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.

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. Its 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, $\tau (<1)$, thus forming a Log-Periodic structure. This balun gives significantly greater bandwidth than the N-section half-wave balun, as shown in section III.

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.
**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,

\[
\frac{1}{\tau} = \frac{d_{n+1}}{d_n} = \frac{l_{n+1}}{l_n} = \frac{\lambda_{n+1}}{\lambda_n} \quad (1)
\]

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

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

\[
\begin{align*}
\text{Fig.4 A typical cell of the Log-Periodic balun}
\end{align*}
\]

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 \(\lambda_{gc}\) is the guide wavelength in microstrip at the band center frequency. For a specified value of \(\tau\), from (1), the lengths of the resonators and the distances between them shown in Fig.3 are given by,

\[
\begin{align*}
l_1 &= \tau^2 \lambda_{gc}/2 & d_1 &= (l_1 + l_2)/2 = \sigma 2 l_1 \\
l_2 &= l_1/\tau & d_2 &= (l_2 + l_3)/2 = \sigma 2 l_2 \\
l_3 &= l_2/\tau &= \lambda_{gc}/2 & d_3 &= (l_3 + l_4)/2 = \sigma 2 l_3 \\
l_4 &= l_3/\tau & d_4 &= (l_4 + l_5)/2 = \sigma 2 l_4 \\
l_5 &= l_4/\tau & \sigma = \frac{\tau + 1}{4\tau} \quad (2)
\end{align*}
\]

From (2), it is evident that the electrical dimensions of successive cells vary according to the geometric ratio \(\tau\), 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 \(Z_0 = 50 \Omega\). At the band center frequency (3GHz), \(\lambda_{gc}\) is 1492.88 mil. The geometric ratio \(\tau\) 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.

**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.
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

It is evident from 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 ±0.5 dB 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