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Research Paper

Study and analysis of discontinuity by using taper baluns

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Abstract

A coplanar stripline (CPS) to microstrip line transition (MSL) are designed with high characteristics, such as wide band, low return loss and high insertion loss. Two types of tapers are proposed, exponential and triangular to decreases of discontinuity in the power flow in transmission line. The suggested design achieved reflection coefficient under -10 dB over wide band from 1 GHz to 3 GHz and insertion losses of less than 1 dB.

Keywords: *Coplanar; Microstrip Line; Balun; Discontinuity; Triangular; Exponential.*

1. Introduction

In order to minimize of feed radiation, the MSL-CPS will be used. There are many balun configurations that can be used for the transition of MSL to CPS. In [1] unipolar balun is used for transmitting coplanar wave guide (CPW) to MSL. The balun has return loss 20 dB with band (1.6:6.4 GHz). New slotted MSL-CPS transition with balance and unbalance transmission line are presented in [2]. The experiment results to the balun gives broad band under 10 dB losses. A broadband unipolar MSL-to-CPS structure finds a good with many applications spatially with wireless communications and photoconductive switch.
In this paper, MSL to CPS T-junction balun transition will be presented, as can be seen in Figure 1.

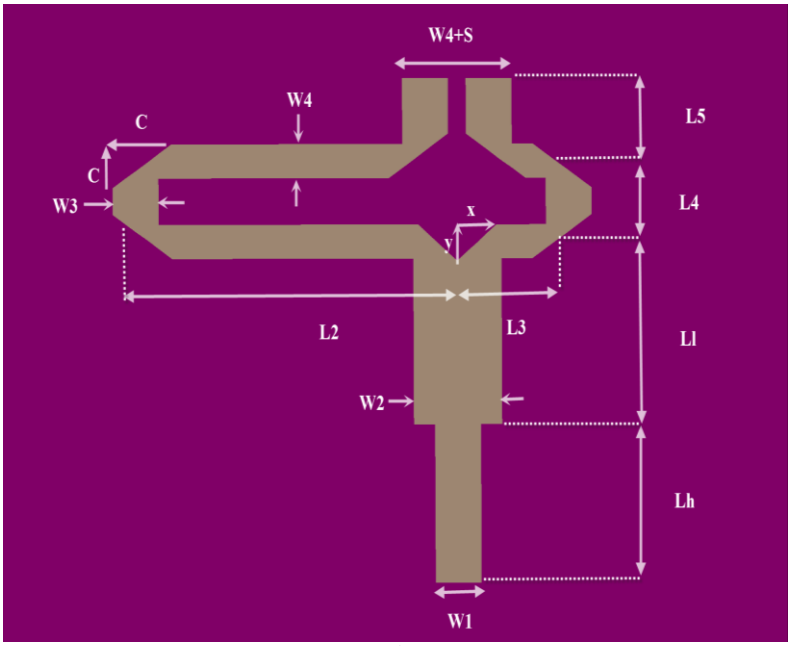

Fig. 1: Geometry of Step-Width Balun

2. Step-width balun design

The T-junction to the step width balun is created to achieve both ends of CPS and MSL to be 50 Ω characteristics impedance [3]. Quarter wavelength 35.5Ω impedance transition is employed for matching between MSL feed and T-junction (divided / combination) TL. 90o miters bends are used to achieve λ/2 transmission line length. At this kind of junctions, discontinuities will occur in the power flow that will be processed in the next section by using taper techniques and it can be accounted by lumped susceptance, B [4]. The following equation is used for designing a divider, matched to the impedance Zo

2.1. Calculation of quarter wave length transition impedance

$$Z_{in} = Z_1 \frac{Z_l + jZ_1 \tan \beta l}{Z_1 + jZ_l \tan \beta l}$$

Where $\beta = \frac{2\pi}{\lambda}$

$$\beta l = \frac{2\pi}{\lambda}.\frac{\lambda}{4} \Rightarrow \beta l = \frac{\pi}{2}$$

Which result to:

$$Z_{in} = \frac{Z_1^{\,2}}{Z_l}$$

2.2. Simulation results of steps-width balun

MSL-to-CPS transition balun is designed by using the equations which were mentioned above to achieve 2.45 GHz resonant frequency and modified by FEKO V.5.5 full wave software simulator. The balun is placed on the RT-Duroid 6010 substrate layer with relative permittivity of 10.2 and thickness of substrate of 2.5mm. All the dimensions of balun are listed in Table 1. At CPS side two kinds of excitation are used, even and odd excitations. When we connect the two ends of CPS with ground plane, it is known as even excitation mode, while the odd mode is that which connect the couple ports with each other. The current will be distributed by 180o phase shift between them.

