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Exponential Tapered Balun with Different Sizes for UWB Elliptical Dipole Antenna

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Abstract

This work presents a broadband tapered balun with different sizes using nonlinear transition particularly suitable for planar and three-dimensional (3-D) dipole antennas for ultra-wideband (UWB) applications such as communication, radar systems and geolocation precision. Four baluns with wideband microstrip-to-parallel-strip transition using an elliptical structure for an elliptical dipole antenna are proposed. The initial balun structure consists of a nonlinear profile with a quarter-wavelength for both height and width. By studying the current distributions at the balun surface, it can be reduced to 25%, 50% and 75% from the original size. Measured results based on the reflection coefficients for all baluns are shown to be better than -10 dB from 1.0 GHz to 10 GHz. These baluns are integrated with an elliptical dipole which acts as a feeding circuit. Eight set of antennas with a planar and 3-D configurations with four different sizes are proposed in this work. The planar configurations are named as Planar 1, Planar 2, Planar 3 and Planar 4 while the 3-D configurations are named as 3D Dipole 1, 3D Dipole 2, 3D Dipole 3 and 3D Dipole 4, respectively. The results show that all antennas with the proposed baluns operates within the UWB frequency range.

Keywords: *Tapered balun, UWB elliptical dipole, planar antenna, 3-Dantenna*

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1. Introduction

A tapered balun with a small size and broadband features has been designed and developed for UWB antenna in both planar and 3-D configurations. By incorporating a nonlinear transition, the bandwidth can be increased as shown from the published literature. Therefore the technique is chosen in this work. The balun has an attractive feature such as a simple design with a wideband characteristic appropriate for many applications in military, civilian and commercial areas. Some of the examples are UWB transceivers, location finding accuracy and radar systems. Figure 1 shows a dipole antenna integrated with a large tapered balun. However, this balun creates a bulky antenna in terms of the size and also increases the size of the RF front-end section when operating at 900 MHz and below. Recently, there are several methods to reduce the balun size [1, 2]. In [1], both baluns structures have been bentby $90^{\circ}$by usingthe microstrip-broadside strip line and microstrip-CPS transitions, respectively.

A linear microstrip-to-parallel-strip transition method for reducing the balun size has been published in [2]. In this work, the smallest balunhas a 75% reduction in the height compared to the original balun [3-11] have reported a linear and a nonlinear exponential, elliptical and a Klopfenstein broadband tapered balunsintegrated with its designated antenna. Otherrelated works that concerning on the synthesis of "minimum-size" antennas are discussed in [12-13].

In this work, an exponential broadband tapered balun with a microstrip-to-parallel-strip transition integrated with an elliptical UWB dipole antenna is proposed. It is observed that this configuration reduces the overall size of the antenna but still offers a similar performance as the original balun.Section 2 presents the design and fabricated prototypes. Simulation and experimental results are discussed in Section 3. The last section concludes the work.

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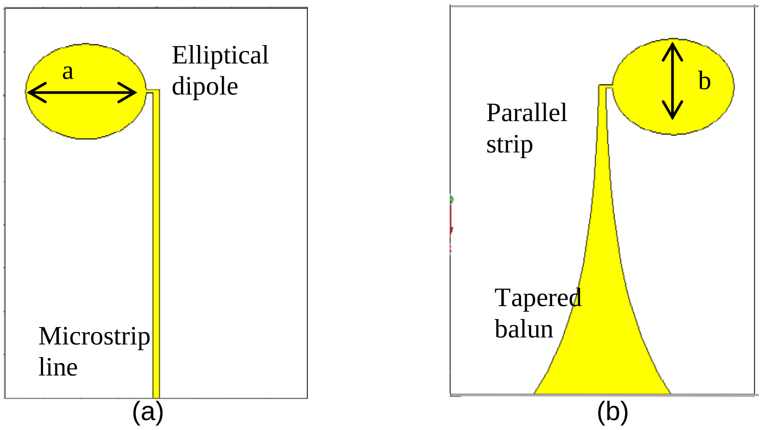

