A 77GHZ CPW BALUN USING WILKINSON STRUCTURE

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Abstract

A novel balun having the simple and basic structure of Wilkinson divider is proposed. A 77GHz MMIC CPW balun is fabricated and measured for an example of the proposed balun, called Wilkinson balun in this work. The input and output ports of the proposed Wilkinson balun form the desirable in-line structure, which is similar to the basic Wilkinson divider. It is illustrated that the measured S21 and S31 are -4.5dB and -3.7dB, respectively. In addition, the matching at all ports and the isolation between two output ports are less than –15dB and -20dB, respectively. The measured phase difference between two output ports agrees excellently with the expected one.

I. INTRODUCTION

Wilkinson power divider is one of the most widely used passive devices for high frequency including RF, microwave, and millimeter-wave region. In general, Wilkinson power dividers have simple in-line structure and without phase difference [1]. Wilkinson divider has been extensively adopted for various high frequency circuits and systems as well as power divider/combiner itself.

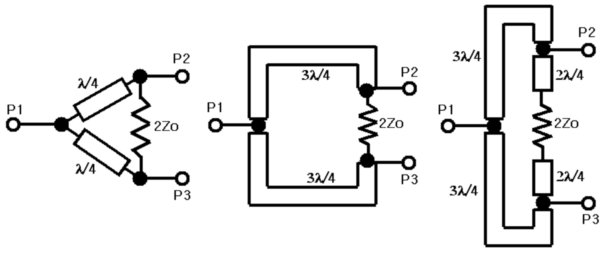
Balun is one of high frequency devices whose two output ports have the opposite phase, i.e. 180° out of phase. It is adopted widely for mixers, high power amplifiers, antenna, and so on. However the 180° ring hybrid, which has been one of the representative balun out of conventional baluns, should have the isolation port. The conventional coaxial balun can be used relatively at low frequency because of relatively large size and realization problem for high frequency region.

The previous baluns using the Wilkinson structure include; 1) the Wilkinson divider combined by lange coupler whose one of output ports is terminated by open or short [2], and 2) the Wilkinson divider composed of lumped elements, and whose output ports are combined by π- and T-type C-L-C lumped element circuits [3]. However, the previous methods also have disadvantages that the size is large and the applicable frequency is limited because the additional circuits should be attached for the "out of phase" characteristic.

In this paper, a novel Wilkinson balun designed by adding only transmission lines is proposed. The principle, structure and layout pattern, and expected and measured performances of the proposed E-band MMIC CPW Wilkinson balun will be discussed.

II. STRUCTURE OF THE PROPOSED WILKINSON BALUN

Fig. 1 (a) ~ (c) show the basic and modified structures of Wilkinson power divider. The basic structure is preferred extensively for RF and relatively low microwave region. On the other hand, the modified Wilkinson structures can be good choices for very high frequency applications, because the length of λ/4 is too short to ignore the undesirable effect due to the discontinuities such as Tee- or Cross-junctions [4].

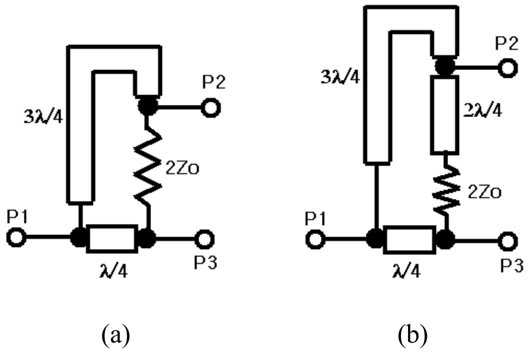


(a) (b) (c)

Fig. 1 Structures of the Wilkinson power divider
(a) basic structure
(b) a modified structure
(c) another modified structure

The modified structures have the transmission line of 3λ/4 for two paths between input and output ports. Although the bandwidth is getting narrower by adding the additional transmission line, the modified structures have been adopted for the practical purpose when the realization of the basic Wilkinson structure is too difficult at very high frequency region.