Table 1: Dimensions of Balun

Balun Element	W1	L1	W2	L2	L3	W3	Lh	L5	S	X	Y
Dimensions (mm)	2.33	11.3	4.48	5.66	16.32	2.33	10.8	5.66	0.9	2	2.5

Figure 2 shows the return loss to the multistep balun in less than 10 dB over wide band (0.9GHz->3GHz) and insertion loss is less than 1dB. VSWR is less than 2 with broadband 1GHz-3GHz as displayed in Figure 3. Note that all the results were compared with Ansoft HFSS 11.2 software full wave simulator in [5].
To minimize the discontinuity in the power flow at this balun, new technique will be apply in balun which is called taper technique. Two kinds of taper technique are used in this balun which are exponential and triangular tapers techniques.

2.3. Exponential taper technique

In the preceding section, we discussed how to use multi-sections for impedance matching. But here, multi-section transformations are replaced with a new exponential tapering technique in order to reduce the reflected signals by 38% compared with the previous technique as shown in figure 5. This will be achieved by reducing the discontinuity in the power flow. The width at the source W (zo) is equal to 2.33 mm to satisfy 50 Ω characteristics impedance and the width at load side W(z.l) 4.48mm to achieved 25 Ω impedance at parallel line to the T-junction.
The following equation will use to design proposed Taper:

$$W(\mathrm{Z}(\mathcal{Z})) = W(\mathrm{Z}_0)\mathrm{e}^{a\mathcal{Z}}$$

Where: W (Z (z)), The width of an exponential tapers.

$$a = \frac{1}{l}\ln\left(\frac{\mathrm{W}(\mathrm{Z}_L)}{W(\mathrm{Z}_0)}\right)$$

