STEPPED COUPLED LINES FOR BANDWIDTH ENHANCED BALUN DESIGN

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1. Abstract

This paper presents a practical design method for the stepped impedance coupled lines balun that combined effective and simple way to increase the balanced output bandwidth of coupled line of the conventional planar Marchand balun. New structure of collateral multi-section with quarter wavelength coupled lines balun is developed to increase at least 40% balanced bandwidth and perfect return loss than the traditional planar Marchand coupled lines balun, hence, the structure of the designed planar microstrip circuit is fairly simple, practical and easily fabricated. The measured results of the design show good agreements with those simulated data.

2. Introduction

Balun is a word derived from terms applied balanced to unbalanced transmission lines that join a balanced structures and unbalanced structures transition [1]. Balanced line which one that has two conductors with equal potential and 180 degrees phase difference, such as a twisted pair cable, coplanar strip line and slot line. Unbalanced line which one that has just one conductor and a ground which unbalanced current flows through a ground plane, such as a coaxial cable and microstrip line [2]. Baluns are used to connect balanced antennas like dipole antenna to unbalanced transmission lines like microstrip line or coaxial [3]. And can also be used as in power or signal isolators anywhere along the transmission line to reject the flow of induced RF current [4]. Then, balun device provide impedance transformation and matching network in addition to conversion between balanced and unbalanced transmission modes or structures transition [5]. For converting balanced input to unbalanced output or vice versa that is to enable transmission lines and equipment having different impedances to be matched and connected for maximum power transfer of the signal with minimum effect to the transmitting signal such as insertion loss, waveform distortion and minimum reflection of the signal in which popular in microwave application like balanced mixers [6], push-pull amplifiers, antennas fed networks and doublers [7]. In this paper presents a practical design and bandwidth enhanced method applied the stepped impedance transformer [8] serve effective and simple way [9] to implement and improve the balanced output bandwidth of coupled line of the conventional planar Marchand balun. Marchand balun of the planar and non-planar variety are widely used at components design. In the recently technology journals which based on impedance transform method, like strip line balun structure which used multiplayer ground plane spacing of section easily to approach various balanced impedance [10] is proposed. Beside, by using mutisection impedance transforming method for coupled line balun [11] is accomplished and usable. In this investigate, new structure of collateral multi-section with only quarter wavelength coupled-line is developed not only increase at least 40% balanced bandwidth and perfect return loss than the traditional planar coupled lines balun, but also balun structure is fairly simple, practical and easily fabricated. The measured results of the design show good agreements with those simulated data.

ISBN: 89-86522-78-0 94460

3. Design and Results

The conventional coupled-lines balun, which the coupling type should be strong coupling coefficient and narrow bandwidth and narrow bandwidth, because, owned high even mode impedance. Therefore, the gap in between the coupled line of the balun by narrow space for coupling is not realizable in the microstrip configuration. In this paper, the symmetric parallel connection is used, as seen in Fig. 2 is studied [9]. It is proved not only easier for implementation but also not limited by etching precise technology for microstrip line and easy to improve bandwidth enhanced. In this discussion, found the traditional planar marchand balun limited by microstrip structure, hence, the usable bandwidth with balanced output and return loss are limited. In this paper, the symmetric multisection stepped impedance coupled line balun is designed, as seen in Fig. 3. The collateral method is to connect a pair of planar coupled line with multisection to become a symmetric structure that to split the strong coupling, therefore the balanced bandwidth can be wider than that conventional design. The bandwidth and high even mode impedance problem can be strictly solved with the stepped impedance transformer and parallel method. Besides, this structure can be used $\Delta\ell$ to compensate for balanced amplitude and phase differences of balun [12]. Therefore, the symmetric parallel connection method and stepped impedance transform are also usable on any coupled line circuits. It is proved not only simple to implementation but also easily approach impedance matching for unbalanced input and balanced output in the desired bands and specification. In this analyze, the operation frequency working at 3 GHz on FR4 substrate (dielectric constant 4.4, loss $\tan\delta$ =0.015 and height 1.5 mm). Proposed structure of $\lambda/4$ collateral multisection stepped characteristic impedance Z_i, where *i* is number of coupled section, with coupled-line is developed to improve at least 40% bandwidth than the traditional $\lambda/4$ collateral coupled line balun design. Using symmetric balun structure and cascade metisection coupled method not only uninfluenced balanced output bandwidth and return loss but also increase effective output bandwidth and easily etching precise technology for microstrip line to replace traditional planar marchand coupled line balun design on microstrip line structure which strong coupling cause by high even mode impedance with perplexity narrow spacing problem. The design equation based on even and odd mode method which calculated characteristic impedance by equation (1) and coupling coefficient *C* of this multiesction coupled line is given by equation (2), so that, the number of coupled line's characteristic and coupling coefficient can be calculated. In this design the balun geometry size is very low profile and practical. In this mutisection balun design assist by EM simulated tool which results by full wave electromagnetic analyses are evidently in good agreement with those experimental data.