Figure 1. Planar UWB elliptical dipole integrated with exponential tapered balun:
(a) Front view (b) Bottom view

2. Balun Transition and Antenna Prototype

The original balun is designed in a similar manner to the work in [2] and [10]. It is fabricated on a FR-4 substrate with a dielectric constant, $\varepsilon_r$of 4.6, loss tangent, tan δ of 0.019 and thickness, h of 1.6 mm. Figure 2 illustrates the layout of the proposed balun with different sizes. The original size of the balun is named as Exponential 1 that has the size of a half-wavelength at 0.9 GHz. The rest of the baluns are reduced in size uniformly to 25%, 50% and 75% from the original size and are named as Exponential 2, Exponential 3 and Exponential 4, respectively. The 50-Ωmicrostrip line is achieved with a top and bottom layer width of 2.93 mm and 18 mm, respectively. On the other hand, the 70-Ω parallel strip is achieved with a 0.88 mm width on the top layer. In this work, a tapered balun with size reduction is used to match the impedance between the 50-Ω microstrip line and 88-Ω parallel stripline.Table 1 tabulates the final dimensions of the balun.

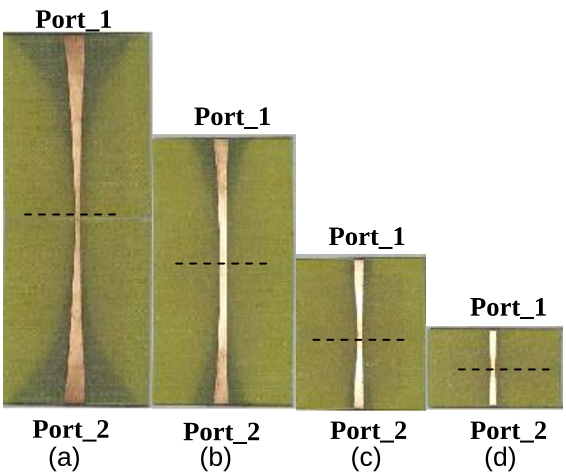

Figure 2. Photograph of the back-to-back configuration with reduced size:
(a) Original size (b) Reduced to 25% (c) Reduced to 50% (d) Reduced to 75%.

The UWB dipole antenna has been designed and simulated in a similar manner to the work in [2] with different sizes. The dipole has an elliptical shape with radius 35 mm and 15 mm for a and$b$, respectively. A linear microstrip-to-parallel-strip transition method for reducing the balun size has been published in [2]. In this work, the smallestbalunobtained has 75% reduction in the height compared to the original balun. Meanwhile, [14-16] have reported an elliptical antenna designated for UWB applications.

Table 1. Dimensions of proposed baluns

Balun Name	Total Size	Remarks
Exponential 1	70.0 x 36 mm^2	Full size
Exponential 2	52.5 x 36 mm^2	25% size reduction
Exponential 3	35.0 x 36 mm^2	50% size reduction
Exponential 4	17.5 x 36 mm^2	75% size reduction

An exponential broadband tapered balun with a microstrip-to-parallel-strip transition integrated with an elliptical UWB dipole antenna is proposed in this research. It is observed that this configuration reduces the overall antenna size but still offer a similar performance as the original balun.

The total size of the radiating element without the balun circuit is 40 × 80 mm^2. The antenna is then integrated with the balun with different sizes. The final prototypes are fabricated and can be viewed in Figure 3. They are named as Planar 1, Planar 2, Planar 3 and Planar 4 based on their total sizes. The final dimensions of the planar antennas with a balun are tabulated in Table 2.