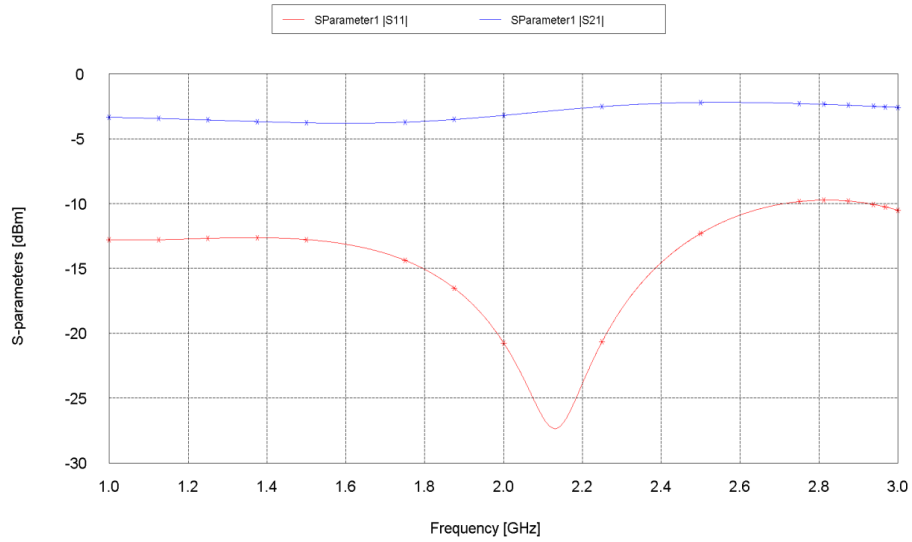

Fig. 2: Balun Return and Insertion Losses

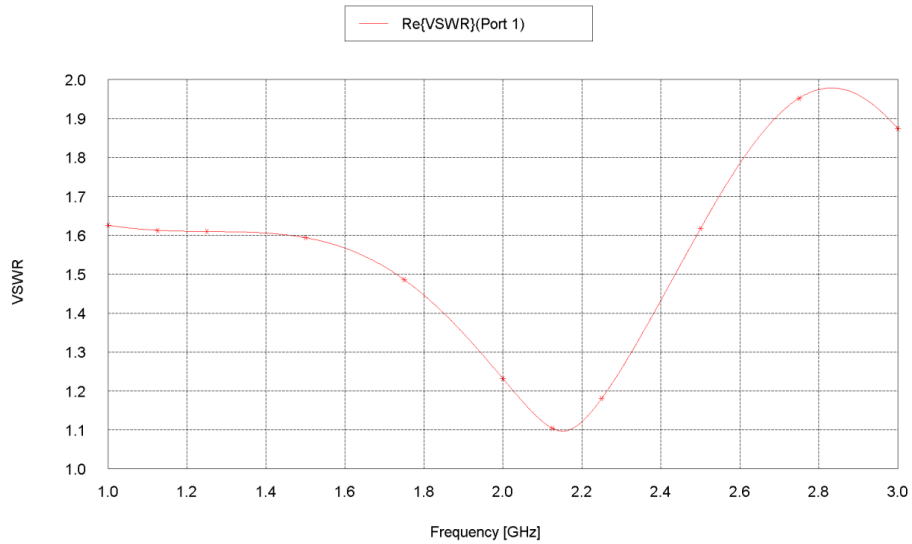

Fig. 3: VSWR of Step-Width Balun

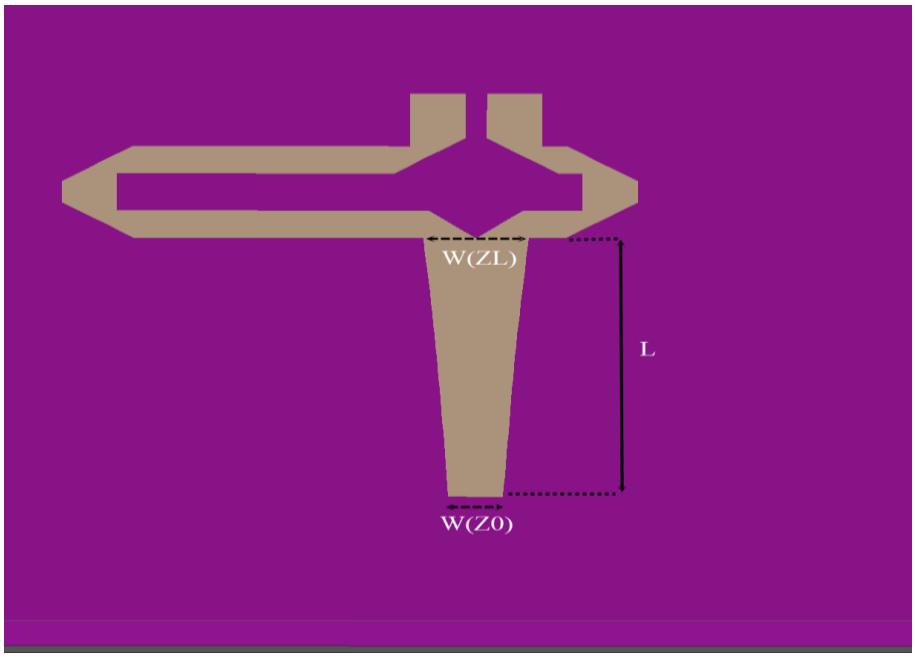

Fig. 4: Double Side Exponential Taper

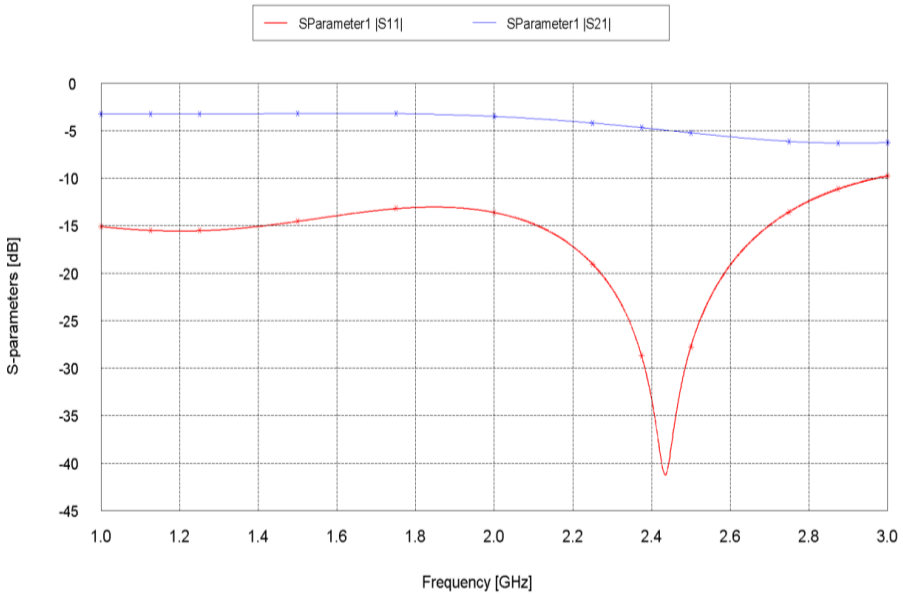

Fig. 5: Reflection Coefficient to the Double Side Exponential Taper

2.6. Triangular taper technique

This section describes triangular in the double side taper schemes as to eliminate a discontinuity in the power flow in Tee-junction balun transitions. We will calculate the width of a triangular taper in terms of equations below:

$$W(Z(z)) = W(Z_0)e^{2(z/L)^2 \ln Z_L/Z_0} \qquad \text{For } 0 \le z \le L/2$$

$$W(Z(z)) = W(Z_0)e^{(4z/L-2z^2/L^2-1)\ln Z_L/Z_0} \qquad \text{For L/2 } L/2 \le z \le L$$

Where: W (Z (z)) = width of taper along L distance [mm]
W (Zo) = width depend on characteristic impedance [mm]
z= length period [mm]
L = length of transmission line
ZL = load impedance[Ω]
ε0 = characteristic impedance [Ω]

Figure 7 shows the balun reflection coefficients are enhanced by 80% comparing with step width balun and 40% comparing with exponential taper balun. This achieved by reduce the discontinuity.

