

Two-Port S-Parameter Measurement of Wide-Band Balun

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Abstract - When a balanced-to-unbalanced transformer circuit is connected directly to an ordinary vector network analyzer, common-mode current flows through the measurement system and introduces measurement error to measurements of the two-port circuit parameters. In this study, the S-parameters of a balun were measured using a combination of the S-parameter method and the calculation procedure of the short–open–load method. The common-mode current was eliminated from the measurement system, and good agreement was found between the measurement and simulation results.

Index Terms — Marchand Balun, S-Parameter, S-Parameter Method, Short–Open–Load Calibration.

1. Introduction

The ports of vector network analyzers (VNAs) are generally unbalanced ports, whereas balanced-to-unbalanced transformer circuits (baluns) are frequently used to measure devices with balanced ports. However, when the unbalanced ports of a VNA are directly connected to the balanced port of the balun, a common-mode current flows into the measurement system, introducing error to the results. Thus, a measurement method must be developed to obtain the correct measurement.

In the well-known back-to-back measurement, two baluns are connected via their balanced ports, and their unbalanced ports are connected to the VNA. The parameters of the unbalanced ports cannot be known. The thru-reflect-line (TRL) method, which utilizes TRL calibration, overcomes this problem [1]. Using this method, the parameters of all ports can be measured. However, the common-mode current flows into the measurement system because the ground plane of the balun is connected to the ground of VNA, and thus significant results cannot be obtained [2]. In the S-parameter method, the differential- and common-mode components are calculated after the S-parameters of the balanced ports are measured [3]. The parameters of the unbalanced ports cannot be obtained using this method.

This paper proposes a method of obtaining significant measurement results for the S-parameters of a balun based on a combination of the S-parameter method and the calculation procedure of the short–open–load (SOL) method. The proposed method can be used to measure all S-parameter components of the balun without being affected by the common-mode current, which flows on the ground plane of the balun.

2. Configuration

A planar Marchand-type balun composed of a microstrip line (MSL) and a coplanar strip line (CPS) is shown in Figure 1. Because this type of balun performs in a wide band, the design and measurement frequency bands were set to 3–11 GHz. The quarter-wavelength ($\lambda/4$) open and short stubs at the intersection of the CPS and MSL were set as the mode transition points. One wavelength λ is defined considering the effective dielectric coefficient in several line widths at the design frequency 7 GHz. The characteristic impedance of the CPS is 100 Ω . Ports B and U are the balanced and unbalanced ports, and their reference impedances are 100 and 50 Ω , respectively. The characteristic impedances of the MSL (Z_{msl}) at Port U and the open stub are 50 Ω . Z_{msl} changes to 60 Ω at the intersection.

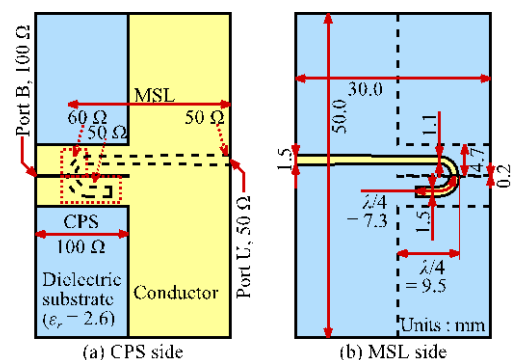


Fig. 1. Configuration of Marchand balun.

3. Measurement Method

The S-parameters of the balun were measured by a combination of the S-parameter method and the SOL calibration procedure. Figure 2 illustrates the configuration of the measurement system. The left side of the balun as the device under test (DUT) was connected to an MSL jig, two subminiature version A (SMA) connectors, and two sets of coaxial cable of the same length. Two conductors at Port B in the balun were connected to Ports B1 and B2 in the MSL jig. These were used in the S-parameter method. The unbalanced port on the right side was connected to the calibration kit via an SMA connector. The SOL calibration procedure was applied to the unbalanced port. The common-mode current did not flow into the measurement

system because the ground plane of the VNA and MSL was physically disconnected from the balun.

