Design of Compact BranchlineBalun

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Abstract. This paper present the compact branch line balun to operate at the frequency range of 2.4GHz. The compact branchlinebalun is designed using the substrate material with the dielectric constant of FR$_4$ material. The proposed balun is designed using different transmission lines. Thus the balun should achieves -3dB power division and 180^0 phase differences between the outputs. The main objective of this design focuses on size reduction. To reduce the size, A balun is realized using the equivalent T-shape structure. After the reduction techniques the implemented size of the balun is 29.41x44.32 mm^2 achieves 35% of size reduction. Thus the measured S$_{11}$ are -23 dB and the S$_{21}$,S$_{31}$ remains -3dB and provide 179^0 phase difference between the outputs at the frequency of 2.4GHz.

Keywords. Branchlinebalun, Transmission lines, Size reduction, T-shaped structure.

1. Introduction

A balun is a device used to balance the unbalanced one. A branch line balun is an important features for designing microwave circuits. The baluns are used in various applications such as mixers, amplifiers, frequency multipliers, couplers and so-on. They are widely used in antennas to balance the circuit design. The microstripbalun are also used in many microwave applications. There are many types of baluns-the designs structures are generally depending on the bandwidth, operating frequency, physical architecture of the network. The branchlinebalun provide equal amplitude and phase difference between the circuit design. The branchlinebalun increases the complexity and also achieves better return loss and isolation loss. The branchlinebalun provide wider bandwidth.

This paper focus on size reduction of the balun with 180^0 of phase differences. The proposed balun is designed using different transmission lines composed of two λ/4 transmission lines on horizontal branches and two λ/2 transmission lines on vertical branches. The characteristic impedances of the balun are $\sqrt{2}Z_0 = 70.7Ω$. When the transmission lengths are reduced, characteristics impedances are increased. The size reduction depends on higher impedance transmission lines. By decreasing the length of transmission lines, the entire size of the structure can became compact. In this paper, the reduced size of the balun is presented.

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2. Related works

M. Y. Algumaeiet. al [1] has proposed single balanced mixers for ultra wide band applications. This balun operates at the frequency of 100MHz. Thus the design obtain the phase difference of 180^0 with the conversion loss of 19dB from 3.1 -10 GHz. Mi Zhou et.al [2] has designed a novel planar branch line balun with the symmetrical network with the transparent port impedance. The balun achieves 180^0 phase difference with the better return loss of -30dB operates at the frequency of 1GHz. Li Chang et.al [3] has demonstrated dual band branch line balun at two different frequencies of 1.5 & 2.5 GHz. The simulated return loss are 16.5dB and also attains 180^0 phase difference between the output ports. Chih-Jung Chen et.al [4] has implemented derivation of T-shaped structures for quarter wave transmission lines at the frequency of 2.4 GHz and achieves 180^0 phase difference. He-XiuXuet. al [5] has proposed a compact balun with enhanced bandwidth with the operating frequency of 1.5 GHz and attains a return loss of 10dB and good amplitude and phase imbalance.Myun-Joo Park [6] has used stubs for reducing the branch length in order to reduce the area of the balun at the centre frequency of 1GHz. Hee-Ran Ahn[7-8] has designed ministurizedbalun at the centre frequency of 900 MHz with short coupled lines to obtain 180^0 phase difference. Ming-GuangChen[9-10] has implemented miniatuirzedbalun design with 2.4GHz for dual band transmission line with 60% size reduction.

3. Structure Description and Analysis

A balun is a three port network with port 1 as a input and port 2 and port 3 as a outputs. Thus each port act as a transmitter and receiver. The structured branch line balun (Fig.1) where Z_A and Z_B represents the characteristic impedance $\sqrt{2}\,Z_0 = 70.7\Omega$ whereas the wavelength of Z_A and Z_B represent the quarter wavelength transmission line ($\lambda/4$) and the half wavelength transmission line ($\lambda/2$).The length and width of both the transmission lines are calcultaed and are mentioned in Table1. The input signal should split equally between the output ports. Thus the balunshould provide -3dB power division and 180^0 phase difference between the two output ports.
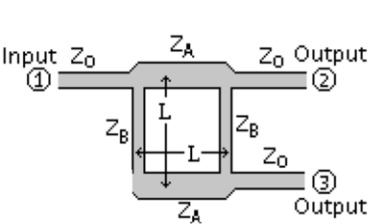
Table 1. Dimensions of Balun

Parameter	Length(mm)	Width(mm)
Z_O	17.2	3.058
Z_A	17.54 ($\lambda/4$)	1.623
Z_B	35.08 ($\lambda/2$)	1.623

