Wideband, Planar, Log-Periodic Balun

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Abstract

This paper presents the design and performance characteristics of a new planar balun structure. The design is based on the log-periodic antenna theory. The design guidelines, as well as simulated and measured results are presented. It is shown that the new balun has greater than one octave bandwidth. The log-periodic balun will find applications in wireless communication circuits such as mixers, amplifiers and antennas.

I. Introduction

The design of planar broadband baluns has been the subject of many investigations [1], [2], [3]. One of the proposed baluns is an N-section half-wave balun [4] shown in Fig. 1.

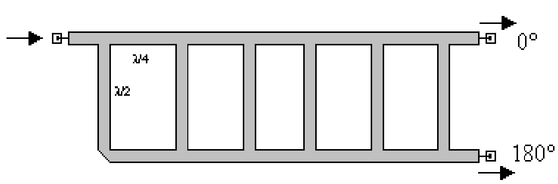

Fig.1 N-section half-wave balun

It consists of several identical half-wave resonators separated by quarter-wave microstrip sections. This balun was designed, fabricated and tested. The 6-section design produced the largest bandwidth of 31% at 3.1 GHz. It's performance characteristics will be compared to that of the Log-periodic balun in section III.

The Log-Periodic balun proposed in this paper [5] is shown in Fig.2. Unlike the N-section half-wave balun, this balun consists of half-wave resonators with lengths that vary according to a fixed geometric ratio, τ (<1), thus forming a Log-Periodic structure. This balun gives significantly greater bandwidth than the N-section half-wave balun, as shown in section III.

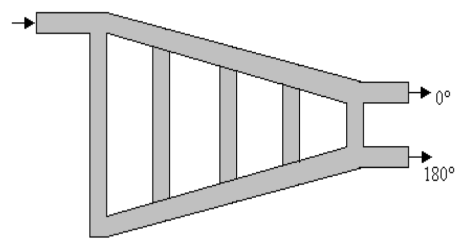

Fig.2 Log-Periodic balun

This balun was designed, fabricated and tested. A 5-resonator design produced one octave (2-4 GHz) bandwidth. The design procedures, as well as simulated and measured results will be presented in the following sections.

II. Log-Periodic Balun Design

The design principles and procedures will be illustrated referring to a 5-resonator Log-Periodic structure shown in Fig.3.

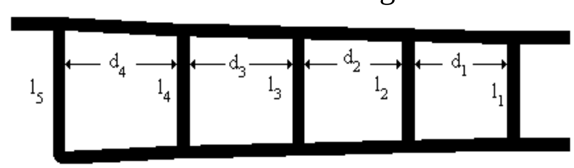

Fig.3 Five-Resonator Log-Periodic Balun

Design Guidelines

The design is based on the Log-Periodic antenna theory [6]. The lengths of the resonators and the distances between them are related by,

$$\frac{1}{\tau} = \frac{d_{n+1}}{d_n} = \frac{l_{n+1}}{l_n} = \frac{\lambda_{n+1}}{\lambda_n} \qquad (1)$$

Where, τ is the geometric ratio (<1), d is the distance between resonators, l is the length of the resonators, and λ is the wavelength.

The balun is a periodic structure in which a typical cell is as shown in Fig.4.

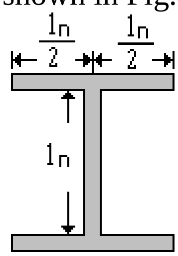

Fig.4 A typical cell of the Log-Periodic balun

In a balun having odd number of cells, the length of the resonator in the central cell is made equal to $\lambda_{gc}/2$, where λ_{gc} is the guide wavelength in microstrip at the band center frequency. For a specified value of τ, from (1), the lengths of the resonators and the distances between them shown in Fig.3 are given by,

$$l_1 = \tau^2 \lambda_{gc}/2 \qquad d_1 = (l_1 + l_2)/2 = \sigma 2\, l_1$$
$$l_2 = l_1/\tau \qquad d_2 = (l_2 + l_3)/2 = \sigma 2\, l_2$$
$$l_3 = l_2/\tau = \lambda_{gc}/2 \qquad d_3 = (l_3 + l_4)/2 = \sigma 2\, l_3$$
$$l_4 = l_3/\tau \qquad d_4 = (l_4 + l_5)/2 = \sigma 2\, l_4$$
$$l_5 = l_4/\tau \qquad \sigma = \frac{\tau + 1}{4\tau} \qquad (2)$$

From (2), it is evident that the electrical dimensions of successive cells vary according to the geometric ratio τ, which is a characteristic feature of a Log-Periodic structure. In the following section, the design of an octave band Log-Periodic Balun based on the above principles will be illustrated by means of an example.

