E-band Wilkinson balun using CPW MMIC technology

J.-S. Lim, H.-S. Yang, Y.-T. Lee, S. Kim, K.-S. Seo and S. Nam

A simple balun having the structure of a Wilkinson divider is proposed, and a 77 GHz CPW balun, as an example, has been fabricated and measured. The input and output ports of the proposed Wilkinson balun form the desirable inline structure. Results show that the measured S_{21}, S_{31}, matching, and isolation are −4.5 and −3.7 dB, less than −15 and −20 dB with the exact out of phase between output ports.

Introduction: The Wilkinson power divider is one of the most widely used passive devices for high frequency. It has a simple inline structure and no phase difference [1]. The Wilkinson divider has been extensively adopted for various high-frequency circuits and systems as well as for power divider/combiner itself.

The balun is a high-frequency device whose two output ports have opposite phases. It is adopted widely for mixers, high-power amplifiers, antennas etc. However, the 180° ring hybrid, which has been a representative balun, should have an isolation port. The conventional coaxial balun can be used at relatively low frequency because of its fairly large size but has a realisation problem for the high-frequency region.

The previous baluns using the Wilkinson structure are: 1 the Wilkinson divider composed of large couplers, one of whose output ports is terminated by an open or short circuit [2], and 2 the Wilkinson divider composed of lumped elements, whose output ports are combined by π- and T-type C-L-C lumped-element circuits [3]. However, the two previous methods have disadvantages in that the size is large and the applicable frequency is limited because additional circuits for the opposite phase need to be attached.

In this Letter, a simple Wilkinson balun designed by only adding transmission lines is proposed, and the measured results of an E-band CPW Wilkinson balun are discussed.

Structure of proposed Wilkinson balun: Figs. 1*a–c* show the basic and modified structures of the Wilkinson power divider. The basic structure is preferred for RF and the low microwave region. However, the modified Wilkinson structure can also be a good choice for very-high-frequency applications, because the length of $\lambda/4$ is too short to ignore the undesirable effect of discontinuities such as tee- or cross-junctions [4]. The modified structures have a transmission line of $3\lambda/4$ for two paths between the input and output ports. Although the bandwidth is made narrower by adding the additional transmission line, the modified structure can be a practical choice when the realisation of the basic structure is too difficult for the very-high-frequency region. For instance, the length of $\lambda/4$ of 70.7 Ω CPW transmission line at 77 GHz is only 366 μm for a GaAs substrate with thickness 650 μm, and so the modified structure is a preferable choice for practical fabrication and measurement.

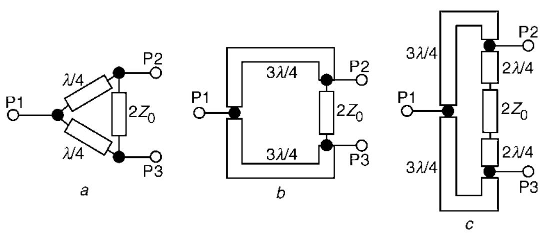

Fig. 1 *Structures of Wilkinson power divider*

a Basic structure
b Modified structure
c Another modified structure

If the length of the transmission line between port 1 and port 3 in Fig. 1*b* is reduced to $\lambda/4$, a new balun shown in Fig. 2*a* is obtained. The additional $2\lambda/4$ transmission line is attached to the isolation resistor for the separation of output ports as shown in Fig. 2*b*. The proposed Wilkinson balun has 1:1 output power dividing ratio and 180° phase difference at output ports. Fig. 3 presents the ideal performance of the proposed Wilkinson balun simulated on a circuit simulator.

Layout and fabrication: Fig. 4 shows the layout of the fabricated 77 GHz CPW Wilkinson balun with practical ports contained for the measurement on the probe station. The dielectric constant (ε_r) and thickness of the GaAs substrate, and the metal thickness for the MMIC process are 12.9, 650 and 3 μm, respectively. Air bridges having a width of 10 μm are connected around discontinuity elements, and the isolation resistor is realised by using 20 Ω/□ thin-film resistor and 1:5 aspect ratio. The circuit size shown in Fig. 4 is 830 × 1240 μm.

