized gain characteristics for three different LPDA antennas: (a) input reflection coefficient and (b) realized gain.

gain is decreased about 2 dB to 3 dB over the whole frequency band.

Finally, a miniaturized LPDA antenna employing all three methods together is fabricated, as shown in Fig. 3. It is fabricated on an FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm (loss tangent=0.025). A coaxial cable is used to feed the antenna, which is soldered along the upper-side transmission line, and the center conductor is connected to the lower-side transmission line through a hole at the end of the feedline. This 'coaxial infinite balun' provides the necessary wideband matching and the appropriate current phase to each dipole [4]. The length of the longest dipole element is reduced to 88 mm ($0.29\lambda_0$ where λ_0 is free-space wavelength at 1 GHz), and the total length of the LPDA antenna is 135 mm ($0.45\lambda_0$). The width and length of the proposed LPDA antenna is reduced to 33% and 45%, respectively, compared to the standard LPDA antenna ($0.43\lambda_0 \times 0.81\lambda_0$). If we compare the frequency bandwidth and
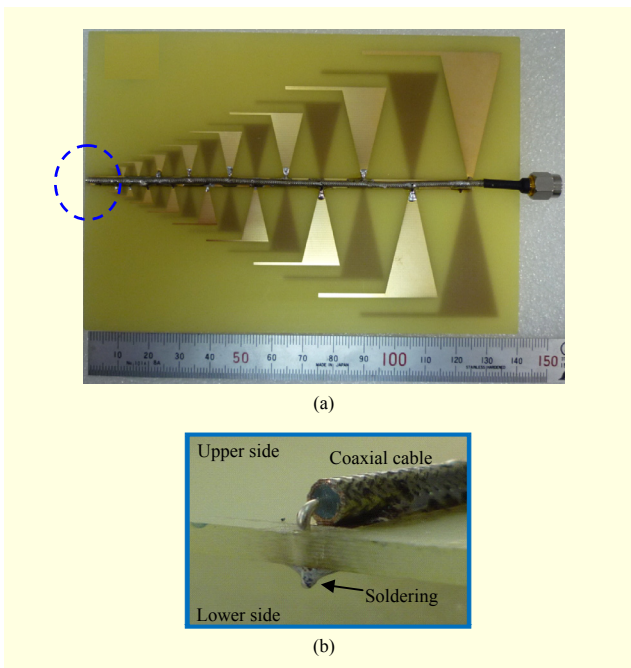
Fig. 3. Photograph of fabricated miniaturized LPDA antenna fed by coaxial cable: (a) antenna and (b) feeding part.
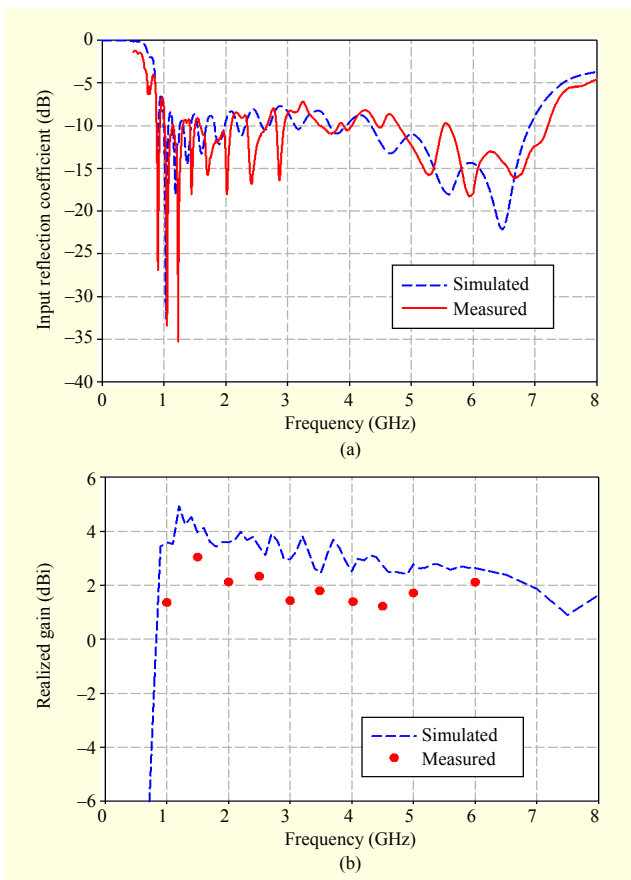

