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Parametric Study of Exponentially Tapered Balun integrated with UWB Spiral Antenna

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Abstract (10pt)

This paper deals with the parametric study of exponentially tapered balun. The exponentially tapered balun acts as an impedance transformer and used between coaxial connector and UWB Archimedean Spiral Antenna. The parameters like balun length, taper factor and twinline width are varied to achieve return loss better than 10 dB over the entire UWB band. The simulations and optimization of structure have been carried out in CST Microwave Studio.

Keywords:

Balun;
UWB;
Spiral Antenna;
Taper factor;
Twinline.

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1. Introduction

Spiral Antenna comes under the category of frequency independent antennas [1]. These antennas operate over broad bandwidth. Spiral antenna exhibit circular polarization and wide beamwidth, therefore widely used in the direction finding applications both for defence and civilian area [2]. The most important part of the spiral antenna is balun which is basically balanced to unbalanced transmission line matching. In order to feed a spiral antenna, the balun consists of microstrip line corresponding to 50 ohm at one end and twinline corresponding to input impedance of spiral antenna at the other end. The transformation from microstrip line to twinline is achieved by gradually tapering the ground plane of the balun [3]. The tapering can be done linearly, exponentially or based on any mathematical equation. In this paper, the tapering is done exponentially and the equation is given as:

$$y = C_1\, e^{Rx} + C_2 \quad \ldots (1)$$

Where,

C_1 and C_2 are constants and R is the taper factor [4].

Based on the equation (1), a balun has been designed for UWB spiral antenna and shown in Fig 1.

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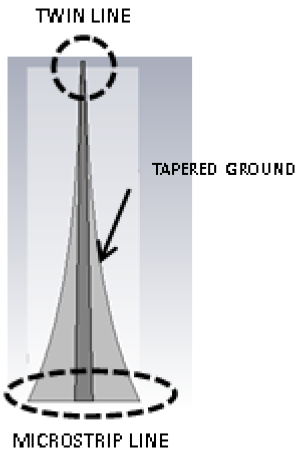

Figure 1. *Exponentially Tapered Balun*

The term UWB means Ultra Wideband and it is defined by FCC as antenna transmission for which the radiated signal bandwidth is greater than 500MHz and 20% of the centre frequency. The frequency range of the UWB ranges from 3.1 GHz to 10.6 GHz. The advantages of UWB are spectrum reuse, high data rate in short range, multipath immunity, low power and low cost.

The presented balun integrated with spiral antenna has been designed, simulated and optimized over UWB band i.e. 3.1-10.6 GHz.

2. Balun Design

The balun is designed on 31 mil thick Rogers/ RT Duroid 5880 substrate. The length of the balun is generally taken as quarter wavelength at centre frequency. The centre frequency is taken for 3.1-10.6 GHz frequency range. The length is varied around quarter wavelength in RT Duroid 5880 substrate.

The taper factor covers the feed line in microstrip configuration hence it plays an important role in achieving twinline with gradual tapering. It is found that as the taper factor reaches to 0.1, the ground plane width becomes smaller than the feed width hence the structure differs from conventional microstrip line.

The impedance corresponding to twinline width on 31 mil thick Rogers 5880 substrate should match with input impedance of spiral antenna. The initial width of the twinline [5] is taken as0.2 mm and varied upto 0.4 mm.

The proposed balun has been integrated with spiral antenna as shown in Fig 2and the parameters are varied within the specified limits.

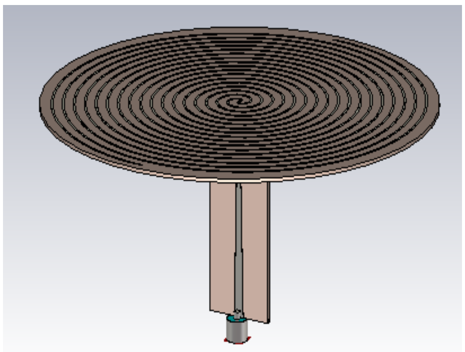

Figure 2. *Integrated Balun with Spiral Antenna*

The reflection coefficient has been achieved better than 10 dB for the UWB for a specific set of parameters. The range and the final values of balun parameters are tabulated in Table 1.

