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A new impedance-transforming dual-band balun with filtering response and favorable output isolations

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ABSTRACT

A new planar dual-band balun with filtering response and output isolations is proposed in this letter. The balun is constructed on a three-layer PCB, whose out-of-phase operation is realized by antisymmetric output configuration. By introducing dual-band resonators and admittance inverters, the circuit is able to operate with designated filtering response, and the source/load impedances could be different. Additionally, the output isolation is reserved by employing two isolation resistors. The experimental results prove that this new balun is a good candidate for multi-standard and multi-functional communications.

1. Introduction

Nowadays, with the increasing demand of "smart" communication, multi-standard and multi-functional communications are of great significance in this era. Therefore, researches on multi-band and functionality-integrated RF components become focused topics. The balun, also known as the out-of-phase power divider, is an indispensable component used for converting the balanced/unbalanced signal and feeding differential antennas. Recently, researches on the balun have been extensively conducted. For example, baluns or in-phase power divider with differential feeds [1], with dual-band operation [2–6], and with impedance transformation [4–7] are reported. Specially, if the function of filters is integrated into a balun, the co-design of baluns and filters would dramatically improve the system integration and facilitate the design process. Some researchers have already focused on filtering in-phase power divider, like the ones presented in [8–11]. However, constructing a balun with simultaneous dual-band and filtering operation is a quite challenging subject. In [12], a dual-band filtering balun is proposed, but the output isolation is not considered in that work.

In this paper, a planar dual-band balun with filtering response and output isolation is proposed. By introducing the dual-band resonators and admittance inverters presented in [13], the power division performs like specific third-order Chebyshev or Butterworth filtering responses, and the input and output ports can be terminated with different source and load impedances. Besides, the out-of-phase operation is realized by an antisymmetric output configuration on a three-layer Planar Circuit Board (PCB). Moreover, two resistors are introduced like the Wilkinson power divider for absorbing the reflected power from outputs and providing good output isolation. In conclusion, the novel balun proposed here can be a suitable candidate for the multi-standard and multi-functional communication systems.

2. Operation principle

Fig. 1 demonstrates the structure of the proposed balun, which is constructed by two layers of back-to-back microstrip lines, two pairs of isolation resistors and an input-feed port using Double-Sided Parallel Strip Lines (DSPSLs). The full symmetric structures at the two layers enable equal power division when power input from port 1. For realizing the out-of-phase operation at the port 2 and 3, the inserted ground plane is led to the bottom and top layer at port 2 and 3 respectively. Three stubs at the top and bottom layers are short-circuited by metalized vias connecting each other, and the two isolation resistors are mounted between the end of the stubs and vias contacting the inserted ground plane. Beside the shorted stubs, three open-circuited stubs are arranged at both the top and bottom layers. The inserted ground plane at the adjacent area of the input feed are cavern out for making open circuit at port 1 when even-mode decomposition is carried out. In addition, this proposed circuit processes the function of impedance

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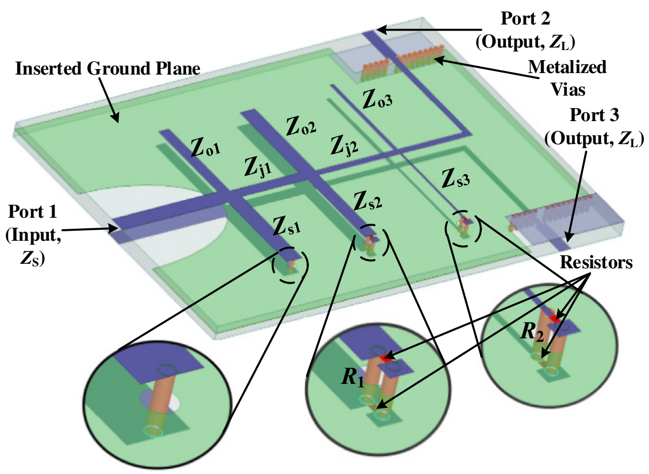

Fig. 1. Structure diagram of the proposed filtering balun.

transformation, which transforms the port 1 impedance Z_S to impedance Z_L at ports 2 and 3.