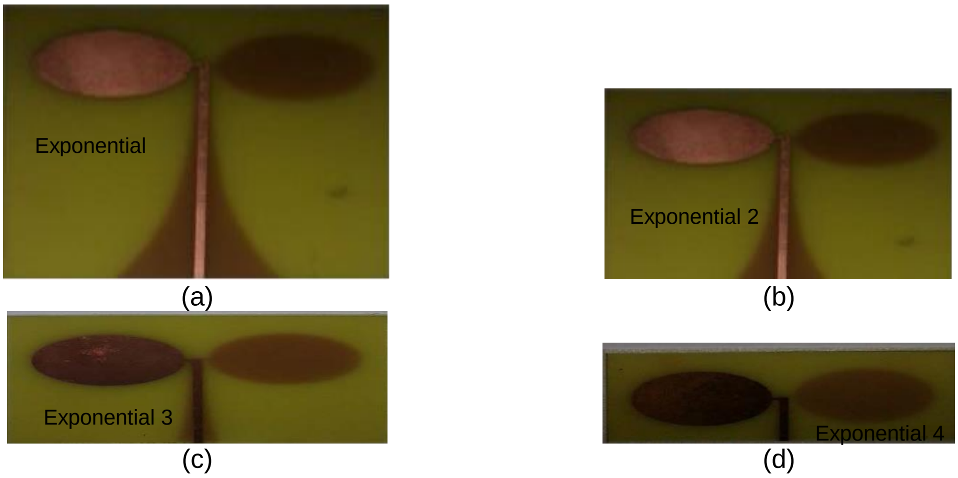

Figure 3. Planar UWB elliptical dipole integrated balun:
(a) Planar 1 (b) Planar 2 (c) Planar 3 (d) Planar 4

Table 2. Dimensions of proposed planar UWB dipoles

UWB Dipole Antenna	Total Size
Planar 1	90.0 x 80 mm^2
Planar 2	67.5 x 80 mm^2
Planar 3	45.0 x 80 mm^2
Planar 4	22.5 x 80 mm^2

The prototypes of the 3D dipole antennas with a balun are shown in Figure 4. They are named as 3D Dipole 1, 3D Dipole 2, 3D Dipole 3 and 3D Dipole 4, respectively. The configuration of the antennas is based on their total 3D sizes. The elliptical dipole is similar to the planar structure in Figure 3 and the balun as shown in Figure 2 is employed to feed the antenna. The total size of the 3D dipole antennas with thebalun are tabulated in Table 3.

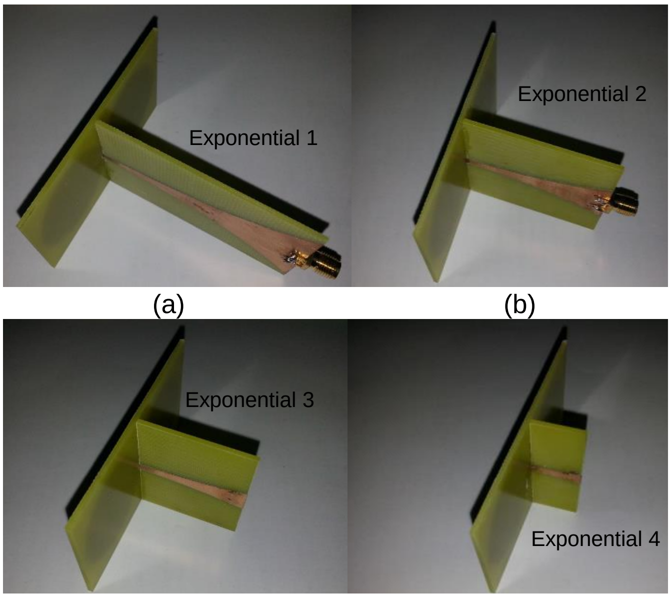

Figure 4. 3-D Elliptical UWB antenna integrated balun:
(a) 3D Dipole 1 (b) 3D Dipole 2 (c) 3D Dipole 3 (d) 3D Dipole 4