Design example

Consider the design of a 5-resonator Log-Periodic balun operating in the range of 2-4 GHz. The circuit board selected is RT Duroid 6010 having a dielectric constant of 10.5 and thickness of 25 mils. The transmission lines to be used are microstrip lines, having Z_o=50 Ω. At the band center frequency (3GHz), λ_{gc} is 1492.88 mil. The geometric ratio τ was chosen to be 0.95. Using the design equation (2), the lengths of the resonators and the distances between them were found. The Balun was simulated using HP-EEsof linear simulator. The balun was fabricated and tested. The photograph of the balun is shown in Fig.5.

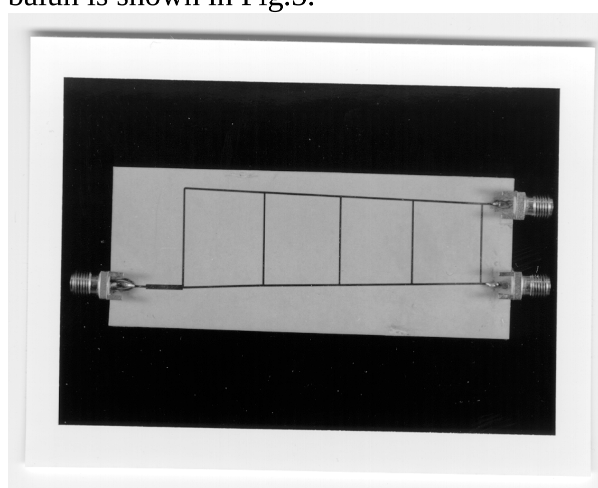

Fig.5 Five-Resonator Log-periodic Balun

III. Simulation and Measured Results

Simulated and the measured results for the magnitude balance ($|S_{21}|-|S_{31}|$) and the phase difference between the output ports are depicted in Figs. 6a and 6b respectively.

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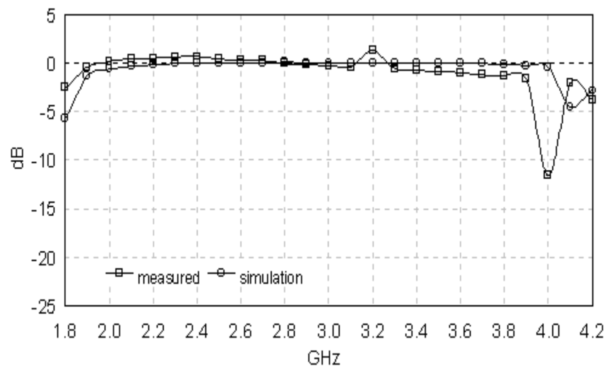

Fig.6(a) Magnitude balance between output ports of Log-Periodic balun

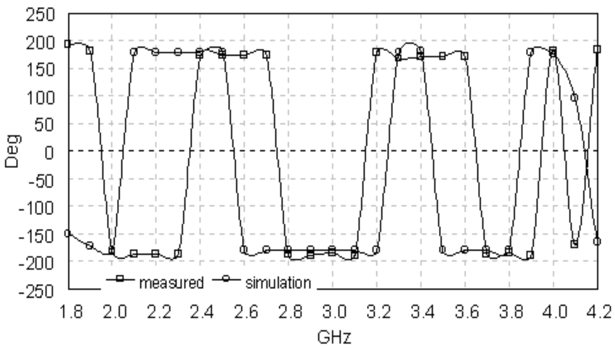

Fig.6(b) Phase difference between output ports of Log-Periodic balun

Simulation results for the reflection coefficient at port 1 (S_{11}) vary from -6.2 to -24 dB; whereas the measured values vary from -6.7 to -13 dB. The behavior of the reflection coefficient at port 2 and port 3 (S_{22} and S_{33}) are nearly identical. The measured and simulated values for most of the band vary from -4dB to -13dB. These values indicate that impedance matching networks are required at the ports.

