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Design of Double-Sided Dipole Array Antenna

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Index Terms

Dipole antenna, printed antenna, wideband antenna

Abstract

A wideband double-sided printed dipole antenna is presented. The antenna is a printed dipole fed by a Microstrip tapered balun. The antenna consists of a tapered balun and a dipole with its arms being printed on opposite sides of the dielectric substrate. The total length of the dipole is 48mm, which is approximately half the guided wavelength at 2.4GHz. A two-element array is also presented by combining two dipoles with a Wilkinson power divider. The achievable –10 dB bandwidth is approximately 21% and 20% for the dipole and array antennas, respectively. The realized gains are 2.5 dB and 3.5 dB, respectively.

تصميم هوائي مصفوفة ثنائي القطب مزدوج الجانب

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الملخص

هذا البحث يستعرض هوائي ثنائي القطب عريض النطاق ثنائي الجانب. يتم تغذية الهوائي بواسطة بالون مدبب صغير. يتكون الهوائي من بالون وهوائي ثنائي القطب ذراعاه مطبوعتان على جانبي الطبقة العازلة. يبلغ الطول الإجمالي لثنائي القطب حوالي 48 مم وهو يعادل تقريبا نصف الطول الموجي عند تردد 2.4 جيجا هرتز. كما يستعرض البحث منظومة ثنائية العنصر بدمج ثنائي القطب مع مقسم ويلكنسون للقدرة. يبلغ عرض حزمة النطاق -10 ديسبل 20% و21% للهوائي ولمنظومة عنصرين على التوالي. اما الكسب المحقق فهو 2.5 و 3.5 ديسبل على التوالي.

الكلمات المفتاحية

هوائي ثنائي القطب، هوائي مطبوع، هوائي واسع النطاق، اتصالات لا سلكية

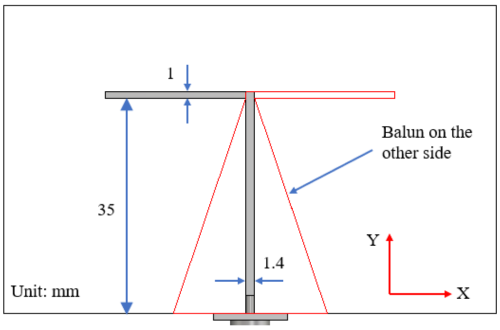
I. INTRODUCTION

A dipole antenna is a small, efficient, inexpensive, and realistic antenna that is widely used in communication, radar, and Broadcasting systems [1]. Printed dipoles offer additional advantages, including low profile and ease of manufacturing. Furthermore, it can be integrated with surface-mountable electronic devices. A major disadvantage of these dipoles is their inherently narrow bandwidth.

Several techniques have been proposed to widen the dipole bandwidth. These techniques involve shape modification [2-3] or adding parasitic elements [4]. Although these techniques improve the bandwidth, they result in radiation pattern distortion because of the unbalanced feeding. Wideband dipoles with balanced feeds have been reported in [5-6]. A dipole antenna and dipole arrays with log-periodic balun feeding are presented in [7]. The achievable bandwidth is about 28% for the single-element, 2x1, and 4x1 dipole arrays. These antennas generate an end-fire radiation pattern because of the ground plane, which acts as a reflector. Marchand Balun is also used to transform the Microstrip line into a parallel-line to feed the dipole antenna [8]. Printed dipole with a bandwidth greater than 70% is proposed in [9]. However, the feeding balun structure is not simple, requiring via hole grounding. A double-sided dipole with flared arms is presented in [10]. The effect of the flared arm width on the input impedance is also investigated. The design was also expanded into a two-element array.

II. Antenna Design and Operation

This paper presents double-sided printed dipole and dipole array antennas. The antenna is implemented with a tapered ground plane that acts as a balun. The taper is usually chosen to be exponential [11]. In this design, however, a linear taper is chosen for simplicity. The antenna is double-sided, where each arm of the dipole is printed on a different side of the dielectric layer, as shown in Fig. 1. The dipole arm is 24.4mm long, which is equivalent to a quarter wavelength at the center frequency of 2.4 GHz. The dipole width is 1mm. The antenna is implemented using a FR4 dielectric substrate. The width and the length of the dielectric layer are 50mm and 60mm, respectively. The height of the dielectric is 0.8mm, and the relative permittivity is 4.3. The feeding Microstrip line has a width of 1.4mm to yield an impedance of 50Ω. The balun transforms the Microstrip line to a parallel-line transmission line to feed the dipole antenna [12]. In order to enhance the directivity and the gain, a 2x1 dipole array is developed as shown in Fig. 2. A truncated ground plane is introduced in order to design the array feeding circuitry. The array consists of two double-sided dipoles connected with a Wilkinson power divider. The power divider provides a power splitting in addition to isolating the radiating dipoles from one another [13]. The power divider is designed to have an elliptical shape in order to minimize the coupling between its output parallel lines. The dimensions of the dielectric layer are 100x100mm. The spacing between the dipole centers is about 48mm, which is approximately 0.5λ long.