Table 3. Dimensions of proposed 3D UWB dipole

UWB Antenna	Total Size
3-D Dipole 1	80 x 40 x 70 mm^3
3-D Dipole 2	80 x 40 x 52.5 mm^3
3-D Dipole 3	80 x 40 x 35 mm^3
3-D Dipole 4	80 x 40 x 17.5 mm^3

3. Results and Analysis

3.1. Exponential Tapered Balun with Reduced Size

The simulated reflection coefficients of the baluns can be viewed in Figure 5. From the Figure, it can be observed thatthe baluns work well in the wideband frequency range from 1.0 GHz to 10 GHz. The Exponential 1 operates with a minimum S_{11} at -15.8 dB and maximum S_{11} at -47.08 dB. The Exponential 2 (with 25% height reduction) operates with a minimum S_{11} at -11.764 dB and maximum S_{11} at -45dB. The Exponential 3 and 4 work with a minimum S_{11} at -18.424 dB and -10.779 dB and maximum S_{11} at -67.441 dB and -46.627dB, respectively. The operating bandwidth of all the baluns is approximately 10 GHz. From the results, it can be concluded that the reduction in the height from the original size does not degrade the balun performance in terms of the reflection coefficient and bandwidth.

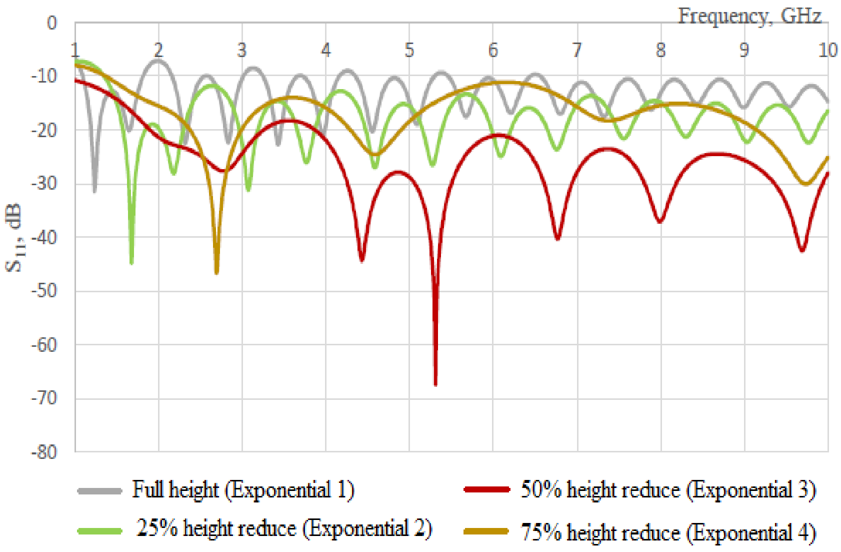

Figure 5. Simulated reflection coefficients of the baluns

3.2. Planar UWB Elliptical Dipole Antennas

The simulated and measured reflection coefficients of the proposed planar UWB dipole antennas are presented in Figure 6. The balun with different sizes is used to feed the antenna. From the figure, the -10-dB bandwidth of the antennas are approximately 9.0 GHz. Moreover, the simulated and measured results are in a good agreement. Therefore, it can be concluded once again that the balun with different sizes as the feeding line does not degrade the performance of the planar UWB antennas.