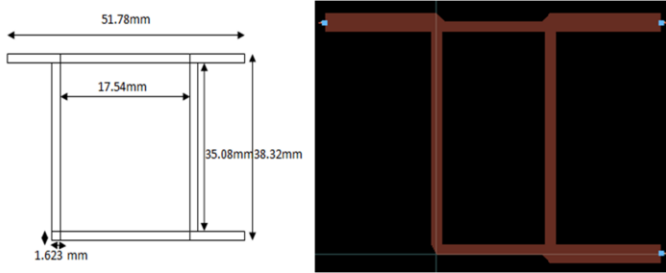**Figure 1. Structure of Branch line Balun**

Figure 2. Layout of the balun designed at 2.4 GHz with its dimensions
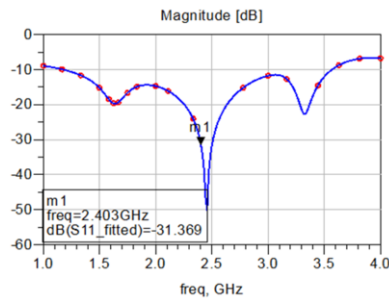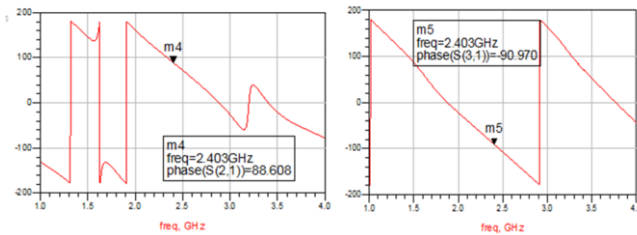

Figure 3. Simulated result of S$_{11}$

Figure 4. Phase of S$_{21}$,S$_{31}$.

The balun is optimized and simulated using ADS software with dielectric constant εr = 4.4(FR$_4$ substrate) and at the thickness of h is 1.6mm. The scattering parameter of this balun is simulated by the Electromagnetic (EM) simulation tool over the frequency of 2.4GHz. Thus the simulated S$_{21,}$ S$_{31}$ are -3.453 and -3.340 dB. The obtained S$_{11}$ are -31 dB over the same frequency. The implemented szie of the branch line balun are 38.32 x 51.78 mm^2 . Therefore the balun obtains 178^0 phase differences between the output S$_{21}$,S$_{31}$ over 2.4 GHz .The main focus of the balun focus on size reduction technique.

4.   Size Reduction Technique

The size reduction technique or miniaturization of the balun can be implemented using various design procedures such as T-shaped structure, stepped impedance of the balun, by adding stubs along its branches, by using different transmission lines. In this proposed design size reduction is done by the equivalent T-shaped structure. The Proposedbalun of $\lambda/4$, $\lambda/2$ transmission lines are replaced by the equivalent T-shaped structure is shown in Fig 5.a. The compact T-shaped structure can be obtained from the

following cases ,Where

$M=Z_1/Z_0$ **(1)**

$K=Z_1/Z_2$ **(2)**

Thus the total electrical length $\Theta_T = 2\Theta_1+\Theta_2$. In order to avoid the overlapping between the stubs length Θ_2 should be lesser than Θ_1 ($\Theta_1 <\Theta_2$) and the stub length of Θ_2 should be plotted against M or Θ_1 can be plotted for the different values of K. The total electrical length Θ_T decreases when K increases, where the Θ_T depends only on M.

Therefore ., $\tan \Theta_1 =1/M$ **(3)**

$\tan \Theta_2 = 1/K(\cot \Theta_1 -\tan \Theta_1)$ **(4)**

First select the parameter for the T-shaped structure whose characteristics impedance $Z_0 =70.7\Omega$, where, $Z_1= M.Z_0 =155.54\Omega$ for M=2.2 of $\Theta_1=24.5^0$ such that $Z_2=Z_1/K=38.85\Omega$ for K=4 of $\Theta_2 =23.5^0$.Thus the total electrical length $\Theta_T =73^0$. Thus the calculated length and width for Z_1 and Z_2 are shown in table.2.

Table 2. Dimensions of conventional Balun

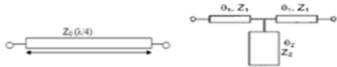| Parameter	Length(mm)	Width(mm)
Z_1	5.046	0.143
Z_2	4.359	5.568

Figure 5. (a) $\lambda/4$ Transmission lines (b)T- shaped structure of $\lambda/4$ Transmission lines.