For an instance, the length of λ/4 for the 70.7Ω CPW transmission line at 77GHz is only 366 μm on the GaAs substrate with the thickness of 650μm, the modified structure can be a preferable choice for the practical fabrication, application, and measurement.



(a) (b)

Fig. 2 Structures of the balun using Wilkinson divider
(a) Structure modified from Fig. 1
(b) the proposed Wilkinson balun

If the length of transmission line between port1 and port3 in Fig. 1 (b) is reduced to λ/4, a new balun shown in Fig. 2 (a) is obtained. However, the isolation property of the balun in Fig. 2 (a) is not good because the potential at both sides of the resistor are opposite to each other. Therefore, the additional 2λ/4 transmission line is required between the isolation resistor and port2 for the completion of the proposed balun.

Fig. 3 shows the principle of the proposed balun by using the Wilkinson structure and potential at both sides of the resistor and/or each port. It is shown that the isolation is being kept by adding the 2λ/4 transmission line.

In addition, in a practical view of point, the separation between output ports is required as shown in Fig. 2 (b) for the practical measurement and application.

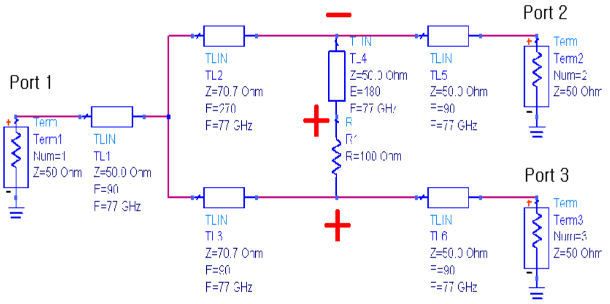


Fig. 3 Potential at both sides of the proposed balun

The proposed Wilkinson balun has exactly 1:1 output power dividing ratio and 180° phase difference at output ports. Fig. 4 presents the ideal performances of the proposed Wilkinson balun simulated on a circuit simulator using the schematic in Fig. 3. All the magnitude of S-parameters in Fig. 4 are the exactly same as that of S-parameters of the ideal Wilkinson power divider.

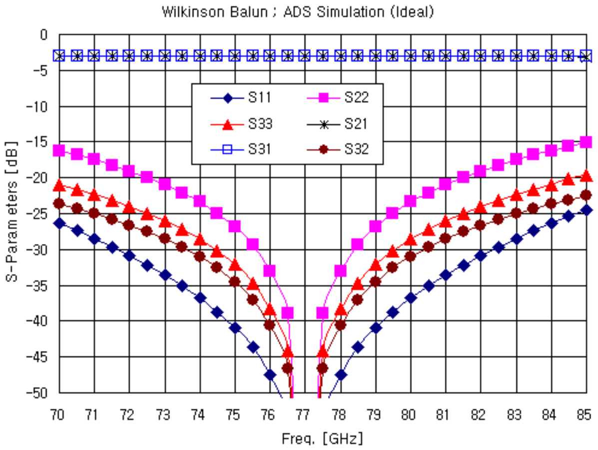


Fig. 4 Ideal S-parameters of the balun shown in Fig. 3.

III. LAYOUT AND FABRICATION

Fig. 5 shows the layout of the fabricated 77GHz MMIC CPW Wilkinson balun with practical ports contained for the measurement on the probe station. The dielectric constant (ε_r), thickness of the GaAs substrate, and metal thickness for the MMIC process are 12.9, 650μm, and 3μm, respectively. Air bridges having the width of 10μm are connected around discontinuity elements, and the isolation resistor is realized by using 20Ω/☐ thin film resistor and 1:5 aspect ratio for 100Ω resistance value. The circuit size in Fig. 5 is 830μm x 1240μm.