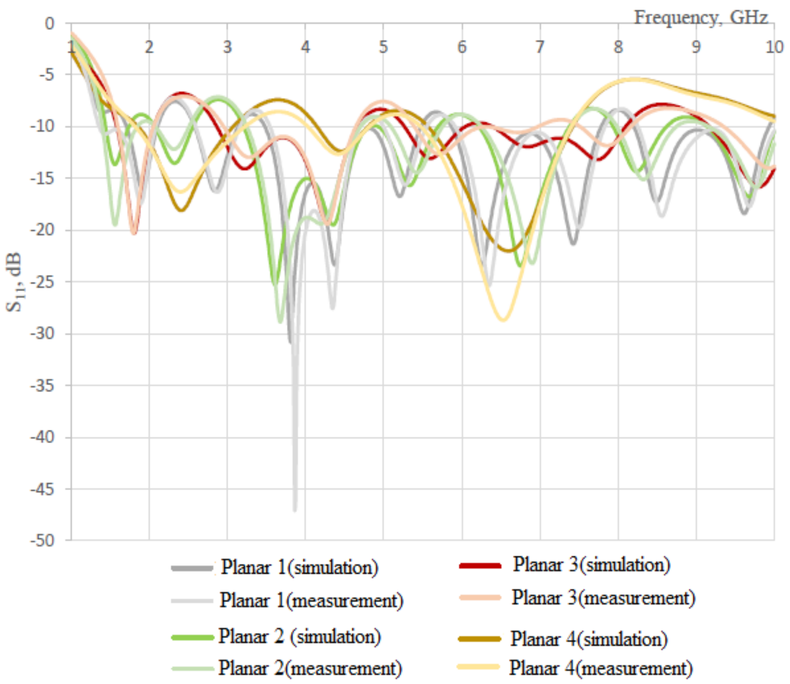

Figure 6. Simulated and measured reflection coefficients of the planar UWB dipoles

3.3. 3D UWB Elliptical Dipole Antennas

The simulated and measured reflection coefficients of the 3D UWB elliptical dipole antennas are presented in Figure 7. From the figure, the antennas have a wideband operating frequency from 1.0 to 10.0 GHz with an operating bandwidth of 10 GHz. In addition, the simulated and measured results agree well with each other. Thus, it is shown that the balun with different sizes also does not degrade the performance of the 3D UWB antennas.

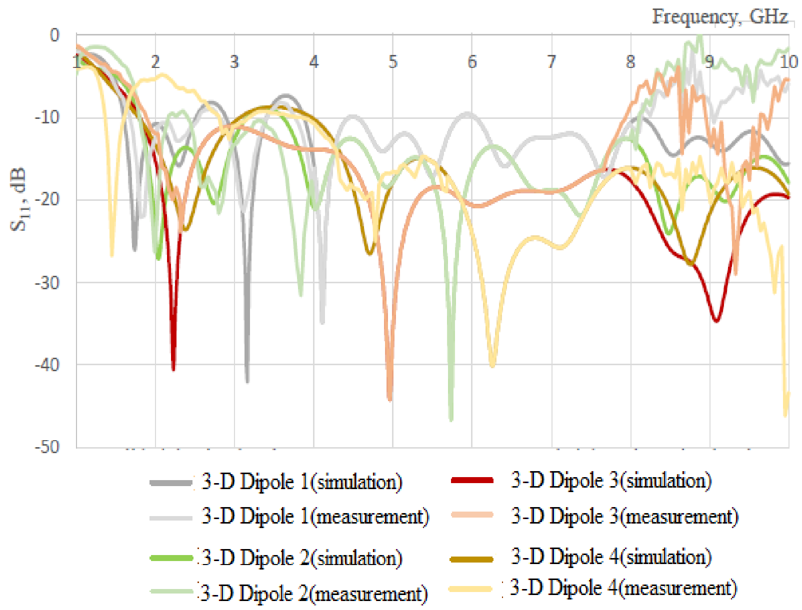

Figure 7. Simulated and measured return loss of a 3-D UWB dipole

4. Conclusion

In this work, four optimized nonlinear tapered baluns using microstrip-to-parallel-strip transition with reduction in sizes for UWB elliptical dipole antenna in planar and 3-D configurations are presented. These baluns have contributed to the impedance matching between the 50-Ωmicrostrip line and 88-Ω parallel strip. The measurements are based on the reflection coefficients of the back-to-back configuration of the baluns that are found better than -10 dB from 1 to 10 GHz frequency. By employing these baluns, four sets of planar dipole as well as 3-D dipole are proposed as the UWB antenna. The results show that these antennas have the capability to operate at the UWB frequency bandand their performances do not degrade regardless of the changes in the balun size.

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