2.1. Even- and odd-mode decompositions

The method of even- and odd-mode decomposition is broadly employed for simplifying the analysis of symmetrical circuits, thus this method is applied for simplifying the proposed circuit in this letter. When identical voltages are excited at port 2 and 3, the virtual plane sandwiched at the substrate will become open circuited as demonstrated in Fig. 2. In this mode, there are no paths for negative current flowing at port 1, due to the absence of ground planes. Hence, port 1 becomes open-circuited in the even-mode decomposition. Meanwhile, the resistors will not be short-circuited to the virtual ground, but connected to the inserted ground. Accordingly, the circuit in Fig. 1 is decomposed into Fig. 3(a).

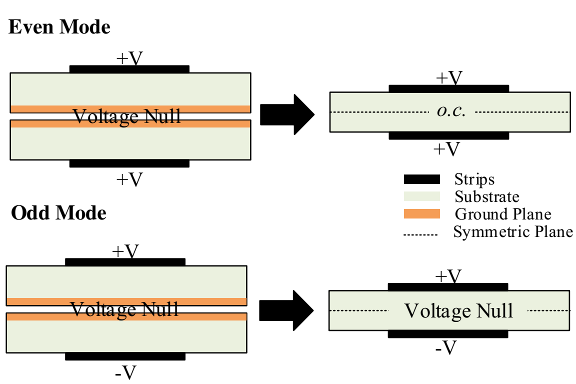

Fig. 2. The voltage configuration for the even- and odd-mode decomposition: the left column is the excitation at port 2 and 3, and the right is the voltage distribution at port 1.

Subsequently, applying voltages with opposite signs at port 2 and 3, the symmetric plane at the longitudinal dimension will become virtually grounded as shown in Fig. 2. Hence, the port termination becomes two series-connected $Z_S/2$ impedances, and the isolation resistors are short-circuited. When under odd-mode excitation, the corresponding equivalent circuits is simplified as depicted in Fig. 3(b) for analyzing the input matching and transmission from port 1.

2.2. The out-of-phase operation

According to the filed distribution of DSPSL mentioned in [7], the inserted conductor plane will not perturb the electromagnetic field distribution. Therefore, the E-field distribution at port 1 are exactly as demonstrated in Fig. 4(a). At port 2, since the inserted grounded plane are led to the bottom layer of the PCB, the form of the E-field is identical to the one in the bisection of the substrate at port 1 as shown in Fig. 4(b). However, unlike port 2, the direction of the E-field is reversed between the strips and ground plane at port 3 like Fig. 4(c). As for the voltage distribution, selecting the voltage at ground plane as reference, the voltages at the strips are positive and negative at port 2 and 3 respectively, indicating a 180° phase difference between port 2 and 3. With this, out-of-phase operation, a significant characteristic of a balun, is accomplished in this three-layer PCB.

3. Design procedure

3.1. Filtering synthesis

Observing the equivalent circuit configuration in Fig. 3(b), the odd-mode circuit shown in Fig. 3(b) is composed of three dual-band resonator and two dual-band J-inverter as proposed in [13]. Hence, the design equations in [13] can be utilized here to extract the required parameter values according to the specific expected performance.

Firstly, a single-band bandpass filter is constructed for the initial design of the proposed power divider. For a third-order bandpass filter centered at the frequency f_0, the J values and capacitance values of the three steps are

$$J_1 = \left(\frac{Z_S}{2Z_L}\right)^{\frac{1}{4}} \tag{1}$$

$$J_2 = \left(\frac{Z_S}{2Z_L}\right)^{\frac{3}{4}} \tag{2}$$

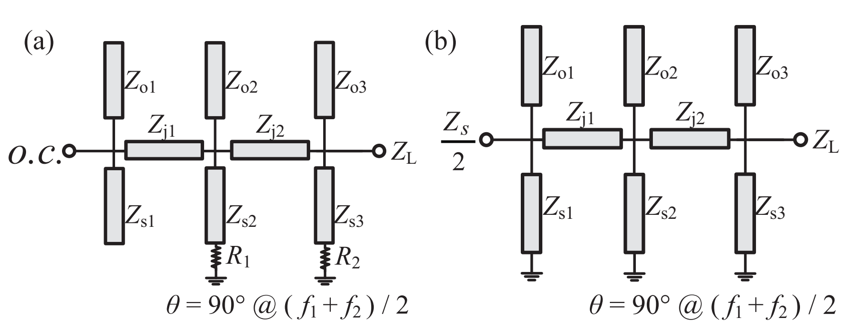

Fig. 3. The simplified circuits after applying (a) even- and (b) odd-mode decompositions.

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