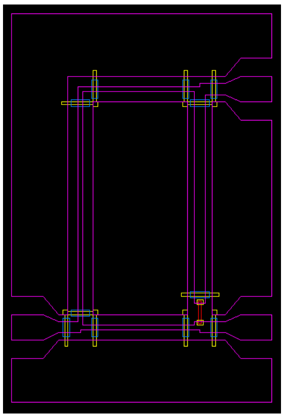


Fig. 5 Layout for the electromagnetic simulation and measurement

IV. PERFORMANCES OF THE 77GHZ MMIC CPW WILKINSON BALUN

Fig. 6 illustrates the performances of the proposed 77GHz balun obtained by an electromagnetic simulation on IE3D. Power division ratio, matching, and isolation characteristics are the expected one as if it is a Wilkinson divider.

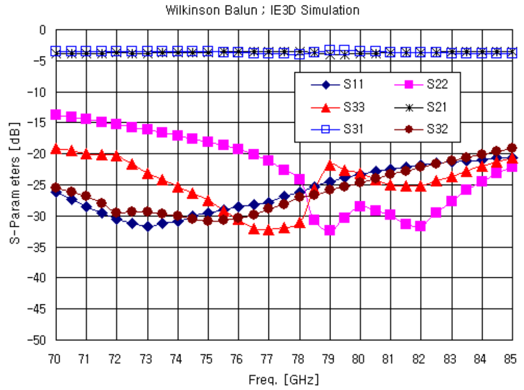


Fig. 6 S-parameters for Fig. 5 calculated from an electromagnetic simulation

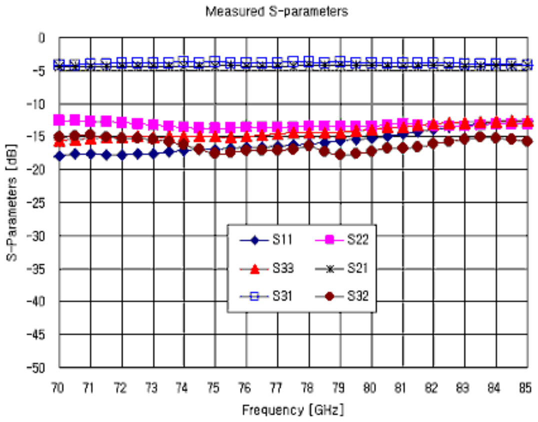


Fig. 7 Measured S-parameters of the balun shown in Fig. 5

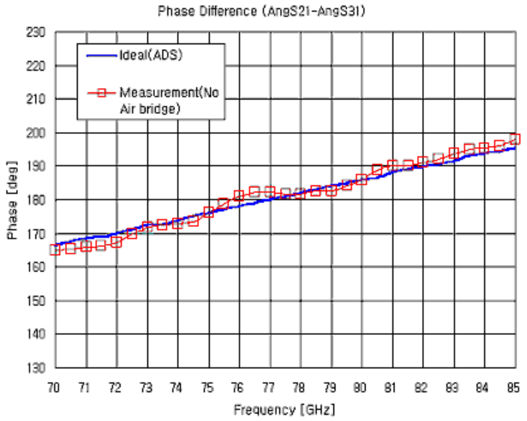


Fig. 8 Measured phase difference of the balun shown in Fig. 5

The measured S-parameter of the 77GHz Wilkinson balun is illustrated in Fig. 7. The measurement for the fabricated MMIC CPW substrate has been performed on the prove station combined by Agilent 8510XF vector network analyzer. The reflection coefficients at all ports are less than 12.5dB and the isolation is 18dB at least over 70~85GHz.

Even though there are discrepancies between the ideal S-parameters shown in Fig. 4 and the measured ones, is should be considered that the physical layout requires different length between two paths, i.e. $\lambda/4$ and $3\lambda/4$. It is shown in Fig. 7 that S21 of -4.4~-4.6dB, S31 of -3.6~-4.1dB, port matching(S11,S22,S33) of -12.5~-19dB, isolation(S32) of -18~-24dB over 70~85GHz.

Fig. 8 presents the ideal phase difference and the measured one of the fabricated CPW balun. Although a little deviation from the ideal phase difference is observed, an excellent agreement has been obtained.