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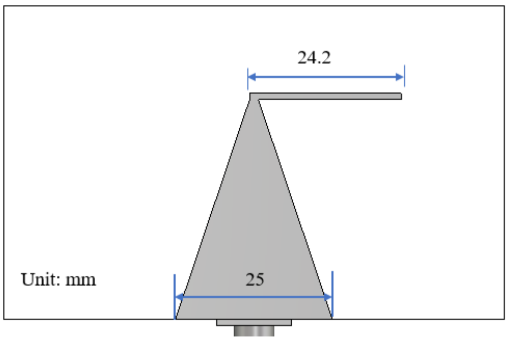

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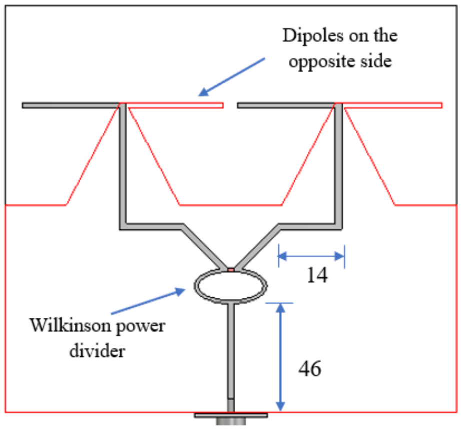
Fig. 1: The double-sided dipole antenna: (a) top layer; (b) bottom layer.



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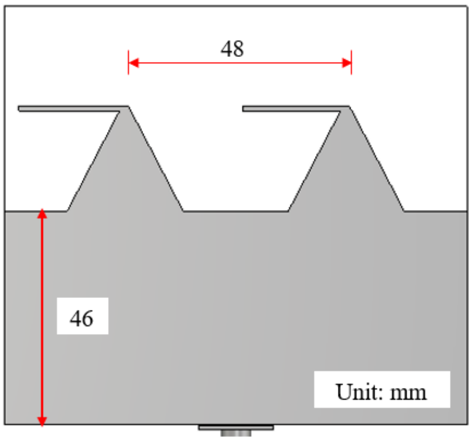


(b)

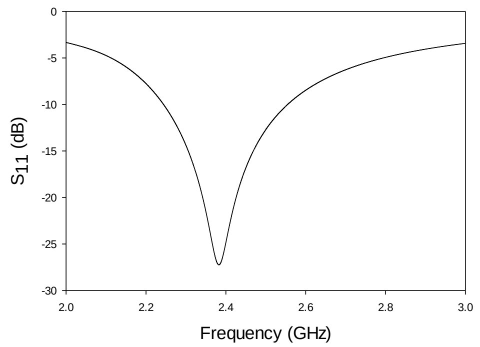
Fig. 2: The dipole array: (a) front layer; (b) back layer

III. Simulation Results and Analysis

Modeling and simulation were carried out using the *CST* MWS program. The proposed antennas were simulated in terms of input impedance, radiation pattern, directivity, and gain. Fig. 3a depicts the simulated S_{11} result for the single dipole antenna. The magnitude of the reflection coefficient is less than – 10 dB from 2.2 to 2.68 GHz. Thus, the realized bandwidth is 20% centered at the resonant frequency of 2.4 GHz. In order to study the effect of the balun width on the input impedance, a parameter sweep was performed. The width varies from W_b = 5mm to W_b = 40mm. The better results were obtained with W_b less than 25mm (approximately λ/4), as shown in Fig. 3b. The best bandwidth result was obtained with W_b= 25mm. The simulated reflection coefficient for the array is depicted in Fig. 4. The array has a -10 dB bandwidth of 21% that spans the frequency range from 2.08 to 2.56GHz.

The radiation pattern of the double-sided dipole is shown in Fig. 5. The pattern is omni-directional with a directivity of 2.5 dB and total efficiency of 91%. The antenna gain is about 2.3 dB. The E field and H field planes of the pattern are shown in Fig. 6. The radiation pattern has some beam squint, which is caused by the imperfect and small size of the ground plane.