Table 1. Parameters of Balun

Parameter Name	Parameter Range	Final Value
Balun Length	25-35 mm	33 mm
Taper Factor	0.05-0.1	0.08
TwinlineWidth	0.2-0.4 mm	0.4 mm

The S_{11} curve, corresponding to final values of parameters, is shown in Fig 3. The curve shows that the reflected power is lesser than 10% for 3-11 GHz.

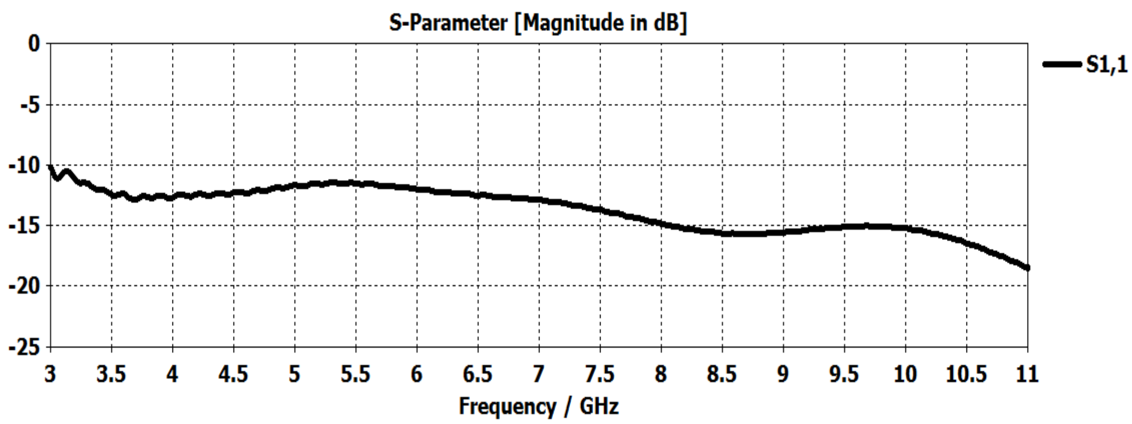

Figure 3. *S_{11} (dB) vs. Frequency*

3. Results and Analysis

The proposed structure has been simulated for 3-11 GHz covering the UWB. The simulated radiation pattern of the spiral antenna with exponentially tapered balun is presented in Fig 4. It is clear that the antenna radiates both in upper and lower directions [6]. The radiation in lower direction can be completely absorbed by employing a lossy cavity [7]. The minimum 3 dB beamwidth of the simulated antenna is 80^0 at 11GHz and maximum beamwidth is 111^0 at 4 GHz.

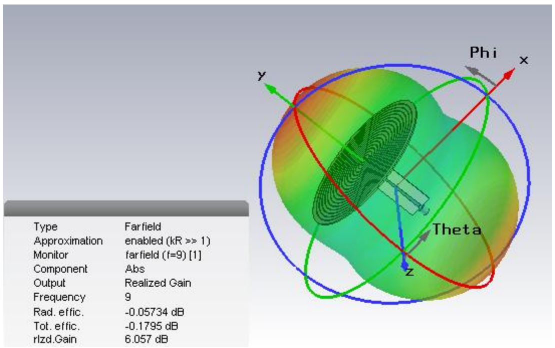

Figure 4. *Radiation Pattern at 9 GHz*

4. Conclusion

The introduction of the exponentially tapered ground instead of the conventional tapered ground improves the impedance matching and provides a good balance between currents in two arms of spiral antenna. It is also observed that performance can also be improved by usinga cylindrical cavity filled with foam absorber. This combination produces wider bandwidth with better return loss and gain.

Due to low gain and circular polariztion, spiral antennas are generally used in receiving mode only. One such application is wideband communication and monitoring of frequency spectrum where spiral antennas are used as single element, array of elements and feed for reflectors.Other applications include Radar Warning Receiver (RWR) where these antennas are used to find the Angle of Arrival (AOA) of the intercepted signals from enemy RADARS.

As an extension of this work, an absorbing cavity can be integrated with the proposed balun and spiral antenna to achieve unidirectional radiation. The cavity length can be optimized to achieve more gain and bandwidth. Further, the cavity backed spiral antenna design can be fabricated and kept in array to find out Angle of Arrival.

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