The simulated and measured reflection coefficients for the Log-Periodic balun are shown in Figs.7a-c

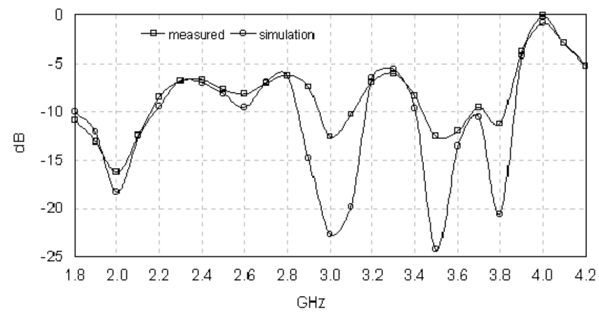

Fig.7a Reflection coefficient at port 1 of the Log-periodic balun

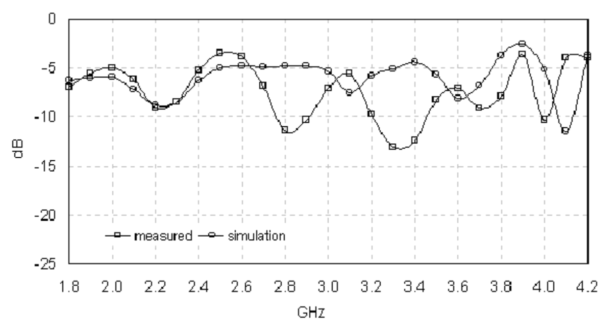

Fig.7b Reflection coefficient at port 2 of the Log-Periodic balun

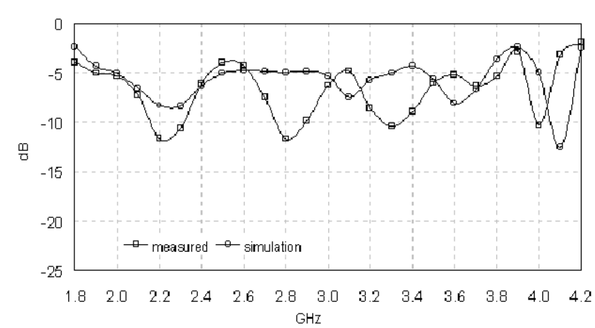

Fig.7c Reflection coefficient at port 3 of the Log-Periodic balun

It is evident form Fig.6a and Fig.6b that the simulated and measured results are in very good agreement. The magnitude balance is within ±0.5 dB in the range 1.9 to 3.9 GHz. The phase difference is 180° ±10°. The input and output return losses are less than -5dB. The insertion loss is less than 1dB.

Comparisons to half-wave balun

The simulated and measured results for the 6-section half-wave balun are shown in Figs.8a and b.

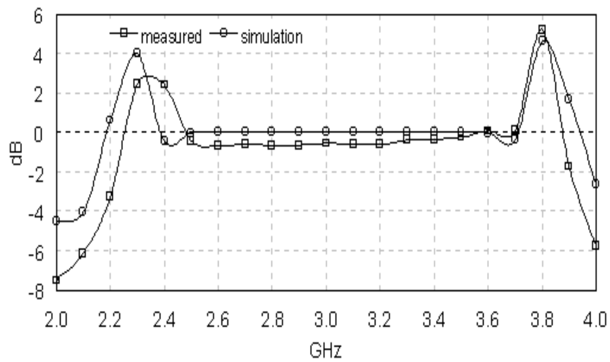

Fig.8(a) Magnitude balance between output ports of half-wave balun

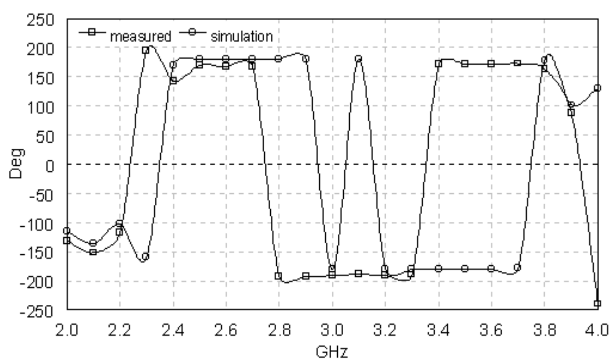

Fig.8(b) Phase difference between output ports of half-wave balun

It is evident from Fig.8a and 8b that for tolerable magnitude balance of ±0.5dB and phase difference of 180° ±10°, the half-wave balun has only 31% bandwidth at 3.1 GHz. This bandwidth is significantly less than the octave bandwidth of the Log-Periodic balun. Furthermore, the half-wave balun required 6-sections to achieve 31% bandwidth, whereas, the Log-Periodic balun required only 5-resonators to achieve one octave bandwidth.

IV. Conclusions

A new, wideband planar balun has been proposed. It is shown that the Log-Periodic balun gives significantly larger bandwidth (one octave or more) than the half-wave balun. The design principles and procedures for the new balun have been presented.

References

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