It should be noted that the phase difference is not 180^{o} at all frequency but there is a frequency-dependent slope in Fig. 8. It is due to the additional transmission lines for $3\lambda/4$ in modifying the basic Wilkinson structure. However, the measured results agree well with the predicted values, even though some minor discrepancies exist.

V. EFFECTS OF ADDITIONAL AIR BRIDGES ON LONG CPW LINES

The layout in Fig. 5 contains two $\lambda/2$ CPW transmission lines. One exists between output ports, the other as a part of $3\lambda/4$ line. In general, a long transmission line may have a ground problem, and especially in CPW, it might be severe. So it is recommended to insert proper means to guarantee grounding effects such as via holes in microstrip and air bridges in CPW transmission lines.

Fig. 9 shows the layout of the fabricated balun having the additional air bridges in the mid of $\lambda/2$ sections. Fig. 10 and Fig. 11 illustrate the measured S-parameters and phase difference, respectively. It is seen that only minor improvements due to the additional air bridges in matching and isolation have been achieved. However, even though the improvements are not much in this measurement, it would be better to insert air bridges in the mid of long transmission lines.

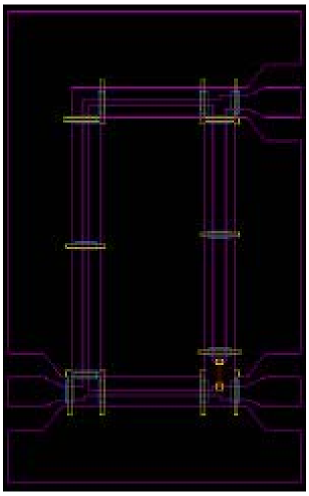


Fig. 9 Layout of the balun having additional air bridges

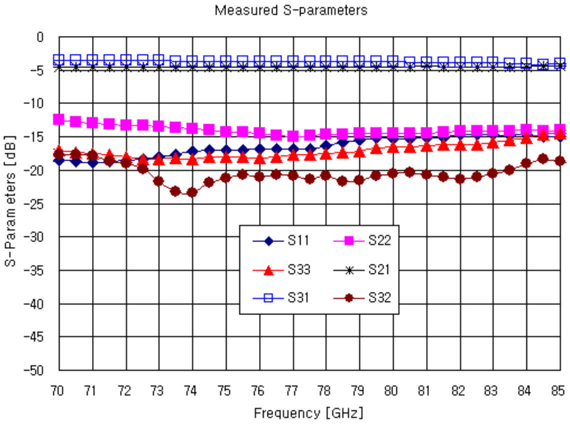


Fig. 10 Measured S-parameters of the balun shown in Fig. 9

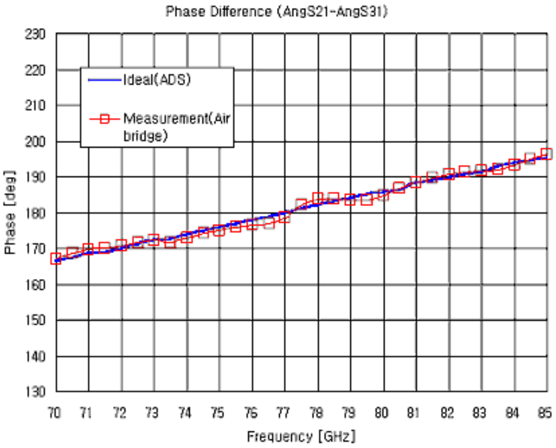


Fig. 11 Measured phase difference of the balun shown in Fig. 9

VI. CONCLUSION

A simple balun using the basic Wilkinson structure has been proposed. In order to verify the structure and performances, an E-band CPW balun has been fabricated using 650µm GaAs MMIC process. The proposed Wilkinson balun has simple and in-line 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; S21 of -4.4~-4.6dB, S31 of -3.6~-4.1dB, port matching of -12.5~-19dB, isolation of -18~-24dB, and the phase difference as has been predicted over 70~85GHz.

ACKNOWLEDGEMENT

This work was supported by KOSEF under the NRL program through the Millimeter-wave Research Laboratory at Seoul National University in Korea.

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