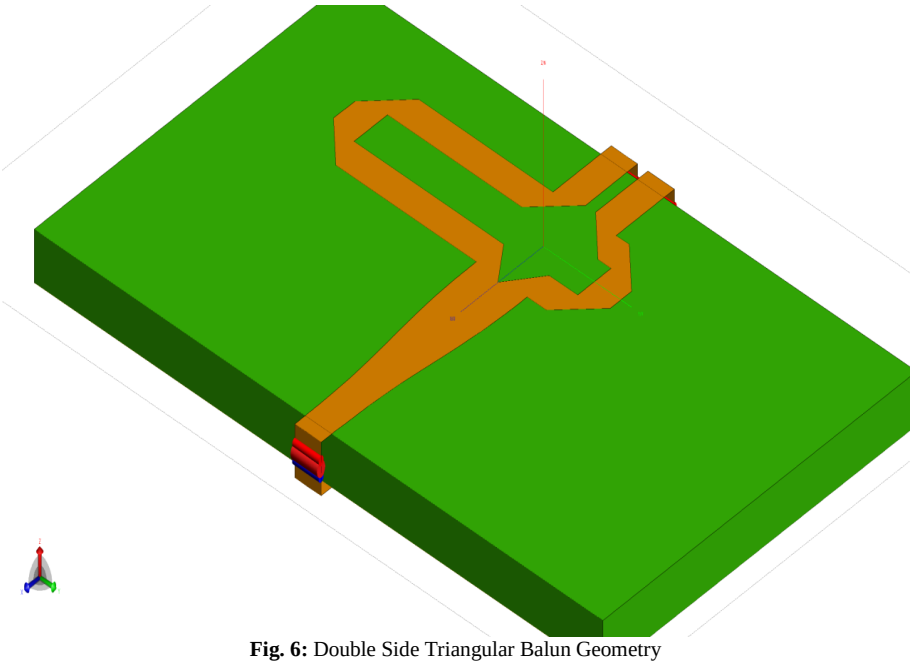

Fig. 6: Double Side Triangular Balun Geometry

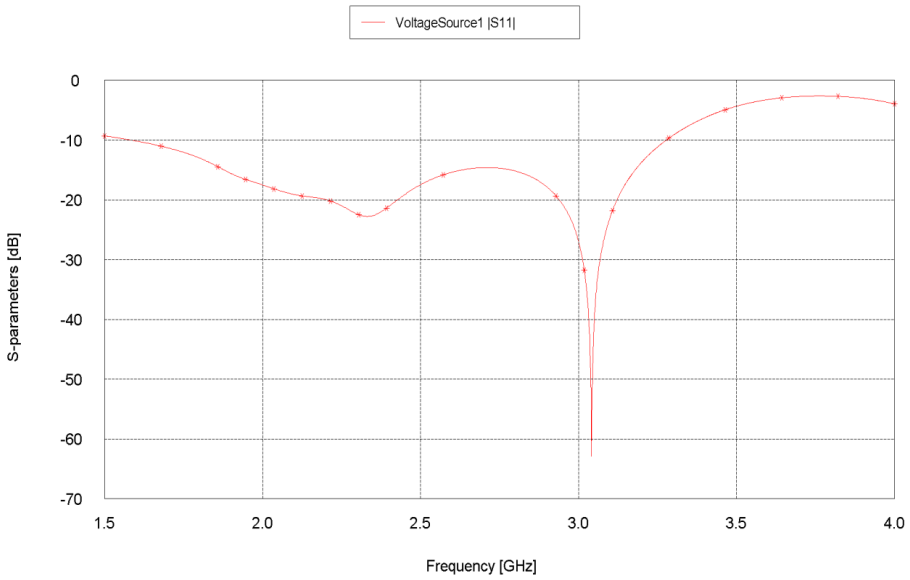

Fig. 7: Return Loss of Double Side Triangular Balun

3. Conclusion

This paper demonstrates how to decrease the discontinuity in power flow by using taper technique. Two kinds of are used to achieved low return losses over wide-band balun characteristics (1:3 GHz). The simulation results show the return loss of the triangular balun is reduced by 80% comparing with step width MSL-CPS transition and 40% comparing with exponential taper technique.

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