Fig. 4. Simulated and measured input reflection coefficient and realized gain characteristics for fabricated LPDA antenna: (a) input reflection coefficient and (b) realized gain.
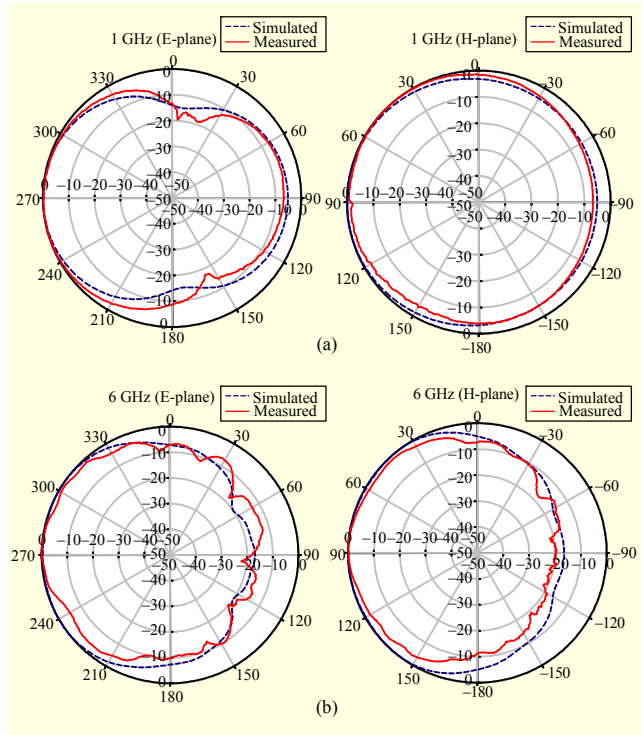

Fig. 5. E-plane and H-plane radiation patterns of proposed LPDA antenna: (a) 1 GHz and (b) 6 GHz.

dimensions of the proposed LPDA antenna with other miniaturized LPDA antenna, 6-element log-periodic Koch dipole array antenna in [4] operates 2.05 GHz to 3.2 GHz (1:1.56), and its width is 51.2 mm ($0.34\lambda_0$ where λ_0 is free-space wavelength at 2 GHz).

Figure 4 compares the simulated and the measured input reflection coefficient and realized gain characteristics. It is observed from Fig. 4(a) that the frequency bandwidth satisfying −6.5-dB input reflection coefficient requirement is 1:8.31 (0.87 GHz to 7.23 GHz) for the simulated result and 1:8.53 (0.87 GHz to 7.42 GHz) for the measured one. These results meet the design frequency specifications of the miniaturized LPDA antenna. The simulated gain of the antenna is from 2.4 dBi to 4.9 dBi, while the measured gain ranges from 1.2 dBi to 3 dBi. We conjecture that the difference might be related to the impedance mismatch and loss caused by the coaxial balun. Figure 5 shows the E-plane and H-plane radiation patterns at 1 GHz and 6 GHz. It is seen that the simulated and the measured results are in good agreement and the F/B ratio ranges from 7 dB to 22 dB.

III. Conclusion

We have proposed a miniaturized LPDA antenna operating from 1 GHz to 6 GHz for portable DF applications. The width and length of the proposed LPDA antenna are reduced to 33%

and 45%, respectively, compared to the standard LPDA antenna, and it has the measured gain of 1.2 dBi to 3 dBi over the 1-GHz to 6-GHz bands. The proposed LPDA antenna can be used for portable direction finding and spectrum monitoring applications.

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