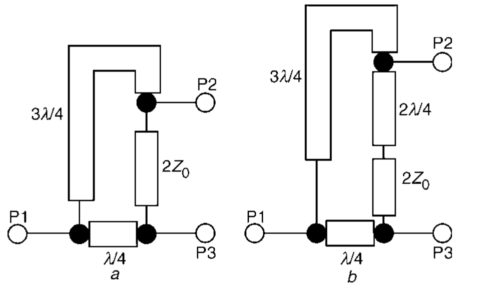

Fig. 2 *Structures of balun using Wilkinson divider*

a Structure modified from Fig. 1*b*
b Proposed Wilkinson balun

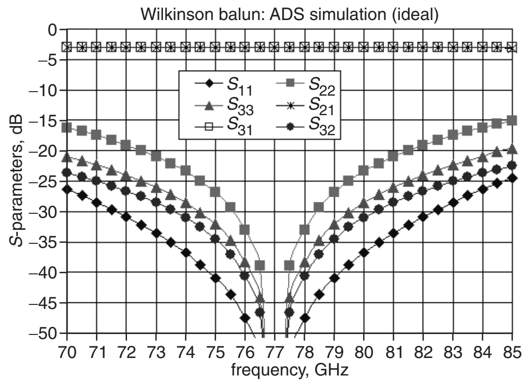

Fig. 3 *Ideal S-parameters of balun shown in Fig. 2b*

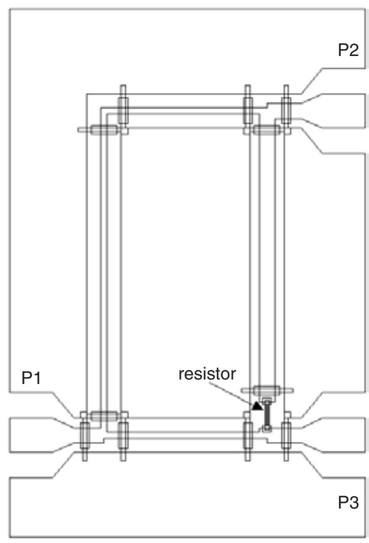

Fig. 4 *Layout for electromagnetic simulation and measurement*

Measured results: The measured *S*-parameters of the 77 GHz Wilkinson balun are illustrated in Fig. 5. The reflection coefficients at the ports are less than 12.5 dB and the isolation is 18 dB at least over the range 70–85 GHz. The small unbalance of the divided power is due to the difference between the two paths.

The measured phase difference is shown in Fig. 6. The frequency-dependent deviation from the ideal phase difference is inevitable because of the additional transmission lines for the modification of the Wilkinson structure. The measured results agree well with the ideal values, even though some minor discrepancies exist.

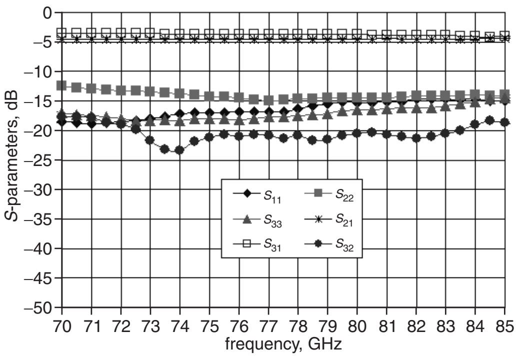

Fig. 5 *Measured S-parameters of balun shown in Fig. 4*

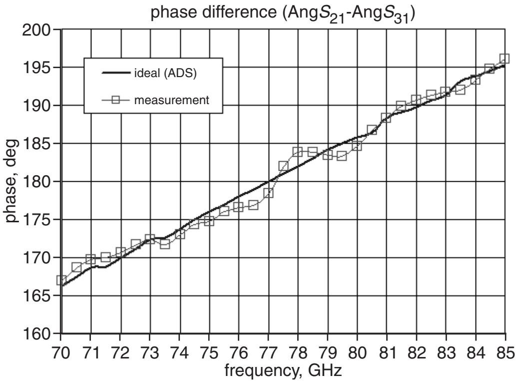

Fig. 6 *Measured phase difference*

Conclusions: A simple balun using a Wilkinson structure has been proposed. To verify the structure and performance, an E-band CPW balun has been fabricated using 650 μm GaAs MMIC process. The proposed Wilkinson balun has simple and inline structure between input and output ports, and does not have any isolation ports. The measured performances of the E-band CPW balun are summarised as follow; S_{21} of −4.4 – −4.6 dB, S_{31} of −3.6 – −4.1 dB, port matching of −12.5 – −19 dB, isolation of −18 – −24 dB, and phase difference, as had been predicted, of over 70–85 GHz.

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