Thus the Proposed branchlinebalun can be realized by the vertical and horizontal branches of T-shaped structure such that the total electrical length will be $\Theta_T =73^0$ for both the branches.
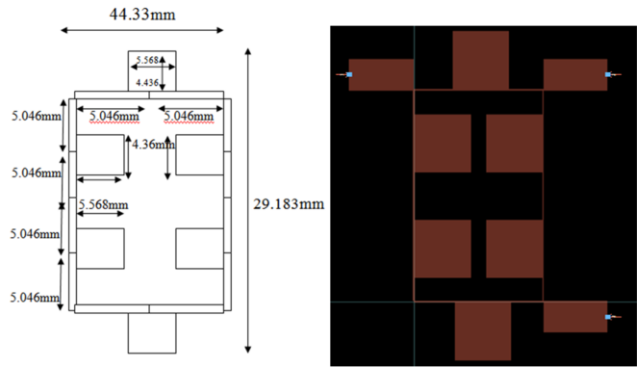
Figure 6. Layout of Proposed T-Shaped balun structure with its dimension.

5.   Results And Discussion

Thus the Proposed T-shapedbalun is designed and simulated using the ADS software are shown in Fig.6 with its dimensions. The balun operates at the frequency of 2.4GHz. Thus the structural balun achieves 38 x51mm^2 of size while the proposed balun achieves 29 x 44mm^{2}of size. Therefore the balun achieves 35% size reduction.
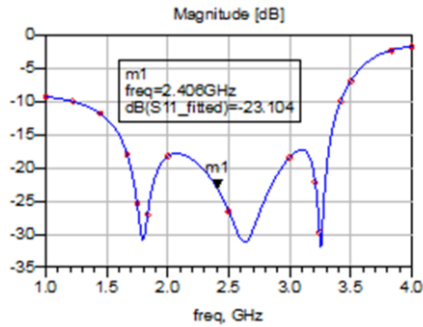
Figure 7. The simulation result of S$_{11}$
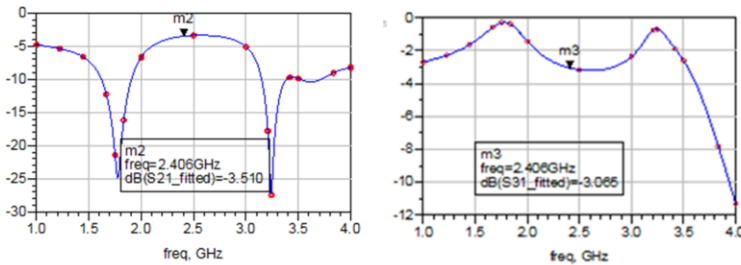
Figure 8. Simulated results of S$_{21}$, S$_{31}$

The simulated S$_{21}$, S$_{31}$ are -3.510 /-3.066 and simulated S$_{11}$ are -23dB. Therefore the balun obtains 179^0 phase differences between the output S$_{21}$,S$_{31}$ of the same frequency of 2.4 GHz . The bandwidth is about 200MHz for S$_{11}$. Also the output of S$_{21}$ lies at constant -3dB from frequency of 2.2 to 2.9GHz and the bandwidth of S$_{21}$ is 700MHz while the output of S$_{31}$ remains at constant -3dB from the frequency of 2.3to2.9 GHz and the obtained bandwidth is 600MHz. The phase imbalance of compact branch line balun is shown in Fig.8. Thus the total phase difference between S$_{21}$& S$_{31}$ is 179^0. The proposed balun obtains 35% of size reduction. Thus the balun achieves better return loss and insertion loss and also results in good amplitude and phase imbalance[11-13].

Thus the performance of the proposed balun parameters are compared with the structural branch line balun is shown in Table3. Thus the proposed design obtain better results and provide good amplitude and phase imbalance and also obtain 179^0 phase difference between the two output. Therefore 35% size reduction is achieved. Thus the performance of the proposed balun parameters are compared with the structural branch line balun.

Table 3. Performance of the proposed balun in comparison with structural branch line balun

Parameters	Structural Balun	Proposed Balun
Frequency	2.4 GHz	
Size (mm2)	38 x51	29 x 44
S11(dB)	-31.369	-23.071
S21,S31 (dB)	-3.453, -3.340	-3.510,-3.066
Phase difference between S21,S31 (0)	1780	1790

6. Conclusion

This paper demonstrates the compact branch line balun with reduced size. To reduce the size, a balun is realized using the equivalent T-shape structure. The T-shaped structures presents the closed form of line equations of both quaterwave and halfwave length transmission lines. After the reduction techniques the balun achieves 35% size reduction. Thus the Branch line balun achieves better return loss and provides good amplitude and phase difference. It provides enhanced bandwidth with low loss and low cost.

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