The radiation pattern for the dipole array is depicted in Fig. 7. The pattern is an endfire pattern. The main beam direction is along the Y axis. The antenna gain and the total efficiency are 3.9 dB and 89.1%, respectively. The array pattern also suffers from a small beam squint due to the imperfect ground plane.



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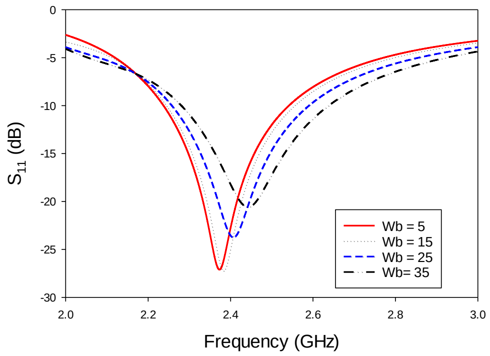


(b)

Fig. 3: (a) The optimized reflection coefficient; (b) S_{11} vs the balun width W_b

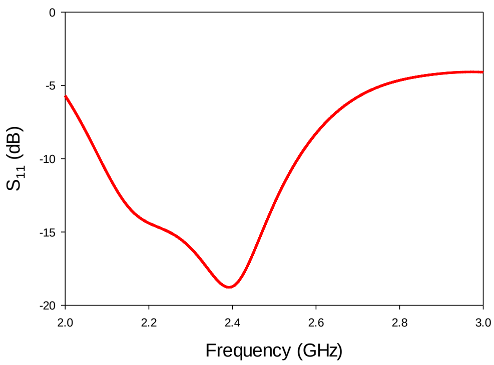


Fig. 4: The reflection coefficient for the dipole array.

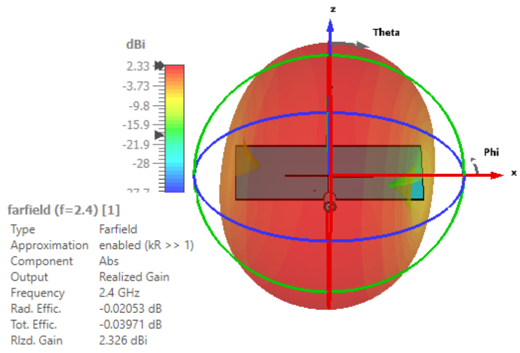
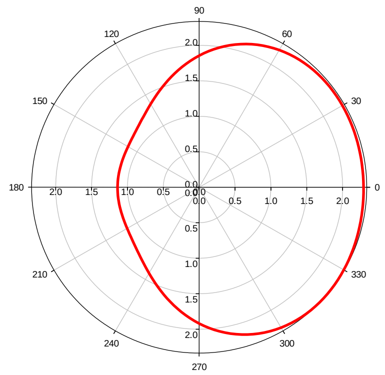


Fig. 5: The radiation pattern of the dipole antenna.



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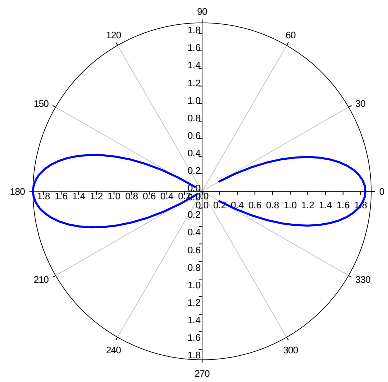

(b)

Fig. 6: The simulated polar radiation pattern for the printed dipole: (a) H-field plane; (b) E-field plane

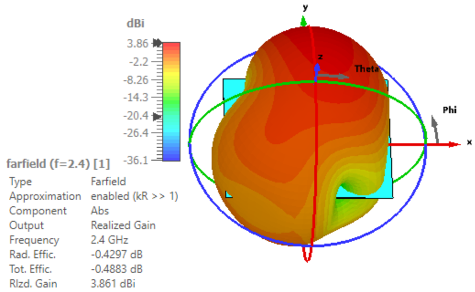

Fig. 7: The 3-D radiation pattern of the printed dipole array antenna.

IV. Conclusion

An effective approach to feed and match the input impedance of a printed dipole antenna is presented. The proposed dipole comprises a tapered balun and a dipole implemented on different sides of the dielectric material. By properly designing the balun, good impedance matching is obtained over a wide frequency range. A single element and a 2x1 array are presented. The bandwidths are 21% and 20% for the dipole and dipole array, respectively. The antennas achieve an omni-directional pattern with a gain of 2.5dB. The array has a higher directivity with a realized gain of 3.5 dB.

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