Characteristic impedance $Z = \sqrt{Z_{odd} \cdot Z_{even}}$ (1)

Coupling coefficient $C = (Z_{even} - Z_{odd})/(Z_{even} + Z_{odd})$ (2)

Based on full-wave spectral domain Galerkin method [13], simulation was made for graphical environment to analyze the electromagnetic performances for the designed quarter wavelength coupled lines balun and mutisection coupled lines balun. Fig. 4 is compared with conventional marchand coupled balun (Fig. 1), parallel coupled lines balun (Fig. 2) and multisection parallel coupled lines balun (Fig. 3) of measured data with return loss. The layout size used 50Ω characteristic impedance *w=2.5 mm,* coupling spacing *s=0.05mm,* and quarter wavelength *L=14 mm* for coupled lines balun as show in Fig. 1. and the layout size used 50Ω characteristic impedance *w=2.5 mm,* coupling spacing *s=0.2mm,* and quarter wavelength *L=14 mm* for parallel coupled lines balun as show in Fig. 2. The proposed balun structure Z_1=50Ω characteristic impedance *w=2.5 mm,* Z_2=90Ω characteristic impedance *w=1 mm,* coupling spacing *s=0.2mm,* and quarter wavelength to 4 segment parts is equal to $\lambda/16$ and then implement on FR4 substrate. Result shown about balanced output bandwidth that the steeped impedance method is increase bandwidth effectively and comparison of measurement data as shown in Fig. 5 and Fig. 6.

4. Conclusion

This paper presents an effective improve balun bandwidth method for multisection coupled line circuits that easily to solve the narrow bandwidth problem. And the new design methodology that combined effective and simple way not only improve the narrow spacing of coupled-line of the conventional planar circuits with parallel method but also get high bandwidth performance for multisection coupled line balun than traditional planar balun design. Full wave with spectral domain Galerkin method simulation will be applied for the design and the implementation are expected to realize. A well-designed balun circuit has the merits such as to simplify the RF block or to increase system's stability and power transformation. The measured results of the design show good agreements with those analysis data.

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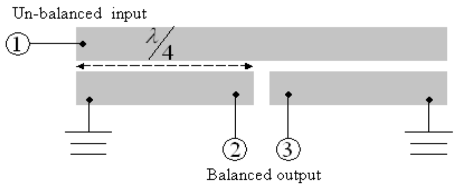

Fig. 1 Conventional marchand coupled lines balun

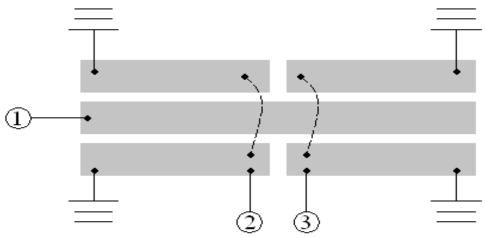

Fig. 2 Parallel coupled lines balun

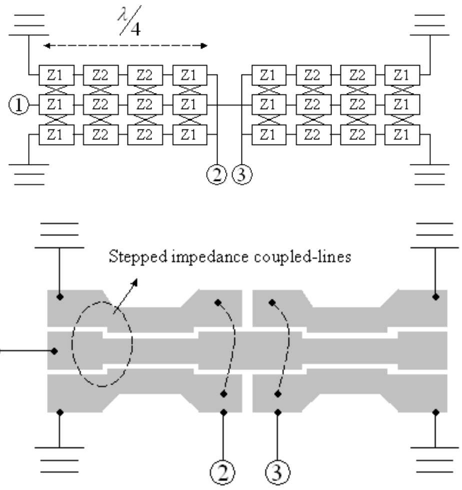

Fig. 3 Multisection for parallel coupled lines balun design

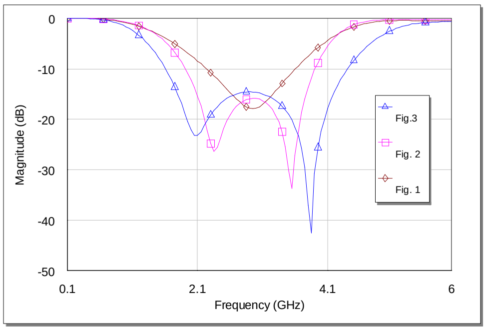

Fig. 4 Comparison of S11 return loss

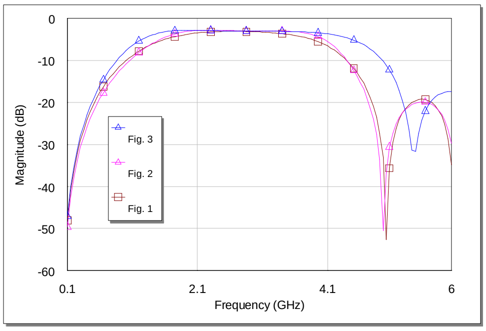

Fig. 5 Comparison of S21 insertion loss

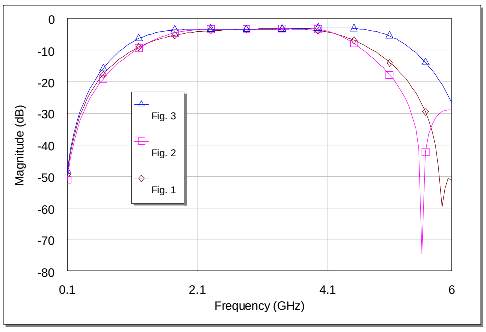

Fig. 6 Comparison of S31 insertion loss