The proposed measurement procedure is as follows. (I) The VNA is calibrated. The reference planes of the VNA are defined as Ports B1 and B2, as shown in Figure 2(I). (II) The S-parameter method is applied to the balanced ports. The differential mode component Γ_b of the reflection coefficient from the balanced port (Port B) of the balun with the SOL calibration kit in Figure 2(II) is derived from the results of Ports B1 and B2 and the following equation: [3]

$$\Gamma_b = \frac{S_{b11} - S_{b21} - S_{b12} + S_{b22}}{2}. \quad (1)$$

When the SOL calibration kit is used, Γ_b can be substituted by Γ_s , Γ_o , and Γ_l . (III) The measurement utilizing SOL calibration is performed. The parameters of the two-port error box and the one-port VNA are measured using the SOL calibration method, as illustrated in Figure 3. The reflection coefficient Γ_b of the balun with the calibration kit is derived using the S-parameter method because the balun can be regarded as the error box in the figure. The two-port parameters of the balun are extracted from the equations [2]

$$S_{bb} = \Gamma_l \quad (2)$$

$$S_{ub}S_{bu} = \frac{2(\Gamma_l - \Gamma_s)(\Gamma_l - \Gamma_o)}{(\Gamma_s - \Gamma_o)} \quad (3)$$

$$S_{uu} = \frac{(2\Gamma_l - \Gamma_s - \Gamma_o)}{(\Gamma_s - \Gamma_o)}, \quad (4)$$

where S_{bb} and S_{uu} are the reflection coefficients from the balanced and unbalanced ports, respectively, and S_{bu} and S_{ub} are the transmission coefficients from the balanced to the unbalanced port and from the unbalanced to the balanced port, respectively.

4. Results

The two-port parameters obtained using the proposed measurement method (Meas.) are compared with the simulation results obtained by the electromagnetic simulator WIPL-D (Sim.) in Figure 4. In the simulation, the S-parameters were obtained using the same procedure with the same model, but the VNA and calibration kit were excluded from the simulation. Therefore, there was no common-mode current flowing into measuring system, and thus the source of the error was eliminated. The common-mode current can be considered to have been removed from the measurement system because the measurement showed good agreement with the simulation. The differences between the S-parameters obtained in the measurement and the simulation were 6.9 dB at 4.8 GHz for S_{bb} and 12.5 dB at 10.6 GHz for S_{uu} . 4.8GHz and 10.6GHz are the matching

frequencies of the test balun, and slight mismatching caused the large differences in the results.

5. Conclusion

The two-port S-parameters of a planar Marchand-type balun were measured using a combination of the S-parameter method and the SOL calibration procedure. The measurement results showed good agreement with the simulation results because the common-mode current flowing into the measurement system was eliminated. The proposed method can be applied to devices with balanced and unbalanced ports to obtain accurate S-parameters.

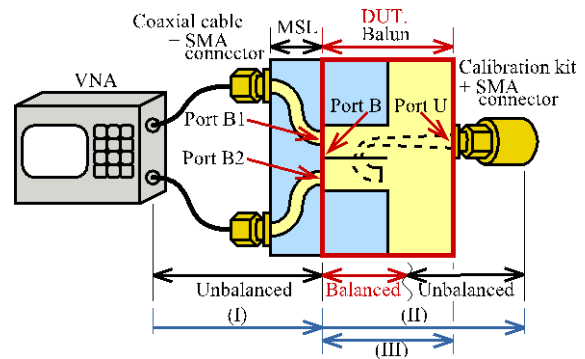


Fig. 2. Configuration of measurement system.

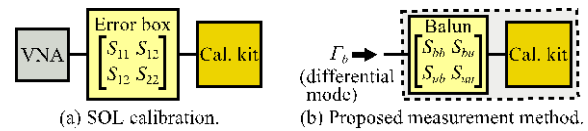


Fig. 3. Measurement using SOL calibration.

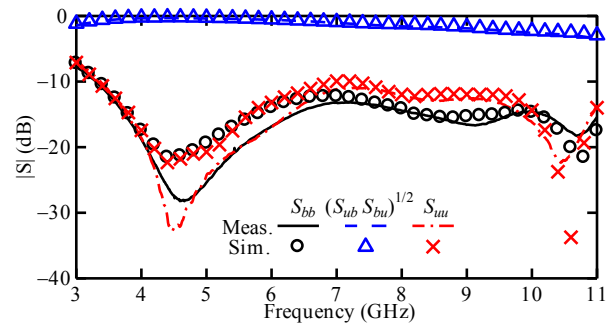


Fig. 4. Measurement results.

References

- [1] Takashi Iwasaki, *Electromagnetic Wave Measurements – Network Analyzer and Antenna*, CORONA PUBLISHING CO., LTD., Tokyo Japan, 2007.
- [2] Kuniaki Suto, Akinori Matsui, "A Consideration on S parameter Measurement of Mode Transition Part on Wide Band Tapered Slot Antenna," *IEICE Conf.* '13, B-1-131, Sept. 2013.
- [3] R. Meys, F. Janssens, "Measuring the impedance of balanced antennas by an S-parameter method," *IEEE Antennas Propag. Mag.*, vol. 40, no. 6, pp. 62 - 65, Dec. 1988.